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# AMA

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# EDITORIAL

According to Dr. Lester R. Brown, President of the Earth Policy Institute, if the Chinese economy keeps growing at the present rate (8 % annually), it is estimated that the Chinese national income per capita in 2030 will equal that of the 2004 per capita income in the United States. About 1.1 billion cars would be used only in China if Chinese people possessed three cars per four persons and used them as Americans presently use them. Daily oil consumption, only in China, would exceed the present total daily world oil production.

National economy keeps growing, not only in China, but also in India and other developing countries. They seem driven toward a wealthy future. Some scientists, however, say that such economic growth is impossible because natural resources are limited.

Unless energy and resource saving technologies become available, a battle over the limited resources will be unavoidable. Engineers should take the mission to develop new alternative energy and energy saving technologies.

Farm machines must be of service to increase the productivity per the unit resource. That means the productivity per the unit farm land, water resource and energy. For this objective, timely and efficient agricultural operations and precision farming by farm machines are needed. The progress of agricultural engineering technologies will be the key to increasing agricultural productivity.

With concerns about the limited oil resource, the production of bio-ethanol from grains is becoming a promising alternative to gasoline throughout much of the world. Agriculture seems to be changing, especially in developed countries, where grains have been in over-supply, but now are in short supply for use in the production of bio-ethanol.

Although the developing countries with expanding population have had a large demand for food, people there were not rich enough to purchase food from developed countries even when suffering with hunger. Therefore, there was no actual demand for surplus food in developed countries. Car drivers who have an adequate income generated a new agricultural demand for bio fuel. This is a historical change! However, a food shortage could easily occur when grains are used for fuel.

The development of more advanced technology is needed to mass-produce environmentally friendly biomass fuel from materials like wood chips and other wastes. The task of engineers is to introduce new technologies that will increase mechanization of agriculture to raise land productivity and avoid the struggle for natural resources.

**Yoshisuke Kishida**
**Chief Editor**

Tokyo, Japan
November, 2007

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**Vol.38, No.4, Dec 2007**

# Design and Testing of a Small-Scale Solar Crop Dryer

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## Abstract

Solar energy in Jordan is abundant and is available over much of the year. In addition, commercial dryers that utilize fuel or electricity are too expensive for most Jordanian farmers. This work primarily involved the design of a solar dryer. A prototype solar heater was fabricated, fitted to the drying bin and tested. Under average ambient conditions of 25 ºC and 55 % RH, a 9-$m^2$ solar heater is capable of drying 30 kg of material from 20 to 10 % moisture (w.b.) in 6 hours. Testing a 1-$m^2$ solar heater (dryer) showed that significant reductions in moisture can be effected.

## Introduction

Drying of agricultural products is one of the most critical postharvest technologies and is a basic practice for product loss reduction (Baryeh, 1985). The purpose of product drying is the prevention or at least reduction of crop spoilage and thus, preserving product quality (Loewer et al., 1994). As far as crop drying in Jordan is concerned, the predominant practice is sun (natural) drying. The latter inevitably leads to contamination by dust, dirt and insects. Also, natural drying is a labor-intensive practice and results in low quality product mainly due to delayed drying. Furthermore, sun drying depends heavily on the uncontrolled weather conditions that may lead to significant reduction in drying efficiency causing a contaminated product (Sodha et al., 1987).

Since solar radiation in Jordan is abundant and spans over much of the year, it is only logical to attempt to utilize this clean and renewable source of energy in numerous activities including crop drying (Baryeh, 1985; Pahoja and Gangde, 1985; Al-Amri, 1997). According to ASAE standards, solar drying in Jordan may be feasible from April through September since the average insolation exceeds 400 W/$m^2$ (ASAE S423). In addition, most of the country lies in an arid or semiarid region where ambient relative humidity is generally low throughout the feasible drying period providing an additional incentive for solar drying.

Solar drying, as compared to sun drying, provides a better means that expedites the drying process and improves product quality. This is especially true in Jordan since it lacks local energy resources and almost all its energy needs are imported. Consequently, using fossil fuel or electricity for drying is costly to the vast majority of Jordanian farmers let alone buying modern dryers, which is probably the case in many developing countries (Hung, 1999; Ampratwum, 1998). In addition to drying of agricultural products, solar heaters may be used for preheating ventilation air and make-up for heating systems of farm environments among other purposes.

In recognition of the arguments made above, this study involved mainly the design of a small-scale solar dryer based on the fundamental solar drying principles, that could be fabricated locally. The dryer was an active indirect batch-type solar dryer, thus, providing an alternative and affordable drying practice for small farmers who are in the majority in Jordan as is the case in other developing countries (Patil, 1984). The device was fabricated in the Engineering Workshops on the JUST campus. The dryer was also evaluated for performance in terms of economics and effectiveness.

## Description of the Dryer

A schematic of the dryer is shown in **Fig. 1**. The material to be dried was loaded in the drawers within the bin as shown. More drawers could be added as the need arises. The bin body and drawers were made of wood. The drawers had metal mesh floors.

The solar heater absorber plate consisted of a black-colored well-insulated rectangular section. Ambient air was brought into the heater by a blower that was directly connected to a black-painted 10-cm diameter PVC pipe on top of the absorber plate. The cover plate had a 50-cm diameter semi-cylindrical shape and was made of transparent plastic for cost reduction (Patil, 1984). The heater was connected to one side of the bin at one end while the other end held the blower. The heater was inclined 30º from the horizontal and faced south, i.e. zero azimuth.

### Design of the Solar Heater

The considerations (assumptions and average conditions) on which the heater/dryer design was based are summarized in **Table 1**. Based on this set of design assumptions and conditions, the values of design parameters for the heater were obtained. The dryer calculations were based mainly on expressions presented in Sodha et al. (1987) as shown below.

$m_w = m_p(M_i - M_f) / (100 - M_f)$ ...(1)

$m_{dr} = m_w / t_d$ ....(2)

$m_a = m_{dr} / (W_f - W_i)$ ....(3)

$E = m_a(h_f - h_i)\, t_d$ ....(4)

$A = E / I\eta$ ....(5)

where:

m: mass, M: moisture content, W: humidity ratio, h: enthalpy, E: energy required, $t_d$: drying time, I: solar radiation, A: heater area, η: heater efficiency

**Table 1** Assumption and conditions underlying the solar dryer design

| Consideration | Assumption/condition (approx. values) |
|---|---|
| Location | Jordan (30º N) |
| Crop | General |
| Drying season | April through September |
| Daily batch/batches, kg | 30 |
| Initial moisture, % (w.b.) | 20 |
| Final moisture, % (w.b.) | 10 |
| Daily drying duration, hr | 5 |
| Ambient conditions | |
| Avg. amb. T, ºC | 25 |
| Avg. amb. RH, % | 55 |
| Max air T, ºC | 40 |
| Collector efficiency, % | 50 |
| Collector azimuth, deg | 0 |
| Collector slope, deg | 30 |
| Incident solar radiation, MJ/m$^2$/day | 28 |
| Wind speed, m/s | < 1.5 |
| Wind direction | Northwesterly |

**Table 2** Results of dryer design parameters

| Consideration | Design value (approx. values) | Comments |
|---|---|---|
| Initial conditions of drying air | | |
| Initial HR, kg water/kg d.a.* | 0.0125 | Psychrometric chart |
| Initial enthalpy, kJ/kg d.a. | 56 | Psychrometric chart |
| Final conditions of drying air | | |
| Final HR, kg water/kg d.a. | 0.0163 | Psychrometric chart |
| Final enthalpy, kJ/kg d.a. | 72 | Psychrometric chart |
| Mass of moisture removed, kg | 3.33 | Calculated (Eqn. 1) |
| Avg. ΔT in the heater, ºC | 16 | Measured |
| Avg. drying rate, kg water/hr | 0.55 | Calculated (Eqn. 2) |
| Air mass flow rate, kg/hr | 132.4 | Calculated (Eqn. 3) |
| Air volume flow rate, m$^3$/hr | 110.3 | Calculated (Eqn. 3) |
| Thermal energy required, kJ | 12,708.6 | Calculated (Eqn. 4) |
| Collector area, m$^2$ | 9.0 | Calculated (Eqn. 5) |

*d.a. stands for dry air

**Fig. 1** Small-scale solar crop dryer

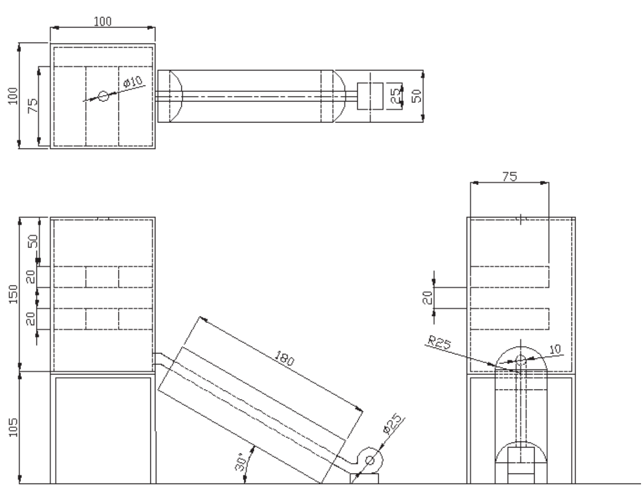
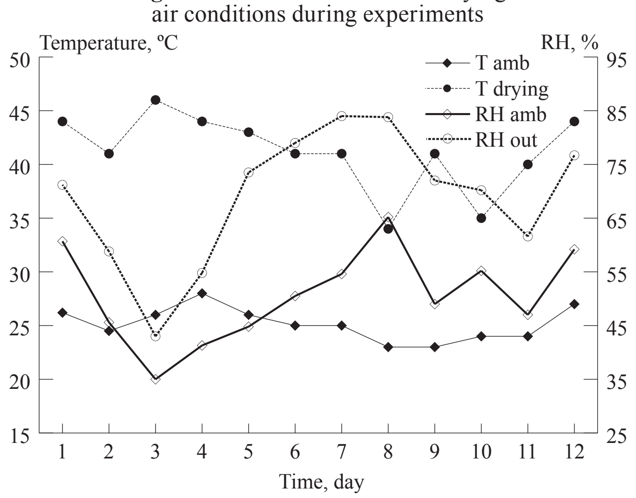



**Fig. 2** Variation of ambient and drying air conditions during experiments



Subscripts:

w: water (moisture) removed, dr: drying rate, p: material to be dried, i: initial, f: final

## Dryer Testing Procedure

Limited tests on the dryer were conducted. Olive cake was chosen as the material to be dried since it is produced locally in large quantities and is widely used as fuel in the countryside and requires substantial drying before use. The material had initial moisture content of 30 % w.b. or less. The material moisture content was determined by oven drying.

Due to locating the dryer among buildings, the heater was exposed to sunrays from about 9:30 am to 3:00 pm, which was roughly the daily drying time throughout the experiments. Moreover, this location had a low wind speed in the range of 1 to 1.5 m/s. All experiments were conducted in the period from late September to late October of the year 2001.

The fan (blower) was turned on for approximately 30 minutes to allow for steady-state conditions prior to drying and data collection for each run. The fan forced ambient air at approximately 25 ºC and 55 % RH into the solar heater raising its temperature to about 41 ºC. A detailed record of the ambient conditions on selected days during the course of testing as well as drying air conditions, are shown in **Fig. 2**. The material (batch) would, then, be loaded in drawers of the dryer and exposed to the hot drying air. Both the dry bulb and wet bulb temperatures were recorded at different locations of the device.

Material drying was tested under one natural drying setting and two forced drying airflow rates. The two airflow rates selected were about 0.025 $m^3/s$ and 0.035 $m^3/s$ mandated by the capacity of the available blower. The psychometric chart was used to determine the relative hu-

**Table 3** Daily moisture content of olive cake under natural drying conditions

| Drying time, day | Sample number | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | Average |
| 1 | 22.35 | 21.88 | 23.80 | 22.12 | 22.74 | 22.53 | 22.58 |
| 2 | 20.88 | 20.60 | 21.17 | 21.13 | 19.36 | 17.81 | 20.63 |
| 3 | 18.31 | 17.67 | 17.91 | 17.55 | 17.85 | 18.06 | 17.86 |
| 4 | 15.94 | 15.92 | 16.83 | 16.90 | 16.56 | 16.99 | 16.43 |
| 5 | 13.55 | 14.06 | 13.92 | 14.63 | 14.14 | 14.24 | 14.06 |
| 6 | 13.57 | 13.39 | 12.67 | 13.84 | 13.26 | 12.30 | 13.35 |

**Table 4** Daily moisture content of olive cake under forced drying - first flow rate

| Drying time, day | Sample number | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | Average |
| 1 | 27.78 | 26.98 | 26.40 | 26.41 | 27.09 | 26.03 | 26.78 |
| 2 | 23.18 | 24.24 | 23.08 | 22.87 | 21.14 | 20.89 | 22.57 |
| 3 | 18.75 | 18.18 | 17.25 | 17.02 | 16.57 | 17.63 | 17.57 |
| 4 | 15.91 | 15.76 | 16.88 | 15.19 | 14.05 | 15.31 | 15.52 |
| 5 | 12.61 | 11.92 | 11.72 | 12.31 | 11.72 | 11.37 | 11.94 |

**Table 5** Daily moisture content of olive cake under forced drying - second flow rate

| Drying time, day | Sample number | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | Average |
| 1 | 30.26 | 29.70 | 29.45 | 29.26 | 28.68 | 29.74 | 29.47 |
| 2 | 28.88 | 28.58 | 28.87 | 27.69 | 27.76 | 28.34 | 28.34 |
| 3 | 26.69 | 24.93 | 26.03 | 24.72 | 25.21 | 25.26 | 25.51 |
| 4 | 21.47 | 21.24 | 20.75 | 21.13 | 22.46 | 21.37 | 21.41 |
| 5 | 18.00 | 18.18 | 17.23 | 16.91 | 16.09 | 16.14 | 17.28 |
| 6 | 15.98 | 15.60 | 15.38 | 15.58 | 15.48 | 14.60 | 15.60 |
| 7 | 14.45 | 14.25 | 13.92 | 13.39 | 14.21 | 13.45 | 14.04 |

**Fig. 3** Moisture reduction with drying time under natural drying conditions (N)

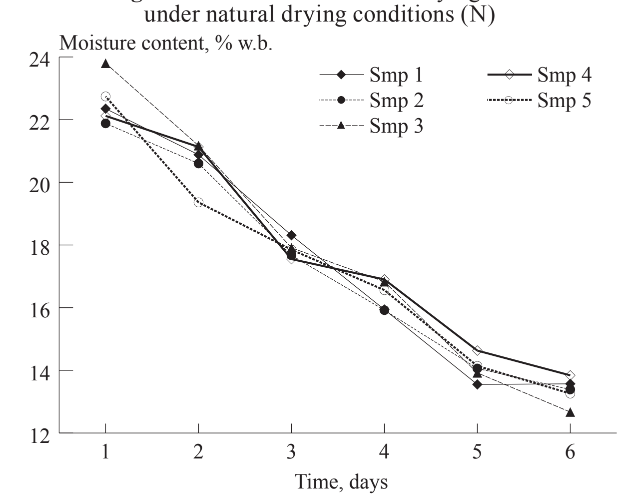
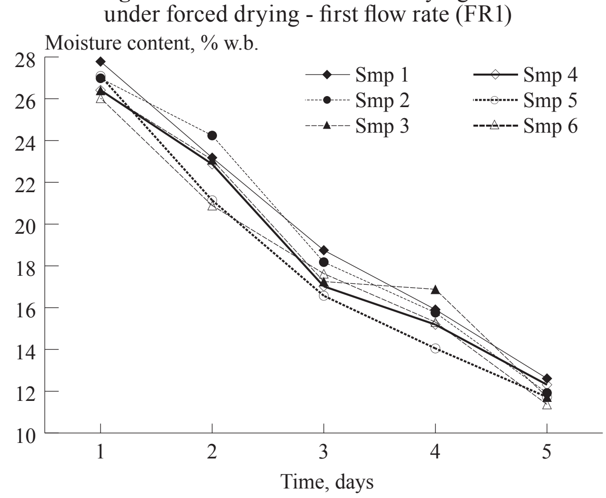



**Fig. 4** Moisture reduction with drying time under forced drying - first flow rate (FR1)



midity (humidity ratio) of drying air as well as the amounts of moisture removed at the three drying settings using the wet and dry bulb temperatures. The major aspect investigated was the ability of the dryer to reduce the material moisture from experimental conditions.

## Results and Discussion

**Dryer Design**

Based on the assumptions listed in **Table 1**, the values of the dryer features were calculated and summarized in **Table 2**. The full-size drying bin plus a small lab-size solar heater measuring 0.5 m wide and 1.85 m long fitted with a transparent plastic semi-cylindrical cover with a 0.5 m diameter were fabricated and fitted to the bin. The test results reported here are based on the lab-size, scaled-down heater rather than the full-size heater.

**Dryer Testing**

Material moisture reduction with drying time is shown in **Figs. 3** through **5** for the three drying settings for the replicates under each setting. It may be readily seen that for all settings, sunrays are capable of effecting significant reductions in material moisture. It may be noted that the moisture was reduced from roughly 23 to 14 % in 6 days under natural conditions. The corresponding values for the first and second forced flow rates were 27 to 12 % in 5 days and 30 to 14 % in 7 days, respectively.

For comparison purposes, the average of all samples for each setting is plotted and fitted in **Fig. 6** for convenience. The figure indicates that utilizing the solar heater with forced air improved and accelerated the drying process as manifested in both the absolute values and slope of each curve. Also, the numerical values above translate to equivalent moisture reduction rates (slopes) of approximately 1.5, 3.0, and 2.7, respectively. Clearly, the first flow rate gave the best results. It seems that the second flow rate was beyond that necessary for the batch size and heater size used in the experiments.

## Conclusions

The findings of this study, both in design and testing, indicate that solar dryers have a significant potential in drying agricultural crops in Jordan. The design results indicate that a 9-$m^2$ solar heater is capable of reducing the moisture content of 30 kg of material from 20 to 10 % in 6 hours under prevailing local conditions in Jordan. A small 1-$m^2$ dryer was field tested and showed potential of solar dryers for local use.

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**Fig. 5** Moisture reduction with drying time under forced drying - second flow rate (FR2)

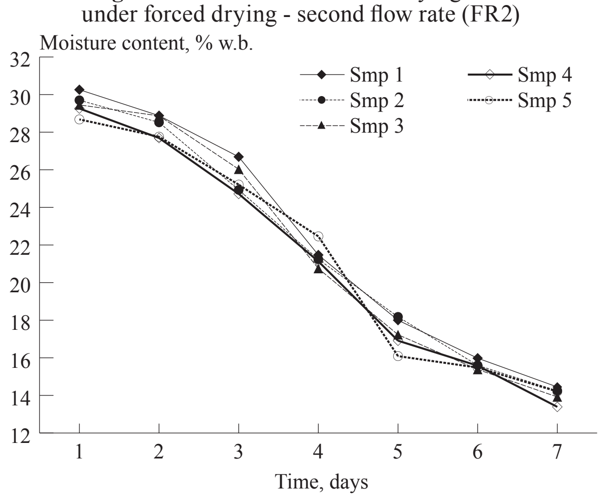
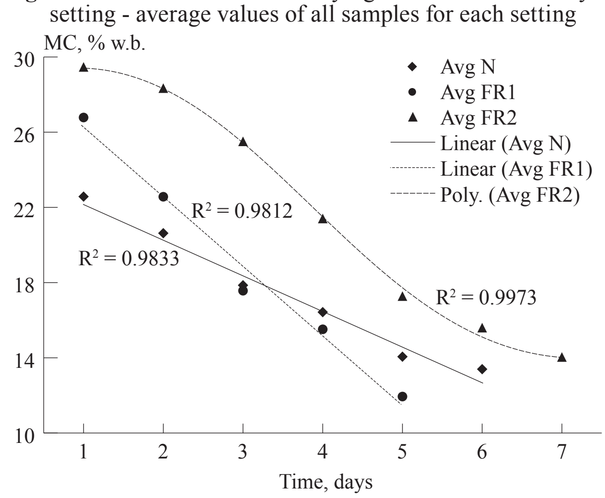



**Fig. 6** Moisture reduction with drying time for the three drying setting - average values of all samples for each setting



# Energetics and Economics in Conventional Processing of Arecanut (*Areca catechu L.*) in India


by

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## Abstract

Arecanut is mostly used by the people as masticatory and is an essential requisite during several religious and social ceremonies. The arecanuts are generally available in trade as (i) raw ripened nuts, (ii) processed green nuts, and (iii) whole or half cut dried ripened nuts. Arecanut processing consists of dehusking, cutting into different grades, boiling, drying and coating with water extract obtained from boiling. Boiling is carried out in conventional open chulhas having three, four or even five pot holes. Based on the study, the operaion-wise and source-wise energy consumption for choor making was 6,279 MJ/t. The thermal efficiency of three-pot chulha was determined as 7.10 %. The benefit cost ratio of arecanut processing carried out in Thondamuthur village of Coimbatore district was found to be 0.0247:1. By using the fuel efficient chulha, the cost involved in boiling could be reduced and increase profit.


## Introduction

Arecanut palm (*Areca catechu L.*) occupies a prominent place among the plantation crops in the states of Kerala, Karnataka, Assam, Meghalaya, Tamil Nadu and West Bengal of India. It is the source of the common masticatory nut, popularly known as *arecanut*, *betelnut* or *supari*. It is extensively used in India by all sections of the people as a masticatory and is an essential requisite during several religious and social ceremonies. India is the largest producer of arecanut in the world with an export value of 0.8 million US dollars annually. The area under arecanut in India was 0.29 Mha during 2002 and the production was 0.33 Mt (FAO, 2003).

Harvest and post harvest technology of any crop produce is very vital in terms of obtaining maximum yield, reduction in field losses and obtaining a quality product. These operations include harvesting at the right stage, primary processing at industries, grading and packaging, storage, transportation and handling. Among the plantation crops, arecanut is the most profitable crop grown in the humid tropics of India. India is the largest consumer of arecanut in the world (Kennedy et al., 2001).

**Processing of Arecanut**

The processing method of areca differs from place to place. In Assam, fresh nuts are preserved in thick layers of mud to have a moist chewing feel in the mouth when consumed. The product is known as bura tumul. In Kerala, fresh fruits are stored by steeping in water. To meet the different requirements of different consumers, arecanut is processed into various types and harvested accordingly (Kennedy et al., 2001). The characteristics of a good nut product are; (1) absence of immature nuts, surface cracking, husk sticking, fungus and insect attack; (2) good cutting feel of inside structure; and (3) taste (Anonymous, 1961; Anonymous, 1962; Dhanraj, et al., 1970). Inadequate drying usually results in fungal infection and in poor quality product.

Sometimes the fruits are cut longitudinally into two halves, to facilitate drying and dehusking, and sun dried for about 10 days. The kernels are scooped out and given a final drying (Shamanna, 1951). This type of product is known as *parcha* and is produced mainly in Kerala and Karnataka. The *supari*, an economic product of the palm, is mostly consumed indigenously for masticatory and socio-religious purposes. In Tamil Nadu state, Salem and Coimbatore districts are mainly involved in arecanut cultivation and processing. In Coimbatore district, arecanut processing is mainly carried out in Thondamuthur and Mettupalayam villages. Arecanut from near by districts of Kerala and far off districts of Assam are also processed here.

The nuts of 6-7 months maturity are soft and are used for making *kalipak*. The processing of *kalipak* consists of a number of unit operations (**Fig. 1**). Depending upon the number of cuts, shape and size of the pieces, they are called by different names viz., *choor* for 6-8 longitudinal cuts, *nuts* or *kottai* for 4-6 transverse cuts and *urundai* for uncut nuts (**Fig. 2**). The processing consists of dehusking, cutting the soft nuts into pieces, boiling the cut pieces with water, partial drying of boiled nuts, concentration of water extract from the previous boiling, coating the partial dried nuts with the water extract concentrate and final drying for safe storage.

### Dehusking and Cutting

Dehusking and cutting of the nuts are normally done manually by using a specially designed curved knife (**Fig. 3**). These knives, made of mild steel and with sharp cutting edge, are mounted on a wooden base. Both women and men labourers carry out the dehusking and cutting operation. After dehusking, the nuts are cut into two types based on the maturity of the fruits. Less matured fruits are cut into longitudinal sections called *choor* and medium matured fruits are cut into trans-

**Fig. 1** Flow chart of making *kalipak* in India

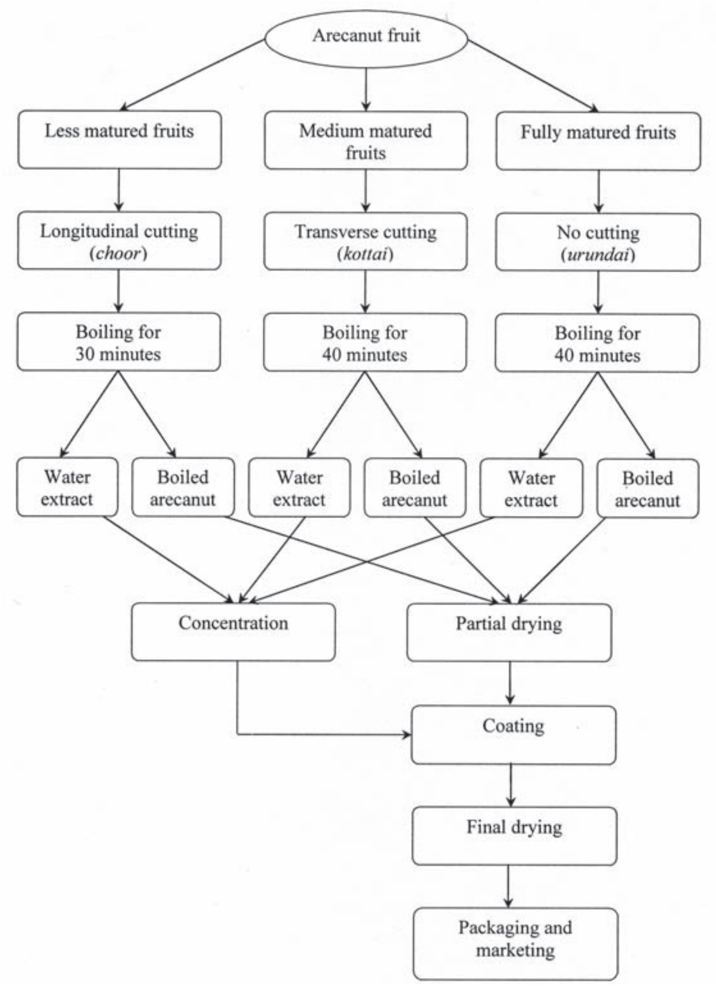



**Table 1** Energy equivalents for various sources of energy

| Particulars, units | Equivalent emergy, MJ | Remarks |
|---|---|---|
| Adult man, man-hour | 1.96 | |
| Adult woman, woman-hour | 1.57 | 1 adult woman = 0.8 adult man |
| Bullocks-medium weight, pair-hour | 10.10 | Body weight 350-450 kg |
| Machinery, kg | 62.70 | Distribute the weight of the machinery equally over the total life span of the machinery (in hours). Find the use of machinery (hours) for the particular operation. |

Source: Mittal and Dhawan, 1988

verse sections called *nut* or *kottai*. Fully matured fruits are not cut and are processed as round nuts called *urundai*. Ripened fruits are segregated and processed separately. Normally one labourer can dehusk and cut about 60-75 kg of fruits in eight hours.

**Boiling**

The two or three pot chulha (stove) is used for boiling (**Fig. 4**). During boiling, about 35-40 kg of arecanuts are kept in the aluminium vessel containing 8-10 litres of water. The boiling will be done for 30 minutes in the case of choor arecanuts and for 40 minutes in the case of *kottai* and *urundai*. Appearance of foam in the vessel indicates the completion of boiling. The water remnant in the vessel after boiling is used for boiling fresh nuts of 4-5 batches. Then the water extract is taken out and concentrated (*kali* or *charu*) for coating the partially dried nuts. Arecanut husk, coconut raiches, coconut husk and other biomass are used as fuel in the chulha.

**Drying**

Normally the arecanuts are dried under sun. For safe storage, choor and kottai grades require 24-36 hours and urundai require 4-5 days of drying depending upon the climatic conditions. If the demand is more, the nuts are sold immediately at a moisture content of 25-30 % (d.b.); otherwise the nuts are dried up to a safe storage level of 12 % (d.b.). During rainy days, drying is carried out in a smoke drying barn, where biomass is burnt to produce hot smoke. The smoke is allowed to pass through the wet boiled nuts kept on top of the barn over a bamboo mat. The hot smoke, while passing through the nuts takes away moisture. The main disadvantage in this method is deposition of soot on nuts, giving some uncharacteristic taste. Fully ripened fruits are dried under the sun (without dehusking) for a period of 35-45 days and dehusked before sending them to the market.

**Coating**

Coating of partially dried (40-45 % d.b.) nuts with *kali* or *charu* (concentrated water extract) gives a glossy appearance to the arecanut. Normally coating is carried out by mixing the nuts along with the *kali*, until a dark brownish red colour is formed on the surface of the nuts. About 500-600 ml of *kali* are required to coat a 5 kg batch of nuts. In some places, a power operated coating machine is used. The machine is operated with 1 hp electric motor and the requirement of *kali* is reduced considerably to 300-400 ml for 5 kg of arecanut. The holding capacity is 20 kg per batch and takes about 5-10 minutes for coating one batch of nuts. Excess *kali*, if left in the processing centers, is sold to dyeing factories. After coating, the nuts are, again, sun dried to the safe storage level. The dried nuts are collected and stored in small rooms in the form of heaps. The nuts are sold depending on the market situation.

The unit operations in processing of the nuts consumes a lot of energy that has not been systematically documented. This study was conducted to determine the energy consumption and cost of processing

**Table 2** Arecanut processing details in Thondamathur village

| Particlars | Total quantity in 20 centers/ years | Average annual quantity/ center | Average quantity in 20 centers/ day | Average quantity/ day/center |
|---|---|---|---|---|
| Fruits purchased for processing, ton | 2,768.50 | 138.43 | 13.84 | 0.69 |
| Raw nut processing, ton | 830.50 | 41.53 | 4.15 | 0.21 |
| Processed nut (sold), ton | 276.80 | 13.84 | 1.38 | 0.07 |
| Ripened nut, ton | 276.80 | 13.84 | 1.38 | 0.07 |
| Processed *choor* nut, ton | 99.75 | 4.99 | 0.50 | 0.03 |
| Processed *kottai* nut, ton | 53.65 | 2.69 | 0.27 | 0.01 |
| Processed *ururndai* nut, tons | 123.25 | 6.16 | 0.62 | 0.03 |
| Water extract obtained, litre | 99,865.00 | 4,993.25 | 499.33 | 25.00 |
| Extract used for coating, litre | 68,065.00 | 3,403.25 | 340.33 | 17.02 |
| Balance extract (or) extract sold, litre | 31,800.00 | 1,590.00 | 159.00 | 7.95 |
| Biomass used for boiling, ton | 1,295.00 | 64.75 | 6.48 | 0.32 |

Total number of processing centers: 20
Number of days of processing in an year: 200

**Fig. 2** Names of arecanut after cutting

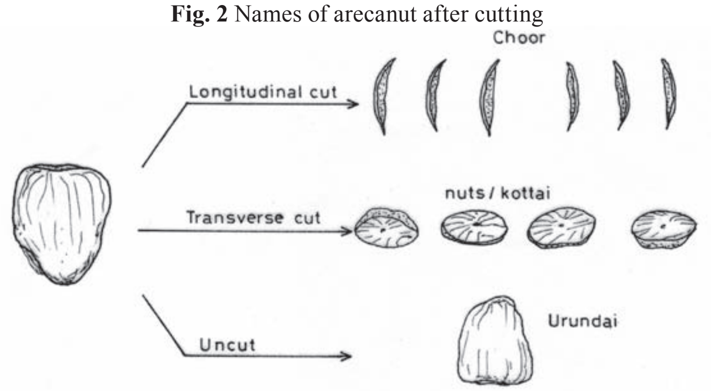
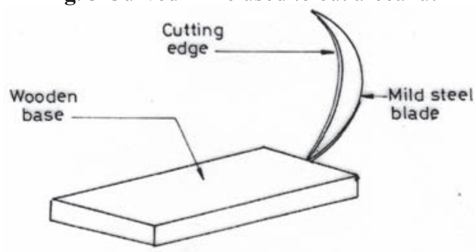



**Fig. 3** Curved knife used to cut arecanut



*kalipak* in and around Coimbatore district.

## Materials and Methods

**Energy Consumption in Arecanut Processing**

Arecanut processing involves different types of energy. In chulha construction, human power, bullock power and machinery power like the bullock cart, spade and pan are used. The different types of energy required for processing the arecanut include human, fuel wood and machinery. Source-wise and operation-wise, the energy spent on processing of arecanut was calculated based on the energy equivalents as given in **Table 1**. For each operation, the work hours were noted and the energy spent for each operation of *choor* processing was calculated from **Table 1**. Similarly, the energy spent by different sources for *choor* processing was calculated.

**Thermal Efficiency of Chulha**

The thermal efficiency of chulha is the ratio of heat actually utilized to the heat supplied by burning the fuel. Experiments were done with the three pot chulha and the thermal efficiency was calculated as per BIS (1991).

The experiment was conducted three times and the average value was used as the thermal efficiency calculation. Ten kilograms of pre-weighed *Acacia coincinna* fire wood ($m_f$) were used for the study. The entire wood was slowly fed into the chulha in 65 minutes time. Eight vessels with lids, each weighing ($m_v$) 2.25 kg were taken and are filled with 8 kg of water ($m_w$). To initiate the burning, 0.34 liter of diesel ($v_d$) was used. Three vessels with lids containing water were kept on the three pot holes of the chulha. The initial temperature ($t_1$) of the water in the vessel was recorded. The fire wood was burnt and the water in the vessel was allowed to warm steadily till it reached a temperature of about 80 ºC. Stirring was then commenced and continued until the temperature of the water reached 95 ºC. This temperature was used as the final temperature ($t_2$). The water in any vessel that reached 95 ºC temperature was replaced with a fresh water vessel. The experiment was continued by consecutively removing the vessels that reached 95 ºC and replacing them with the vessels filled with fresh water until there was no visible flame in the chulha. The final temperatures of the water in the last three vessels kept on three pot chulhas were recorded as $t_3$, $t_4$ and $t_5$.

The thermal efficiency was calculated as follows.

Heat utilised =

$$(m_v \bullet s_v + m_w \bullet s_w)\left[n(t_2 - t_1) + \sum_{f=3}^{5} t_f - t_1\right]$$

Heat supplied = $m_f \bullet c_f + m_d \bullet c_d = m_f \bullet c_f + v_d \bullet d_d \bullet c_d$

where,

$m_v$ = mass of the vessel, kg
$m_w$ = mass of the water, kg
$m_f$ = mass of the fire wood, kg
$m_d$ = mass of the diesel, kg
$s_v$ = specific heat of vessel, kcal/kg. ºC (0.214 kcal/kg. ºC)
$s_w$ = specific heat of water, kcal/kg. ºC
$c_f$ = calorific value of fire wood, kcal/kg [4,360.13 kcal/kg (Rao, 1991)]
$c_d$ = calorific value of diesel (10,135 kcal/kg)
$v_d$ = volume of diesel, lit
$d_d$ = density of diesel, kg/lit (0.832

**Fig 4.** Three pot arecanut boiling chulha

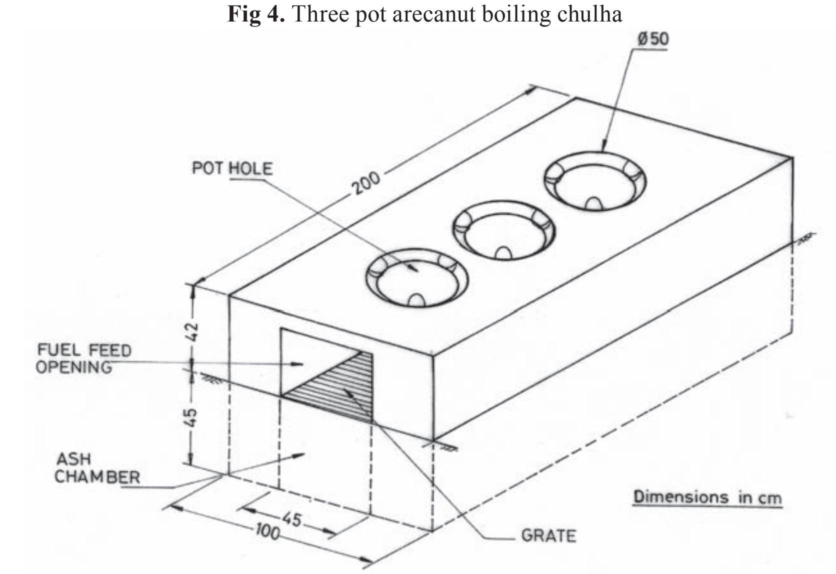



**Table 3** Operation-wise energy for choor processing

| Operation | Energy, MJ/t | % of total energy |
|---|---|---|
| Chulha construction and maintenance | 1 | 0.02 |
| Dehusking and cutting | 187 | 2.98 |
| Boiling | 6,017 | 95.83 |
| Drying | 46 | 0.73 |
| Coating (manual) and storing | 28 | 0.44 |
| Total | 6,279 | 100.00 |

**Table 4** Source-wise energy for choor processing

| Source | Energy, MJ/t | % of total energy |
|---|---|---|
| Human | 296 | 47.1 |
| Bullock | 1 | 0.02 |
| Fuel wood | 5,971 | 95.09 |
| Machinery and tools | 11 | 0.18 |
| Total | 6,279 | 100.00 |

kg/lit)

n = number of vessels changed after its water reached 95 ºC

$t_1$ = initial temperature of water in the vessel, ºC

$t_2$ = temperature of water reached to 95 ºC

$t_f$ = final temperature of water recorded in different vessels kept on chulhas, ºC

Thermal efficiency =

$$\frac{\text{Heat utilised}}{\text{Heat supplied}} \times 100$$

**Cost Analysis of Arecanut Processing**

The necessary data was collected from 20 processing centres (**Table 2**) and used to calculate the cost of arecanut processing.

## Results and Discussion

Energy required for *choor* processing, operation-wise and source-wise, is presented in **Tables 3** and **4**. Among the total operations required in choor processing, boiling of arecanut consumed more energy (95.83 %) whereas chulha construction consumed less energy (0.02 %). Similarly, among the source-wise energy required in *choor* processing, the requirement of fuel wood was more (95.09 %) compared to the bullock energy (0.02 %). Based on the study, the operation-wise and source-wise energy consumption for *choor* making was 6,279 MJ/t.

The thermal efficiency of three pot chulha was calculated as 7.10 %. As the boiling of arecanut was carried out with a traditional three pot chulha, it consumed a lot of fuel wood (5.970 MJ/t of arecanut) as the efficiency of chulha was much less (7.10 %). Out of all the operations required in *choor* processing, the boiling is the main operation and the energy required in the way of fuel wood can be decreased to a great extent, if the fuel efficient chulhas (up to 20 % efficient) can be used instead of low efficient traditional three pot chulhas which are widely used in arecanut processing.

The cost-estimation of arecanut processing and net returns of the processed product are presented in **Tables 5** and **6**. The cost estimation of processing of one ton of arecanut was US $336.575 and the net return was US $344.910. It means that the net profit was US $8.335 per ton of processed arecanut. The benefit cost ratio of arecanut processing carried out in Thondamuthur village of Coimbatore district was found to be 0.0247:1. If the fuel efficient chulha can be used, the cost involved in boiling can be reduced, which in turn will enhance the net profit.

**Table 5** Cost estimation of arecanut processing

| Description of items | Amount, US $/t |
|---|---|
| **A. Fixed cost** | |
| Chulha | 0.066 |
| Drying floor | 0.444 |
| Miscellaneous/vessel/cutting tools | 0.444 |
| Interest on fixed cost @ 12 % | 0.111 |
| Total fixed cost | 1.065 |
| **B. Operating cost** | |
| Arecanut fruit | 233.333 |
| Cutting cost | 16.000 |
| Boiling cost | 14.889 |
| Drying cost | 10.000 |
| Coating cost | 14.889 |
| Fuel cost | 19.333 |
| Miscellaneous/maintenance of chulha/supervision | 2.222 |
| 8 % interest on operating cost | 24.844 |
| Total operating cost | 335.510 |
| **Total processing cost** | **336.575** |

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# Hill Agricultural Mechanization in Himachal Pradesh - A Case Study in Two Selected Districts

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## Abstract

The present study analyses the status of agricultural mechanization in Himachal Pradesh along with in depth assessment of existing farm tools, implements and machines used by the farmers. The study was conducted in two districts Kangra and Una. For each selected district, a random sample of 40 villages was selected. Keeping in view the level and adoption of mechanization in selected village, a sample of 10 households was selected. It is clear that animate power dominates all agricultural operations in hill farming.

The average annual use of animal power is 80 % and 75.71 % in Kangra and Una, respectively, mainly for land preparation (ploughing, puddling and planking). Tractor power is utilized about 60 % for transportation because of unique topographical features and small sized fields in both districts. The study shows that the farmers are still utilizing the traditional farm tools and implements. The main implements used by the farmers are Desi plough, clod breaker, soil stirring plough, wooden planker, khunti, plain sickle and Kudali in both districts.

Most of the farm operations except ploughing, puddling and planking were carried out by farm women with traditional tools. Only small manufacturers of agricultural tool/implements were identified which are fabricate only small equipment like soil stirring plough, kudali, hand rake, digging hoe and gardening hoe. It was also clear from the survey that 87.25 % and 73.5 % of the farmers in Kangra and Una, respectively, fall under the marginal group. Focus was placed on the identification of farmers' needs for different farm tools and implements. Successful implementation of farm mechanization in rural areas will require an effort to introduce suitable technology at the farmers' fields.

## Introduction

Agriculture is the main occupation in the Himachal Pradesh. About 71 % of the main workers are engaged in agriculture pursuits. Therefore, improvement of agricultural production is the prerequisite for overall development of the state. In this regard, the improvement of agricultural production and productivity depends, not only on the availability of improved seed and fertilizer, but also on the timeliness of agricultural operations. The level of productivity in the state is very low due to low level of mechanization. The power availability is the state is about 0.60 kW/ha, which is very low for timely sowing of crops and, in particularly under rain-fed conditions, which occupies 82 % of net cultivatable area of the state. Studies on farm mechanization have shown that mechanization of crop production increases total production by improving yields, expanding the agricultural area and increasing land use intensities (Anazodo, 1986). Traditional manual tools and animal drawn implements form the mainstay of agricultural tools in the state. About 80 % of all available farm power use in farming comes from draft animals. Several reasons can be attributed to the slow progress of agricultural mechanization in state. The state topography and small sized fields make it difficult for the use of heavy mobile machinery on the steep slopes of hills and mountains. Lack of accessible roads to the fields has aggravated this problem. Small and fragmented land holdings, high capital investment, low purchasing power of the farmers, traditional methods of farming, abundance of unemployed labour and lack of clear government policies are some other factors hindering the pace of agricultural mechanization in the state. So, there is great need to mechanize hill farming with suitable power source and implements with a view to modernize mountain farming. This paper should help researchers and government planners make log-term policies on the hill mechanization for overall development of mountain farmers.

## Aims of the Study

The main purpose of the study was to identify the farmers' need for a power source, farm tools, implements and machines, and to formulate the long-term strategies and programmes for mechanization of mountain agriculture. The specific objectives of the study were:

1. To study the present status of farm power and implements used in various agricultural operations.
2. To study and assess the use pattern of implements and machinery by the farmers.
3. To study the status of manufacturers of agricultural tools and implements.
4. To suggest long-term strategies and programmes for mechanization of agriculture in mountain regions.

## Methodology

Two districts in Himachal Pradesh, Kangra and Una, (**Fig. 1**) were selected covering about 20 % of the districts and representing a mix of developed, developing and least developed pockets. The sampling design was Stratified Multistage Random Sampling. From each selected district, a random sample of 40 villages was selected. Keeping in view the level and adoption of mechanization (holding-size wise), out of each selected village; a sample of 10 households was selected. Hence, the total number of randomly selected households surveyed were 800. Interviews were conducted with a structured questionnaire separately prepared for different target groups. The information received from various sources was analyzed with respect to percentage of power source, implement and machines available, annual use of power source and gender participation for various farm operations. Manufacturers engaged in fabrication of agricultural tools/

**Fig 1** Agro-climatic zones of Himachal pradesh and location of study areas

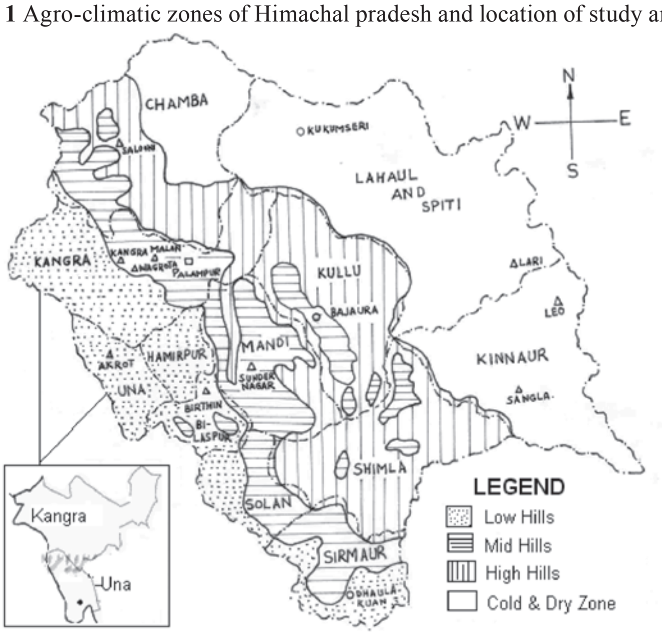



**Table 1** Area under four agro-climatic zones of Himachal Pradesh and their salient features

| Particulars | Overall view | Agro-climatic zones | | | |
|---|---|---|---|---|---|
| | | Sub montane and low hills sub-tropical | Mid hills sub humid | High hills temperate wet | High hills temperate dry |
| Geographical area, 000 ha | 5,567.3 | 913.2 (16.4 %) | 1,183.2 (21.3 %) | 1,280.9 (23.0 %) | 2,190.6 (39.0 %) |
| Total cropped area, 000 ha | 956.8 | 335.1 (38.0 %) | 383.4 (41.0 %) | 171.8 (18.4 %) | 24.3 (2.6 %) |
| Elevation (amsl), m | - | Below 650 | 651-1,800 | 1,801-2,200 | Above 2,201 |
| Soil texture | - | Coarse | Coarse | Shallow in depth & sloppy | Coarse |
| Irrigated area, % | 101.9 | 16.6 | 17.3 | 7.8 | 10.6 |
| Rainfall, mm | - | 1,000 | 1,500-3,000 | 100 | 250 |
| Field crops | - | Wheat, Maize, Rice, Pulses | Rice, Wheat, Maize, Barley, Pulses | Wheat, Maize, Potato | Barley, Potato, Wheat |
| Fruit crops | - | Subtropical fruits | Apple, Other temperate fruits, Stone fruits, Nuts, Mango, Litchi | Apple, Other temperate fruits, Stone fruits, Nuts | Nuts, Dry fruits, Apple |

implements in both districts were also interviewed personally with a separately prepared questionnaire.

## An Over-view of Hill Agricultural Mechanization

Himachal Pradesh is a hilly state of India situated between 30.3 and 33.3º North Latitude and 75.3-79.0º East Longitude. The elevation of the state widely ranges from 350 m to 6,975 m above mean sea level. Because of wide variations in altitude and topography, the state has broadly been classified into four agro-climatic zones, i.e. sub montane and low hills sub-tropical, mid hills sub humid, high hills temperate wet and high hills temperate dry. Area under different zones of Himachal Pradesh is given in **Table 1** (Singh, M. et al., 1982). The state receives 1,067.5 mm average annual rainfall. The land under cultivation is 10 % of the geographical area and about 82 % of the net area sown is rain-fed. The major crops are maize-wheat and paddy-wheat. The average yield in the state is 1,570 kg/ha for wheat, 1,500 kg/ha for rice and 2,270 kg/ha for maize (Anonymous, 2001-02). Agriculture in Himachal Pradesh is totally dependent upon animate power (Vatsa et al., 1996) because it involves a large working population. The trend of farm power availability from different sources in India and Himachal Pradesh is shown in **Table 2**. It is clear from the table that power availability in Himachal Pradesh is only 48 % (0.60 kW/ha) of India's 1.25 kW/ha.

The share of animate power in the state is 77 %. The power availability in 1982 was 0.39 kW/ha and increased up to 0.60 kW/ha in 2002, which is still quite low for timely farm operations. For increasing the production, there is a need for increased farm power up to 2.0 kW/ha (Srivastava, 1999). It is also clear from the table that animate power share was 92.7 % in 1982, whereas it was 77.0 % in 2002. On the other hand, mechanical power increased from 6.7 % to 20.5 % for the same period. The total population of state is 6,070,000 with 863,000 land holdings. The operational land holdings and the percentage distribution of area operated by major size group of Himachal Pradesh and India are presented in **Table 3**. The average size of operated land holdings in the state is 1.15 ha which, is 32 % less than average operated holding size in India. The trend of farm machinery availability is shown in **Table 4**. The most common implement is the animal drawn plough, numbering more than 0.7 million. Other common implements used by the farmers are sprayer and thresher. The table shows that the number of mechanical power sources, i.e., tractor and power tiller, are increasing day by day and replacing animal power in spite of terraced fields. The power tiller is popularizing very fast in the state due to its unique features.

Further, no major research work on farm mechanization especially farm power and machinery has been done in the state due to poor infrastructure and manpower. The availability of improved farm tools and equipment to the farmers is very poor because of poor infrastructure of manufacturers of agricultural equipments and tools.

## Findings and Discussions

Of the households surveyed in Kangra district, 87.25 % farmers were marginal in farm group size; 12.5 % small; 0.25 % medium whereas in Una district 73.5 % fall under marginal; 20.0 % small; 6.25 % medium and 0.25 % in large group size. Maize, paddy and wheat were the major crops grown in the districts. **Table 5** shows the power source availability by different farm groups in both the districts. The ma-

**Table 2** Availability of farm power from different sources

| Year | Total power, kW/ha | | Source wise, % | | | | | |
|---|---|---|---|---|---|---|---|---|
| | India | H.P.[1] | Animate | | Mechanical | | Electrical | |
| | | | India | H.P. | India | H.P. | India | H.P. |
| 1982 | 0.48 | 0.39 | 38.15 | 92.7 | 44.15 | 6.7 | 17.7 | 0.60 |
| 1987 | 0.64 | 0.44 | 31.5 | 90.38 | 49.0 | 8.83 | 19.5 | 0.79 |
| 1992 | 0.75 | 0.47 | 25.17 | 87.1 | 53.93 | 11.8 | 20.90 | 0.99 |
| 1997 | 1.02 | 0.51 | 20.5 | 82.4 | 58.8 | 16.95 | 20.18 | 1.01 |
| 2002 | 1.25 | 0.60 | 16.38 | 77.0 | 62.42 | 20.5 | 21.2 | 1.20 |

[1] H.P. = Himachal Pradesh

**Table 3** Operational land holding and the percentage distribution

| Class | Size holding | Percent distribution operated | | No. of operational holdings, lakh[1] | | Average size of operational holding, ha | |
|---|---|---|---|---|---|---|---|
| | | H.P. | India | H.P. | India | H.P. | India |
| Marginal | < 1 ha | 23.1 | 13.18 | 5.56 (64.4) | 567.48 | 0.41 | 0.38 |
| Small | 1-2 ha | 24.1 | 15.88 | 1.73 (20.1) | 178.81 | 1.38 | 1.43 |
| Semi-medium | 2-4 ha | 25.5 | 22.32 | 0.95 (11.0) | 132.54 | 2.68 | 2.76 |
| Medium | 4-10 ha | 19.5 | 28.68 | 0.34 (4.0) | 79.20 | 5.66 | 5.94 |
| Large | > 10 ha | 7.8 | 20.24 | 0.047 (0.5) | 19.25 | 16.50 | 17.20 |
| Total | | 100.0 | 100.0 | 8.63 (100.0) | 977.28 | 1.15 | 1.68 |

[1] one lakh = 100,000

jor power sources available with all farm groups were bullocks. About 82.75 % farmers in Kangra and 68.25 % in Una district have their own bullocks. Only 1.25 % farmers in Kanga and 8.5 % in Una have their own tractor as a farm power source. The rest of the farmers depend on hiring of bullocks and tractors. Tractor power availability is more in Una district because of plain topography and some larger plots as compared to Kangra district where 80 % fields are less than 100 $m^2$ and irregular in shape. Similarly, the number of machines/tools/implements available by different farm groups (**Table 6**) shows that the farmers were dependant mainly on bullock drawn plough and planker for tillage operation as some farmers kept more than one plough per farm household. The tractor drawn cultivator was used for tillage operations by 8.5 % of farmers of the Una district. The diesel powered maize sheller and thresher were owned by the farmers that owned a tractor in the Una district. Hill agriculture systems are still dominated by human power as most of the farming operations are performed traditionally using manual tools and implements like clod breaker, khutti, kudali and plain sickle (**Fig. 2**). The table shows that the farmers of both the districts were using the manual and animal drawn tools/equipment.

**Table 7** shows the use trends of farm implements and machines by the farmers for various operations in both districts. Ploughing in both the districts was accomplished by thebullock drawn plough for 95.0 % of thefarmers in Kangra and 79.5 % in Una (**Fig. 3**). Tractor power in the Una district was used only by 20.5 % of the farmers for land preparation. In the Una district, due

**Table 4** Farm machinery population in Himachal pradesh

| Type of equipment/machinery | Population 1987 | Population 1992 | Population 1997 |
|---|---|---|---|
| Tractor | 1,319 | 2,189 | 3,466 |
| Power tiller | - | 12 | 25 |
| Diesel engine | 2,358 | 1,299 | 1,150 |
| Electric motor | 934 | 1,222 | 1,346 |
| Tractor drawn implements | | | |
| 1. Trailer | 1,306 | 2,124 | 3,385 |
| 2. Cultivator | 1,162 | 2,017 | 3,211 |
| Animal drawn implements | | | |
| 1. Plough | 799,207 | 710,349 | 689,562 |
| 2. Bullock cart | 4,722 | 1,128 | 532 |
| Sprayers | 11,607 | 10,525 | 11,815 |
| Thresher | 8,847 | 10,692 | 12,695 |

**Table 5** Power source availability with different farm groups

| Farm group | No. of farmers | | Animal owned | | Tractor owned | | Animal hired | | Tractor hired | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kangra | Ura | Kangra | Ura | Kangra | Ura | Kangra | Ura | Kangra | Ura |
| Marginal | 349 (87.25) | 294 (73.5) | 291 (83.38) | 200 (68.02) | 2 (0.57) | 11 (3.74) | 46 (13.18) | 41 (13.94) | 10 (2.86) | 42 (14.28) |
| Small | 50 (12.5) | 80 (20.0) | 40 (80.0) | 56 (70.0) | 2 (4.0) | 14 (17.5) | 3 (6.0) | 4 (5.0) | 5 (10.0) | 6 (7.5) |
| Medium | 1 (0.25) | 25 (6.25) | - | 17 (68.0) | 1 (100.0) | 8 (32.0) | - | - | - | - |
| Large | - | 1 (0.25) | - | - | - | 1 (100.0) | - | - | - | - |
| Total | 400 (100) | 400 (100) | 331 (82.75) | 273 (68.25) | 5 (1.25) | 34 (8.5) | 49 (12.25) | 45 (11.25) | 15 (3.75) | 48 (12.0) |

Note: Figure in parentheses are percentage of power source

**Table 6** Number of implements/machines available with different groups in Kangra and Una district

| Farm group | No. of farmers surveyed | | Manual operated: Kudali | | Sickle | | Clod breaker | | Sprayer | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kangra | Ura | Kangra | Ura | Kangra | Ura | Kangra | Ura | Kangra | Ura |
| Marginal | 349 | 294 | 957 | 986 | 1,465 | 1,427 | 1,186 | 283 | 8 | 38 |
| Small | 50 | 80 | 185 | 180 | 220 | 372 | 193 | 90 | 10 | 23 |
| Medium | 1 | 25 | 3 | 4 | 5 | 130 | 4 | 26 | 1 | 12 |
| Large | - | 1 | - | 3 | - | 7 | - | - | - | 1 |
| Total | 400 | 400 | 1,145 | 1,173 | 1,690 | 1,936 | 1,383 | 399 | 19 | 74 |

| Farm group | Animal drawn: Plough | | Planker | | Dandral | | Tractor/Power operated: Cultivator | | Maize sheller | | Thresher | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kangra | Ura | Kangra | Ura | Kangra | Ura | Kangra | Ura | Kangra | Ura | Kangra | Ura |
| Marginal | 442 | 373 | 284 | 212 | 250 | 178 | 2 | 13 | 1 | 12 | 1 | 16 |
| Small | 91 | 85 | 46 | 45 | 42 | 46 | 2 | 14 | 1 | 7 | 1 | 13 |
| Medium | 2 | 26 | - | 15 | 2 | 20 | 1 | 7 | - | - | 1 | 6 |
| Large | - | - | - | - | - | - | - | 1 | - | - | - | 1 |
| Total | 535 | 484 | 330 | 272 | 294 | 244 | 5 | 35 | 2 | 19 | 3 | 36 |

to plain topography and bigger size of fields compared to Kangra district, tractor power dominated. Clod formation after ploughing in hard soil after paddy is a major problem in the Kangra district.

The farmers of the Kangra district (89 %) were mainly using wooden clod breaker for clod breaking (**Fig. 4**). However, some farmers in both districts were using a bar harrow for the same purpose. The sowing operation was totally traditional and a majority of the farmers in Kangra (85 %) and Una (78 %) were using the broadcasting method of sowing. However, some farmers in both districts were also using the kera method for sowing of maize crop. Paddy sowing was mostly performed in Kangra district. The practice used for paddy sowing by a majority of the farmers (72 %) of Kangra was broadcasting of sprouted seed in puddled soil (**Fig. 5**) followed by thinning after one month.

A few farmers in the district (28 %) used nursery raising and then manual transplanting for paddy. For weeding operation 100 % farmers in both the districts were using manual operated khutti (local name) and kudali. A majority of the farmers in Kangra (92 %) and Una (78 %) were using a plain sickle for harvesting of crops. Only 8 % of farmers in Kangra and 22 % farmers in Una district were using serrated sickle. Wheat threshing operation was totally mechanized and accomplished by power operated wheat threshers by 100 % farmers of both districts. The tables show that 90 % of farmers in the Kangra district were using the traditional method of paddy thresh-

**Table 7** Use trends of farm implements and machines by the farmers for various operations

| Farm operations | Power source | Tools/implements/device used for different operations | Farmers used, % | |
|---|---|---|---|---|
| | | | Kangra | Una |
| Land preparation | | | | |
| a. Ploughing | Bullock | Desi plough, Soil strring plough | 95.0 | 79.5 |
| | Tractor | Cultivator | 5.0 | 20.5 |
| b. Clod breaking | Manual | Wooden hammer | 89.0 | 25.0 |
| | Bullock | Dandalti/Bar harrow | 11.0 | 20.0 |
| c. Planking | Bullock | Wooden planker | 95.0 | 79.5 |
| | Tractor | Wooden planker | 5.0 | 20.5 |
| d. Puddling | Bullock | Puddler/plough | 95.0 | 25.0 |
| | Tractor | Lugged wheel and cultivator | 5.0 | 10.0 |
| Sowing | Manual | Broadcasting | 85.0 | 78.0 |
| | Bullock | Kera | 15.0 | 22.0 |
| Transplanting/sowing | Manual | By hand transplanting | 28.0 | 25.0 |
| | Manual | Broadcasting of sprouted seed and then thinning after one mouth | 72.0 | 10.0 |
| Weeding | Manual | Khunti, kudali | 100.0 | 100.0 |
| Harvesting | Manual | Plain sickle | 92.0 | 78.0 |
| | Manual | Serrated sickle | 8.0 | 22.0 |
| Threshing | | | | |
| Wheat | Engine/tractor/motor | Thresher | 100.0 | 100.0 |
| Paddy | Bullock | Bullock treading | 90.0 | 10.0 |
| | Manual | Manual beating | 10.0 | 25.0 |
| Maize | Manual | Beating with stick/removing by fingers | 80.0 | 25.0 |
| | Engine/motor/tractor | Maize sheller | 20.0 | 75.0 |
| Winnowing | Manual | By hand | 86.0 | 62.0 |
| | Electric operated | Winnowing fan | 14.0 | 38.0 |
| Transportation | Manual | Manual | 90.0 | 65.0 |
| | Tractor | Trolley | 10.0 | 35.0 |

**Fig. 2** Traditional tools and implemets

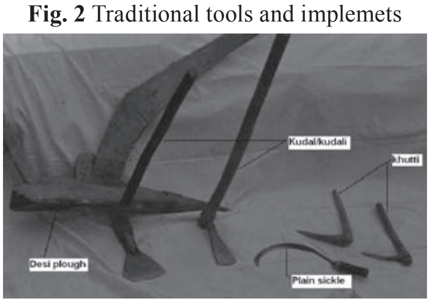



**Fig. 3** Ploughing of fields

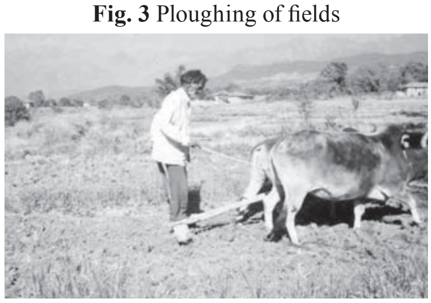


**Fig. 4** Wooden clod breaker in operation

ing, i.e., bullock treading. Maize shelling operation was performed manually by fingers or beating with a stick by 80 % farmers of the Kangra district. The same operation was mechanized in the Una district where 75 % of farmers used a power operated maize sheller. Manual winnowing was used by 86 % of farmers in Kangra and 62 % in the Una district. However, some farmers (38 %) in Una used a winnowing fan for winnowing of various crops. Transportation of farm products was mostly by manual power because of topography and poor network of roads in the farms.

The average annual use of a power source and matching implements for different operations is shown in **Table 8**. The average annual use of animal power was 265 h in Kangra and 140 h in Una. The use at the owners farm was 64.52 % in Kangra and 66.42 % in Una. For the rest of the time the power was utilized for custom hiring. The tractor annual use was 539 h and 756 h in Kangra and Una of which 20.22% and 23.67% were for land preparation, 16.69 % and 14.81 % for threshing and 61.78 % and 60.84 % for transportation in Kangra and Una, respectively. The tractor use was 17.63 % and 22.62 % at the owners farms; 82.37 % and 77.38 % for custom hiring in Kangra and Una, respectively. The maximum use of tractor was for transportation in both districts as small field size restricts the use of tractor in most of the farm operations.

**Table 9** shows the percentage of gender participation in various farm operations as carried out by the hilly farmers. Human power was predominantly used on farms. The table show that the ploughing, planking and puddling operations were carried totally (100 %) by the men whereas in other operations their involvement was much less than the women's except plant protection operation in both districts. The women were involved 60-85 % in various operations using mostly inefficient and drudgery oriented traditional tools.

The production status per year of manufacturers of agricultural tools and implements in both districts is given in **Table 10**. Only eight small units having annual sale ranging from Rs.250,000 to Rs.5,828,000 were identified. These manufacturers were engaged in fabricating/manufacturing conventional tools like the plough, digging hoe, khutti and hand rake. However, some units in Una district, adjoining Punjab were fabricating a few tractor drawn implements only on demand of the

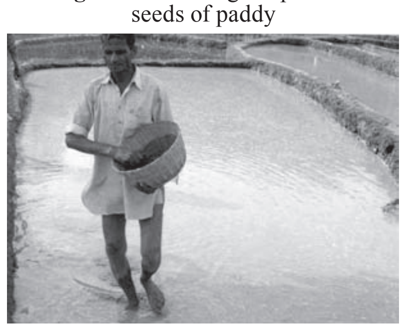
**Table 8** Average annual use of power source and maching implements for various operations in hours

| Power source | Use at own farm | | Custom hiring | | Total | |
|---|---|---|---|---|---|---|
| | Kangra | Una | Kangra | Una | Kangra | Una |
| **Animal power** | | | | | | |
| Ploughing | 74 | 56 | 48 | 30 | 122 | 86 |
| Planking | 15 | 10 | 8 | 5 | 23 | 15 |
| Puddling | 42 | 5 | 25 | - | 67 | 5 |
| Sowing | 12 | 8 | 5 | 6 | 17 | 14 |
| Interculture | 10 | 8 | - | 6 | 10 | 14 |
| Threshing | 8 | - | - | - | 8 | - |
| Transported | 10 | 6 | 8 | - | 18 | 6 |
| Total | 171 | 93 | 94 | 47 | 265 | 140 |
| **Tractor power** | | | | | | |
| Ploughing | 21 | 48 | 66 | 98 | 87 | 146 |
| Planking | 6 | 10 | 16 | 23 | 22 | 33 |
| Puddling | - | 5 | - | - | - | 5 |
| Sowing | 4 | - | 3 | - | 7 | - |
| Interculture | - | - | - | - | - | - |
| Threshing | 16 | 22 | 74 | 90 | 90 | 112 |
| Transported | 48 | 86 | 285 | 374 | 333 | 460 |
| Total | 95 | 171 | 444 | 585 | 539 | 756 |

**Table 9** Percentage of gender participation in various farm operations

| Farm operation | Men | | Women | |
|---|---|---|---|---|
| | Kangra | Una | Kangra | Una |
| Ploughing | 100 | 100 | - | - |
| Clod breaking | 22 | - | 78 | - |
| Planking | 100 | 100 | - | - |
| Puddling | 100 | 100 | - | - |
| Mannuring | 36 | 42 | 64 | 58 |
| Sowing | 28 | 24 | 72 | 76 |
| Transplanting | 30 | 25 | 70 | 75 |
| Interculture | 15 | 22 | 85 | 78 |
| Plant protection | 76 | 80 | 24 | 20 |
| Harvesting | 32 | 38 | 68 | 62 |
| Threshing | 48 | 45 | 52 | 55 |
| Winnowing | 15 | 18 | 85 | 82 |
| Transportation | 35 | 42 | 65 | 58 |

**Fig 5** Broadcasting of sprouted seeds of paddy



farmers. The tables show that conventional tools like the hand rake, soil stirring plough and digging hoe were fabricated in thousands per year but tractor drawn implements like the cultivator, thresher and trolley were in hundreds. The common facilities available for manufacturing the agricultural tools and equipment with manufacturers included the lathe, power hacksaw, welding set, hand shearing machine, portable drill, grinder, power press, gas welding set, pillar drills and spray painting equipment.

During the study, the farmers' responses were taken for improved farm tools, implements and machines for different farm operations (**Table 11**). The response from various farm groups shows that 90 % marginal farmers needed improved manual and animal drawn implements whereas the small farmers group showed keen interest in the power tiller with matching implements followed by animal drawn implements. The medium group of farmers needed the power tiller or tractor with matching implements.

Points suggested for mechanization in the state

Agricultural mechanization in the state is in its early stage and requires efforts/attention by policy makers, institutions and extension agencies to introduce suitable and efficient technology at the farmers' field. Based on the farmers need and topography of the region, the following steps are suggested for enhancing the pace of hill mechanization in the state.

1. Strengthening of the agricultural engineering department in the state and placement of agricultural engineers by the state government at various positions.
2. Adequate manual and animal drawn women friendly implements should be designed and developed to meet the need of marginal and small farmers.
3. Based on the topography and field size of the region, an appropriate source of farm power should be identified with matching implements.
4. Irrigation facilities should be provided by creation of small ponds/water harvesting device/ water lifting devices by the state government.
5. There should be a strong network of extension agencies for demonstration of the latest technology at the farmers' fields.
6. Small scale industries should

**Table 10** Production status per year of manufactures of agricultural tools and equipment (in thousand)

| Tools and equipment | M/s Pamico Industries, Sirat Road Mohtli, Kangra | M/s Kumar Steels Products, Damtal, Kangra | Himagrico Implements and Tools, H.P. Agro Industries, Jassur, Kangra | M/s Sarthak Agro Industries, Rampur, Una | M/s Jagdambe Industries, Jhalera, Una | M/s Niranjan Agro Industries, Amb Road, Una | M/s Ajit Engineering Works, Jhalera, Una | M/s Santokh (Onkar) Iron and Steel Fabrication, Una | Total |
|---|---|---|---|---|---|---|---|---|---|
| Hand rake | 1.5 | 1.5 | 1.5 | - | - | - | - | - | 4.5 |
| Digging hoe | 4.0 | 1.0 | 1.9 | - | - | - | - | - | 6.9 |
| Kudali | 1.2 | - | 3.4 | - | - | - | - | - | 4.6 |
| Tubular maize sheller | 15.2 | - | - | - | - | - | - | - | 15.2 |
| Gardening hoe | 0.4 | - | 2.1 | - | - | - | - | - | 2.5 |
| Spade | 0.05 | 3.0 | 2.3 | - | - | - | - | - | 5.35 |
| S.S. plough | 2.0 | 0.3 | 8.0 | - | - | - | - | - | 10.3 |
| Bar harrow | 0.1 | - | 0.2 | - | - | - | - | - | 0.3 |
| Khunti | - | 3.0 | - | - | - | - | - | - | 3.0 |
| Maize sheller | 0.9 | - | - | - | 0.01 | - | - | 0.03 | 0.94 |
| Cultivator | - | - | - | 0.06 | 0.05 | 0.1 | 0.01 | 0.03 | 0.25 |
| Leveller | - | - | - | 0.03 | 0.02 | 0.05 | 0.01 | 0.02 | 0.13 |
| Disc harrow | - | - | - | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 | 0.08 |
| Bund former | - | - | - | 0.04 | 0.01 | 0.03 | - | 0.02 | 0.10 |
| Trailer | - | - | - | 0.04 | 0.05 | 0.05 | 0.01 | 0.02 | 0.17 |
| Thresher | - | - | - | - | 0.03 | - | - | 0.04 | 0.07 |
| Seed drill | - | - | - | - | 0.02 | - | - | - | 0.02 |

**Table 11** Farm power source and tools/implements/machines required by farmers of different farm groups

| Type of power source, tools and implements | Response of various farm groups, % | | | |
|---|---|---|---|---|
| | Marginal | Small | Medium | Large |
| Manual drawn improved seed drill, paddy transplanter, sickle, weeder, paddy thresher | 58.5 | 18.6 | 7.8 | 2.0 |
| Animal drawn improved plough, clod breaker, seed drill, potato planter, digger | 31.2 | 32.8 | 21.3 | 10.4 |
| Power tiller with matching implements | 10.3 | 42.4 | 39.2 | 29.0 |
| Tractor with matching implements | - | 6.2 | 31.7 | 58.6 |

be encouraged by the state government for manufacturing of agricultural tools and implements to ensure availability to the farmers.

7. There should be frequent training programmes for the farmers/rural artisan on operation, fabrication, repair and maintenance of agricultural implements and machineries.
8. The state/central government should formulate a mechanization strategy for hill agriculture/horticulture and give a special separate package for hills.

## Conclusions

There is a tremendous scope of mountain agriculture mechanization in spite of the slow pace of hill agriculture mechanization in the state. About 80 % of the cultivated area falls under low and mid hills, which has potential to grow various horticultural and agricultural crops using a mechanical farm power source like tractors and power tillers with suitable matching implements. Availability of improved manual and animal drawn farm tools/implements to the farmers should be ensured by establishing small scale industry by the state government. There is a need to formulate policies, strategies and programmes in relation to total demand of farm power in agriculture, based on timeliness of operation and increased production goal in hills. For this purpose, a master plan for agricultural mechanization should be prepared and implemented keeping in view the long term objectives of the mountain agricultural development.

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# Design and Evaluation of Portable Tunnels for Summer Growth of Ornamental Plants

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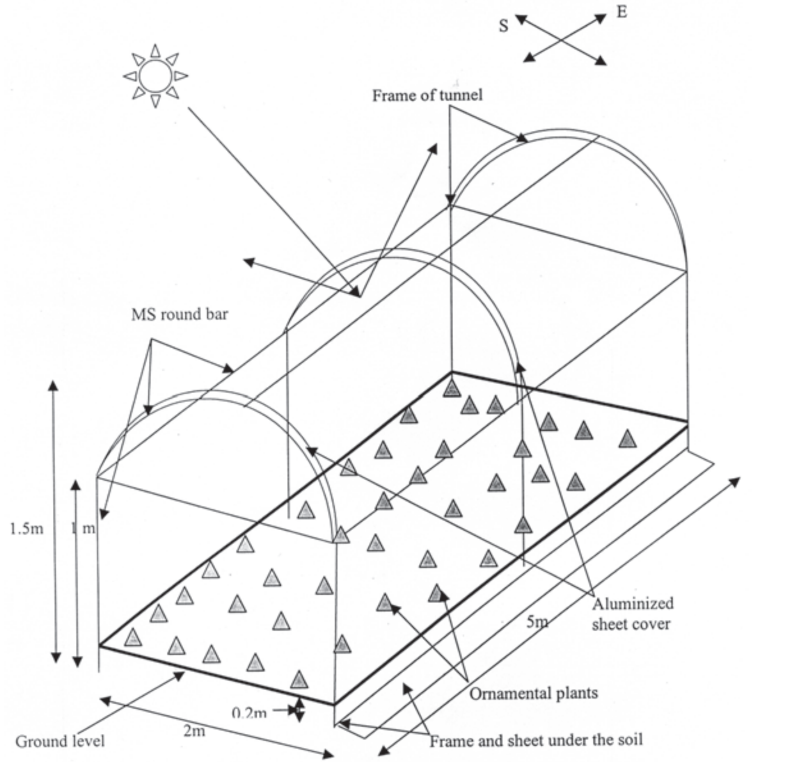
## Abstract

Tunnels with a new type of covering material, Aluminized Polyester Sheet (APS), have been designed and fabricated for improving the growth of ornamental plants in extreme summer. Experiments conducted for two consecutive years reveal that the designed tunnels are capable of improving the microclimate required for the selected ornamental plants namely chrysanthemum (*Chrysanthemum morifolium*) and balsam (*Impatient balasamina*) in extreme summer conditions. Changes in the microclimate and plant growth under the APS tunnels were recorded during the summer months of 2002 and 2003 and compared with that of outside environmental conditions. It was observed that the total average solar radiation and light intensity entering the APS tunnels reduced by about 78 % and 68 % and 80 % and 67.7 % respectively in the 2002 and 2003 as compared to open field conditions. The average plant and soil temperature was 5.5 ºC & about 2 ºC lower as compared to open field conditions. However, the average air temperature remained almost the same as compared to open field conditions. The average plant height of chrysanthemum and balsam was about 27 % and 40 % more as compared to the plants in open field conditions. This improvement in growth was attributed to the favorable microclimate like reduced light intensity, solar radiation and plant temperature achieved under the APST.

## Introduction

Protective cultivation is practiced in order to protect the ornamental plants against adverse weather conditions and to regulate better growth. Under Northern India climatic conditions, there are more sunshine hours all the year round. In hot summer months, maximum ambient air temperature and polyhouse air temperature exceed 42 ºC and 50 ºC, respectively, and become fatal for the plants grown inside the polyhouse. The plants grown in open field conditions during these months also do not grow properly and show stunted growth. There are many cooling techniques by which inside air temperature of the polyhouse can be controlled. Ventilation (natural or forced) of the polyhouse can lower the inside air temperature during autumn and spring but it becomes ineffective during hotter months of summer. Other methods like the fan and pad system and high pressure mist system must be employed for effective cooling of greenhouses during these months. These methods are economically not feasible at the small farmer level since they involve high initial and running costs. These methods also depend upon electricity, which is not regularly available in the villages of Punjab, India. There are many types of greenhouses using different types of cover materials. These can be used for growing ornamental plants and vegetables and by controlling the inside microclimate, depending upon the climatic conditions of an area. Albright (1978) tested a night curtain with both sides reflective. The polyhouse had 40 tons of rock for storage of solar energy in cold environment. During night, the curtain called "thermal screen" enclosed the heated rocks and the plants grown with less than a meter of clearance above plant height. It was observed that nighttime heating requirements were reduced by about 70 %. Cucumber was successfully grown by Campiotti (1988) in a 300 $m^2$ polycarbonate covered greenhouse at Rome, Italy. As reported by Kumar (2000), in order to control the light intensity, shading of the greenhouse roof was practiced during hot summer months. Commercial shading compounds prepared with paint pigments were used for this purpose. Lagier (1988) reported the effect of shading on the quality of tomatoes grown under a plastic greenhouse, which improved the growth of plants. Levev et al. (1987) constructed a greenhouse of 1,000 $m^2$ floor area for the cultivation of roses at Bet-Dagan, Ireland. The cover material was polyethylene (P.E.). Rebuck (1977) observed savings up to 60 % in heating requirements by using a night curtain of an aluminum foil hybrid fabric. Simpkins (1976) experimentally evaluated a number of curtain materials for conserving the heat during winter months. It was estimated that using a highly reflective internal curtain could save half of the energy needed to heat a double layer inflated polyethylene greenhouse. Sorenson (1989) used a greenhouse of 1,000 $m^2$ area for raising tomatoes at Copenhagen, Denmark in which glass was used as a cover material for creating the greenhouse effect. Yiannoulis (1990) used double PVC as a cover material over a greenhouse for growing tomatoes at Helsinki. Controlling the microclimate means modification of different thermal parameters like temperature, relative humidity, light and radiation inside the greenhouse. In developed countries, these protective structures fitted with cooling/heating systems are extensively used for raising full crops due to scientific and mechanized agriculture. Many studies like this have been conducted during the last two decades relating to the use of different covering materials and reflector sheets as night curtains to reduce the radiation heat loss from the greenhouse to the surroundings in cold environmental conditions of Europe and Canada. However, in tropical climates like India, environmental conditions are exactly opposite and greenhouses are required to be cooled for a longer time of the year rather than heating for the winter since they receive excessive solar radiation during the summer months of the year, which is much more than the requirements of the plants. The authors studied the different night curtains materials and thought of using these night curtains as reflector sheets to control the inside microclimate of a polyhouse. Studies conducted by Sethi et al. (2004) revealed that the Aluminized Polyester Sheet (APS) is capable of modifying the microclimate of the polyhouse by reducing the solar radiation, light intensity and air temperature. APS was used during peak hours (11 am to 4 pm) inside of a 100 $m^2$ polyhouse at a height of 2.5 m from the ground to reflect back the excessive solar radiation falling on the polyhouse. It was observed that the average daily direct solar radiation reduced by about 43 % and the average daily light intensity was reduced by about 50 %. The inside air temperature was decreased by 3 ºC as compared to the other polyhouse. These encouraging results inspired the authors to design and fabricate APS tunnels for the growth of ornamental plants during summer conditions of the year 2002.

**Fig. 1** Isometric view of a tunnel with aluminized polyester sheet as a cover material




The advantage of using an APS tunnel is that the reflection of direct solar radiation from the outer surface of the tunnel does not allow the inside air temperature to rise above the ambient. The reflection of direct solar harmful UV radiation does not reach the plants. Also, the amount of diffused light falling on the plants increased by about 30 % due to reflection of light from the internal metalized surface of the sheet, thereby satisfying the light requirements of the plants for effective photosynthesis. Moreover, the cost of APS is about four times less than UV stabilized polyethylene sheet at the current prices. Therefore, it was decided to design and fabricate APS tunnels for improving the microclimate during the extreme summer conditions when the conventional polyethylene sheet tunnels do not work at all due to very high inside air temperature. The growth of selected ornamental plants namely chrysanthemum (*Chrysanthemum morifolium*) and balsam (*Impatient balasamina*) was observed under these tunnels during the summer months of 2002 and 2003, respectively.

## Methods and Materials

Six APS tunnels of 5 m length x 2 m width and 1.5 m height were designed and fabricated in the Department of Mechanical Engineering, Punjab Agricultural University, and Ludhiana, Punjab, India (30º 15' N 77º 55' E), as shown in **Fig. 1**. The edges of the tunnel from east and west were not covered with the sheet in order to allow free movement of the air under the tunnels. Chrysanthemum plants already planted in the open field conditions were selected and two rows of three tunnels were placed over the plants in the month of June 2002. Orientation of the tunnels was kept as east-west. The entire thermal and plant data were recorded under tunnels and for open field conditions. The experiments were repeated in the summer months of 2003 and all environmental data were again recorded to confirm the results obtained in the previous year. This time the growth of balsam plants was observed under the APS tunnels. Plant growth was also recorded on a weekly basis.

The environmental data after each hour was recorded from 7 am to 7 pm each day. The weekly average of each parameter was taken, including the maximum and minimum values of each day. Air temperature under the tunnel was recorded vertically and horizontally at three places by hanging the sensors at different heights (0.5 m, 1 m) from the ground and lengths (2 m and 4 m from the east side). The temperature in an open field was recorded by hanging the sensor in a shade 2 m above the ground with digital thermometers. Plant temperature means of the leaf were recorded with a gun type infrared thermometer. The

**Table 1** Comparative environment data for open field conditions and under tunnels, summer 2002

| Mouth | Week | Open field | | | | | Under APS tunnel | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Air temp., ºC | Soil temp., ºC | Radition, W/m$^2$ | Light, Klux | Plant temp., ºC | Air temp., ºC | Soil temp., ºC | Radition, W/m$^2$ | Light, Klux | Plant temp., ºC |
| June | I | 37.2 | 29.0 | 385 | 66.6 | 39.6 | 37.4 | 28.0 | 52.0 | 15.0 | 33.8 |
| | II | 39.3 | 31.1 | 345 | 63.8 | 42.5 | 39.1 | 27.2 | 37.7 | 12.2 | 36.5 |
| | III | 34.4 | 29.5 | 330 | 60.4 | 37.8 | 33.5 | 26.4 | 69.2 | 16.9 | 32.0 |
| | IV | 37.1 | 30.6 | 425 | 75.7 | 40.3 | 38.3 | 28.1 | 88.7 | 24.0 | 34.1 |
| July | I | 32.1 | 30.6 | 288 | 60.3 | 35.3 | 32.3 | 28.9 | 67.6 | 18.2 | 30.6 |
| | II | 34.6 | 34.1 | 384 | 72.7 | 38.4 | 35.9 | 33.3 | 95.2 | 23.6 | 33.1 |
| | III | 33.8 | 31.8 | 381 | 73.7 | 37.5 | 34.1 | 32.6 | 76.2 | 18.5 | 31.7 |
| | IV | 32.3 | 33.2 | 334 | 62.2 | 33.9 | 33.5 | 30.7 | 51.6 | 15.1 | 28.9 |
| Aug. | I | 33.0 | 33.0 | 294 | 59.8 | 35.8 | 34.6 | 32.4 | 90.6 | 23.9 | 30.2 |
| | II | 32.0 | 32.7 | 350 | 68.0 | 35.6 | 33.2 | 29.8 | 77.2 | 22.2 | 30.1 |
| | III | 32.5 | 32.3 | 266 | 53.7 | 35.4 | 32.7 | 30.2 | 102.0 | 25.7 | 29.7 |
| | IV | 32.8 | 33.1 | 220 | 46.7 | 36.2 | 34.5 | 31.0 | 76.0 | 25.9 | 31.1 |
| Average | | 34.2 | 31.7 | 333.5 | 63.63 | 37.3 | 34.9 | 29.9 | 73.6 | 20.1 | 31.8 |

**Table 2** Comparative environment data for open field conditions and under tunnels, summer 2003

| Mouth | Week | Open field | | | | | Under APS tunnel | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Air temp., ºC | Soil temp., ºC | Radition, W/m$^2$ | Light, Klux | Plant temp., ºC | Air temp., ºC | Soil temp., ºC | Radition, W/m$^2$ | Light, Klux | Plant temp., ºC |
| June | I | 31.9 | 28.7 | 302 | 62.7 | 34.3 | 31.7 | 26.8 | 54.3 | 19.5 | 29.5 |
| | II | 33.7 | 30.1 | 356 | 61.9 | 37.5 | 33.2 | 28.7 | 78.6 | 20.4 | 31.2 |
| | III | 34.5 | 29.3 | 349 | 63.7 | 38.4 | 34.4 | 27.5 | 79.9 | 21.3 | 32.7 |
| | IV | 32.4 | 30.3 | 389 | 67.9 | 35.8 | 32.8 | 28.2 | 80.3 | 22.5 | 30.8 |
| July | I | 33.6 | 30.9 | 378 | 69.6 | 37.9 | 33.3 | 27.9 | 75.4 | 22.9 | 32.5 |
| | II | 31.7 | 30.1 | 335 | 65.9 | 34.8 | 30.8 | 29.1 | 65.9 | 19.6 | 29.9 |
| | III | 31.7 | 29.9 | 389 | 69.2 | 34.5 | 29.6 | 28.6 | 74.6 | 21.8 | 29.5 |
| | IV | 32.2 | 30.3 | 423 | 72.9 | 36.5 | 31.3 | 28.6 | 85.7 | 25.4 | 31.2 |
| Aug. | I | 29.7 | 26.7 | 316 | 61.8 | 33.7 | 31.2 | 25.2 | 58.9 | 20.1 | 28.6 |
| | II | 28.8 | 25.7 | 278 | 64.2 | 32.1 | 24.9 | 24.3 | 46.7 | 22.7 | 28.1 |
| | III | 34.6 | 32.8 | 224 | 51.7 | 38.3 | 33.2 | 31.6 | 40.1 | 14.5 | 32.6 |
| | IV | 33.1 | 31.3 | 213 | 52.3 | 36.8 | 31.8 | 30.8 | 35.6 | 13.4 | 30.3 |
| Average | | 32.3 | 29.6 | 329.3 | 63.9 | 35.9 | 31.5 | 28.1 | 64.6 | 20.6 | 30.5 |

thermometer was pointed towards the leaf of 4-5 plants from about 30 cm and an average taken. Relative humidity was recorded with a thermo hygrometer. Direct as well as diffuse radiation in W/m$^2$ was measured using a suryampi also called solarimeter. A digital luxmeter was used to measure light intensity in kilo lux. Cost of the designed tunnel with aluminized polyester sheet as a cover material is very low since the proposed aluminized polyester sheet is one-fourth the cost of the polyethylene sheet. The APS is very light weight and is tough enough to withstand wind loads up to 60 km/hr. With only about 1.5 kg of sheet, one APS tunnel of 5 m x 2 m x 1.5 m size can be covered. The MS round bar used for one tunnel frame weighs only about 10 kg, as shown in **Fig. 1** and the low weight of the tunnel makes it portable. The major advantage of the tunnel is that there is no need to grow the plants under the tunnel; instead the plants can be grown in the open field during the months of mild summer. When the extreme summer starts, these tunnels can be placed over the plants for providing favorable microclimate, hence saving them from unnecessary heat and light. During the rainy season of July and August in India, these plants can also be saved from rain. It is only when the weather improves during the month of September, i.e. when the solar radiation and light intensity decreases, these tunnels can be removed thereby providing the congenial environment to the plants for their further growth.

## Results and Discussion

Complete micro climatic data were recorded for open field conditions and under the APS tunnels during the summer months of year 2002 and 2003 is shown in **Table 1** and **2**.

**Solar Radiation**

Total average solar radiation for three months for open field conditions and under the APST was 333.5 W/m$^2$ and 73.6 W/m$^2$ in 2002 and 329.3 W/m$^2$ and 64.6 W/m$^2$ for 2003. This reduction in the total solar radiation was about 78 % in 2002 and is about 80 % in 2003, which was comparable. This significant reduction is because of the reflection of the direct solar radiation by the aluminized sheet during the day. It was also observed that the amount of diffused radiation falling under the tunnel increased by about 30 % due to the re-reflection of the diffused light from inside of the aluminized sheet.

**Air Temperature**

Total average air temperatures under the APS tunnel in the open field for three months were 34.2 ºC and 34.9 ºC in 2002 and 32.3 ºC and 31.5 ºC in 2003. This difference was almost the same each year because of full ventilation of tunnel due to free flow of the air under the tunnels. There was no rise in inside air temperature due to any greenhouse effect thus keeping the inside air temperature under control. Whereas Sethi (2004) reported that air temperature inside the polyhouse increased by 8-10 ºC as compared to open field conditions, which made it impossible to grow vegetables or ornamental plants inside the greenhouse during extreme summer months in Northern India climatic conditions.

**Plant Temperature**

Total average plant temperature for three months in open field conditions and under APS tunnel was 37.3 ºC and 31.8 ºC in 2002 and 35.9 ºC and 30.5 ºC for 2003. This reduction in the plant temperature was about 5.5 ºC for both the years, which showed that the plants absorbed less solar radiation due to reflection of the direct radiation falling on the tunnel. Hence, the temperature of the inside plants remained lower, which was favorable for their better growth.

**Soil Temperature**

Total average soil temperature for

**Fig. 2** Compared growth of chrysanthemum plants

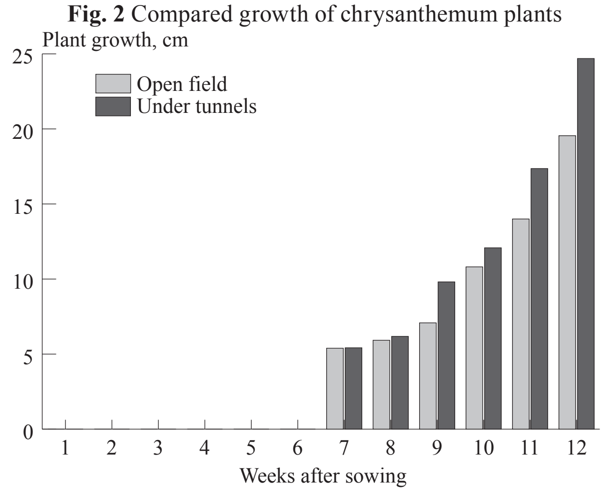
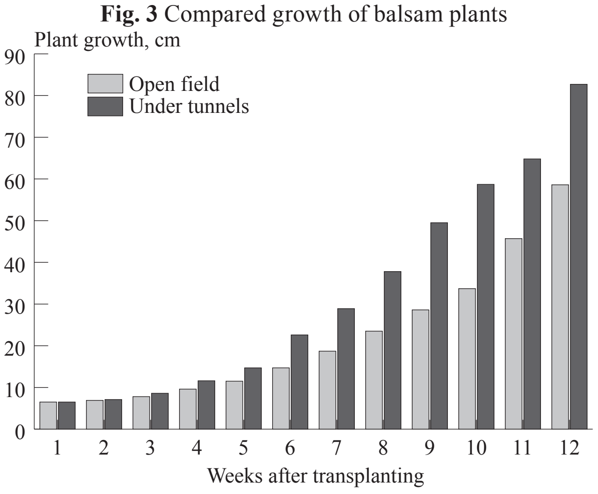



**Fig. 3** Compared growth of balsam plants



three months in open field conditions and under the APS tunnel was 29.9 ºC and 31.7 ºC in 2002 and 30.5 ºC and 35.9 ºC for 2003. This reduction in the soil temperature was less than 2 ºC as compared to open field conditions for both the years, which showed that less solar radiation falling on the sod floor under the tunnels absorbed less heat.

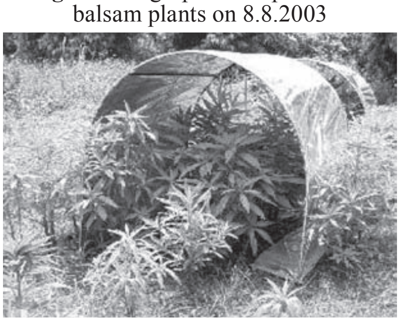
**Light Intensity**

Total average light intensity for three months in open field conditions and under the APST was 63.6 kilo lux and 20.1 kilo lux in year 2002 and 63.9 kilo lux and 20.6 for 2003. This reduction in the light intensity was about 68 % in 2002 and is about 67.7 % in 2003, which was comparable. This significant reduction was, again, due to the reflection of direct sun light falling on the APS tunnel. However, Kumar (2000) reported that light requirements of selected ornamental plants for photosynthesis were about 20 kilo lux only and the leaf even becomes light saturated at about 12 kilo lux. Thus, the reduction in the intensity of light inside the APS tunnel was sufficient during summer months to meet the photosynthesis requirements of the plants.

**Relative Humidity**

Relative Humidity for each day in the month of June 2002 was recorded under APST and in open field conditions. The difference was negligible so the further recording of this parameter was stopped.

**Fig. 4** Photographic comparison of balsam plants on 8.8.2003



**Plant Growth**

Plant growth data were recorded from the sixth week onwards in 2002 for chrysanthemum plants. The plants under APS tunnels showed a significant increase in the height as compared to the plants under the open field conditions. The growth of the plants was about 19.5 cm after twelfth week, whereas, the plants grown under the reflector sheet tunnels were about 24.7 cm high, which was almost 27 % more, as shown in **Fig. 2**. The plant growth of balsam plants was also recorded on weekly basis in the year 2003, as shown in **Fig. 3**. A significant increase in the growth of plants was observed under the APS tunnels. After the end of twelfth week, the average height of plants outside in the open field conditions was 58.6 cm and was 82.7 cm under the tunnels, which was about 40 % more as compared to the open field conditions. Actual growth of the plants has been shown in **Fig. 1** by removing the central tunnel. Due to better growth under the tunnels, some of the plants showed early flowering. After August, environmental conditions improved in the open field, therefore, the APS tunnels were removed from above the plants for their natural growth. This increase in the plant growth was attributed to the overall favorable microclimate, namely, reduction in the solar radiation, light intensity and plant temperature during the summer months of both the years using APS tunnels.

## Conclusions

Based on the results the following conclusions can be drawn.

1. Tunnels with aluminized polyester sheet as a cover material can significantly improve the microclimate required for the ornamental plants under extreme summer months.
2. The growth of chrysanthemum plants improved by about 27 % and balsam plants by about 40 % as compared to open field conditions when these plants were grown under the aluminized polyester sheet tunnels.

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# A Simulation Program for Predicting Haulage Performance of 2WD Tractor and Balanced Trailer System


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## Abstract

A windows based user-friendly simulation program on haulage performance of 2WD tractor and balanced (four wheels or two axles) trailer system for different terrains and operating conditions was developed in Visual Basic 6.0 programming language to meet the requirements for both educational and research programs. The program predicted the haulage performance of a selected tractor-trailer system by linking databases such as tractor specification, trailer specification and operating conditions. To validate the developed program, field experiments were carried out on a 23 kW 2WD tractor coupled with balanced trailer on three different terrains. It was found that the program over predicted the draft upto 17.0 % and under predicted the fuel economy and transport productivity to an extent of 12.5 and 15.7 % respectively for the selected tractor-trailer system.


## Introduction

The production and use of tractors in India have increased drastically in the last two decades. Most of them, especially the small, light units, were used for hauling with trailers throughout the year, furnishing indispensable transportation on country roads for rural economic development. However, in developing countries, tractors have been mostly designed to meet the requirement of field operations. Not much attention has been paid by the designers to the requirement of haulage work while designing a new tractor. This has led to fatal accidents on bumpy, curved and uneven surfaces when the tractor has been used with a trailer. Despite this difficulty, transportation of commodities through a tractor-trailer system has been popular and amounts to as much as 70 percent of total use of tractor (Mohan, 1990). In view of greater use of tractors for haulage work, it is desirable to evaluate the performance of the tractor-trailer system for varying loads and surface conditions and suggest remedial measures for their safe and efficient operation.

Computer models and simulation programs for predicting tractor haulage performance under various terrains and operating conditions help researchers to determine the relative importance of many factors affecting the haulage performance of tractor-trailer systems without conducting expensive, time consuming field experiments. They also help researchers to improve the haulage performance by comparing and analyzing various parameters that influence the tractor-trailer system performance. With the fast development in computer software and hardware, it is necessary to take advantage of the recently introduced programming tools such as Visual Basic for developing flexible and user-friendly programs for various applications. It is considered as a new approach to study the haulage performance for the need of educational and research institutions. In light of the above, a study was undertaken to develop mathematical models from the mechanics of the 2WD tractor-balanced trailer combination on an inclined surface in accelerated mode and to develop a simulation program using Visual Basic 6.0 for predicting the haulage performance.

## Literature Review

Although much research has been

conducted on the dynamics, stability and performance of an agricultural tractor alone, the system with a trailer has been received less attention. Most studies on the tractor-trailer system have been conducted in European countries (Dwyer, 1970; Sagi et al., 1972; Crolla and Hales, 1979; Hunter, 1981; and Xie and Claar II, 1985). Research on this area has concentrated on the determination of the braking performance of different tractor-trailer systems under various loading conditions and braking arrangements. Crossley (1982) designed a computer program to predict vehicle performance and costs based on the combination of a number of technical, agricultural and economic factors concerned with the vehicle and terrain over which it was operated. Bheemsen and Datta (1995) carried out field experiments, which were time consuming and laborious to optimize some operational parameters of a 2WD tractor operated with a four-wheel trailer for haulage work from the standpoint of fuel economy. Al-Hamed and Al-Janobi (2001) developed a computer program on tractor performance in Visual C++ using Brixius (1987) tractive prediction models that predicts the performance of 2WD and 4WD/MFWD tractors for both bias ply and radial tires to meet the requirement of both educational and research programs.

## Mathematical Models Development

The free-body diagram of a 2WD tractor with balanced trailer to study the longitudinal stability, tractive ability and transport performance is shown in **Fig. 1**. The force analysis was done for trailer and tractor separately and are as follows:

**Balanced Trailer's Equations**

The vertical force exerted at hitch point for balanced trailer is very small and, thus, assumed to be zero for simplification of the analysis.

Referring to **Fig. 1**,

$D = W_t (\sin \beta + a/g) + \rho_{tr} W_t \cos \beta + (\rho_{tf} - \rho_{tr}) R_{tf}$ ..........................(1)

where,

D = draft or horizontal force at tractor hitch point,

$W_t$ = gross weight of the trailer,

a = acceleration,

g = acceleration due to gravity,

$\rho_{tr}$ = coefficient of rolling resistance of rear tires of the trailer,

$\rho_{tf}$ = coefficient of rolling resistance of front tires of the trailer,

$R_{tf}$ = normal reaction on front tires of the trailer, and

$\beta$ = upward inclination of surface.

Considering the moment of all the forces about ground contact point '$C_1$' of rear axle tire, the normal reaction at front tires, $R_{tf}$ is obtained as follows:

$$R_{tf} = \frac{W_t [(L_{tr} - \rho_{tr} r_t) \cos \beta - h_t (a/g + \sin \beta)] + IH_v}{L_a - (\rho_{tf} - \rho_{tr}) H_v} \qquad (2)$$

where,

$I = \rho_{tr} W_t \cos \beta + W_t \sin \beta + W_t a/g$

$h_t$ = overall C.G. height of loaded trailer above the ground,

$H_v$ = tractor's hitch point height above the ground,

$L_a$ = horizontal distance between axles of balanced trailer,

$L_{tr}$ = horizontal distance between

**Fig. 1** Free-body diagram of 2WD tractor and balanced trailer system on an inclined surface

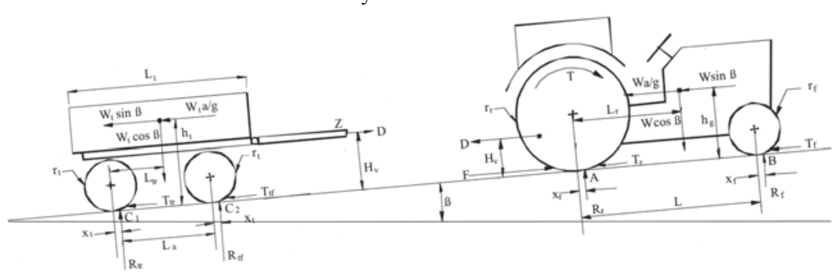


**Fig. 2** Opening screen of the haulage performance program

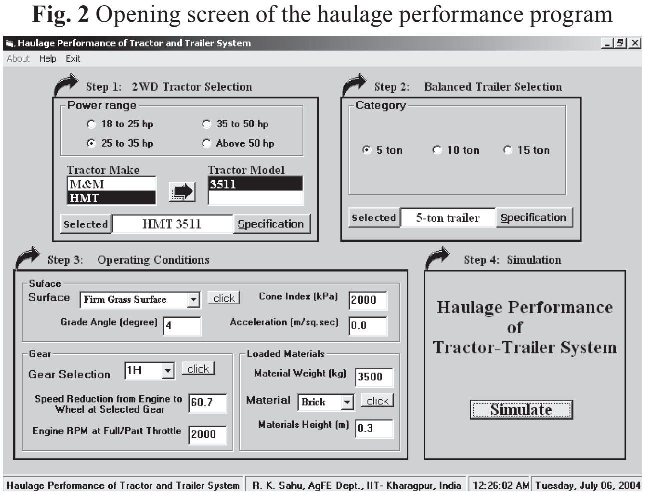
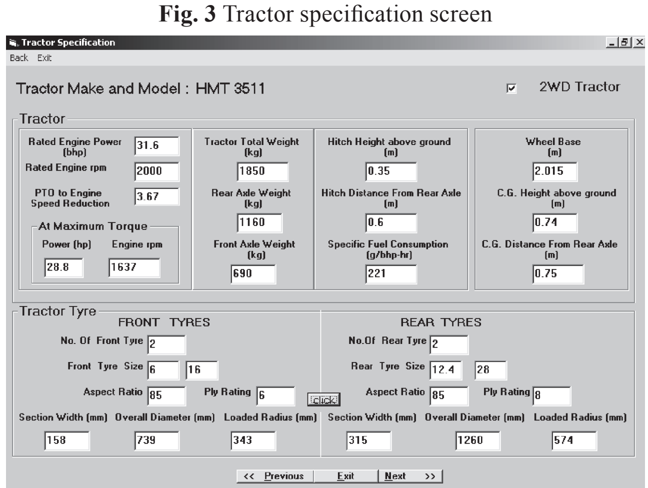



**Fig. 3** Tractor specification screen



C.G and center of rear axle of the trailer, and

$r_t$ = rolling radius of the trailer tire.

The normal reaction at rear tires, $R_{tr}$ is given by

$R_{tr} = W_t \cos\beta - R_{tf}$ ......................(3)

**2WD Tractor Equations**

Referring to **Fig. 1**,

$F = D + W\, a/g + W \sin\beta + T_f + T_r$ ...........................(4)

$R_f = W \cos\beta - R_r$ ........................(5)

where,

F = thrust required at tire-surface interface,

W = weight of the tractor,

$T_f$ = rolling resistance of front tires of the tractor = $\rho_f \bullet R_f$,

$T_r$ = rolling resistance of rear tires of the tractor = $\rho_r \bullet R_r$,

$\rho_f$ = coefficient of rolling resistance of front tires of tractor,

$\rho_r$ = coefficient of rolling resistance of rear tires of tractor,

$R_f$ = normal reaction at front axle of tractor, and

$R_r$ = normal reaction at rear axle of tractor.

Taking the moment of all forces about the contact point 'B' of front tire with ground (**Fig. 1**), the normal reaction at rear axle is expressed as follows:

$$R_r = \frac{[W(L + x_f - L_r)\cos\beta + W h_g (a/g + \sin\beta) + DH_v]}{L + x_f - x_r} \quad \text{...........................(6)}$$

where,

L = wheel base of tractor,

$L_r$ = distance between C.G. and center of rear axle of tractor,

$h_g$ = C.G. height of tractor above the ground,

$x_f$ = eccentricity of front tires of tractor = $\rho_f \bullet r_f$ (Liljedahl et al., 1978),

$x_r$ = eccentricity of rear tires of tractor = $\rho_r \bullet r_r$ (Liljedahl et al., 1978),

$r_f$ = rolling radius of front tire of tractor, and

$r_r$ = rolling radius of rear tire of tractor.

The coefficients of rolling resistance of the driving wheels as well as towed wheels are calculated using Brixius' equation (Brixius, 1987).

**Thrust Developed at Soil-tire Interface**

Thrust developed depends on the axle torque available in each gear, slip and soil-tire interaction. The governing equations used for predicting tractive force based on engine torque and traction potential of tire are as follows:

**Tractive Force Based on Engine Torque**

The tractive force developed, particularly in higher gears where it is not limited by soil-tire interaction, (Liljedahl et al., 1978) is given by the following relationship:

$F_t = T/r$ ..........................................(7)

where,

T = axle torque,

$F_t$ = tractive force, and

r = rolling radius of driving wheel.

**Tractive Force Based on Soil-tire Limitation**

The maximum tractive force ($F_b$) on any surface, limited by soil-tire interaction is determined using Brixius' equation (Brixius, 1987):

$F_b = R_r\,[0.88\,(1 - e^{-0.1Bn})(1 - e^{-7.5S}) + 0.04]$ ..........................................(8)

where,

$B_n$ = Brixius number, and

S = wheel slip.

In actual working condition, the tractive force developed will be lower of the two values given by Eqns. (7) and (8) and equal to the tractive force required to overcome draft, rolling resistance, grade resistance, etc.

## Models Used for Predicting Haulage Performance

Haulage performance parameters include tractive and transport performance parameters. The tractive performance was evaluated based on coefficient of traction (COT), wheel slip (S), and tractive efficiency (TE) and was determined by using Brixius (1987) equations. The transport performance was evaluated based on transport productivity

**Fig. 4** Trailer specification screen

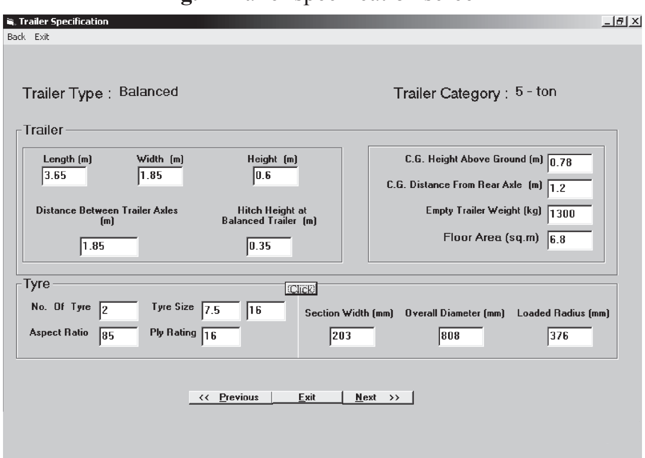
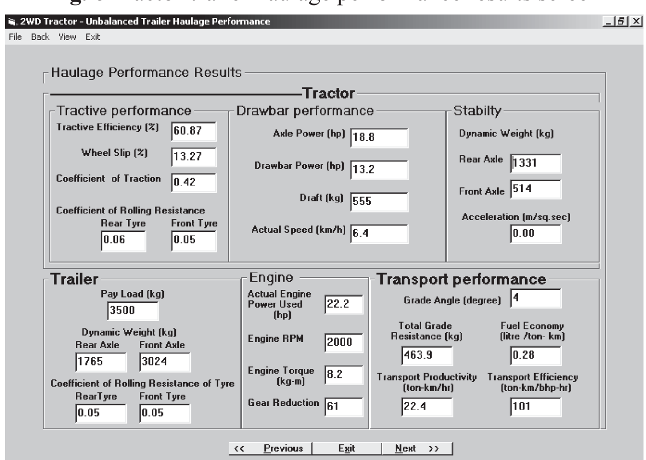



**Fig. 6** Tractor-trailer haulage performance results screen



(TP), transport efficiency (TPE), fuel economy (FE) and upward grade resistance (GR) as described by Wong (1993). Fuel consumption of a tractor was calculated using the ASAE Standards (2001).

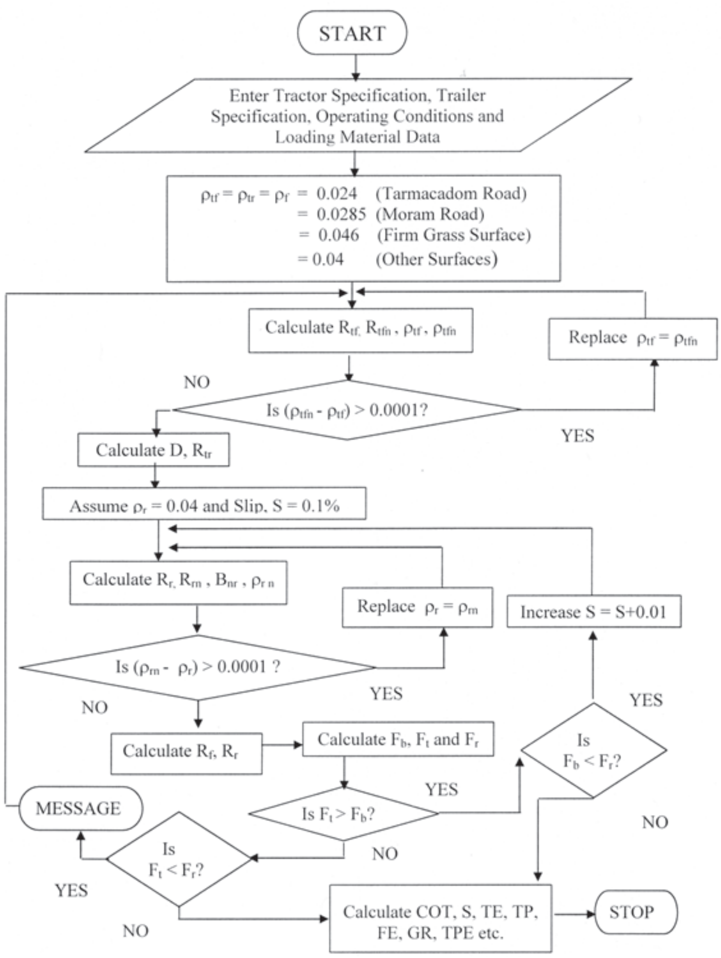
## Development of Haulage Performance Program

Visual programming provides a set of screens, object buttons, scroll bars and menus. The objects can be positioned on a form and their behaviors are described through the scripting language associated with each one. Visual Basic environment containing several windows that serve specific purposes in the development process was used to develop this program. The developed simulation program on haulage performance of tractor-trailer system mainly consists of two sections, menus and four frames (**Fig. 2**). Each menu and frame has specific use based on the requirement. The working and simulation of the program are discussed in the following paragraphs.

The program starts with an opening screen as shown in **Fig. 2**. It consists of menus like About, File, Help and Exit and four frames. As soon as the program opens the About menu is activated and, thus, the four frames, input boxes, command buttons, etc. are visible to the user. The File menu has the option for saving the input data. The Help and Exit menus guide the user for proper execution and to close the program respectively. The first frame guides the user to select a tractor make and model. A particular tractor make and model can be selected from the tractor selection database, which contains a number of tractors manufactured by different companies and the corresponding model number. This database is linked to the tractor specification database (**Fig. 3**) and in effect linked to the other databases. The second frame of the main screen provides information on selection of trailer and its specifications (**Fig. 4**). The third frame of the opening screen contains information on the operating parameters such as type of surface, cone index, upward slope of the surface, acceleration, gear, engine rpm, type of material and its weight. All these input data set can be displayed to the user for any change if needed without affecting the databases before simulation.

The haulage performance of the selected tractor-trailer system on a particular operating condition is predicted by clicking the Simulate (**Fig. 2**) button. The flowchart for predicting haulage performance is given in **Fig. 5**. The simulation results screen (**Fig. 6**) with menus File, Back, View and Exit is intuitive to users and highly flexible in specifying the type of output from the simulation. The View menu has three dropdown menus like tractor specification sheet, trailer specification sheet and operating parameters sheet. By clicking any of them, the user can access that screen for any modification of data before another simulation. The command buttons like Previous, Next and Exit are provided in different screens to access the previous and next screens and to end the program whenever required. The haulage performance program developed in visual programming environment is illustrated by selecting an example of HMT 3511 tractor and 5 ton trailer from the tractor and trailer specification databases respectively. The various stages of predicting tractor haulage performance parameters are shown in **Figs. 2**, **3**, **4** and **6**.

**Fig. 5** Flowchart for the haulage performance program



tractor-trailer system.

## Field Experiments to Validate the Program

Field experiments were conducted with 23 kW 2WD tractor and 5 ton balanced trailer on three different terrain surfaces (namely tarmacadom, moram and firm grass surfaces) in second high (2H) gear at full throttle position for validation of the developed program. The payload on the trailer was varied from 0 to 4,200 kg in four steps with loading brick on the trailer The tractor-trailer system was operated in the selected gear and throttle position over a distance of 250 m to measure the draft, fuel consumption and actual forward velocity of the system during the test. A three-point hitch platform was used to mount a spring dynamometer for measuring draft experienced at hitch point. An auxiliary fuel measuring system measured fuel consumption of the tractor during the tests. The actual forward velocity of the test tractor was calculated by measuring the time taken over a fixed distance with a stopwatch. A total number of 36 experiments with three replications were conducted using the tractor-trailer system.

## Results and Discussion

**Experimental Data Analysis**

The average values of the experimental data on haulage performance of the 2WD tractor with balanced trailer are given in **Table 1**. The data indicated that the experimental draft with the trailer increased from 30 to 125 kg on tarmacadom surface, 35 to 145 kg on moram surface and 55 to 240 kg on firm grass surface with increase in payload from 0 to 4,200 kg. Comparing the results on different surfaces, it was noticed that the draft was maximum on firm grass surface followed by moram and tarmacadom surfaces with the trailer. This was mainly due to higher rolling resistance of the trailer on firm grass surface compared to other two surfaces. During the experiments, the fuel consumption of the tractor was measured and then expressed as fuel economy in terms of l/ton-km. From the **Table 1**, it can also be seen that the experimental fuel economy with the trailer decreased from 0.26 to 0.10 l/ton-km on tarmacadom surface, 0.27 to 0.11 l/ton-km on moram surface and 0.32 to 0.13 l/ton-km on firm grass surface with increase in payload from 1,250 to 4,200 kg. The fuel economy of the tractor was higher on firm grass surface due to high rolling resistance compared to other two surfaces. From the field experiments, the transport productivity was calculated by multiplying payload on the trailer and the actual forward speed of operation and then was expressed in terms of ton-km/h. It was found from the **Table 1** that the variation of transport productivity among the three surfaces was much less.

**Validation of the Developed Program**

In order to validate the developed program, the program was executed 12 times, maintaining the same operating conditions during the field experiments. The simulation results on haulage performance of the tractor-trailer are also shown in **Table 1**. The variation between experimental and simulation results was calculated by the following expression and presented in **Table 2**.

Variation, % = (Experiment value - Simulation value) / Experiment value x 100

**Table 1** Haulage performance parameters of 2WD tractor with balanced trailer in 2H gear and full throttle position on level surface

| Payload, kg | Experimental results | | | Simulation results | | |
|---|---|---|---|---|---|---|
| | D, kg | FE, l/ton-km | TP, ton-km/h | D, kg | FE, l/ton-km | TP, ton-km/h |
| **a. Tarmacadom surface** | | | | | | |
| 0 | 30 | - | 0.00 | 31 | - | 0.00 |
| 1,250 | 55 | 0.26 | 16.99 | 61 | 0.24 | 14.40 |
| 2,500 | 80 | 0.16 | 33.98 | 91 | 0.17 | 28.80 |
| 4,200 | 125 | 0.10 | 56.18 | 132 | 0.09 | 48.00 |
| **b. Moram surface** | | | | | | |
| 0 | 35 | - | 0.00 | 37 | - | 0.00 |
| 1,250 | 65 | 0.27 | 17.08 | 73 | 0.26 | 14.40 |
| 2,500 | 95 | 0.17 | 34.00 | 108 | 0.15 | 28.70 |
| 4,200 | 145 | 0.11 | 56.18 | 157 | 0.10 | 47.80 |
| **c. Firm grass surface** | | | | | | |
| 0 | 55 | - | 0.00 | 60 | - | 0.00 |
| 1,250 | 100 | 0.32 | 16.87 | 117 | 0.31 | 14.30 |
| 2,500 | 160 | 0.19 | 33.22 | 175 | 0.18 | 28.30 |
| 4,200 | 240 | 0.13 | 54.52 | 253 | 0.12 | 47.00 |

**Table 2** Variation of simulated results from experimental results in 2H gear and full throttle

| Payload, kg | Variation in percentage | | |
|---|---|---|---|
| | D | FE | TP |
| **a. Tarmacadom surface** | | | |
| 0 | -3.33 | - | - |
| 1,250 | -10.91 | 7.69 | 15.24 |
| 2,500 | -13.75 | 12.50 | 15.24 |
| 4,200 | -5.60 | 10.00 | 14.56 |
| **b. Moram surface** | | | |
| 0 | -5.71 | - | - |
| 1,250 | -12.31 | 3.70 | 15.69 |
| 2,500 | -13.68 | 11.77 | 15.59 |
| 4,200 | -8.28 | 9.09 | 14.92 |
| **c. Firm grass surface** | | | |
| 0 | -9.09 | - | - |
| 1,250 | -17.00 | 3.13 | 15.23 |
| 2,500 | -9.38 | 5.26 | 14.81 |
| 4,200 | -5.42 | 7.69 | 13.79 |

-ve value shows over prediction and +ve value shows under prediction

It can be seen from **Table 2** that the program over predicted the draft (3.33 to 17 %) and under predicted the fuel economy (3.13 to 12.5 %) and the transport productivity (13.79 to 15.69 %) for the selected tractor-trailer system on different terrain surfaces.

## Conclusions

A user friendly windows based simulation program was developed in Visual Basic 6.0 programming language to predict the haulage performance of 2WD tractor-balanced trailer system by linking databases such as tractor specification, trailer specification and operating conditions. For the users, the program developed in visual programming environment is highly flexible and easy to learn and operate as compared to program developed using any other software tool prior to the visual programming tool. While validating the program, it was found that the program over predicted the draft upto 17.0 % and under predicted the fuel economy and transport productivity upto 12.5 and 15.7 % respectively for the selected tractor-trailer system on different terrain surfaces. The low values in variation between experimental and simulated data show that this approach will be of great use for educational and research program in predicting haulage performance parameters of the tractor-trailer system. Also, the advantage of developing the simulation program is that it can simulate the tractor-trailer system motion under various surfaces and operating conditions to know the safe payload on the trailer for safe and efficient operation of tractor-trailer system. It was found during simulation of the program that the evaluation of haulage performance of the tractor-trailer system was very quick and consistent.

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# Comparative Performance of Four Bullock Drawn Puddlers

by

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## Abstract

Four different bullock drawn puddlers were tested under wet sandy clay loam soil conditions and the comparative performance was evaluated from mechanical, ergonomical and economical aspects. It was found that the improved rotary puddler gave better performance. The puddling index, draft requirement, vibration level and energy expenditure rate were, respectively, 67.9 %, 42.3 kg, 0.910 RMS/acc. m/s$^2$ and 5.02 kcal/min. The work load was graded as moderately heavy. The cost of operation for two passes was calculated to be Rs.224.00/ha.

## Introduction

Paddy is by far the most important food crop in Asia and is the most important stable food in the world (Gee-Clough and Salokhe, 1989). Much of the paddy is produced and consumed in Asia. It is cultivated on about 129.6 million ha of land which is more than 46 % of the area under cereal crops (Awadhwal and Singh, 1985). India ranks the second in the world for total paddy production with about 22 % of total world production (Shrivastava, 1995). Paddy is usually grown under wet land conditions. Paddy farmers of India, primary use the bullock drawn implements for the puddling operations. However, a small percentage of progressive farmers, the use power tiller and tractor drawn implements as well. The bullock drawn puddling implements include local ploughs, 3-tine tiller and wet land rotary puddlers. But, the existing rotary rectangular blade puddler does not perform as well in the terms of quality and quantity puddling. Therefore, the new rotary concave blade was designed and developed from both the mechanical and ergonomical point of view for sandy clay loam and designated as the improved rotary puddler. Many researchers have studied the mechanical performance of different puddling implements under actual field conditions (Parihar and Khera, 1976; Rao and Sirohi, 1975; Rautary, 1993; Sharma, Jain and Premi, 1991; Sharma and Singh, 1984; Singh and Singh, 1973). But, unfortunately, the ergonomic considerations were not included in most of their studies. Hence an investigation was undertaken to evaluate the performance of four bullock drawn puddling implements under wet saturated soil conditions from me-

**Fig. 1a** Schematic diagram of improved rotary puddler

All dimension in cm

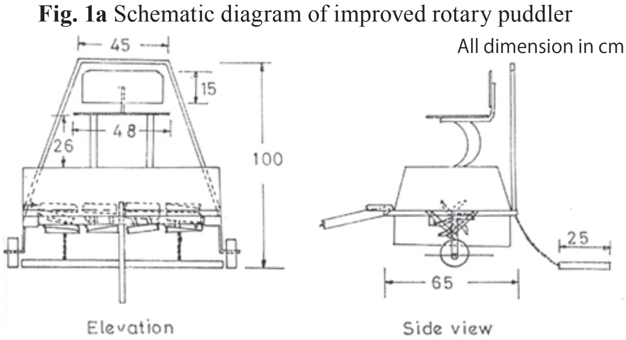
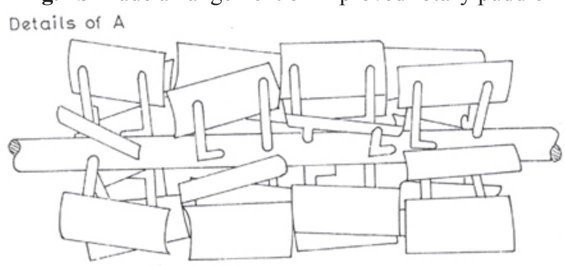



**Fig. 1b** Blade arrangement of improved rotary puddler




1. Six rectangular concave blades in one row, 2. Blade width 15 cm, 3. Blade depth 85 cm, 4. Blade angle w.r.t. shaft 30º

chanical, ergonomical and economic considerations.

## Method and Materials

A bullock drawn improved rotary puddler ($I_4$) was designed and developed (**Fig. 1a** and **1b**) at the Indian Institute of Technology, Kharagpur, India (Shrivastava, 1995). The performance of this improved rotary puddler ($I_4$) was compared with existing rotary puddler ($I_1$), 3-tine tiller ($I_2$) and local plough ($I_3$) in the farm attached to the Agriculture Engineering Department. The **Figs. 2**, **3** and **4** show the rotary puddler ($I_1$), 3-tine tiller ($I_2$) and local plough ($I_3$). The soil was sandy clay loam soil. The physical properties of the soil were evaluated. The average values of fifteen observations at two different depths are given in **Table. 1**.

The primary tillage treatments were given only in the case of rotary puddler and 3-tine tiller with the help of a mould board. After that the field was flooded with water to a depth of 100 mm for 24 hours and, thereafter, a 30 mm deep layer of water was maintained on the soil surface for testing of all puddling implements. The experiments followed the randomized block statistical design (RBD) with each measuring 10 m x 5 m.

Three subjects $S_1$, $S_2$ and $S_3$, representing the $5^{th}$, $50^{th}$ and $95^{th}$ percentile of operator population were selected (Shrivastava, 1995). During the experiments, the depth of puddling was maintained at about 7.5 cm for all the treatments. The draft was measured with the help of a spring dynamometer.

The vibration of implements during operation was measured with an "integrating vibration meter (type -4384)". The puddling index, field capacity; field efficiency and cost of puddling operation were also computed for each treatment, following the standard procedure.

The following equal on (Pandey and Ojha, 1973) was used to determine the puddling index (PI).

$PI = (V_1 / V_2) \times 100$ ......................(1)

Where,

PI = Puddling index,

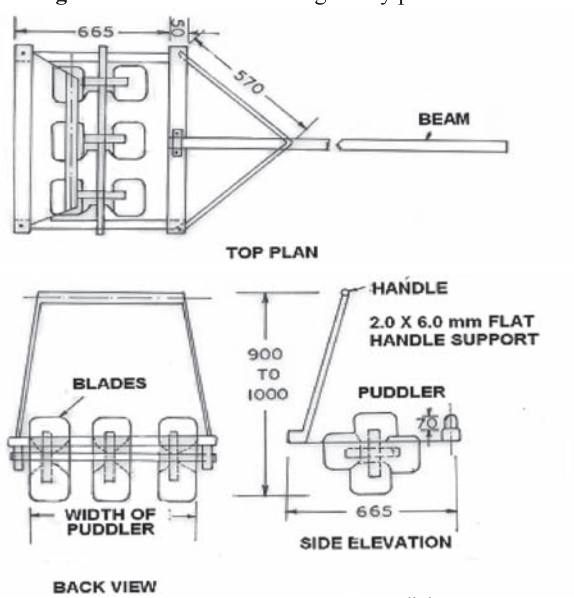
**Table 1** Average values of soil physical properties

| Soil properties | Soil depth, cm | |
|---|---|---|
| | 0-7.5 | 7.5-12.5 |
| Bulk density, gm/cc | 1.670 | 2.688 |
| Cone index, kPa | 169.150 | 262.820 |
| Shear strength, N/m$^2$ | 6,884.790 | 6,125.330 |
| Hydraulic conductivity, cm/h | 0.191 | 0.167 |

**Table 2** Average values of different observations

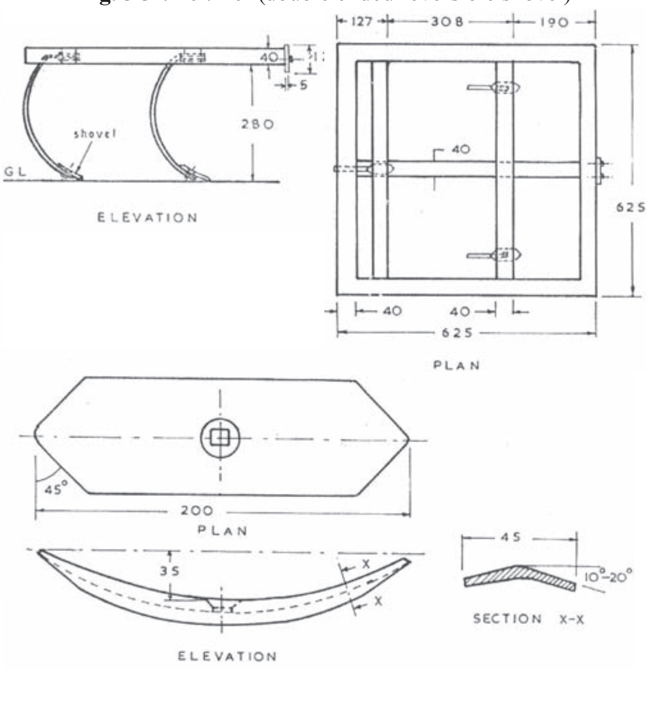
| Name of implements | Draft, kg | Field capacity, ha/h | | Field efficiency, % | Vibration RMS acceleration, m/s$^2$ |
|---|---|---|---|---|---|
| | | Theoretical | Actual | | |
| Existing rotary puddler, $I_1$ | 48.4 | 0.126 | 0.101 | 80.23 | 1.271 |
| 3-tine tiller, $I_2$ | 39.5 | 0.105 | 0.081 | 77.23 | 1.377 |
| Local plough, $I_3$ | 28.9 | 0.280 | 0.019 | 68.93 | 1.785 |
| Improved rotary puddler, $I_4$ | 42.3 | 0.126 | 0.105 | 83.65 | 0.910 |

**Fig. 2** Bullock drawn existing rotary puddler




All dimension in mm

**Fig. 3** 3-tine tiller (double ended reversible shovel)



$V_1$ = Volume of settled soil, and
$V_2$ = Volume of soil sample.

During the experiment the ambient temperature and relative humidity were measured. Before the start of the experiment, the operator was allowed to rest and his Heart Rate (HR) measured (at rest condition). During operation his HR was measured for 1 min. and then at an intervals of 10 minutes for each treatment by an E.C.G. telemetry system. Five readings were taken for each replication. After the operation, the HR of operator was measured during recession period till this value returned to near normal. The HR was used to compute the oxygen consumption rate and the Energy Expenditure Rate (EER) was calculated by the Brody equation (Shrivastava, 1995):

EER = 4.825 OCR ......................(2)

Where,

EER = Energy expenditure rate (kcal/min), and

OCR = Oxygen consumption rate ($O_2$ lit/min).

EER values were used to compute and classify work loads according to the prescribed scale (Christensen, 1959).

## Results and Discussions

**Draft Requirement**

The draft requirement of the improved rotary blade puddler ($I_4$) was lower than the other implements as shown in **Fig. 5** and **Table 2**. Although, the mode of operation of $I_2$ and $I_4$ was passive and different from the $I_1$ and $I_4$ (rotary). This impellents were used by the farmer for puddling and, therefore, draft was measured. The draft per cm width of cut was 0.705 kg/cm for $I_4$, 0.806 kg/cm for $I_1$, 0.79 kg/cm for $I_2$ and 3.84 kg/cm for $I_3$. The statistical analysis showed that the draft requirement with four puddling implements was significant at 1 the percent level of significance.

**Quality of Puddling**

**Fig. 5** and **Table 2** illustrate the quality of puddling in terms of puddling index (PI). It was found that the PI for treatment $I_4$ was more than $I_1$, $I_2$ and $I_3$ by 21.4, 35.4 and 39.5 %, respectively, after two passes of the puddling implements. Values of PI were significant at the 1 % level. However, treatments $I_2$ and $I_3$ were at the 5 % level of C.D. value.

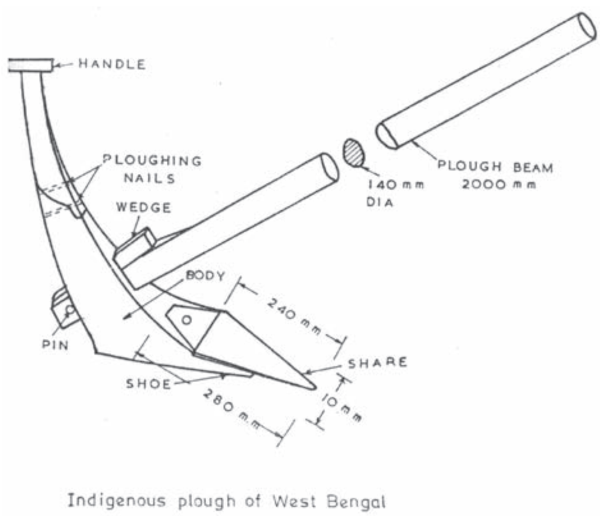
**Field Capacity and Field Efficiency**

**Table 2** shows that the performance of treatment $I_4$ (improved rotary puddler) was marginally better than other treatments in terms of field capacity and field efficiency. For $I_4$, the field efficiency was found to be 3.42 % more than $I_1$, 6.42 % more than $I_2$ and 14.72 % more than $I_3$.

**Vibration of Implements During Operation**

The level of vibration at the seat of the improved rotary puddler ($I_4$)

**Fig. 4** Indigenous plough



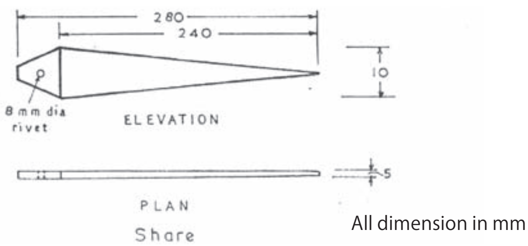




**Table 4** Score of comfort

| Subject | IIT rotary puddler | Existing rotary puddler | 3-tine tiller | Local plough |
|---|---|---|---|---|
| $S_1$ | 9.00 | 8.00 | 7.00 | 8.00 |
| $S_2$ | 9.00 | 8.00 | 7.00 | 7.00 |
| $S_3$ | 8.00 | 7.00 | 6.00 | 6.00 |
| Average | 8.70 | 7.60 | 7.67 | 7.00 |

**Table 3** Average values of heart rate, recovery period and energy expenditure rate of three subjects for operating four puddling implements

| Particulars | Existing rotary puddler | | | Tine tiller | | | Local plough | | | Improved rotary puddler | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ |
| Heart rate (HR) in beats/min | 109.91 | 108.57 | 110.53 | 111.53 | 113.13 | 115.59 | 119.04 | 120.53 | 121.37 | 93.38 | 93.75 | 95.57 |
| Average HR for three subjects in beats/min | | 109.67 | | | 113.41 | | | 120.31 | | | 93.56 | |
| Energy expenditure (EER) rate, kcal/min | 5.92 | 5.83 | 5.96 | 5.13 | 5.99 | 6.05 | 6.07 | 6.08 | 6.27 | 4.92 | 5.03 | 5.13 |
| Average EER for three subject | | 5.90 | | | 6.03 | | | 6.21 | | | 5.02 | |

was 0.910 RMS acceleration m/s$^2$ (**Table 2**). This vibration was lower than the existing rotary puddler ($I_1$), 3-tine tiller ($I_2$) and local plough ($I_3$) by 0.36 m/s$^2$, 0.461 m/s$^2$ and 0.875 m/s$^2$. This may be attributed to superior mechanical and ergonomical design of puddler seat/machines. In the 3-tine tiller ($I_2$) and local plough ($I_3$) the vibration level was measured at the handle of implements, i.e. 1.37 m/s$^2$ and 1.785 m/s$^2$, respectively. As such these were not compared with those of rotary implements. Although, minimum vibration was found in the case of treatment $I_4$.

**Energy Expenditure Rate (EER) for Operating Four Different Implements**

The puddling implements were evaluated from the ergonomical point of view. From **Table 3**, it is seen that the computed values of EER range between 5.83 to 5.96 kcal/min, 5.99 to 6.07 kcal/min, 6.08 to 6.29 kcal/min and 4.92 to 5.13 kcal/min. for the treatment $I_1$, $I_2$, $I_3$ and $I_4$, respectively. All the four implements fell under the category of moderately heavy range (Zander, 1973). **Fig. 6** shows that the average recovery period is lower in for $I_4$ as compared to other implements. This means that, it was less arduous than the other implements.

The subjects were asked to give the comfort score while operating the four puddling implements (**Table 4**). The score of 8.70 for $I_4$ was higher than other three. Therefore, from the ergonomic point of view, it was found that $I_4$ was better.

**Yield**

The performance of puddling implements was interpreted in terms of yield. It was found that, with all other parameters constant, the yield with the improved rotary puddler ($I_4$) was higher. The values were 27.21, 24.30, 22.34 and 29.53, for $I_1$, $I_2$, $I_3$ and $I_4$, respectively. This higher yield for $I_4$ may be attributed to better puddling of soils with the improved puddler. This might have resulted in better rice-plant growth and yield. This is in agreement with the findings of Naphade et al. (1971), Kisu (1978), De Datta (1981) and Sharma et al. (1985).

**Cost Analysis**

The cost of the puddling operation for $I_1$, $I_2$, $I_3$ and $I_4$, were found to be Rs. 246.00/ha, Rs.272.00/ha, Rs.1,046.00/ha and Rs.244.00/ha, respectively.

## Conclusions

1. The draft requirements per cm width of cut was found to be minimum for $I_4$. The total draft of $I_4$ was within the working range of average local pair of bullocks, i.e. 500 kg/pair.
2. Quality of puddling was found better for $I_4$. The PI was 21.4, 35.4 and 39.4 % more in the case of $I_4$ than $I_1$, $I_2$ and $I_3$, respectively.
3. Vibration was minimum for $I_4$ and was under the tolerance limit of operator.
4. The work load of the operation of all the four implements could be scaled as "moderately heavy".
5. Recovery period in the case of $I_4$ was lower than other treatments. It indicated a relatively lower load and lower health hazard with the improved rotary puddler.
6. The yield of paddy as well as the cost of puddling was found to be lower for $I_4$ than other treatments.

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**Fig. 5** Average value of puddling index and draft of four different bullock drawn puddling implements under actual field condition

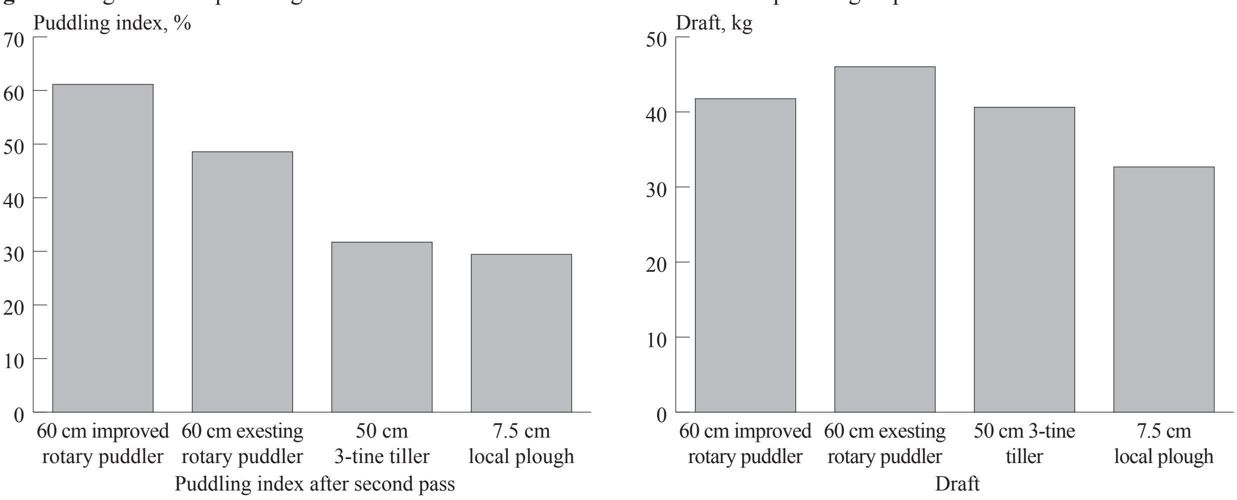

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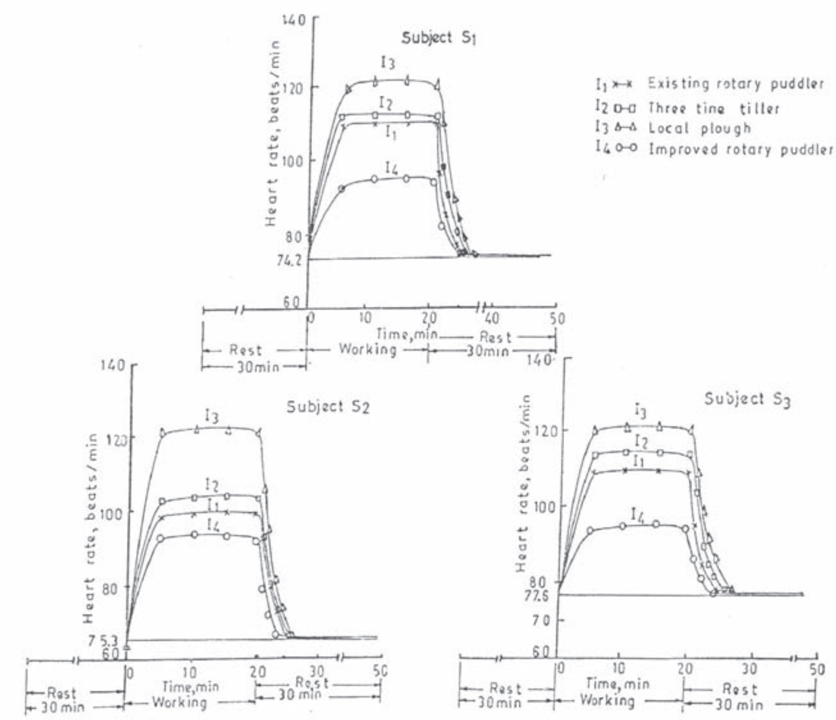
**Fig. 6** Heart rate and recovery time for operating four different puddling implement



# Design and Testing of a Mangosteen Fruit Sizing Machines

by

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## Abstract

This research concerns the development of a rotating disk, mangosteen sizing machine for fruit growers and small entrepreneurs. The methodology comprised design, construction, testing, and engineering and economic evaluation of a laboratory prototype machine. The laboratory prototype featured slope or step-type sizing gaps. Testing of the laboratory prototype indicated that varying the two control factors (the rotating disk speed and sizing gap type) significantly affected mean contamination ratio ($\bar{C}_R$), sizing efficiency ($E_W$), and throughput capacity (Q) at 5 % significance level. The most efficient configuration was a rotating disk speed of 21 rpm using a step-type aperture, which can be represented as $\bar{C}_R$ = 14.7 %, $E_W$ = 84.7 % and Q = 1,076.6 kg/hr. The laboratory prototype was used as the model for a factory prototype, which was fabricated and tested through the co-operation of the authors and the Jakawal Car Center factory in Ayuthaya, Thailand. The factory prototype is 820 mm wide, 820 mm long, 960 mm high and comprises 40 mm x 40 mm L-steel beams, a 600 mm diameter rotating disk, sizing boards, and a 370 W, 220 V electric motor.

Performance testing of the factory prototype showed that minimal fruit damage (0.48 %) occurred at $\bar{C}_R$ = 22.8 % and Q = 1,026 kg/hr. The sized mangosteen was very well accepted by fruit wholesalers at Prathom Mongkol fruit market in Nakhon Pathom, Thailand. An engineering economic analysis showed that the break even point and pay back period for a commercially available machine would be 46,020 kg/yr and 6½ months respectively, assuming a construction cost of USD453 and a rental rate of USD2/ton. In contrast, mangosteen growers and traders can manually size mangosteen at the rate of 153.4 kg/hr/person at $\bar{C}_R$ = 33.7 %.

## Introduction

Mangosteen is a locally prized tropical fruit and is an important economic crop in Thailand. In 2002, the total cultivation area in Thailand was 48,000 hectares, which yielded 160,000-190,000 tons. The crop's export value was USD10,000,000 with annual growth running at 102 % (Department of Agricultural Extension, 2002). Mongosteen flesh is highly nutritious and its peel can be used as medicine (Sermpakdee, 2000). However, despite its importance, sorting of the fruit for local and export consumption has largely been manual and inefficient.

This is not the case for other spheroidal fruit. For example, sizing machines have been developed commercially for apples, oranges and tangerines (Peleg, 1985; Jarimopas, 2001). These machines can be divided into several categories:

- belt and board sizer,
- perforated conveyer sizer
- weight sizer (Peleg, 1985).

There are two main sizing systems currently used in Thailand. The first is mechanical and uses perforated cylinders to sort tangerines. There are about 600 mechanical tangerine sizers in use in Thailand. Their capacity typically is 1.5 ton/hr with a mean contamination ratio of about 13 %. Each unit costs is in the range of USD875-1,000 (Jarimopas et al., 1988).

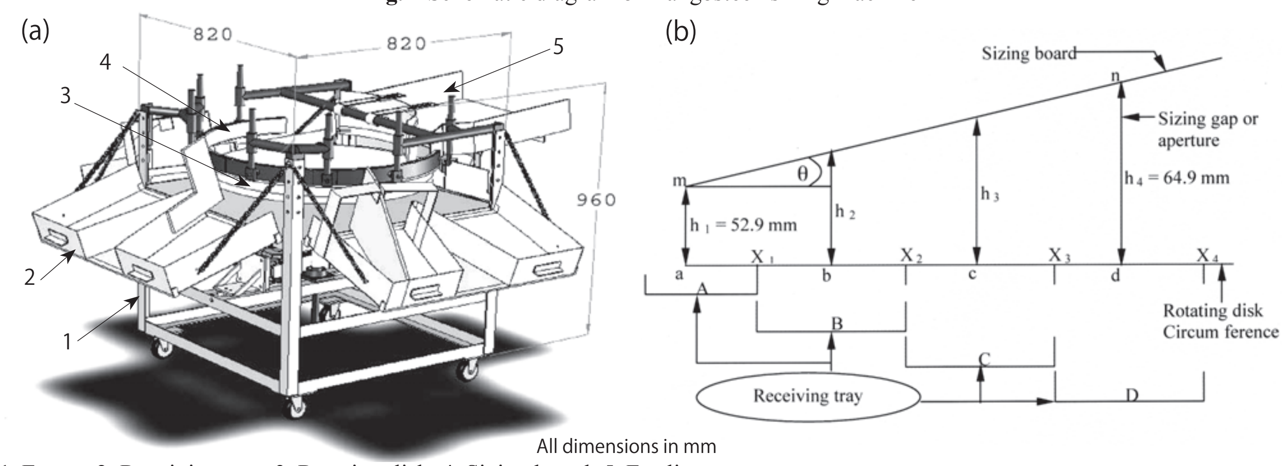
However, the mechanical system used for tangerines is not suitable for sizing mangosteens because of the fruit's large calyx. This causes it to deviate from spheroidal assumptions and to have an average sphericity of 67 % (Toomsaengtong, 2003). Due to the absence of appropriate commercially available sizing machinery, mangosteens have been historically sized by weight but not by appearance. Attempts have been to made to introduce efficient sizing apparatus, but with little success. One commercially available mangosteen sizing machine features 10 kg loadcells and weigh fruit dynamically in a continuous packing line. However, there are many disadvantages in this approach, including high initial and operating costs and complicated maintenance procedures. Furthermore, a microcomputer is required to operate them, which is difficult for farmers who have little formal education. Jarimopas et al. (1988) tried to solve this problem by developing a diverging belt mangosteen sizing machine, which resulted in sizing efficiency of 80 % and a throughtput capacity of 1 ton/hr. However, this machine was not accepted by farmers because it was too long and heavy to be carried on a 1-ton pick-up truck. Rotating disk sizing machines have also been used to size mangosteens, with results indicating a sizing capacity of 500 kg/hr and mean contamination ratio of 44 % (Roongsobsaeng et al., 1997). In comparison, an experienced farmer could manually size mangosteen at a rate of 153.4 kg/hr, with a mean contamination ratio of 33.7 % (Toomsaengtong, 2003). The advantage of the rotating disk is that it is mainly a mechanical system, so the initial and operating costs are low. Furthermore, as its mechanism is simple, rugged and compact, it is easy to maintain and transport. However, local vendors and exporters require a rotating disk machine that can size mangosteen at the rate of 1 ton/hr with a contamination ratio of about 15 % (Toomsaengtong, 2003). The challenge therefore was to improve the performance of rotating disk mangosteen sizing machines so they would be acceptable to local producers.

## Design and Operation

The mangosteen sizing machine (**Fig. 1a**) comprises a rotating disk, a sizing board, a feeding tray, a receiving tray, and a power drive, all attached to a steel frame, which rides on four small wheels. The frame is 820 mm wide by 820 mm long by 960 mm high and made of 40 mm by 40 mm steel L-beams. The rotating disk is made of 12 mm thick steel plate and is 600 mm in diameter. The top surface is formed into a conical shape with a 10-degree slope, which allows the fruit to roll down to the sizing gaps by gravity. The center of the disk is connected to a 50-mm diameter steel shaft, which is driven by a 187 W, 220 V electric motor through a 1:40 gear reducer and pulleys. Above the edge of the rotating disk is a 50 mm wide by 9 mm thick vertically adjustable steel sizing board curved along the disk circumference (viz. a slope-type sizing board). The feeding and receiving trays are made of 1.5 mm thick steel sheet.

The diameter of the rotating disk is determined as follows. Imagine the circumference of the disk) as line ad (**Fig. 1b**), and the sizing board mn as θ degrees inclined to the ad level. The sizing gap is designed such that the gap height, $h_i$ ($i = 1,...,4$)), at the mid point of each sizing range is equal to the average diameter of the fruit in that size range (size i). Each sizing gap has equal length along the circumference of the rotating disk. Since

**Fig. 1** Schematic diagram of mangosteen sizing machine




1: Frame, 2: Receiving tray, 3: Rotating disk, 4: Sizing board, 5: Feeding tray

$$\tan\theta = \frac{h_2 - h_1}{ab} + \frac{h_3 - h_2}{bc} + \frac{h_4 - h_3}{cd} \text{ and}$$

$$ab + bc + cd = ad,$$

therefore, the total length of the sizing board is

$$ad = \frac{h_2 - h_1 + h_3 - h_2 + h_4 - h_3}{\tan\theta} = \frac{h_4 - h_1}{\tan\theta},$$

where $h_4$ = average diameter of the largest size (64.9 mm), and $h_1$ = the average diameter of the smallest size (52.9 mm). Since each size range is narrow, the opening corresponding to each receiving tray should be wide enough to maintain small error. For this reason a small angle of 0.5 degrees was selected for θ. Therefore, the total circumference needed for the sizing board is

$$ad = \frac{649 - 529}{\tan 0.5} + \frac{12}{\tan 0.5}.$$

In addition to the sizing board, the feeding tray also occupies a space of 500 mm of the circumference of the rotating disk. Therefore, the total circumference should be

$$\pi D = \left[\frac{12}{\tan 0.5} + 500\right],$$

where D is the diameter of the rotating disk. Therefore,

$$D = \left[\frac{12}{\tan 0.5} + 500\right] / \pi \cong 600 \text{ mm.}$$

During operation, mangosteen fruit is continuously poured onto the feeding tray and then rolled down onto the rotating disk in clusters of 6 to 10 pieces at a time. The fruit is then brought into contact with the sizing board and the rim of the rotating disk through gravitational and centrifugal forces. They are measured by the sizing gap while moving along it. Whenever the diameter of the fruit is less than the sizing gap, the fruit will drop through the gap down to the receiving tray of that given size. Small fruit, thus, will be sized before big fruit.

## Test Procedure

### Laboratory Prototype

The laboratory prototype test was programmed to be factorial in completely randomized design (CRD) to determine the effect of variations in control factors upon the prototype performance. The CRD comprised two control factors:

- type of sizing gap (step, slope)
- disk speed (7, 14, 21, 25 rpm).

Step sizing gap is characterized by a constant aperture equal to the maximum diameter of mangosteen fruit of that range minus 2 mm. Observed performance parameters were the mean contamination ratio ($\bar{C}_R$), sizing efficiency ($E_W$) and throughput capacity (Q). Five replications were used for each combination of control factors and thirty newly harvested mangosteens were sampled for each size. The maximum diameter in the plane perpendicular to the calyx axis of each fruit was measured and recorded. The experiment was begun with slope aperture and fruit samples of three sizes. Separation points were set between adjacent sizes for the slope aperture by means of the following equation;

$$X_{12} = \left[\frac{\mu_2\sigma_1^2 - }{\mu_1\sigma_2^2}\right] \pm \left[\left(\frac{\mu_2\sigma_1^2 - }{\mu_1\sigma_2^2}\right)^2 - \frac{\mu_2^2\sigma_1^2 - \mu_1^2\sigma_2^2 - 2\sigma_1^2\sigma_2^2 \ln(\sigma_1 - \sigma_2)}{\sigma_1^2 - \sigma_2^2}\right]^{1/2} \qquad \text{....................(1)}$$

where $X_{12}$ = sizing gap width at the separation point between mangosteen size 1 and 2,

$\mu_1$ and $\mu_2$ = mean diameter of mangosteen size 1 and 2,

$\sigma_1$ and $\sigma_2$ = standard deviation of mangosteen size 1 and 2.

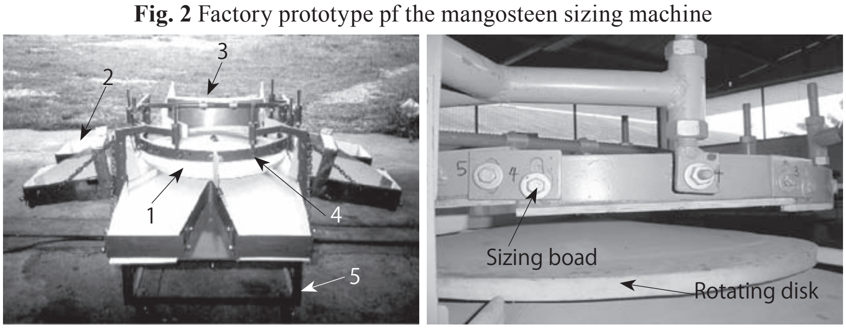
The mangosteen was fed into the prototype at a turn rate of 7 rpm and the associated feeding time was measured. Thereafter, the correct and incorrect fruit were sorted out of each grade. All data, including electrical power consumption, was measured with a *Yogokawa Yew 1502* energy meter. This process was repeated four times. Similar experiments at different speeds of 14, 21 and 25 rpm - five replications for each speed - were further performed. Then, the metering gap was rearranged to be step and the previous experiment was repeated. Error, efficiency and capacity can be

**Table 1** Statistics* of contamination ratio, throughput capacity and sizing efficiency with respect to metering gap and disk speed

| Disk speed, rpm | $C_R$ (%) Metering gap | | Q (kg/hr) Metering gap | | $E_W$ (%) Metering gap | |
|---|---|---|---|---|---|---|
| | Step | Slope | Step | Slope | Step | Slope |
| 7 | $20.9_a$ | $36.9_a$ | $525.8_b$ | $634.8_c$ | $82.4_b$ | $65.7_c$ |
| 14 | $13.8_a$ | $34.2_a$ | $650.0_b$ | $948.2_b$ | $87.7_a$ | $72.3_b$ |
| 21 | $14.7_a$ | $23.1_b$ | $1,076.6_a$ | $1,074.0_{ab}$ | $84.7_{ab}$ | $81.3_a$ |
| 25 | $17.3_a$ | $34.2_a$ | $1,026.6_a$ | $1,211.4_a$ | $82.1_b$ | $70.6_b$ |
| Mean | 16.7 | 32.8 | 819.7 | 967.1 | 84.2 | 72.5 |

*All data was analyzed by analysis of variance (ANOVA) and inspected the mean differences by duncan's new multiple range test. The letters, following tabulated average numbers, were different implying statistical difference of the numbers at $P < 0.05$.

**Fig. 2** Factory prototype pf the mangosteen sizing machine




(a) General view (b) Step sizing gap

1: Rotating disk, 2: Receiving tray, 3: Feeding tray, 4: Sizing gap, 5: Frame analyzed from the following equations:

$$W_i = \frac{K_i P_i}{\sum K_i P_i} \quad \text{.....................................(2)}$$

$$\bar{C}_R = \frac{\sum N_{ij}}{\sum N_i} \quad \text{.....................................(3)}$$

$$P_{gi} = \frac{N_{gi}}{Nt_i}$$

$$Q = \frac{W_t}{t}$$

$$E_W = \frac{\sum(P_{gi} W_i G_i)}{QP_i} \quad \text{.........................(4)}$$

$$G_i = \frac{W_i}{t}$$

$$N_{ti} = N_{gi} + N_{ij}$$

$$P_i = \frac{N_i}{\sum N_i}$$

where

$E_W$ = Sizing efficiency (%)

Q = Inflow rate of mangosteen (kg/hr)

$G_i$ = Outflow rate or mangosteen size i (kg./hr.)

$N_i$ = Number of mangosteen size i inputing to the sizing machine

$\sum N_i$ = Total number of inputing to the sizing machine

$P_i$ = Fraction of size i of total fruit at the beginning of sizing

$N_{ij}$ = Number of size i dropping into receiving tray size j

$N_{gi}$ = Number of size i dropping correctly into receiving tray size i

$N_{ti}$ = Total number of fruit dropping into receiving tray size i

$P_{gi}$ = Fraction of fruit size i of total fruit dropping into receiving tray size i

T = Sizing time

$W_i$ = Weighted function

$w_i$ = Total weight of mangosteen fruit in receiving tray size i

$w_t$ = Total weight of mangosteen corresponding to $\sum N_i$

$\bar{C}_R$ = Mean contamination Ratio

$K_i$ = Relative value fraction of grade i

**Table 2** Weight and related diameter of mangosteen fruit

| Size number | Weight, g | Average diameter, mm |
|---|---|---|
| A | 50-70 | 49.6 |
| B | 70-90 | 54.1 |
| C | 90-110 | 59.7 |
| D | > 110 | 63.5 |

**Factory Prototype**

After the laboratory prototype was tested and evaluated, the most efficient rotating disk speed and sizing gap was determined. A factory prototype based on the appropriate operating conditions was built at Chakrawal Car Care factory in Ayuttyah provice, Thailand. The factory prototype was tested and evaluated by continuously operating the machine with 650 kg, newly-harvested, mixed-size mangosteen fruit. All the prepared mangosteens were first weighed and 20 percent of the fruit was selected at random. The maximum diameter and weight of each mangosteen was measured and the aperture of the metering gap for each size was derived from the measurements. The randomly selected fruit was returned to the original mixture and the experiment was started. Continuous fruit feeding was conducted and 1-minute sampling was taken at each receiving tray every four minutes until the fruit supply was finished. The samples were kept in separate plastic bags which were labeled with unique codes. The packed sampled fruit were sorted into correct and incorrect sizes and weighed separately. The factory prototype was then evaluated from the following equations: Equ. A,

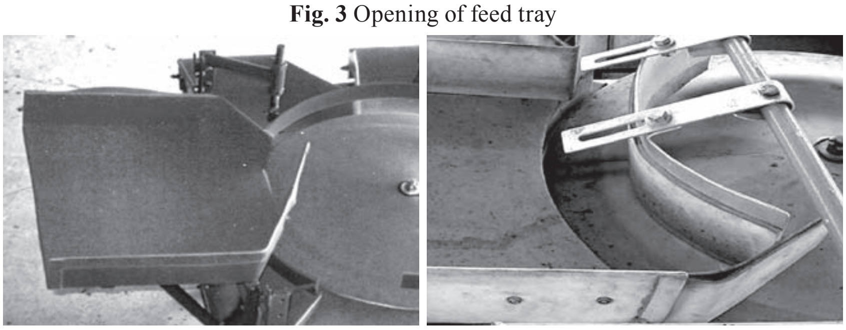
$\bar{C}_R$ = Average of $C_R$,

...Equ. B.

$$C_R = \frac{\text{Sum of weight of the incorrect fruit in the receiving tray i (i = 1,2,3) of one sampling}}{\text{Sum of total mangosteen weight in every receiving tray}} \quad \text{.......Equ. A}$$

$$Q = \frac{\text{Total weight of mangosteenfruit before sizing}}{\text{Feeding time}} \quad \text{....................................Equ. B}$$

**Fig. 3** Opening of feed tray



(a) Typical (b) New design

**Engineering Economic Analysis**

The three parameters of concern are the total annual cost of mechanical sizing of mangosteen AC, the break even point (BEP) and the pay back period (PBP) (Wijirawanich and Ploymeekha, 1995). They can be evaluated as follows:

- AC = FC + VC, where FC = Fixed cost, which is depreciation (D) and opportunity cost (O)
- VC = Variable cost, which includes wages (W), electricity (E), and maintenance (M)
- D (straight line method) = (P - S) / L, where
- P = buying price or construction cost of the mangosteen sizing machine (USD)
- S = machine cost after 10 years = 0.1 P (USD)
- L = Life time of the sizing machine = 10 years
- O = (P + S) x i / 2; i = interest rate = 6.75 % per year
- BEP = FC / (SUU - VCU), where SUU = Unit price of the sizing machine (USD / machine)
- VCU = Variable cost of a sizing machine (USD / machine)
- PBP = AC / p
- p = profit = R - AC

• R = income.

## Results and Discussion

A variance analysis conducted using IRRI STAT (Version 93) software shows that metering gap and disk speed settings markedly affected the contamination ratio $C_R$, sizing efficiency $E_W$ and throughput capacity Q at a significance level of 5 %. **Table 1** shows the average values of $C_R$, Q and $E_W$ at different combinations of speed and metering gaps. Overall, the step-type metering gap resulted in a lower $C_R$ (16.7 %) than the slope-type (32.8 %). Furthermore, although a disk speed of 21 rpm produces a slightly higher $C_R$ than at 14 rpm, throughput capacity at the higher rpm (1,076.6 kg/hr) is much higher than that at the speed of 14 rpm (650 kg/hr). The value of $E_W$ (84.6 %) at the speed of 21 rpm is not significantly different from $E_W$ at the speeds of 14 and 25 rpm. Based on these findings, a step-type metering gap and an operating disk speed of 21 rpm were selected as the final design parameters for the factory prototype (**Fig. 2**).

Performance tests in real situations with 650 kg naturally mixed mangosteen fruit and continuous operation resulted in $C_R$ of 22.8 % and Q of 1,026 kg/hr, with a small percentage (0.48 %) of mechanical damage in the form of cracks. $C_R$ of the factory prototype was higher than that of the laboratory prototype because the mangosteen that were selected for testing by the laboratory prototype had a size distribution close to the center of its size range (coefficient of variation, CV = 2.5 %), while the fruit used with the factory prototype had a size distribution further removed from the center of its size range (CV = 6.2 %). Nevertheless, fruit growers and merchants were satisfied with the sized mangosteens and performance of the sizing machine compared with results achieved by manual sorting (153.4 kg/hr with $C_R$ = 33.7 %) (Toomsaengtong, 2003).

Sizing the mangosteen into four sizes with the factory prototype (**Table 2**) gave a $C_R$ of 28.2 %. This is expected, according to equation 3, because sorting into more sizes produces more errors even in the same sample, resulting in a greater contamination ratio.

Throughput capacity for the factory prototype is about 100 percent greater than that of the commercially available machines due to the construction of a 40 cm-wide feeding opening (**Fig. 3**). This enables the mangosteens to move in clusters instead of individually, as is the case with the machines currently in operation, which require manual single feeding due to their small openings.

The engineering economic analysis of the mangosteen sizing machine indicated that the break even point and pay back period would be 46,020 kg/yr and 6½ months respectively, where construction cost was USD453 and renting rate was USD2/ton.


## Acknowledgements

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# Extraction of Essential Oil: an Appropriate Rural Technology for Minimizing Wastage of Surplus Betel Leaves

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## Abstract

Fresh green leaves of betel vine (*Piper betle L.*), locally known as Paan are used for chewing along with many other ingredients, mainly for mouth freshening, digestive and stimulating effects. India is the largest producer of betel leaf in the world producing a crop of about Rs. 9,000 million every year on about 700,000 "*Borozes*" (small huts wherein vines are grown in rural areas). Over 10 % of the production of betel leaves remain surplus and subjected to wastage every year particularly during the rainy season. This calls for the development of an appropriate rural technology for minimizing the wastage.

In view of the above, attempts were made for extraction of essential oil from five prominent varieties of betel leaves with the help of a Betel leaf oil extractor. The results indicate that the average oil content in the Bangla varieties was 1.7 % and in the *Mitha* varieties it was 2.0 % whereas in the *Sanchi* variety it was only 0.8 % on dry weight basis. This oil, which is the major ingredient imparting particular aroma and medicinal properties to the betel leaves, can be preserved for more than three years. The oil has a multidimensional potential use in cottage industry for manufacturing of numerous commercial products like medicine, *Gutkha* (chewable mouth freshener), incense sticks, fragrant and flavouring agent etc. Establishment of rural industry for extraction of essential oil from betel leaves at a very reasonable initial investment of Rs. 10,000-20,000/- along with the suitable "*Borozes*" is envisaged to minimize the wastage of surplus betel leaves besides increasing the agricultural as well as industrial employment opportunities in the betel leaf growing regions of India and other countries.

## Introduction

The fresh green leaves of betel vine (*Piper betle L.*) are used for chewing along with many other ingredients like betel nut-chips, slaked lime, catechu, aniseed, coriander seed, pepper mint, cardamom seed, clove, sweeteners and tobacco. Such practice of chewing the fresh green leaves for mouth freshening, digestive and stimulating effects is an age-old practice in many countries of the world including India, Pakistan and Bangladesh. In India alone about 15-20 million peoples consume betel leaf on a regular basis (Guha, 1997) and a crop of about Rs. 9,000 million is produced every year on about 55,000 ha of land (Guha and Jain, 1997). There are about 500,000 *Borozes* (small huts wherein vines are grown in rural areas) in West Bengal (Samanta, 1994) employing about the same number of rural families and a fair estimate indicates that there are about 700,000 *Borozes* in the country including those of the other states. About 66 % of Indian production comes from the state of West Bengal with a 30 % contribution from its Midnapore district (Guha and Jain, 1997). But unfortunately, over 10 % of the gross production remains surplus particularly during the rainy season (Glut season). These leaves are subjected to forced marketing (distress-selling) followed by wastage every year due to improper production strategy, inadequate transportation facilities; poor postharvest handling, processing, packaging and storage technology (Guha and Jain, 1997). In the forced marketing stage, these leaves are sold at a throw away price due to its highly perishable nature (Guha, 1997 and 2000). Subsequently in the wastage stage, the unsold betel leaves become a big burden upon the producers for quick and safe disposal and thus, are totally wasted. Therefore, there is an urgent need for research work for minimizing such wastage by development of an appropriate rural technology (post-harvest technology), which may be simple enough for direct adoption by the concerned rural population without undergoing any special training. In view of the above, the present work was planned and carried out to extract essential oil from betel leaves from which manufacturing of relevant commercial products like mouthwash, *paan masala* (Spiced and processed betel leaf), medicine, *Gutkha* (Chewable mouth freshener which is very popular in India), fragrant and flavouring agents can be done at village level cottage industry (Guha, 1997). This may not only minimize the wastage of surplus betel leaves but also improve the employment status in India and other countries and thereby bringing about a big revolution (Guha, 2000) particularly in the rural areas.

## Materials and Methods

Fresh betel leaves of five prominent varieties, namely, *Kali Bangla*, *Sada Bangla*, *Ramnagar Mitha*, *Tamluk Mitha* and *Sanchi* were collected from the nearby *Borozes* located in the Radhamohanpur village of Midnapore district of West Bengal and were utilized for oil extraction on the same day. The leaves were rinsed thoroughly with water and blotted dry before recording fresh weight. The petioles were then removed and weighed separately and the leaf blades were minced into 1-cm$^2$ (approx.) size before placing into a round bottom flask of 20-litre capacity of a Betel leaf oil extractor (Glass and Silver made) developed at IIT, Kharagpur by the author (**Fig. 1**). In one-batch 2.0 kg leaves i.e. 200-400 leaves were used along with about 2.0-litre of water for hydro-distillation. The round bottom flask was heated by heaters with maximum capacity of 3 kWh and cold tap water (~15 ºC) was used as cooling agent. The heating continued for about two and half hours and the oil was collected in the oil collection tube (receiver), then transferred to volumetric flasks of appropriate size, corked well and kept in darkness. The essential oil was separated from water by floating over 15 % saline water (w/w) in a separating funnel. The whole extraction process has been illustrated by a flow chart (**Fig. 2**). Comparative organoleptic tests were also carried out with the stored and freshly extracted oil samples for determination of loss of aroma and taste due to storage at an interval of six months up to three years. Photographs were also taken in the field to show the wastage of surplus betel leaves during rainy season (**Figs. 3** and **4**).

## Results and Discussion

The photographs taken in the field clearly show that the unsold betel leaves were offered to the

**Fig. 1** Betel leaf oil extractor

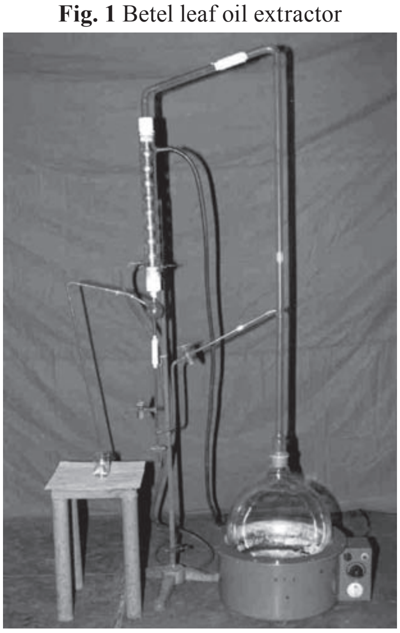
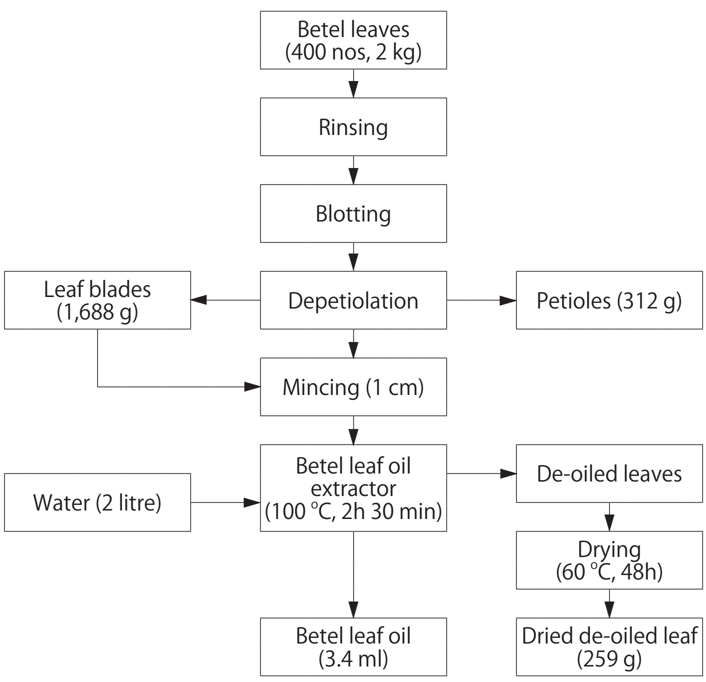


**Fig. 2** Process and material flow chart for extraction of betel leaf oil



bovines (**Fig. 3**) and they refused to eat much due to their pungency and then the leaves were buried in the ground (**Fig. 4**) to avoid health hazards. These evidences clearly point to an alarming situation encompassing excessive production and distress selling which leads to the subsequent total wastage of the leaves (Guha, 1997 and 2000) and (Guha and Jain, 1997). These observations strongly justify the need for an appropriate post-harvest technology suitable for the existing rural conditions. Therefore, to cope up with such a situation, oil extraction trials were carried out which indicated that the average oil content of the two *Bangla* varieties was 1.7 % and of the two *Mitha* varieties it was 2.0 %, whereas in *Sanchi* variety it was only 0.8 % on dry basis (**Table 1**). Thus, the results clearly indicate that the *Mitha* varieties contained the highest percentage of oil and the *Sanchi* variety had the lowest.

The essential oil extracted from leaf blades of all the varieties had a colourless appearance in the beginning that turned gradually into light straw colour and then to dark brown colour with lapse of time. The oil extracted from *Mitha* varieties had a sweet and spicy fragrance while that from the *Bangla* varieties was pungent and spicy. The *Sanchi* variety however, had the most intense spicy and pungent odour. The comparative organoleptic examinations of stored and freshly extracted oil samples indicated that the oil can be preserved easily at room temperature without significant loss of aroma for more than three years and can be used in cottage industry for manufacturing of *Gutkha* (chewable mouth freshener which is very popular in India), mouthwash, *Paan Masala* (spiced and processed betel leaf), medicine, fragrant and flavouring agents, etc. (Guha, 1997).

It may be expected that commercial exploitation of this essential oil may bring about a big revolution (Guha, 2000) as would be evident from its financial implications, particularly in the state of West Bengal where the raw material is produced in excess of demand, invariably, during the rainy seasons. This may be very attractive to the business community concerned with a country like India where investments are invited for capturing the fabulous market consisting of 15-20 million buyers who consume betel leaves on a regular basis (Guha, 1997). The cost of fabrication of a 20-liter size oil extractor is about Rs.20,000/ and that of the 10-litre size is Rs.10,000/, which is well within the affordable limits of the betel leaf growers. Therefore, the farmers themselves, at a rural industry, can take up such oil extraction work. This will help farmers minimize the wastage of surplus betel leaves that are otherwise sold at a throw away price (Guha, 1997 and 2000), fed to the bovines or buried in to the ground. The 20-litre size oil extractor can easily process 200-400 leaves/batch and about 800-1,600 leaves/day, whereas the daily production of the leaves may not normally exceed 500 leaves/Boroz of average size, i.e., 0.02 ha. Therefore, in all accounts a small oil extractor of 20-litre capacity would be sufficient to process the surplus leaves on any day. Further, even if the 10 % surplus leaves of one week are accumulated (i.e. 50 x 7 = 350 leaves) then the same can be processed conveniently within a day. In any case, whenever required, multiple sets of oil extractors may also be put into use along with a

**Table 1** Essential oil content (%) of different varieties of betel leaves*

| Name of variety | Trials | | | | | |
|---|---|---|---|---|---|---|
| | I | II | III | IV | V | Average |
| Sanchi | 0.8 | 0.8 | 0.8 | 0.9 | 0.8 | 0.8 |
| Sada bangla | 1.7 | 1.7 | 1.7 | 1.8 | 1.7 | 1.7 |
| Kali bangla | 1.7 | 1.8 | 1.7 | 1.7 | 1.8 | 1.7 |
| Ramnagar mitha | 2.0 | 1.9 | 2.0 | 2.0 | 1.9 | 2.0 |
| Tamluk mitha | 2.0 | 2.0 | 1.9 | 2.0 | 2.0 | 2.0 |

*The leaf blades contain about 16 % dry matter

**Fig. 3** A cow feeding upon surplus betel leaves

**Fig. 4** Graveyard of surplus betel leaves where the leaves are buried into the ground

**Fig. 5** Photograph of betel reaf

bigger Boroz in order to process the surplus leaves within a day or two. Similarly, a single unit can also be shared by several farmers to make this rural technology more cost effective. Such oil extraction will provide employment opportunities to the family members of the cultivators (Guha, 2000) counting over 500,000 in West Bengal alone (Samanta, 1994) for collection, washing, depetiolation, mincing, and processing of the leaves as well as product development and manufacturing work. This may also provide business opportunities for manufacturing, repairing and servicing the betel leaf oil extractors in addition to the essential oil traders, *Gutkha* manufacturers and others. Further, bigger and metallic units can be installed if sufficient capital is available which would magnify the agricultural as well as industrial employment opportunities besides enhancing wealth generation.

## Conclusion and Recommendation

1. It may be concluded from the present study that wastage of betel leaves worth millions of rupees may be minimized through extraction of essential oil from the surplus betel leaves.
2. It is recommended that the essential oil extracted from the betel leaves may be used in a cottage industry for manufacturing of different commercial products, particularly the non-tobacco based *Gutkha* (chewable mouth freshener which is very popular in India).

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# Effect of Operational Speed and Moisture Content of Wheat Crop on Plot Combine Harvester

by

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## Abstract

The performance of the plot combine harvester manufactured by M/S Wintersteiger, Austria (Model: Nursery Master Elite) was evaluated at three levels of moisture content and operational speed in wheat. The cutter bar, shaker, sieve and total combine losses were 9.16, 10.35 and 11.40 % moisture content and 1.0, 1.5 and 2.0 km/h speed. The grain breakage, performance and threshing efficiency were also determined at these moisture contents and speeds. On the basis of total losses, grain breakage, performance and threshing efficiency, the speed of 1.5 km/h gave better results at 9.16 % moisture content than the other two speeds. The field capacity of the plot combine harvester was 0.11, 0.18 and 0.23 ha/h, respectively, for speeds of 1.0, 1.5 and 2.0 km/h speeds.

**Fig. 1** Plot combine harvester (Nursery master elite)

## Introduction

In India today, the rate of food production is matching well with the population growth due to the consistent efforts made by the bio-scientists like agronomists, plant breeders, plant physiologists and agricultural engineers. Together, they have considerable impact in increasing the yield per unit area through varietal development using high inputs and assuming the high degree of risk of imported varietal technology. The yield potential of most of crops has more or less stagnated. But, the population in India is growing at an alarming rate of around 1.93 percent per year. This makes it necessary that the food grain production should also increase at least at the same rate or faster to meet out the total food demand of the masses. Thus, the use of the experimental field plot machinery may contribute considerably in pushing the yield towards the genetic maximum potential of the crop (Segler, 1977). Hence, mechanization of field operations on experimental plots is considered a key input to the agricultural research. Due to many errors in the handling of the experimental harvest, the small annual genetic gain of 1 % increase in yield made through plant breeding efforts gets unnoticed.

There are many State Agriculture Universities and ICAR institutions with many affiliated research stations. Even on these research centres the experimental plot machines are not in use. Instead, manual methods and traditional tools are used. The basic reasons may be attributed to the non-availability of field plot machines or limited information on proper use and performance of these machines.

## Material and Methods

**Details of the Machine**

The plot combine harvester manufactured by M/S Wintersteiger, Austria was specially designed to meet the harvesting needs of breeding and agronomical experiments for different crops. The reel height and speeds are adjustable. If the reel is set too low or too high, reel winding or wrapping may occur. The reel height is hydraulically controlled and its speed may be adjusted to suit the crop and forward speed by a two step pulley. The reel, also, has

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provision for extension. The cutter bar height may also be adjusted by means of the adjusting screws on the skid shoes and its height is also hydraulically controlled. The combine has a 1.50 m long cutter bar. The feeder conveyor belt of the plot combine has one drive roll and one idler roll. Both may be adjusted but normal tension adjustments are made on the idler roll. The threshing concave has provisions for quick change in clearance adjustments and swinging shaker. The cylinder concave clearance and rotational speed of the cylinder are adjusted from the driver's seat matching the requirement for the different crops. The combine is 5.40 m length, 2.10 m width and 2.40 m height (**Fig. 1**).

**Experimental Methodology**

The experiment was conducted to evaluate the effect of several varieties of wheat at different moisture contents and forward speeds (throughput) on combine losses. The harvesting was carried out at three different times, i.e. 6-7 AM, 10-11 AM and 1-2 PM to ensure variation in moisture content of crop. The experiments were laid out in randomized block design with three replications. The plot combine settings were:

1. Reel index: 1.25
2. Cylinder speed: 610-640 rpm
3. Concave clearance: 6 mm (front) and 4 mm (rear)

The independent and dependent variables were:

1. Independent variables:
   a. Operational speed-3 levels: 1.0, 1.5 and 2.0 km/h
   b. Crop moisture content-3 levels: 11.40, 10.35 and 9.16 %
2. Dependent variables:
   a. Cutter bar loss, %
   b. Cylinder loss, %
   c. Shaker loss, %
   d. Sieve loss, %
   e. Total loss, %
   f. Visible seed damage, %
   g. Performance efficiency, %
   h. Threshing efficiency, %
   i. Field capacity, ha/h

**Analysis of Data**

The plot combine performance was evaluated by determining different component losses, seed damage, performance efficiency and threshing efficiency. The gross yield was expressed in terms of net yield and combine losses a follows:

Gross yield = Net yield + combine losses (cutter bar + cylinder + shaker + sieve loss), and Equation 1 to 4.

Total combine loss for a given variety was calculated by summing the header loss, cylinder loss, shaker loss and sieve loss.

The visible seed damage was determined by collecting the broken grain from the shaker, sieve and grain tank: Equation 5 to 7.

## Results and Discussions

The relationship between cutter

$$\text{Grainbar loss, \%} = \frac{\text{Cutterbar loss, g}}{\text{Gross yield, g}} \times 100 \quad \text{......(1)}$$

$$\text{Cylinder loss, \%} = \frac{\text{Unthreshed grain collected from shaker and sieve, g}}{\text{Gross yield, g}} \times 100 \quad \text{...(2)}$$

$$\text{Shaker loss, \%} = \frac{\text{Threshed grain collected from shaker, g}}{\text{Gross yield, g}} \times 100 \quad \text{......(3)}$$

$$\text{Sieve loss, \%} = \frac{\text{Threshed grain collected from sieve, g}}{\text{Gross yield, g}} \times 100 \quad \text{......(4)}$$

$$\text{Visible seed damage, \%} = \frac{\text{Total broken seed, g}}{\text{Gross yield, g}} \times 100 \quad \text{......(5)}$$

$$\text{Performance efficiency, \%} = \frac{\text{Total grain in tank, g}}{\text{Gross yield, g}} \times 100 \quad \text{......(6)}$$

$$\text{Threshing efficiency, \%} = \frac{\text{Total threshed grain, g}}{\text{Gross yield, g}} \times 100 \quad \text{......(7)}$$

**Fig. 2** Effect of plot combine speed on cutterbar loss at different moisture contents of the crop

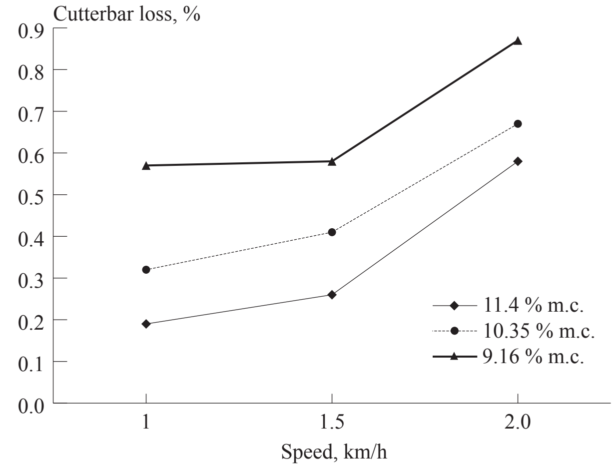
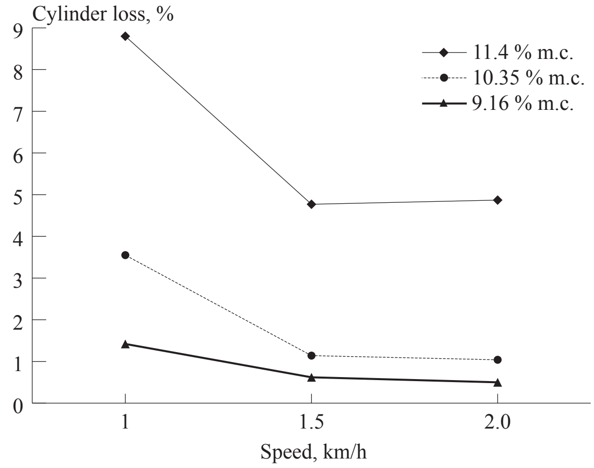



**Fig. 3** Effect of plot combine speed on ctlinder loss at different moisture contents of the crop



bar loss and speed with different crop moisture contents is shown in **Fig. 2** for moisture content of 11.40 %. The cutter bar loss was observed to be 0.19, 0.26 and 0.58 % at 1, 1.5 and 2.0 km/h speed, respectively. Similarly, at 10.35 % moisture content, it was calculated as 0.32, 0.41 and 0.67 % at 1, 1.5 and 2.0 km/h speed respectively. Further, at 9.16 % moisture content this loss was 0.57, 0.58 and 0.87 % at the above three levels of speeds, respectively. The above data indicated that the cutter bar loss increased with increasing operational speed and decreasing moisture content. The cutter bar loss was higher at 2.0 km/h due to greater reciprocating movement of the crop by the cutter bar.

**Fig. 3** illustrates that the cylinder loss decreased with increasing operational speed from 1 to 1.5 km/h and thereafter showed almost marginal differences up to 2 km/h speed at each level of moisture content of the crop. The findings are in conformity with results obtained by Johnson (1959). The cylinder loss was highest (8.86 %) at 1 km/h speed for 11.40 % crop moisture content. This was due to the fact that at 1.0 km/h, the cylinder speed was also quite low, which was not at all sufficient for threshing the grain. The cylinder loss was lowest (0.50 %) at 9.16 % moisture content and 2 km/h.

The shaker loss decreased with increasing speed from 1.0 to 1.5 km/h at all three levels of moisture content (**Fig. 4**). Thereafter, it increased with further increase of speed from 1.5 to 2.0 km/h for 11.40 and 10.35 % moisture content; however, it decreased slightly at 9.16 % moisture content. It was also observed that the shaker loss was minimum at 1.5 km/h for each moisture content of the crop. The shaker loss was highest (1.81 %) at 1.0 km/h for 11.40 % moisture content of the crop. Whereas, at 1.5 and 2.0 km/h, it was 1.45 and 1.69 %. The minimum shaker loss was 1.45 % and 0.75 % at 11.40 % and 10.35 % moisture content, respectively, for 1.5 km/h. However, the minimum shaker loss was 0.54 % at 2 km/h for of 9.16 % moisture content. This was due to

**Fig. 4** Effect of plot combine speed on shaker loss at different moisture contents of the crop

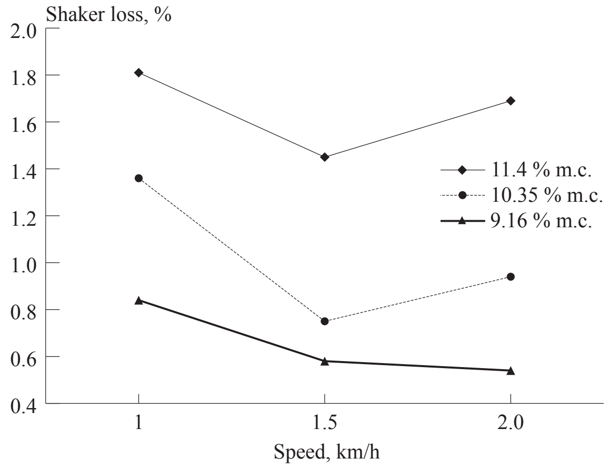



**Fig. 5** Effect of plot combine speed on sieve loss at different moisture contents of the crop

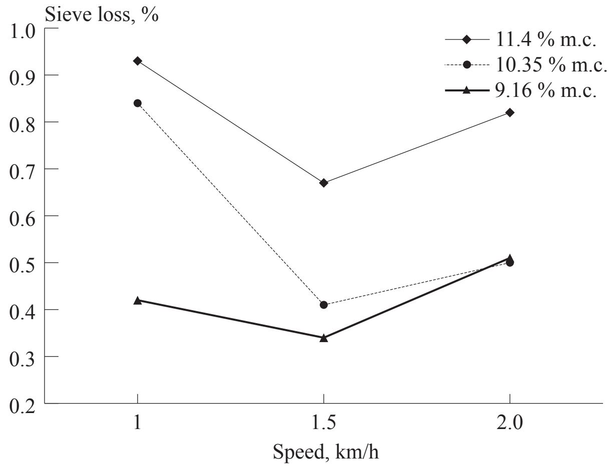



**Fig. 6** Effect of plot combine speed on total loss at different moisture contents of the crop

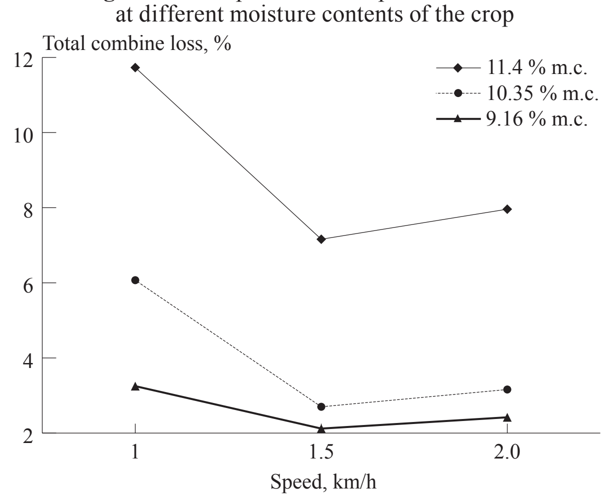
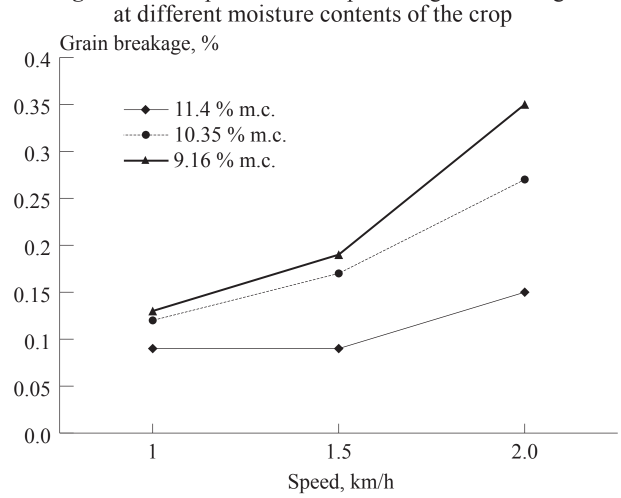



**Fig. 7** Effect of plot combine speed on grain breakage at different moisture contents of the crop



better threshing and more sun drying of the crop resulting in lower moisture content.

**Fig. 5** shows that the sieve loss decreased with increasing the speed from 1.0 to 1.5 km/h. Thereafter, it increased with increasing speed from 1.5 to 2.0 km/h. The sieve loss was minimum (0.34 %) at 1.5 km/h and 9.16 % moisture content followed by 1.0 km/h and 2.0 km/h for other moisture contents. The sieve loss was maximum (0.93 %) for 11.40 % moisture content at 1.0 km/h speed. This was due to overloading at 1.0 km/h in the cylinder and less time available for shaking the seed at 2.0 km/h. The sieve loss at 2 km/h was more than 1.5 km/h speed. This corroborates with the findings of Mohammed and Abdoun (1978).

The total combine losses with regards to speed and moisture content are given in **Fig. 6**. The above figure shows that the total losses were decreased by increasing the operational speed from 1.0 to 1.5 km/h for each crop moisture content and increased with further increase in speed from 1.5 to 2.0 km/h. The total losses were minimum (2.17 %) at 1.5 km/h operational speed for 9.16 % moisture content and maximum (11.73 %) at 1.0 km/h with 11.40 % moisture content of the crop. This was mainly due to higher cylinder loss at these operational parameters.

It is evident from **Fig. 7** that grain breakage increased with increasing the operational speed in case of each level of moisture content of the crop. These findings are in agreement with Singh et al. (1975). The mechanical grain breakage ranged from 0.09 to 0.15 %, 0.12 to 0.27 % and 0.13 to 0.35 % at 11.40, 10.35 and 9.16 % moisture content, respectively. The grain breakage was minimum (0.09 %) at 1.0 km/h with 11.04 % moisture content and maximum (0.35 %) at 9.16 % moisture content for 2 km/h operational speed. In general, the grain damage increased with decreasing moisture content of crop and increasing the operational speed of the combine.

The performance efficiency of the combine increased with increasing operational speed from 1.0 to 1.5 km/h for each level of moisture content of the crop (**Fig. 8**). It was maximum (97.88 %) at 9.16 % moisture content with 1.5 km/h speed followed by 2.0 and 1.0 km/h at the same moisture content. It was also clear from the figure that further increase in speed from 1.5 to 2.0 km/h decreased the performance efficiency of the combine for all the three levels of moisture content of the crop.

**Fig. 9** shows that the threshing efficiency increased with increasing speed as well as moisture content of the crop. It was maximum (99.19 %) at 2.0 km/h speed for 9.16 % moisture content followed by 10.30 and 11.40 % moisture content. These observations are in accordance with results reported by Singh et al. (1975). The threshing efficiency was minimum (8.36 %) at 1 km/h with 11.40 % moisture content, which was due to over loading at lower speed with less time available for threshing at higher speed. The field capacity of the plot combine harvester was 0.11, 0.18 and 0.23 ha/h while operating the combine at 1.0, 1.5 and 2.0 km/h speeds. Statistical analysis (AVOVA) indicated that moisture content and speed of operation have significant effect on the cutter bar loss, cylinder loss, shaker loss, sieve loss, total combine losses, mechanical grain breakage, threshing and performance efficiently at 1 % level of significance.

## Conclusions

On the basis of total losses, grain breakage, performance efficiency and threshing efficiency, the operational speed of 1.5 km/h gave better results at 9.16 % moisture content of crop than the other two operational speeds. However, grain breakage

*(continued on page60)*

**Fig. 8** Effect of plot combine speed on performance efficiency at different moisture contents of the crop

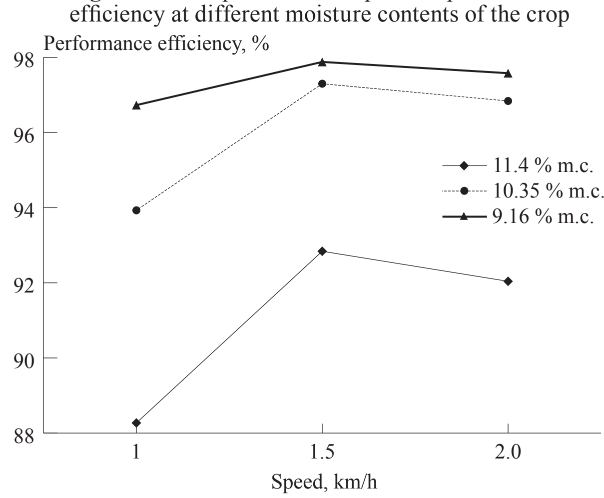
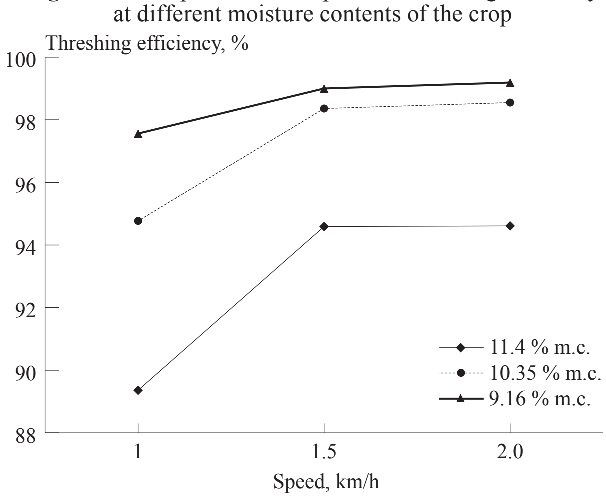



**Fig. 9** Effect of plot combine speed on threshing efficiency at different moisture contents of the crop



# Enhancing the Shelf Life of Fully Ripe Guava and Mango Fruits Using Wax Emulsions


by

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## Abstract

Shelf life of fully matured guava and mango fruits was assessed by coating with wax emulsions. Four levels of wax emulsions viz., 3 %, 4 %, 5 % and 6 % were prepared by adding oleic acid, triethanolamine and hot water. A hand operated wax coating machine was developed to coat wax on fruits. Physiological loss in weight (PLW) and organoleptic properties of wax coated fruits and unwaxed fruits (control) were measured periodically during the storage period. It was observed that the PLW was lower in wax coated samples than the control. Based on the results of the organoleptic properties, it was also found that the shelf life of 6 % wax emulsion coated guava and mango fruits could be extended up to 7 and 12 days against 4 and 7 days only for the untreated guava and mango.

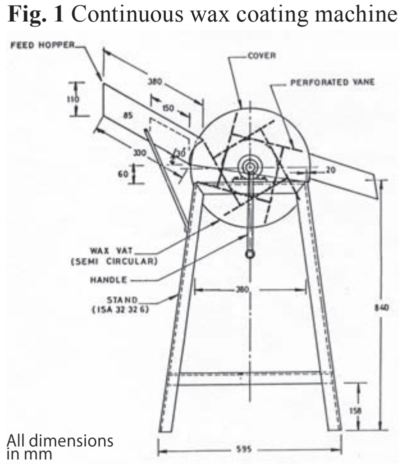

## Introduction

Fruits like guava and mango are highly perishable and utmost care should be taken in handling and processing to reduce the post harvest losses. Incompetent handling of fruits results in injury to the surface layer making them more susceptible to attack by spoilage organisms with consequent reduction in consumer appeal in the market. The fruits being a seasonal commodity create a glut during the season and become scarce during the off- season.

It has been estimated that inadequate storage and handling facilities result in losses in the order of 35 to 40 % of the total production of fruits. By considering the nutritive value, it is necessary to deploy modern methods to extend the shelf life for better distribution and also processing techniques to preserve them for off season usages. There are different methods of extending shelf life of fruits viz., pre-cooling, cold storage, controlled atmosphere storage and wax coating. In all these methods, the shelf life is extended by reducing the respiration rate and moisture loss from the fruits.

Except wax coating method, all the methods are sophisticated and costly. Also in India, cold storage facilities are not within the easy reach

**Fig. 1** Continuous wax coating machine




All dimensions in mm

of farmers/fruit venders. Waxing of fruits and vegetables is mainly done to extend their shelf life, especially when they are to be transported to distance places. The application of wax can be carried out by dipping the fruits in the wax emulsion or by spraying the wax solution as a mist over the fruits or vegetable surface. However, in both the cases, the application of wax should be in a thin uniform coating for easy drying and also to avoid the development of mould and other microorganisms.

Therefore, the wax coating method seems to be the cheapest and easy to practice for prolonging the shelf life of fruits by considering the following advantages viz., controlling moisture loss and respiration rate and enhancing appearance by the glossiness of the wax. The role of skin coating for extending the storage life of fruits has been reported by several workers (Alache and Munoz, 1998; Castrillo and Bemudez, 1992; Dhalla and Hanson 1988; Diaz-Sobac et al., 1996; Erbil and Muftagil, 1986; Kahlon and Bajwa, 1991; Ozdemir and Dunder, 2001; Thomas et al., 1971).

## Materials and Methods

A hand operated wax applicator has been fabricated and the schematic diagram is shown in **Fig. 1**. It consists of a feed hopper, cylindrical drum known as wax vat, impeller fitted with four paddles mounted on a shaft and outlet chute. A handle is provided at one end of the shaft to rotate the impeller at 10 rpm. The vanes are made up of perforated sheets with oblong perforations. The vanes are positioned at an angle of 45º to the tangent. This angle is greater than the angle of repose of guava and mango fruits used for the experiment. The impeller is housed inside a casing which is split into two halves. The bottom half of the casing is used to hold the wax, also known as wax vat. The successive vanes of the impeller along with the casing form four pockets. These pockets receive the fruits from the feed hopper, conveying them through the wax emulsion contained in the wax vat and also deliver the fruits due to gravity through the outlet chute. The entire unit is supported on an L angle frame of convenient height.

Experiments were carried out to standardize the wax formulations to arrive at a consistent thin wax emulsions. Wax formulations were tried with paraffin wax since it is the cheapest wax when compared to carnauba wax and bee wax. The wax was first melted at a temperature of 65 ºC in a water bath. Oleic acid and triethanolamine were added as solving and emulsifying agents. The mixture was stirred vigorously to form wax emulsions. Then the specified quantity of hot water was added slowly with constant stirring to dilute the wax emulsion with

**Table 1** Wax emulsion treatments

| Treatments | Wax, g | Oleic acid, ml | Triethnolamine, ml | Hot water, ml | Wax emulsion, % |
|---|---|---|---|---|---|
| $T_1$ | 100 | 80 | 150 | 3,013 | 3 |
| $T_2$ | 100 | 80 | 150 | 2,180 | 4 |
| $T_3$ | 100 | 80 | 150 | 1,680 | 5 |
| $T_4$ | 100 | 80 | 150 | 1,346 | 6 |

**Table 2** Physiological loss in weight (percent) for guava fruits

| Treatments | Initial weight, g | Weight loss % during storage period | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| $T_1$ | 65.41 | 2.36 | 4.49 | 6.37 | 8.33 | 9.87 | 11.26 | 13.82 |
| $T_2$ | 64.89 | 2.00 | 3.75 | 5.38 | 6.89 | 8.25 | 9.43 | 15.12 |
| $T_3$ | 66.12 | 1.88 | 3.40 | 4.79 | 6.04 | 7.20 | 8.16 | 9.02 |
| $T_4$ | 64.12 | 1.55 | 2.86 | 4.01 | 5.07 | 5.99 | 6.85 | 7.55 |
| Control | 64.15 | 4.62 | 8.26 | 11.35 | 14.23 | 17.21 | 20.48 | 22.29 |

| Treatments | SED | CD (5 %) | CD (1 %) |
|---|---|---|---|
| Wax emulsion | 0.034 | 0.067 | 0.08 |
| Storage | 0.025 | 0.049 | 0.06 |
| Interaction | 0.09 | 0.17 | 0.23 |

**Table 3** Physiological loss in weight (percent) for mango fruits

| Treatments | Initial weight, g | Weight loss % during storage period | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| $T_1$ | 208.52 | 1.51 | 2.53 | 3.47 | 4.41 | 5.30 | 6.19 | 7.01 | 7.77 | 8.48 | 9.15 | 11.89 | 13.15 |
| $T_2$ | 209.32 | 1.49 | 2.50 | 3.46 | 4.41 | 5.31 | 6.12 | 6.91 | 7.63 | 8.30 | 8.91 | 10.11 | 11.54 |
| $T_3$ | 209.41 | 1.34 | 2.29 | 3.14 | 3.95 | 4.70 | 5.42 | 6.05 | 6.66 | 7.16 | 7.62 | 8.05 | 8.48 |
| $T_4$ | 212.56 | 1.30 | 2.20 | 3.02 | 3.75 | 4.45 | 5.11 | 5.71 | 6.20 | 6.64 | 7.06 | 7.45 | 7.83 |
| Control | 213.41 | 2.29 | 4.09 | 5.45 | 6.63 | 7.67 | 8.66 | 9.60 | 11.89 | 13.15 | 14.78 | 16.89 | 18.46 |

| Treatments | SED | CD (5 %) | CD (1 %) |
|---|---|---|---|
| Wax emulsion | 0.09 | 0.177 | 0.08 |
| Storage | 0.08 | 0.170 | 0.06 |
| Wax x storage | 0.31 | 0.611 | 0.23 |

various concentrations viz., 3 %, 4 %, 5 % and 6 %. The wax emulsion was removed from the bath and then again it was stirred rapidly in a mechanical stirrer. Then the emulsion was cooled for the wax applications (Nithya Devi, 2003).

Wax emulsion was filled in the wax vat to the level of 1 inch above the bottom of the impeller. The impeller was given a constant rotation of about 10 rpm through the handle manually for 2 minutes. Uniform size and weight of guava (60-70 g) and mango (205-215 g) fruits were selected for wax coating. The fruits were fed through the feed hopper. These fruits were received by the impeller blades, taken through the wax column; the wax coated fruits were passed on to the outlet chute. Then these fruits were collected on perforated trays and finally dried by blowing air for 20 min to remove the excess moisture in the wax emulsion.

Physical characteristics, viz. texture, flavour, taste and overall acceptability were judged organoleptically by a panel of seven judges based on the hedonic scale ranging from 1-dislike extremely to 9-like extremely. The physiological loss in weight (PLW) was measured by weighing the fruits during the storage period. The results are given in **Tables 2** and **3** for guava and mango fruits, respectively. The titratable acidity was determined by titrating the pulp against 0.1N NaOH, using phenolphthalein as an indicator. The total sugar content was determined by using Anthrone method (Ranganna, 1997). The storage life was assessed based on the organoleptic evaluation. The data were evaluated statistically.

**Table 4** Effect of wax emulsion on flavour, texture, taste and overall acceptability of guave fruits based on organoleptic evaluation

| Treatments | Flavor | Texture | Taste | Overall acceptability | Flavor | Texture | Taste | Overall acceptability |
|---|---|---|---|---|---|---|---|---|
| | 4th day of storage | | | | 5th day of storage | | | |
| $T_1$ | 7.92 | 7.35 | 8.01 | 7.92 | 7.23 | 7.48 | 7.15 | 7.02 |
| $T_2$ | 8.05 | 8.23 | 8.15 | 8.25 | 8.01 | 8.13 | 7.48 | 7.83 |
| $T_3$ | 8.15 | 8.31 | 8.15 | 8.34 | 8.13 | 8.11 | 8.09 | 8.09 |
| $T_4$ | 8.35 | 8.15 | 8.15 | 8.41 | 8.31 | 8.18 | 8.19 | 8.36 |
| Control | 6.97 | 6.85 | 7.21 | 7.15 | 6.01 | 5.49 | 5.09 | 5.12 |
| | 6th day of storage | | | | 7th day of storage | | | |
| $T_1$ | 6.08 | 6.09 | 6.12 | 6.08 | 2.23 | 2.34 | 2.67 | 2.13 |
| $T_2$ | 7.64 | 7.13 | 7.16 | 7.12 | 4.98 | 5.15 | 4.05 | 4.01 |
| $T_3$ | 8.04 | 7.96 | 7.90 | 7.82 | 7.25 | 7.36 | 7.24 | 7.21 |
| $T_4$ | 8.07 | 8.01 | 7.86 | 8.06 | 7.54 | 7.23 | 7.36 | 7.25 |
| Control | 3.51 | 3.34 | 3.12 | 3.04 | 1.97 | 2.05 | 1.95 | 1.55 |

Mean values of three replications

| Treatments | SED | CD (5 %) | CD (1 %) |
|---|---|---|---|
| Wax emulsion | 0.082 | 0.163 | 0.216 |
| Storage days | 0.045 | 0.090 | 0.120 |
| Interactions | 0.165 | 0.327 | 0.433 |

**Table 5** Effect of wax emulsion on flavour, texture, taste and overall acceptability of mango fruits based on organoleptic evaluation

| Treatments | Flavor | Texture | Taste | Overall acceptability | Flavor | Texture | Taste | Overall acceptability |
|---|---|---|---|---|---|---|---|---|
| | 7th day of storage | | | | 9th day of storage | | | |
| $T_1$ | 7.99 | 7.46 | 8.01 | 7.92 | 7.18 | 7.48 | 7.15 | 7.02 |
| $T_2$ | 8.04 | 8.21 | 8.12 | 8.19 | 8.12 | 8.13 | 7.48 | 7.83 |
| $T_3$ | 8.12 | 8.29 | 8.11 | 8.24 | 8.17 | 8.11 | 8.09 | 8.09 |
| $T_4$ | 8.27 | 8.14 | 8.19 | 8.24 | 8.21 | 8.18 | 8.19 | 8.36 |
| Control | 6.86 | 6.81 | 7.16 | 7.15 | 4.95 | 4.18 | 4.16 | 4.01 |
| | 11th day of storage | | | | 12th day of storage | | | |
| $T_1$ | 4.16 | 3.18 | 4.15 | 4.03 | 2.87 | 2.16 | 2.32 | 2.12 |
| $T_2$ | 4.87 | 4.43 | 4.18 | 4.13 | 3.45 | 3.41 | 3.75 | 3.54 |
| $T_3$ | 8.04 | 8.11 | 7.90 | 7.82 | 7.21 | 7.09 | 7.10 | 7.18 |
| $T_4$ | 8.07 | 8.47 | 7.86 | 8.06 | 7.45 | 7.31 | 7.31 | 7.29 |
| Control | 3.98 | 3.07 | 3.95 | 3.04 | 2.01 | 2.05 | 1.92 | 1.98 |

| Treatments | SED | CD (5 %) | CD (1 %) |
|---|---|---|---|
| Wax emulsion | 0.085 | 0.161 | 0.213 |
| Storage days | 0.041 | 0.092 | 0.119 |
| Interactions | 0.155 | 0.321 | 0.419 |

## Results and Discussion

**Physiological Loss in Weight (PLW) on Wax Coated Guava Fruits**

The physiological loss in weight (PLW) gradually increased when the storage period extended. From the **Fig. 2** it is seen that the PLW varied between 7.55 % and 13.82 % for the wax emulsions coated guava fruits after seven days of storage period. The PLW was significantly less (7.55 %) in $T_4$ and higher (13.82 %) in $T_1$. During this period, the unwaxed guava fruits recorded the highest PLW of 22.29 % after 7 days of storage.

Generally, after the above said storage periods, the guava fruits devoid of wax showed decay symptoms rendering it unfit for further evaluation.

**Physiological Loss in Weight (PLW) on Wax Coated Mango Fruits**

Mango fruits pretreated with wax

emulsions were stored under ambient condition and analysed up to 12 days. Thereafter, the fruits were completely spoiled due to excessive shrinkage, senescence and mould growth. Generally, with the passage of storage time, the fruits softened differently. The results indicated that the physiological loss in weight on wax coated mango fruits were influenced by the wax emulsion concentration.

From the **Fig. 3**, it was found that the PLW varied between 7.83 % and 13.15 % for the wax emulsion coated mango fruits after 12 days of storage. Among the treatments, $T_4$ recorded the lowest PLW of 7.83 % followed by $T_3$ after 12 days of storage period. At the same time, the unwaxed (control) mango fruits recorded the highest PLW of 18.46 %.

The wax emulsion treatments significantly reduced the physiological losses in weight of fruits. Slower rates of weight loss of coated fruits were mainly due to the barrier properties for gas diffusion of stomata, the organelles that regulate the transpiration process and gas exchange between the fruit and the environment (Kester, 1989).

The shelf life of wax emulsion coated mango fruits could be extended up to 12 days and with the unwaxed (control) mango fruits it was only seven days. Generally after the above said storage periods, the mango fruits devoid of wax showed decay symptoms rendering it unfit for further evaluation.

The capacity of the wax coating machine was 300 kg per hour. The cost of operation was Rs. 63/-per hour (US$ 1.26) inclusive of cost of wax. The wax emulsion requirement to coat 100 kg of mango and guava fruits was 275 ml.

**Flavour**

Data presented in **Table 4** indicate that there was significant loss of flavour during the storage period. The loss was highest in control (1.97) than with wax emulsion treated fruits. Among the wax emulsion treated guava fruits, the flavour retention was highest (7.54) in $T_4$ after seven days of storage. In the case of mango as given in **Table 5**, the flavour retention was highest (7.45) in $T_4$ after 12 days of storage followed by $T_3$. The loss was higher in the control (2.01) than with wax emulsion treated fruits. Jawanda et al. (1978) stated that kinnow mandarin treated with 6 % wax emulsion retained the usual flavour during the storage period.

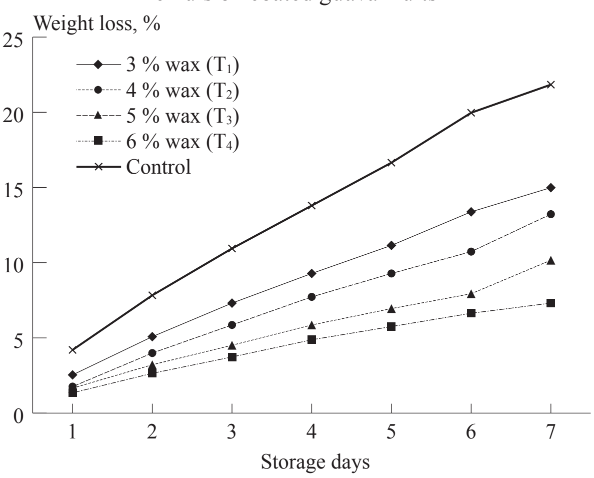
**Texture**

The highest texture value was with 6 % wax emulsion treated guava fruits after seven days of storage. However, there was no significant difference in texture value for the fruits coated with 5 and 6 % wax emulsions. But, guava fruits coated with 4 %, 3 % and control recorded the lowest texture values. For mangoes, 6 % wax emulsion treatment recorded the highest texture value after 12 days of storage followed by $T_3$. The lowest texture value was recorded in control. It may be possible that the higher concentration of wax emulsion reduced microbial activity and respiration rate of cells there by helping in retaining good texture (Vihol, 1982).

**Taste**

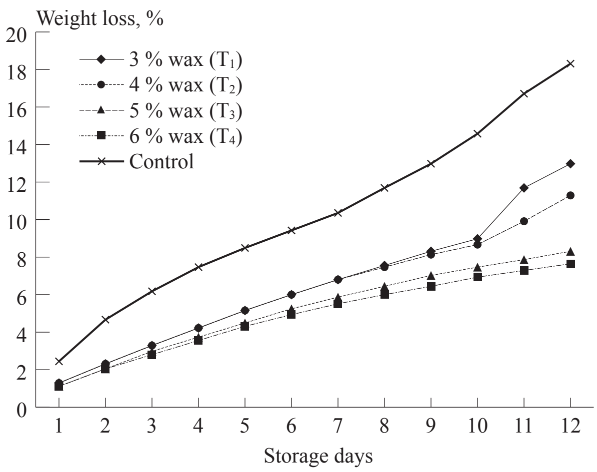
Wax emulsion treatments significantly helped in retaining the taste of guava fruits after seven days of storage. The highest taste value of 7.36 was recorded in $T_4$ followed by $T_3$ and $T_2$. The control lost all its taste after seven days of storage. The highest taste in mango of 7.31 was recorded in $T_4$ followed by $T_3$

**Fig. 2** Physiological loss in weight of wax emulsion coated guava fruits




$T_1$: y = 2.9763x + 2.1552, $R_2$ = 0.9955
$T_2$: y = 2.0658x + 1.0721, $R_2$ = 0.9972
$T_3$: y = 1.8371x + 0.7232, $R_2$ = 0.9954
$T_4$: y = 0.9991x + 0.8439, $R_2$ = 0.9904

**Fig. 3** Physiological loss in weight of wax coated mango fruits




$T_1$: y = 1.3289x + 1.8199, $R_2$ = 0.9891
$T_2$: y = 0.9812x + 0.3604, $R_2$ = 0.9753
$T_3$: y = 0.6445x + 1.2150, $R_2$ = 0.9831
$T_4$: y = 0.5860x + 1.2504, $R_2$ = 0.9795

after 12 days of storage. The control lost all its taste after seven days of storage. Banana treated with wax and rice starch possessed better taste than control during the 15 days storage period (Sarkar et al., 1995).

**Overall Acceptability**

Based on the organoleptic evaluation performed on the guava fruits, the shelf life of 6 % wax emulsion treated fruits was seven days and unwaxed (control) could be stored only up to 4 days. The other wax emulsion treatments like 3 % and 4 % treated fruits could be stored up to 5, and 6 days, respectively.

For mangoes, the organoleptic evaluation showed that the shelf life of 6 % wax emulsion treated fruits could be stored up to 12 days and unwaxed (control) could be stored only up to seven days. The other wax emulsion treatments like 3 % and 4 % treated fruits could be stored up to 10 days respectively. It was also found that by increasing the wax concentrations the shelf life of fruits could be increased.

**Titratable Acidity**

The titratable acidity of guava fruits decreased during the storage period. The maximum decrease in acidity (0.15 %) was recorded in control. The acidity reduction was less in $T_4$ and $T_3$. In the case of mango fruits, the acidity was 0.7 % for the fully ripe mangoes just after harvest and showed a significant reduction in control samples within seven days. Whereas, in the wax emulsion coated samples, the rate of decrease is slow. This is due to the wax emulsion treatments helped in higher retention of acidity with lower conversion of acid to sugar.

**Total Sugar**

Increasing trend in total sugar is shown in **Table 6**. The highest amount of total sugar 13.17 % was recorded in control followed by $T_1$ and $T_2$. The sugar content was less in 5 % and 6 % wax emulsion treated fruits after seven days of storage. For mangoes, the total sugar content was increased rapidly in control samples, whereas in wax emulsion coated samples these sugar levels were reached after 10 to 12 days, which confirmed the delay in ripening in wax treatments (Dhoot et al., 1984).

From the study, it was found that the wax emulsion could be prepared by using oleic acid as a solvent and triethanolamine as an emulsifying agent with hot water the wax could be stabilized as liquid under atmospheric temperature. The wax applicator could be effectively used for coating fruits for extending the shelf life. It was also found that the wax emulsion coated guava and mango fruits could be extended up to 7 and 12 days against 4 and 7 days only for the unwaxed (control) guava and mango fruits.

The authors wish to thank the ICAR PHT Scheme for providing necessary financial assistance for carrying out the research work.

**Table 6** Variation of titratable acidity of guavas and mangoes with different wax emulsions

| Treatments | Guava, storage days | | | | Mango, storage days | | | |
|---|---|---|---|---|---|---|---|---|
| | 4th day | 5th day | 6th day | 7th day | 7th day | 9th day | 11th day | 12th day |
| $T_1$ | 0.28 | 0.21 | 0.19 | 0.18 | 0.54 | 0.52 | 0.37 | 0.30 |
| $T_2$ | 0.29 | 0.24 | 0.21 | 0.19 | 0.52 | 0.51 | 0.39 | 0.34 |
| $T_3$ | 0.31 | 0.24 | 0.22 | 0.20 | 0.51 | 0.49 | 0.42 | 0.37 |
| $T_4$ | 0.31 | 0.25 | 0.23 | 0.20 | 0.51 | 0.49 | 0.42 | 0.38 |
| Control | 0.25 | 0.17 | 0.16 | 0.16 | 0.35 | 0.31 | 0.28 | 0.24 |

Mean values of three replications; Initial titratable acidity-
Guava: 0.32 %, Mango: 0.58 %

| Treatments | Guava | | | Mango | | |
|---|---|---|---|---|---|---|
| | SED | CD (5 %) | CD (1 %) | SED | CD (5 %) | CD (1 %) |
| Wax emulsion | 0.004 | 0.007 | 0.010 | 0.004 | 0.077 | 0.010 |
| Storage days | 0.004 | 0.007 | 0.009 | 0.004 | 0.008 | 0.009 |
| Interactions | 0.007 | 0.015 | 0.020 | 0.077 | 0.015 | 0.020 |

**Table 7** Variation of total sugar of guavas and mangoes with different wax emulsions

| Treatments | Guava, storage days | | | | Mango, storage days | | | |
|---|---|---|---|---|---|---|---|---|
| | 4th day | 5th day | 6th day | 7th day | 7th day | 9th day | 11th day | 12th day |
| $T_1$ | 9.42 | 10.97 | 12.29 | 12.75 | 14.1 | 15.5 | 16.3 | 16.4 |
| $T_2$ | 9.12 | 10.83 | 12.16 | 12.20 | 14.0 | 15.2 | 16.0 | 16.1 |
| $T_3$ | 9.12 | 10.35 | 11.41 | 12.13 | 12.7 | 13.1 | 15.2 | 15.9 |
| $T_4$ | 8.97 | 10.07 | 11.11 | 12.02 | 12.3 | 13.5 | 14.8 | 15.5 |
| Control | 12.12 | 12.35 | 12.87 | 13.17 | 16.1 | 16.7 | 16.9 | 17.0 |

Mean values of three replications; Initial value total sugar-
Guava: 9.23 %, Mango: 10.5 %

| Treatments | Guava | | | Mango | | |
|---|---|---|---|---|---|---|
| | SED | CD (5 %) | CD (1 %) | SED | CD (5 %) | CD (1 %) |
| Wax emulsion | 0.005 | 0.009 | 0.013 | 0.005 | 0.009 | 0.013 |
| Storage days | 0.004 | 0.008 | 0.011 | 0.004 | 0.008 | 0.011 |
| Interactions | 0.009 | 0.019 | 0.026 | 0.010 | 0.020 | 0.027 |

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## Effect of operational Speed and Moisture Contents of Wheat Crop on Plot Combine Harvester

was found a bit higher at 1.5 km/h in comparison to 1.0 km/h. Hence, it may be concluded that the plot combine harvester should be operated at 1.5 km/h speed and 9.16 % moisture content of the crop.

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# Development of an Aqueous Palm Oil Extraction System

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## Abstract

Continuous attempts have been made to re-examine the aqueous extraction of palm oil by pit technology and devise a means of improving the technology particularly for the small-scale processors. A novel aqueous batch extraction system was developed and was subsequently evaluated for its performance in palm oil processing.

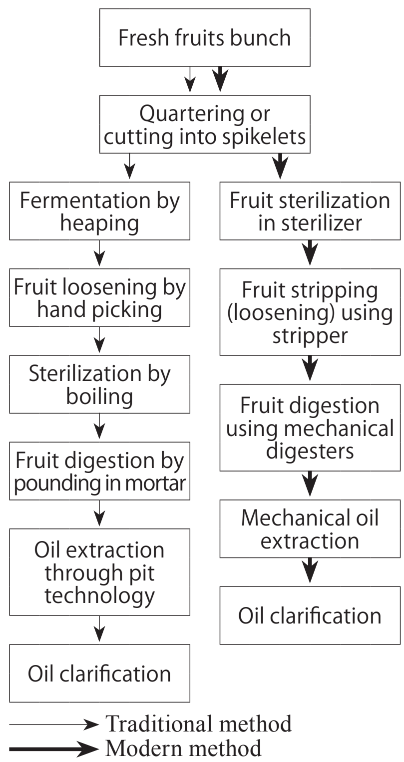
The crude oil produced from the traditional pit technology and aqueous batch extraction system was compared and evaluated using a $2^3$ factorial experimental design. The factors considered were variety of fruit, fruit sterilization time and processing technology. The crude oil produced at different factor levels was assessed for its solid impurities, moisture content and oil content. The results indicated that the crude oil yield from batch extraction system were higher with values of 30.4 % (for local variety and sterilisation time of 60 min), 30.9 % (for local variety and sterilisation time of 90 min), 42.0% (for improved variety and sterilisation time of 60 min) and 43.2 % (for improved variety and sterilisation time of 90 min) compared with pit technology method with 26.8 % (for local variety and sterilisation time of 60 min), 27.7 % (for local variety an sterilisation time of 90 min), 38.6 % (for improved variety at sterilisation time of 60 min) and 39.6 % (for improved variety at sterilisation time of 90 min), respectively. The throughput of the batch extraction system (120 kg of mash/h) was found to be higher than pit technology that could take only 65 kg of mash/h. Therefore, the batch extractor is effective and capable of replacing the traditional pit technology system.

## Introduction

Palm oil is an important agricultural product used as cooking oil in most African countries. It serves as raw material for the manufacture of margarine, soap and other industrial products. Processing of palm fruits obtained from freshly harvested palm fruit bunches to obtain palm oil involves five basic operations, namely, fruit loosening, sterilization, digestion, oil expression/extraction and clarification (**Fig. 1**).

All the processing plants, small, medium and large, perform these operations. The only difference is

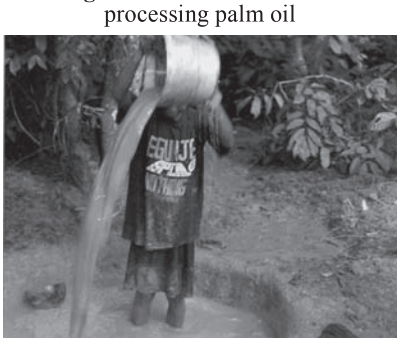
**Fig. 1** Flow chart of palm fruit processing



the method and sequence of performing the operations. The large-scale plants use sophisticated equipment to achieve high productivity and good quality oil. However, most of the large scale equipments are too expensive for the small-scale processors who dominate the palm fruit processing industry (Badmus 1991; Taiwo, et al., 2000)

Continuous efforts are being made to develop appropriate technologies for the small-scale processors in order to improve their efficiency in performing the operations. Such efforts include the development of fruit sterilisers, digesters, presses and oil clarifier (which exist in different versions and capacities). Oil separation remains a critical bottleneck. The use of a press is still not widely adopted because of its limitation in terms of energy requirement versus the extraction efficiency. In most small scale processing centres, the use of pit technology is still common (Taiwo et al., 2000). The pit technology is an aqueous extraction method, which involves the use of cemented pits and buckets. The digested palm fruit mash is poured into the pit and then diluted by adding water in a water-to-mash ratio of 2:1 by volume. The mixture is constantly agitated using a bucket. The mixture is raised above the head and poured into the pit (**Fig. 2**). As mixing continues, components of the mash are separated into layers. The oil floats on top surface, the kernel sinks to the bottom while the fibre settles in between. The oil is manually scooped with a small bowl into a bucket.

**Fig. 2** Traditional method of processing palm oil



The effectiveness of the operation depends on how assiduous the operator is. Apart from the fact that the oil yield from the process is low, their crude oil is prone to contamination since the operator stands in the pit to perform the operation. The process is also strenuous and results in waist-pains and backaches. In general, the method is not hygienic. In some few centres where the processors utilise hydraulic or screw press, the extraction efficiency is improved but the processors still prefer the pit technology after using the press due to the fact that it is far away (in principle) from their usual system while the presses were even abandoned in others (Taiwo et. al, 2000). There is, therefore, need for a technology that is closer to and more effective than the pit technology.

Mixing or agitation is the main essential operation employed in the traditional method of aqueous extraction. Agitation of liquids is done for several purposes viz., suspension of solid particles, blending miscible liquids, dispersing a gas through the liquid in the form of small bubbles, dispersion a second, immiscible liquid with the first to form an emulsion, suspension of fine drops and promoting heat transfer between the liquid and a cod or jacket (McCabe and Smith, 1976).

McCabe and Smith (1976) reported that liquids are most often agitated in a tank or vessel, usually cylindrical in form and with a vertical axis. The top of the vessel may be opened to the air, or it may be closed. Usually an impeller is mounted on an over-hung shaft. Impeller agitators are divided into two classes viz.: axial flow impellers, which generate currents parallel to the axis of the impeller shaft and radial flow impellers, which generate current in a tangential or radial direction. Impellers are further subdivided into propellers, paddles and turbines. Propellers and turbines operate at high speed while paddles turn at low to moderate speeds. An industrial paddle agitator turns at speeds between 20 and 150 rpm. Paddles push the liquid radially and tangentially. The currents they generate move outward to the vessel wall and then either upward or downward, and this creates turbulence. This study considers the possibility of having a mechanical device to replace the traditional pit

**Table 1** Experimental factors and levels

| Factors | Levels | |
|---|---|---|
| Sterilization | (-) 60 mins | (+) 90 mins |
| Variety of oil palm* | (-) Local (dura) | (+) Improved (tenera) |
| Technology | (-) Pit technology | (+) Batch extraction |

*The local variety refers to the dura while the improved variety refers to the tenera

**Table 2** Yield of crude oil and throughput of processing condition

| Sterilization time, mins | Variety | Technology | *Crude oil yield, % |
|---|---|---|---|
| -60 (-) | Local (-) | Pit (-) | 26.8 |
| +90 (+) | Local (-) | Pit (-) | 27.7 |
| -60 (-) | Improved (+) | Pit (-) | 38.6 |
| +90 (+) | Improved (+) | Pit (-) | 39.6 |
| -60 (-) | Local (-) | Batch (+) | 30.4 |
| +90 (+) | Local (-) | Batch (+) | 30.9 |
| -60 (-) | Improved (+) | Batch (+) | 42.0 |
| +90 (+) | Improved (+) | Batch (+) | 43.2 |

*Values represent average oil yield

technology. A batch extractor system was designed and evaluated in comparison with the pit technology. The paddle type of impeller was adopted in the design based on the speed required for the system.

## Materials and Methods

**The Aqueous Batch Extractor**

The principle of the paddle as employed in this study disperses the crude palm oil in the mixture of palm fruit mash and water and, thus, produces the crude oil in the form of emulsion, which is skimmed off. The oil extractor (**Figs. 3** and **4**) consists of a drum 570 mm diameter and 900 mm long and has an opening at the top. The drum houses a 50 mm diameter shaft supported on ball bearing at the two ends. Eight paddles were mounted on the section of the shaft between the shaft bearings. The drum is equipped with a screw drain plug through, through which the wastewater could be drained.

The whole assembly rests on a standing frame 850 mm high at the back and 610 mm at the front. The drum rests on the frame as shown in **Fig. 3**. The arrangement facilitates tilting of the drum to discharge unwanted residue (fiber and nut) when necessary. There is a lid 370 mm wide, which runs down the upper face of the drum.

**Operating Principle of the Machine**

The machine is a simulation of the pit technology in which agitation of palm fruit mash-water mixture is achieved without the processor entering the pit. The mash obtained from a digesting machine is poured into the drum and enough water is added to submerge the paddles when the paddles are horizontal. The mixture is agitated for about three to five minutes by rotating the shaft through a lever, at a speed varying between 60 and 90 rpm, depending on the physical condition of the operator. The crude oil forms an emulsion that floats on top of the water and is scooped off, using a small bowl. This process continues until it is impossible to scoop any more or until it is a waste of time and energy to continue scooping. The effluent is drained by removing the drain plug located at the base of the drum. The nuts and fibre residue, which settle at the bottom, are evacuated by tilting the drum through 90º, and rotating the shaft for the paddles to push out the residue.

**Process Equipment**

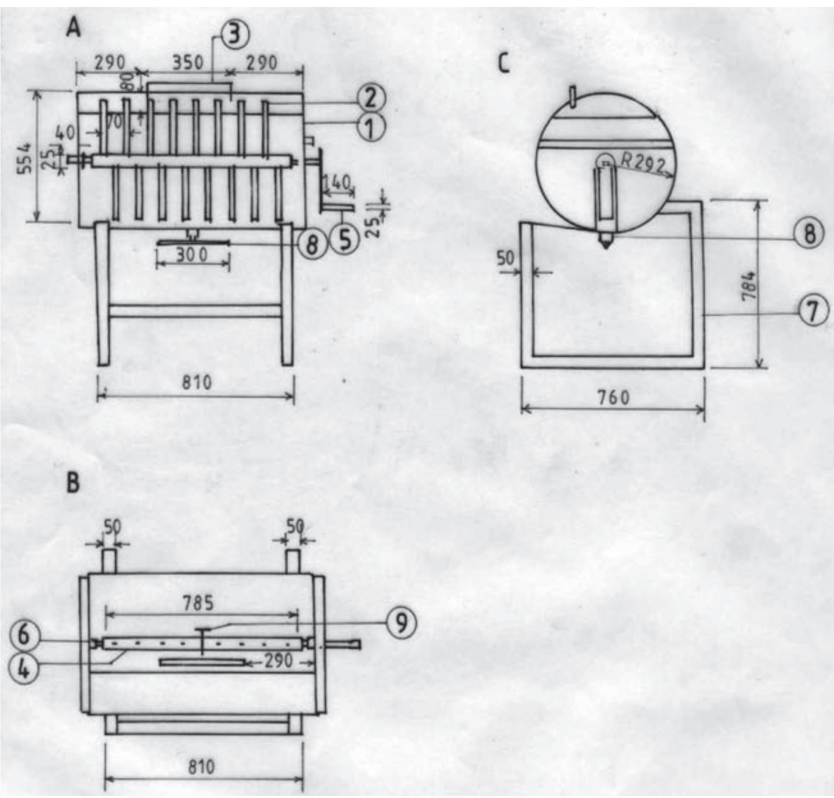
The equipment used for the study consists of axe (used for cutting the bunches into spikelets), steriliser (used to sterilise the spikelets), fruit stripper (for striping the fruit from spikelets), vertical digester, (used in digesting the sterilised palm fruit), aqueous batch extractor (the machine to be evaluated) and cemented trough (used for traditional aqueous extraction).

**Experimental Methods**

***(a) Oil Extraction by the Pit Technology (traditional method)***

Fresh fruit bunches were cut into spikelets using an axe and sterilised with steam at a temperature of about 100 ºC for 60 min and 90 min. The fruits were then removed from the sterilised spikelets with the stripper and transferred into a vertical digester for digestion. Ten kilograms of digested fruit mash was then poured into the cemented pit. The mash was diluted with about twice its volume of water and stirred vigorously by using a bucket to raise the mixture high above the head and allowed to fall into the pit in order to create turbulence. As the raising and falling continued, components of the mash were separated into layers. The crude oil floated on top

**Fig. 3** The aqueous batch extractor (orthographic projection)




A- Front view, B- Plan view, C- Side view
1: Drum, 2: Paddle, 3: Drum cover handle, 4: Shaft, 5: Shaft handle, 6: Ball bearing, 7: Angle iron frame, 8: Outlet valve, 9: Shaft keyway

and was scooped off and collected in a container of known weight. The kernel sank to the bottom, while the fibre settled in between. This scooping process was repeated until no more oil was floating. The container and oil content was then weighed on a Mettler-type weighing balance, and the weight of the crude oil was obtained by subtracting the weight of the container from the total weight. The time taken for the skimming process was also recorded, using a stopwatch.

***(b) Oil Extraction by the Aqueous Batch Extractor (improved method)***

For this system, 10 kg of the mash from the digested fruits, as in (a) above, was poured into the batch extractor and about 48 litres of water was poured on it. The mixture was agitated for about 10 minutes by manually rotating the shaft and paddles to achieve mixing (as in the pit technology). The oil floated on top of the water, the kernels sank to the bottom, while the fibre was in between. The oil was manually scooped with a small bowl into a container of known weight, and the process was repeated until no oil appeared on the water surface. The wastewater was drained out through the outlet valve. The weight of the crude oil obtained and the time taken for the skimming process was recorded as described in (a) above.

The crude oil obtained in each method was clarified using a clarifier in the laboratory and subjected to physical and chemical analysis in order to assess the performance of the aqueous batch extractor in comparison with the pit extraction method. In order to fully articulate the advantages of the improved method in terms of processing time and other parameters, the pit-technology was carried out exactly the way the village women do it. The factors considered in the study are, fruit variety, sterilization time and processing technology. Based on the work of Owolarafe (1999), a 23 factorial experiment was used in the study as shown in **Table 1**.

The two varieties of oil palm fruit used in the experiment were the dura (refered to as the local) and the tenera (refered to as the improved). About 10 kg of local and improved fruit varieties sterilised for 60 min and 90 min were processed using the aqueous batch extractor and pit technology. Each experiment was replicated twice. Data include skimming time and crude oil yield. The crude oil obtained was also analysed for quality using Soxhlet extraction method (AOAC, 1984). The quality parameters used were moisture content, oil content and solid impurities.

**Fig. 4** The picture of the batch extractor

## Result and Discussion

**Table 2** shows the average yield of crude oil from the processed fruits at different combinations of sterilization time, variety and extraction method. Generally, increasing the sterilization time from 60 min to 90 min increased crude oil yield. This result has also been observed by Baryeh (2001). The increase in crude oil yield with sterilization time can be attributed to the fact that there was improved heat treatment and moisture absorption of the mash, which tends to weaken the fruit mesocarp thereby facilitating and improving the digestion and extraction operations. Increase in ster-

**Table 3** Statistical analysis of the effect of processing factors on crude oil yield

| $S_T$ | $V_A$ | $T_C$ | Crude oil yield, % | $C_1$ | $C_2$ | $C_3$ | Divisor | Estimate* | Effect |
|---|---|---|---|---|---|---|---|---|---|
| - | - | - | 26.8 | 54.5 | 132.7 | 279.2 | 8 | 34.9 | Mean |
| + | - | - | 27.7 | 78.2 | 146.5 | 3.6 | 4 | 0.9 | $S_T$ |
| - | + | - | 38.6 | 61.3 | 1.9 | 47.6 | 4 | 11.9 | $V_A^{**}$ |
| + | + | - | 39.6 | 85.2 | 1.7 | 0.8 | 4 | 0.2 | $S_TXV_A$ |
| - | - | + | 30.4 | 0.9 | 23.7 | 13.8 | 4 | 3.45 | $T_C^{*}$ |
| + | - | + | 30.9 | 1.0 | 23.9 | -0.2 | 4 | -0.05 | $S_TXT_C$ |
| - | + | + | 42.0 | 0.5 | 0.1 | 0.2 | 4 | 0.05 | $V_AXT_C$ |
| + | + | + | 43.2 | 1.2 | 0.7 | 0.6 | 4 | 0.15 | $S_TXV_AXT_C$ |

$S_T$: Sterilization; $V_A$: Variety; $T_C$: Technology; $C_1$, $C_2$, $C_3$: Constants
*Singnificant at 95 %, **Singnificant at 99 %

**Table 4** Effect of processing factors on oil content, moisture content and impurity of the crude oil

| Sterilization | Variety | Technology | Moisture content, % | Oil content, % | Impurity level, % |
|---|---|---|---|---|---|
| - | - | - | 44.75 | 16.2 | 39.05 |
| + | - | - | 45.39 | 16.4 | 38.21 |
| - | + | - | 44.78 | 15.9 | 39.32 |
| + | + | - | 44.73 | 16.0 | 39.27 |
| - | - | + | 43.05 | 18.3 | 38.65 |
| + | - | + | 43.26 | 18.4 | 38.34 |
| - | + | + | 42.13 | 18.1 | 39.77 |
| + | + | + | 40.60 | 18.0 | 41.40 |

ilization time also reduces the viscosity of the oil, which makes oil to flow out easily. These results agree with the findings of Babatunde et al. (1988) and Owolarafe (1999).

The oil yield analysis presented in **Table 2** showed that the improved variety has a high yield compared with the local variety when the same quantity of fruit was processed. This is due partly to the fact that the improved variety has a high mesocarp content. It can also be observed that the crude oil yield of the batch extractor are higher with values of 30.4 % 30.9 %, 42.0 % and 43.2% compared with the pit technology method of 26.8 %, 27.7 %, 38.6 %, and 39.6 %, respectively. Yield of the batch extractor for sterilisation time of 60 min is higher than that of the pit technology for 90 min sterilization time. This is because the batch extractor provides adequate agitation to enable the oil to separate easily.

The separate and interactive effect of the processing factor compared by using Yate's algorithm (Box et al., 1978) is shown in **Table 3**. The separate effects of sterilisation time, variety and technology were all positive. The interactive effects of sterilisation time and variety; variety and technology; and sterilisation time, variety and technology; were also positive. However, the interactive effect of sterilisation time and technology was negative (Table 3). Further analysis using the SAS statistical package (SAS 1987) indicated that technology and variety had significant effect at 95 % and 99 % levels, respectively. The effect of sterilization time and the interactive effects of other factors were not significant.

In **Table 4** the average oil content, moisture content and impurity values of the crude oil are presented. The batch extractor method has a higher oil content than pit technology method. The high oil content achieved with the use of the batch extractor can be attributed to the smaller volume of water required for extraction, which results in less dilution of the crude oil compared to the pit technology method.

The effect of the processing factors on oil content of the crude oil (**Table 5**) indicated that the separate effect of sterilization time and technology were positive while that of variety was negative. The interactive effect of variety and technology was also positive. However, interactive effects of sterilisation time and variety, and sterilisation time and technology were observed to be negative. Further analysis using the statistical package (SAS, 1987) indicated that technology and variety were significant at 99 % and 95 % levels, respectively.

From **Table 4**, it can be observed that the moisture content of batch extractor method was lower compared with the pit technology. The small volume of water required by batch extractor method reduced the moisture content. The result of the statistical analysis of the data on moisture content (**Table 6**) indicated that all the separate and interactive effects were negative. However, further analysis, indicated that the separate effect of technology was significant at 99 % level while the separate effect of variety was significant at 95 %. All other interactive effects of the factors considered in the study were not significant (**Table 6**).

The impurity level of the crude oil was not affected by processing condition (**Table 4**). The statistical analysis shown in **Table 7** indicates that all the separate effects were positive. Further statistical analysis revealed that none of the separate effects and interactive effects were significant.

**Table 8** shows the result of the analysis of the quality of palm oil from the two extraction methods. There was no significant difference

**Table 5** Statistical analysis of the effect of processing factors on content of the crude oil

| $S_T$ | $V_A$ | $T_C$ | Oil content, % | $C_1$ | $C_2$ | $C_3$ | Divisor | Estimate* | Effect |
|---|---|---|---|---|---|---|---|---|---|
| - | - | - | 16.2 | 32.6 | 64.5 | 137.3 | 8 | 17.2 | Mean |
| + | - | - | 16.4 | 31.9 | 72.8 | 0.3 | 4 | 0.08 | $S_T$ |
| - | + | - | 15.9 | 36.7 | 0.3 | -1.3 | 4 | -0.325 | $V_A^*$ |
| + | + | - | 16.0 | 36.1 | 0.0 | -0.3 | 4 | -0.08 | $S_TXV_A$ |
| - | - | + | 18.3 | 0.2 | -0.7 | 8.3 | 4 | 2.08 | $T_C^{**}$ |
| + | - | + | 18.4 | 0.1 | -0.6 | -0.2 | 4 | -0.08 | $S_TXT_C$ |
| - | + | + | 18.1 | 0.1 | -0.1 | 0.2 | 4 | 0.03 | $V_AXT_C$ |
| + | + | + | 18.0 | -0.1 | -0.2 | 0.6 | 4 | -0.03 | $S_TXV_AXT_C$ |

$S_T$: Sterilization; $V_A$: Variety; $T_C$: Technology; $C_1$, $C_2$, $C_3$: Constants
*Singnificant at 95 %, **Singnificant at 99 %

**Table 6** Statistical analysis of the effect of processing factors on moisture content

| $S_T$ | $V_A$ | $T_C$ | Moisture content, % | $M_1$ | $M_2$ | $M_3$ | Divisor | Estimate* | Effect |
|---|---|---|---|---|---|---|---|---|---|
| - | - | - | 44.75 | 90.14 | 179.65 | 348.69 | 8 | 43.60 | Mean |
| + | - | - | 45.39 | 89.51 | 169.04 | -0.73 | 4 | -0.18 | $S_T$ |
| - | + | - | 44.78 | 86.13 | 0.59 | -4.21 | 4 | -1.05 | $V_A^*$ |
| + | + | - | 44.73 | 82.73 | -1.32 | -2.43 | 4 | -0.61 | $S_TXV_A$ |
| - | - | + | 43.05 | 0.64 | -0.64 | -10.61 | 4 | -2.65 | $T_C^{**}$ |
| + | - | + | 43.26 | -0.05 | -3.58 | -1.91 | 4 | -0.48 | $S_TXT_C$ |
| - | + | + | 42.13 | 0.21 | -0.69 | -2.95 | 4 | -0.74 | $V_AXT_C$ |
| + | + | + | 40.60 | -1.53 | -1.74 | -1.05 | 4 | -0.26 | $S_TXV_AXT_C$ |

$S_T$: Sterilization; $V_A$: Variety; $T_C$: Technology; $M_1$, $M_2$, $M_3$: Constants
*Singnificant at 95 %, **Singnificant at 99 %

between the quality parameters of palm oil sample from the two systems. The high Free Fatty Acid (FFA) obtained might have been due to the delay in processing of fruits. Fermentation increased the FFA values of the oil and lowered the extraction efficiency (Badmus, 1991). The peroxide value and specific gravity of the oil sample from both systems showed that the extraction method had no effect on the quality of the oil. Also, the viscosity values showed that all the samples from the two systems were viscous and not adulterated.

The throughput, which is the rate at which the digested mash comprising oil, fibre and nuts were processed, was also determined for both extraction methods. Throughput of the batch extractor was 120 kg/hr as compared to 65 kg/hr for the pit extraction method.

## Conclusion

The study presented an aqueous batch palm oil extraction system designed to replace the existing pit technology. The pit extraction method is not only inefficient, but also the fact that the processor stands in the pit during processing makes it hazardous. The pit extraction method also exposes the oil to contamination from the surrounding. This makes the traditional method unhygienic. The new device was efficient and yielded more oil compared with the pit technology. It is expected that the device will be incorporated into the palm fruit processing technologies among the small-scale processors to improve their productivity. The authors feel that the use of hot water for the extraction process can improve the extraction efficiency and that this is an area for further study.

**Table 7** Statistical analysis of the effect of processing condition of crude oil impurity

| $S_T$ | $V_A$ | $T_C$ | Impurity level, % | $T_1$ | $T_2$ | $T_3$ | Divisor | Estimate* | Effect |
|---|---|---|---|---|---|---|---|---|---|
| - | - | - | 39.05 | 77.26 | 155.85 | 314.01 | 8 | 39.25 | Mean |
| + | - | - | 38.21 | 78.59 | 158.16 | 0.43 | 4 | 0.11 | $S_T$ |
| - | + | - | 39.32 | 76.99 | -0.89 | 5.51 | 4 | 1.38 | $V_A$ |
| + | + | - | 39.27 | 81.17 | 1.32 | 2.73 | 4 | 0.68 | $S_TXV_A$ |
| - | - | + | 38.65 | -0.84 | 1.33 | 2.31 | 4 | 0.58 | $T_C$ |
| + | - | + | 38.34 | -0.05 | 4.18 | 2.21 | 4 | 0.55 | $S_TXT_C$ |
| - | + | + | 39.77 | -0.31 | 0.79 | 2.85 | 4 | 0.71 | $V_AXT_C$ |
| + | + | + | 41.40 | 1.63 | 1.94 | 1.15 | 4 | 0.29 | $S_TXV_AXT_C$ |

$S_T$: Sterilization; $V_A$: Variety; $T_C$: Technology; $T_1$, $T_2$, $T_3$: Constants
*None of the factors and their interactions is significant

**Table 8** Quality of the palm oil produced from the two systems

| Quality parameter | Value in processing method | |
|---|---|---|
| | Pit technology | Batch extractor |
| Free fatty acid, % | 5.781 | 5.534 |
| Peroxide value, mg/g | 1.64 | 1.5 |
| Specific gravity | 0.8876 | 0.8855 |
| Viscosity | 59.8219 | 59.9250 |

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# The Response of Two-Sorghum Cultivars to Conventional and Conservation Tillage Systems in Central Sudan

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## Abstract

Water conservation becomes the ultimate goal of crop producers under rain fed agriculture. In this regard, different tillage systems can produce varying effects on soil physical properties and consequently soil moisture content and crop yield. Three tillage systems were selected to study the effect on some soil physical properties and yield of two grain-sorghum cultivars. The experiments were carried out for two consecutive seasons at two sites in central Sudan. The three tillage systems were conservation using chiseling to a depth of 30 cm, conventional using ridging to a depth of 8 cm and no-till as control. Conservation tillage showed a significant effect on all soil physical properties as well as sorghum yield components. Soil bulk density with conservation and conventional tillage decreased below the control value by 20.0 % and 6.6 %, respectively, while soil porosity increased over the control value by 52.0 % and 9.8 % under the aforementioned tillage systems, respectively. As a result, the soil moisture content increased beyond the control by 244.5 % in the case of conservation tillage and by 122.4 % with conventional tillage system. Grain yield increased by 596.3 % under conservation tillage and by 200 % under conventional tillage. On the other hand, the dry matter yield was 188.2 % and 30 % higher than the control under conservation and conventional tillage systems, respectively.

## Introduction

Soil moisture conservation becomes the ultimate objective of producers under rainfed agriculture and in areas where rainfall varies greatly. Different techniques are employed to assist water infiltration into the soil. Conventionally, water bounds are formed using high dykes to trap as much rainwater as possible on the field surface. One more sound technique is to practise certain conservation tillage to create the best seedbed that can retain rainfall and enhance crop establish-

**Table 1** Monthly rainfall records (mm) at the two study sites in season 1 and season 2

| Location | Mouths | | | | Total |
|---|---|---|---|---|---|
| | August | September | Octobar | November | |
| **Season 1** | | | | | |
| *Abu Diling* (site 1) | 173.0 | 62.0 | 76.0 | 0.0 | 311 |
| *Alwan* (site 2) | 77.0 | 96.0 | 85.5 | 2.5 | 261 |
| **Season 2** | | | | | |
| *Abu Diling* (site 1) | 103.0 | 135.0 | 291.0 | 11.5 | 530.5 |
| *Alwan* (site 2) | 89.0 | 89.0 | 232.0 | 35.5 | 445.5 |

ment and yield. Different tillage implements and depths are used depending on the region, soil type and rainfall. It is, thus, important that the proper types of implement are selected for different soil and crop conditions, in order to achieve a suitable seed environment (Shiekh et al., 1978).

Different tillage operations have different effects on crop establishment, growth and yield. However, the effect of tillage system on crop yield should be evaluated objectively, based on the changes to the soil physical properties rather than on crop yield only.

The objective of this study was to examine the effect of conventional conservation and no-till systems on soil physical properties and the yield of two sorghum cultivars grown under rainfed conditions in the semi arid zone of central Sudan.

## Materials and Methods

This study was conducted in the semi-arid climate zone in Eastern Nile Province, 60 km east of Khartoum North city, at latitudes 15º 15' and 15º 35' N; and longitudes 33º 00' and 33º 35' E. The area slopes generally (at 8 %) from North East to the South West. The average annual rainfall for the last 15 years ranged between 200 and 350 mm during the period from August to November, with the bulk of rains falling during September and October. The average rainfall is less than 50 % of the total potential evapotranspiration in all months, but practically, during one month (September) rainfall covers more than 20 % of the evapotranspiration.

The texture of the top layer (30 cm from the soil surface) is sandy clay, while the layer of the 30-60 cm depth is clayey. Due to wind erosion, a sandy layer of about 3-5 cm deep covers the soil surface.

The bulk of the area is devoted to sorghum (*Dura*) production during the rainy season. People in the area are used to cultivating sorghum in small rainfed plots known as "*Bildat*". They construct low bounds "*Terus*" around an area of about 2.1 hectares so as to avoid surface runoff of rainwater. Seedbeds are prepared using ridgers to make furrows across the slope. Manual seeding is used to grow local early maturing cultivars of sorghum for food and forage.

Three tillage systems and two grain-sorghum cultivars were studied at two different sites for two consecutive seasons under rain-fed conditions. Site 1 (*Abu Dilig*) lies 8 km to southeast of site 2 (*Alwan*).

**Table 2** The effect of tillage system on soil bulk density (g/cm$^3$), porosity (%), and basic infiltration rate (cm/h)

| Tillage system | Soil physical properties | | |
|---|---|---|---|
| | Bulk density, g/cm$^3$ | Porosity, % | Basic infiltration rate, cm/h |
| **Abu Dilig** | | | |
| No-till | $1.80^{*}_{a}$ | $28.0^{**}_{a}$ | $4.38^{**}_{a}$ |
| Conventional tillage | $1.75_{b}$ | $30.0_{b}$ | $4.38_{a}$ |
| Conservation tillage | $1.44_{c}$ | $42.0_{c}$ | $6.42_{b}$ |
| LSD | 0.023 | 1.80 | 1.80 |
| **Alwan** | | | |
| No-till | $1.83^{**}_{a}$ | $27.0^{*}_{a}$ | $3.18^{*}_{a}$ |
| Conventional tillage | $1.74_{b}$ | $30.4_{b}$ | $3.18_{a}$ |
| Conservation tillage | $1.46_{c}$ | $41.6_{c}$ | $6.42_{b}$ |
| LSD | 0.024 | 2.90 | 0.90 |

$^{*}$, $^{**}$: means are significantly different at $P \leq 0.05$ and $P \leq 0.01$, respectively.
Means followed by the same subscript within a column are statistically similar.
LSD: Least significant difference.

**Fig. 1** Soil moisture content (%) as affected by tillage system at three growth stages during the two seasons at *Abu Dilig* (site 1)

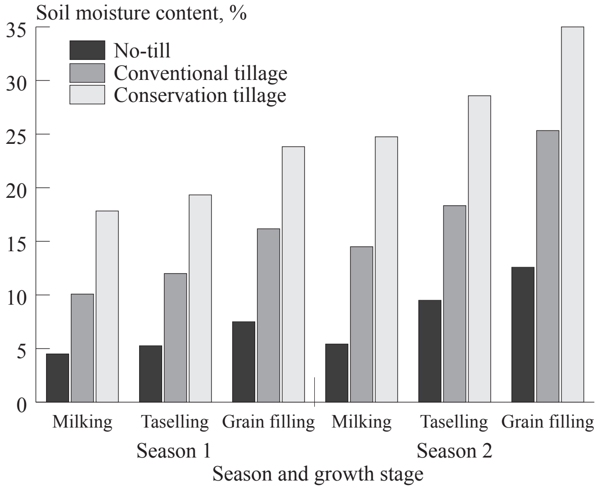
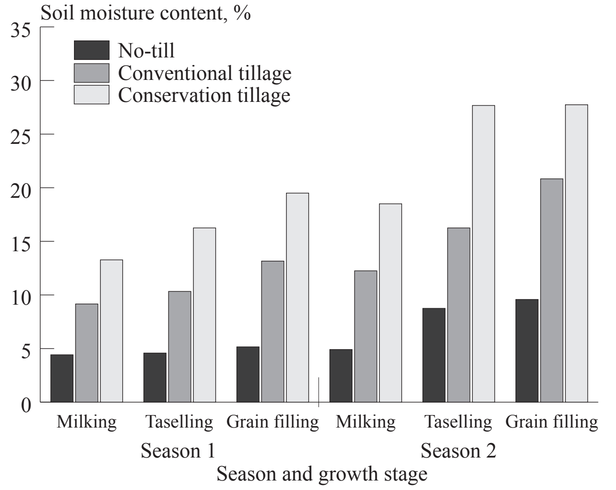



**Fig. 2** Soil moisture content (%) as affected by tillage system at three growth stages during the two seasons at *Alwan* (site 2)



The randomized complete block design (RCBD) was used to layout the experiments. The experiments consisted of three treatments for seedbed preparation; chiseling to 30 cm soil depth (conservation tillage), ridging to 10 cm soil depth (conventional tillage) and no-till (control). Each treatment was replicated three times. A plot of 40 m x 50 m was used for each treatment. Each plot was divided into two sub-plots 40 m x 25 m each. After the first showers, two local early maturing sorghum cultivars (*Hemesi* and *Feterita*) were planted in each sub-plot.

Undisturbed soil samples were taken from the surface down to 60 cm depth at two increments of 30 cm each from three different locations in each plot to determine the effect of tillage practice on bulk density and porosity (%), recording its mean values. The bulk density (g/cm$^3$) was determined, using the paraffin wax method (Johnson, 1945). The porosity of the aforementioned samples was calculated using the following equation:

Porosity (%) = 100 (1- bulk density/ particle density)

Water infiltration rate was measured at three different locations in each plot using the double ring infiltrometer as described by Michael (1978) and the mean was recorded.

During the main stages of crop growth (milking, taselling and grain filling), four soil samples were taken at two incremental soil depths (0-30 cm and 30-60 cm) from each plot to determine the mean residual moisture content using the gravimetric method. The split-split plot design was adopted to statistically analyze the moisture content, porosity and bulk density results. Rain gauges were installed at the experimental site in order to measure rainfall amounts throughout the seasons.

The final head weight and yield of each plot (grain and dry matter) were selected as yield indicators, and the mean value of each sub-plot was recorded.

## Results

Rainfall records of the two study sites are presented in **Table 1**. At both sites the seasonal rainfall of the second season was higher than that of the first one. However, the seasonal records lie in the average range of rainfall reported by Abu Dilig Meteorological Station.

Soil bulk density (g/cm$^3$), porosity (%) and basic infiltration rate of the two study sites as affected by tillage system, are shown in **Table 2**. With exception to the basic infiltration rate in site 2, tillage system had a highly significant effect on the soil physical properties studied ($P \leq 0.01$). In that season, tillage system had a significant effect on the basic infiltration rate at $P \leq 0.05$ level.

Conservation tillage recorded the lowest bulk density, highest porosity and highest basic infiltration rate. Soil bulk density and porosity were significantly different under the conventional when compared with the no-till system ($P \leq 0.01$). Nevertheless, both systems recorded similar values of basic infiltration rate in both study sites.

Soil moisture content (%) was significantly affected by tillage system at all growth stages in both seasons and study locations ($P \leq 0.01$). **Figs 1** and **2** show soil moisture content records of the three tillage systems for site 1 (*Abu Dilig*) and site 2 (*Alwan*), respectively. The highest moisture content values were recorded under conservation tillage followed by conventional tillage, while no-till system recorded the lowest values at both sites and seasons. Records of the second season were higher than those of the first season at both study sites. For the individual tillage system, soil moisture content increased with growth stage (although, at low rates with no-till system in the first season at *Alwan*).

Results of the effect of tillage systems and sorghum cultivars on head weight (g), grain yield and dry

**Table 3** The effect of tillage system and sorghum cultivars on yield components at the two study sites (season 1)

| Parameter | Sorghum cultivars | Tillage system | | | |
|---|---|---|---|---|---|
| | | No-till | Conventional tillage | Conservation tillage | Mean |
| **Abu Dilig** (site 1) | | | | | |
| Head weight, g | Hemesi | 10.23 | 45.70 | 100.60 | $52.18^{**}_{a}$ |
| | Feterita | 8.67 | 35.43 | 90.43 | $44.48_{b}$ |
| | Mean | $9.45^{**}_{a}$ | $40.57_{b}$ | $95.52_{c}$ | |
| Grain yield, ton/ha | Hemesi | 0.25 | 1.00 | 2.00 | $1.08^{*}_{a}$ |
| | Feterita | 0.10 | 0.80 | 2.00 | $0.97_{b}$ |
| | Mean | $0.18^{**}_{a}$ | $0.90_{b}$ | $2.00_{c}$ | |
| Dry matter yield, ton/ha | Hemesi | 4.30 | 5.70 | 17.80 | $9.27^{*}_{a}$ |
| | Feterita | 4.20 | 4.70 | 17.00 | $8.63_{b}$ |
| | Mean | $4.25^{**}_{a}$ | $5.20_{b}$ | $17.40_{c}$ | |
| **Alwan** (site 2) | | | | | |
| Head weight, g | Hemesi | 5.00 | 30.63 | 80.73 | $38.79^{**}_{a}$ |
| | Feterita | 3.73 | 27.33 | 70.50 | $33.85_{b}$ |
| | Mean | $4.37^{**}_{a}$ | $28.98_{b}$ | $75.62_{c}$ | |
| Grain yield, ton/ha | Hemesi | 0.15 | 0.80 | 1.80 | $0.92^{*}_{a}$ |
| | Feterita | 0.10 | 0.60 | 1.55 | $0.75_{b}$ |
| | Mean | $0.13^{**}_{a}$ | $0.70_{b}$ | $1.68^{**}_{c}$ | |
| Dry matter yield, ton/ha | Hemesi | 4.00 | 5.40 | 14.00 | $7.80^{**}_{a}$ |
| | Feterita | 3.80 | 4.80 | 12.50 | $7.03_{b}$ |
| | Mean | $3.90^{**}_{a}$ | $5.10_{b}$ | $13.25_{c}$ | |

$^{*}$, $^{**}$: means are significantly different at $P \leq 0.05$ and $P \leq 0.01$, respectively.
Means followed by the same subscript within a row or a column are statistically similar.
LSD: Least significant difference.

matter yield (ton/ha) are shown in **Tables 3** and **4**. Tillage systems had a consistent high significant effect on all yield parameters studied at both study sites and seasons ($P \leq 0.01$). All systems recorded significantly different results from each other, with conservation tillage out yielding conventional and no-till systems. However, the response of yield parameters to tillage systems ranked in the following order: conservation tillage > conventional tillage > no-till. On the other hand, sorghum cultivars' effect on yield parameters was significant at different levels, with Hemesi cultivar out yielding Feterita in all the studied parameters.

## Discussion

Amounts of rainfall at the two study sites were in the average range reported by Abu Dilig Meteorological Station. A high variability was noticed in the distribution of amounts of rainfall throughout the season at both study sites. This can be attributed to the characteristics and nature of rainfall in the area. This variation will reflect, in a way, on crops' response to the amount of rainfall as it determines the extent to which rainfall water is being successfully translated into economic yield. The high intensity of rainfall had a mechanical impact on soil aggregates and resulted in different degrees of crust formation. This was particularly observed with the no-till system. Crust formation hinders water infiltration and leads to seedling stress when it occurs at the germination stage. However, these observations are consistent with the results reported by Agassi et al (1981). Site 1 (*Abu Dilig*) recorded higher amounts of rainfall in both seasons, this is attributed to the geographical location of the two sites, as site 1 lies southwards of site 2 (Alwan), hence rainfall amounts are expected to be higher.

It is evident that tillage, in most cases, has a positive impact on soil physical properties. The extent to which these properties are improved often depends on the tillage system, plough type and ploughing depth along with the initial soil conditions from degree of compaction, moisture content and previous crop. This highlights that different tillage practices can produce different effects on soil physical properties because of the varying degrees on physical manipulation. In the conservation tillage system under this study, the chisel plough operated deeper, hence it had the highest effect on soil bulk density, porosity and basic infiltration rate. On the other hand, conventional tillage had an intermediate effect on soil bulk density and porosity. Basic infiltration rate under conventional and no-till systems was similar at both sites. This can be attributed to the presence of cracks and fissures in the no-till plots, which enhanced water infiltration and compensated for the effect of tillage on infiltration rate. However, this effect subsided when the soil swelled after saturation. The results obtained are in conformity with those reported by Unger (1984) and Moreno et al. (1998). The low results of basic infiltration rate under conventional and no-till systems can be attributed to the development of a compacted layer at shallow depths just below the ploughing depth as a consequence of continuous ploughing as mentioned by Maurya (1993). Basic infiltration rate results are consistent with those reported by Bezidicek et al. (1998).

The highest soil moisture content values recorded under conservation tillage can possibly be attributed to two main reasons. One being the improvement in soil physical properties due to tillage, and the other is the low rate of water loss through evaporation of the deeply infiltrated and retained water. On the other hand, less water infiltrated into the

**Table 4** The effect of tillage system and sorghum cultivars on yield components at the two study sites (season 2)

| Parameter | Sorghum cultivars | Tillage system | | | |
|---|---|---|---|---|---|
| | | No-till | Conventional tillage | Conservation tillage | Mean |
| **Abu Dilig** (site 1) | | | | | |
| Head weight, g | Hemesi | 60.66 | 98.60 | 170.74 | $110.00^{**}_{a}$ |
| | Feterita | 31.34 | 69.40 | 101.26 | $67.33_{b}$ |
| | Mean | $46.00^{**}_{a}$ | $84.00_{b}$ | $136.00_{c}$ | |
| Grain yield, ton/ha | Hemesi | 0.50 | 1.00 | 2.10 | $1.2^{**}_{a}$ |
| | Feterita | 0.35 | 0.70 | 2.00 | $0.83_{b}$ |
| | Mean | $0.43^{*}_{a}$ | $0.85_{b}$ | $2.05_{c}$ | |
| Dry matter yield, ton/ha | Hemesi | 7.40 | 9.70 | 20.00 | $12.37^{*}_{a}$ |
| | Feterita | 7.20 | 9.70 | 18.70 | $11.87_{b}$ |
| | Mean | $7.30^{**}_{a}$ | $9.70_{b}$ | $19.40_{c}$ | |
| **Alwan** (site 2) | | | | | |
| Head weight, g | Hemesi | 20.50 | 46.00 | 85.50 | $50.67^{**}_{a}$ |
| | Feterita | 11.67 | 20.66 | 65.83 | $32.72_{b}$ |
| | Mean | $16.08^{**}_{a}$ | $33.33_{b}$ | $75.67_{c}$ | |
| Grain yield, ton/ha | Hemesi | 0.40 | 0.85 | 1.75 | $1.00^{**}_{a}$ |
| | Feterita | 0.30 | 0.70 | 1.60 | $0.87_{b}$ |
| | Mean | $0.35^{**}_{a}$ | $0.78_{b}$ | $1.68^{**}_{c}$ | |
| Dry matter yield, ton/ha | Hemesi | 6.80 | 9.30 | 14.50 | $10.20^{**}_{a}$ |
| | Feterita | 6.50 | 8.20 | 12.50 | $9.20_{b}$ |
| | Mean | $6.65^{**}_{a}$ | $8.75_{b}$ | $13.70_{c}$ | |

$^{*}$, $^{**}$: means are significantly different at $P \leq 0.05$ and $P \leq 0.01$, respectively.
Means followed by the same subscript within a row or a column are statistically similar.
LSD: Least significant difference.

no-till plots, which recorded the poorest bulk density and porosity values. This was reflected in low moisture content values. Moreover, more water is exposed to loss through direct evaporation from the soil surface.

The conventional tillage system had an intermediate effect on soil physical properties and consequently on soil moisture content. The trend of soil moisture content under the three tillage systems was consistent with the results reported by Phillip et al. (1980). The difference in moisture content between the two study sites and seasons is attributed to the differences in the amounts of rainfall.

The significant effect of conservation tillage on soil physical properties resulted in the highest yield components and grain yield. This is consistent with the findings of Alem (1993), who found that improved seedbeds are consistently superior to the traditional ones in terms of available water and grain yield. Further, Kirkegaard et al. (2001) reported that tillage system, which promotes greater infiltration and storage, results in increased crop yield. The low yield under conventional and no-till systems can be attributed to the limitations on crop yields and grain quality, which are likely to occur as a result of long-term unfavorable tillage practices.

## Conclusion

Under rainfed conditions, tillage systems are determinal to water conservation and crop yield. Conservation tillage using the chisel plough produced a good soil tilth, conserved water and recorded the highest grain yield.

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# Tillage and Planting Management for Improving the Productivity and Profitability of Rice-Wheat Cropping System


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## Abstract

A 3 year field experiment was conducted to evaluate the performance of zero till drilling, strip till drilling, bed planting and conventional sowing in wheat under varying planting methods of rice, viz. dry seeding (unpuddled), sprouted seeding (puddled), manual transplanting and mechanical transplanting by a self-propelled transplanter. The mechanical transplanting of rice produced 6.25 t/ha grain and 6.94 t/ha straw yields that were at par with manual transplanting but significantly higher than the two direct seeding methods. The mechanical transplanting was the most cost effective and energy efficient method requiring lowest specific energy (408 kcal/kg) and specific cost (49.3 US $/t); and providing maximum benefit: cost ratio (2.34) and energy output: input ratio (7.36). For wheat, strip till drilling produced higher values of growth; yield attributing characters; grain (5.67 t/ha) and straw (7.82 t/ha), followed by zero till drilling, conventional sowing and bed planting. The strip till drilling was the most cost effective and energy efficient method requiring lowest specific energy (430 kcal/kg) and specific cost (41.8 US $/t), and providing maximum benefit: cost ratio (3.67) and energy output: input ratio (6.98). However, the conventional sowing was least cost effective and energy efficient requiring maximum specific energy (543 kcal/kg) and specific cost (54.8 US $/t), and providing minimum benefit: cost ratio (2.81) and energy output: input ratio (5.52).


## Introduction

Rice-wheat is a predominant cropping system in India and contributes 74 % of the total food grain production of the country. In this system, rice is taken mainly as a manually transplanted crop in puddle condition. Rice transplanting in puddle soil is complicated and highly labour intensive. The timely availability of labour for transplanting is a big problem in most areas. Moreover, under puddle conditions, though the yield is higher, it has its own limitations and ill-effects on soil health. Besides other things, wheat sowing is also delayed resulting in linear decline in wheat productivity equivalent to 1-1.5 % per day when sowing occurs after November (Hobbs et al., 1997).

Use of long duration rice varieties and delayed transplanting of rice for want of sufficient monsoon rain for puddling are major causes of late wheat sowing. The conventional method of wheat sowing by giving repeated tillage further delays sowing and adversely affects the yield. Keeping these facts in view, a field experiment was conducted to find out suitable sowing/transplanting methods of rice and wheat under different tillage practices in rice-wheat system.

## Materials and Methods

A 3 year field study was conducted at the experimental farm of the Project Directorate for Cropping Systems Research, Modipuram during 2000-2003. The experimental soil was sandy loam (sand, silt and clay contents of 64, 19 and 17 %, respectively), having pH, organic carbon, and available N, P, K of 8.29, 53 g/kg, and 130, 24.4, 275 kg/ha, respectively. The design of experiment was split plot having four sowing/transplanting methods of rice [dry seeding (unpuddled); and sprouted seeding, manual transplanting and mechanical transplanting by self-propelled transplanter, all in puddle condition] in main plots and four sowing methods of wheat (zero till drilling, strip till drilling, bed planting and conventional sowing) in sub plots replicated four times. Twenty-two days old seedlings were used for manual as well as mechanical transplanting at row spacing of 238 mm and hill spacing of 120 mm. Recommended dose of fertilizers (120 kg N, 26 kg P and 33 kg K/ha) was applied to both the crops. Need based irrigation, interculture and plant protection were applied. Data were statistically analyzed by using randomized block design and split plot design for rice and wheat, respectively.

## Results and Discussion

**Effect of Planting Methods on Rice**

***(A) Growth and Yield Attributes***

The planting methods significantly affected the plant growth (height, total panicles/m$^2$ and dry matter) and yield attributes (effective panicles/m$^2$, grain weight/panicle and test weight) of rice (**Table 1**). The maximum values of these parameters were recorded with mechanical transplanting of rice closely followed by manual transplanting. Yield attributes were better under transplanting than dry seeding, because puddling has great significance in rice culture. It facilitates transplanting, increases the availability of water and nutrients, ensures better germination or plant establishment, kills the weeds and helps the plants to grow vigorously (Prasad et al., 2002). The early establishment and subsequent growth of the transplanted seedlings by self-propelled transplanter were faster, as reflected in taller plants, higher number of total panicles/m$^2$ and shoot dry matter production giving significantly higher number of effective panicles/m$^2$ (398), grain weight/panicle (1.80 g) and test weight (22.8 g). Apart from this, the uniform growth of crop was also observed due to placement of seedlings at a uniform depth and spacing with equal number of seedlings per hill under mechanical transplanting. Garg et al. (1997) also reported the similar results.

***(B) Yields***

Different planting methods had significant effect on yield of rice during all the three years (**Table 2**). Maximum pooled grain (6.25 t/ha) and straw (6.94 t/ha) yields were obtained with mechanical transplanting followed by manual transplanting, dry seeding and sprouted seeding. Overcrowding in dry and sprouted seeding methods might have increased the inter- and intra-plant competition for resources. The mechanical transplanting produced 8, 25 and 30 % higher grain; and 2, 18 and 19 % higher straw as compared to manual transplanting, dry seeding and sprouted seeding, respectively. This was because of better growth parameters and yield attributes through optimum utilization of resources, which had direct

**Table 1** Growth parameters, yield attributes and yield of rice as influenced by different planting methods (Pooled data of 3 years)

| Planting method | Plant height, cm | Total panicles, m$^2$ | Plant dry matter, g/m$^2$ | Effective panicles, m$^2$ | Panicle length, cm | Grains/ panicle, No. | Grain weight/ panicle, g | Test weight, g |
|---|---|---|---|---|---|---|---|---|
| Dry seeding | 73 | 403 | 739 | 313 | 21.0 | 88 | 1.63 | 20.4 |
| Sprouted seeding | 76 | 354 | 677 | 304 | 20.4 | 89 | 1.48 | 19.1 |
| Manual transplanting | 89 | 465 | 998 | 366 | 20.9 | 88 | 1.72 | 21.7 |
| Mechanical transplanting | 92 | 495 | 1,034 | 398 | 21.6 | 93 | 1.80 | 22.8 |
| CD (P = 0.05) | 9.2 | 42 | 108 | 35 | NS | NS | 0.19 | 2.19 |

**Table 2** Grain and straw yields of rice as influenced by different planting methods

| Planting method | Grain yield, t/ha | | | | Straw yield, t/ha | | | |
|---|---|---|---|---|---|---|---|---|
| | 2000-01 | 2001-02 | 2002-03 | Pooled | 2000-01 | 2001-02 | 2002-03 | Pooled |
| Dry seeding | 5.20 | 4.50 | 5.30 | 5.00 | 5.85 | 5.17 | 5.93 | 5.65 |
| Sprouted seeding | 5.10 | 4.35 | 5.01 | 4.82 | 6.07 | 5.25 | 6.11 | 5.81 |
| Manual transplanting | 5.60 | 5.40 | 6.40 | 5.80 | 6.67 | 6.49 | 7.18 | 6.78 |
| Mechanical transplanting | 6.06 | 6.10 | 6.59 | 6.25 | 6.67 | 6.81 | 7.34 | 6.94 |
| CD (P = 0.05) | 0.67 | 0.73 | 0.78 | 0.71 | 0.74 | 0.89 | 0.97 | 0.78 |

bearing on the higher yield of rice. The results corroborated with that of Sharma et al. (2002) and Jaiswal and Singh (2001).

***(C) Economics and Energy Use***

The comparison of economics and energy use in different planting methods of rice revealed that the mechanical transplanting (net returns, 412 US $/ha; benefit: cost ratio, 2.34; energy output: input ratio, 7.36; specific cost, 49.3 US $/t; and specific energy, 408 kcal/kg) was better in all the aspects of comparison than rest of the planting methods (**Table 3**). However, dry seeding was better compared to sprouted seeding in all the aspects. It was also better than manual transplanting in case of benefit: cost ratio. The least beneficial method was manual transplanting due to high cost of production (335 US $/ha) along with maximum specific cost (57.8 US $/t). Sharma et al. (2002) had also reported the similar findings.

**Effect of Rice Planting Methods on Wheat**

***(A) Growth and Yield Attributes***

Direct dry seeding adopted in rice produced significantly higher total tillers/m row length, plant dry matter (g/m row) and effective tillers/m$^2$ of wheat compared to mechanical transplanting of rice (**Table 4**). However, different planting methods remained statistically at par in respect of other growth and yield attributing characters. The better growth parameters and yield attributes of wheat on the plots following direct seeded rice were attributed to its effect on providing ideal seedbed for wheat sowing, which resulted in better growth of the crop. Sharma et al. (2002) also reported the similar findings.

***(B) Yields***

Different methods of planting adopted in preceding rice did not affect the wheat yield in any year, however, maximum pooled grain (5.41 t/ha) and straw (7.49 t/ha) yields of wheat were obtained from direct seeded rice plots, (**Table 5**). This was mainly due to more effective ears/m$^2$ and higher test weight. Tripathi et al. (1999) also reported the similar results.

**Effect of Planting Methods on Wheat**

***(A) Growth and Yield Attributes***

The strip till drilling produced significantly higher growth (plant height, total tillers and plant dry matter) and yield attributing characters (effective ears/m$^2$) over zero till drilling (**Table 4**). It also recorded significantly higher plant height, grains/ear and test weight than conventional sowing. However, zero till drilling, bed planting and conventional sowing remained at par with each other in respect to these characters. The higher values of growth and yield attributes might be due to higher germination percentage, adequate plant population per unit area and side placement of fertiliz-

**Table 3** Economic comparison and energy use of different planting methods of rice (Pooled data of 3 years)

| Parameter | Dry seeding | Sprouted seeding | Manual transplanting | Mechanical transplanting |
|---|---|---|---|---|
| Cost of production, US $/ha | 266 | 260 | 335 | 308 |
| Net returns, US $/ha | 310 | 296 | 333 | 412 |
| Benefit: cost ratio | 2.17 | 2.14 | 1.97 | 2.34 |
| Input energy, kcal/ha (x $10^6$) | 2.57 | 2.67 | 2.49 | 2.55 |
| Output energy, kcal/ha (x $10^6$) | 15.01 | 14.47 | 17.41 | 18.76 |
| Energy output: input ratio | 5.84 | 5.42 | 6.99 | 7.36 |
| Specific energy, kcal/kg | 514 | 553 | 429 | 408 |
| Specific cost, US $/t | 53.2 | 53.9 | 57.8 | 49.3 |

**Fig. 1** A view of straw/stubble left on the field after grain combining

**Table 4** Growth parameters, yield attributes and yield of wheat as influenced by different planting methods (Pooled data of 3 years)

| Planting method | Plant height, cm | Total tillers/m$^2$ | Plant dry matter, g/m$^2$ | Effective tillers/m$^2$ | Grains/ear, No. | Grain weight/ear, g | Test weight, g |
|---|---|---|---|---|---|---|---|
| **Rice** | | | | | | | |
| Dry seeding | 100 | 585 | 1,040 | 385 | 54 | 2.20 | 41.3 |
| Sprouted seeding | 100 | 570 | 995 | 374 | 53 | 2.06 | 40.2 |
| Manual transplanting | 99 | 545 | 980 | 366 | 54 | 2.23 | 40.6 |
| Mechanical transplanting | 99 | 530 | 970 | 364 | 51 | 2.13 | 40.7 |
| CD (P = 0.05) | NS | 45 | 69 | 19.4 | NS | NS | NS |
| **Wheat** | | | | | | | |
| Dry seeding | 99 | 520 | 920 | 339 | 55 | 2.25 | 40.8 |
| Sprouted seeding | 101 | 580 | 1,055 | 404 | 56 | 2.33 | 41.7 |
| Manual transplanting | 100 | 580 | 1,035 | 377 | 51 | 2.09 | 41.0 |
| Mechanical transplanting | 98 | 550 | 975 | 369 | 50 | 1.95 | 39.2 |
| CD (P = 0.05) | 1.84 | 57 | 115 | 39.3 | 5.46 | NS | 2.06 |

ers under strip till drilling. The side placement of fertilizer increased the availability of nutrients to the growing roots, which resulted in vigorous growth of plants.

***(B) Yields***

The yield of wheat was influenced significantly due to different sowing methods during all the three years (**Table 5**). Maximum pooled grain (5.67 t/ha) and straw (7.82 t/ha) yields were obtained under strip till drilling that were significantly higher than rest of the sowing methods. The higher yield under strip till drilling could be attributed to better pulverization of soil, resulting in proper seed and soil contact, which caused good germination, growth and development of plants that improved the effective ears/$m^2$, grain weight/ear and test weight. However, the lower yield in conventional sowing was perhaps because the strip till drill created a desired tilth of seedbed and further tillage operations did not improve the quality of seedbed. The pooled grain yields were 5.06, 5.04 and 5.01 t/ha in zero till drilling, conventional sowing and bed planting, which were, respectively, 11.0, 11.1 and 11.6 % less compared to strip till drilling. Samra and Dhillon (2000) also reported higher grain yield by sowing of wheat by strip till drill over broadcasting (conventional sowing/farmer's practice). The ancillary characters such as tillers/$m^2$, grains/ear and test weight were also improved when crop was sown by drill compared with broadcasting method. The results are also in line with those of Gogoi and Kalita (1995). It is interesting to note that zero till drilling produced statistically similar grain yield to that of conventional sowing and bed planting. The yield compensation under zero till drilling was partially contributed by 5-6 days advance sowing than conventional sowing (Tripathi and Chauhan, 2001). The beneficial effects of reduced/strip tillage over conventional tillage have also been reported by Hobbs et al. (1997).

***(C) Economics and Energy Use***

The comparison of economics and energy use in different sowing methods of wheat by various machines is presented in **Table 6**. The strip till drilling produced maximum wheat yield along with lowest cost of production (237 US $/ha), resulted in highest net returns (632 US $/ ha) and benefit: cost ratio (3.67) compared to other planting methods. It also gave highest energy output: input ratio (6.98) and lowest specific energy (430 kcal/kg) and specific cost (41.8 US $/t) and, therefore, proved most remunerative. Zero till drilling in most of the aspects of comparison closely followed it. The cost of cultivation in zero till drilling was around 242 US $/ha whereas in conventional sowing it was 276 US $/ha. This shows that zero till drilling was cost effective compared to conventional

**Fig. 2** Field operation of the straw harvester

**Table 6** Economic comparison and energy use of different sowing methods of wheat (Pooled data of 3 years)

| Parameter | Zero till drilling | Strip till drilling | Bed planting | Conventional sowing |
|---|---|---|---|---|
| Cost of production, US $/ha | 242 | 237 | 242 | 276 |
| Net returns, US $/ha | 534 | 632 | 526 | 500 |
| Benefit: cost ratio | 3.20 | 3.67 | 3.18 | 2.81 |
| Input energy, kcal/ha (x $10^6$) | 2.37 | 2.44 | 2.39 | 2.74 |
| Output energy, kcal/ha (x $10^6$) | 15.19 | 17.02 | 15.04 | 15.13 |
| Energy output: input ratio | 6.41 | 6.98 | 6.29 | 5.52 |
| Specific energy, kcal/kg | 468 | 430 | 477 | 543 |
| Specific cost, US $/t | 47.8 | 41.8 | 48.3 | 54.8 |

**Table 5** Grain and straw yields of wheat as influenced by different planting methods

| Planting method | Grain yield, t/ha | | | | Straw yield, t/ha | | | |
|---|---|---|---|---|---|---|---|---|
| | 2000-01 | 2001-02 | 2002-03 | Pooled | 2000-01 | 2001-02 | 2002-03 | Pooled |
| **Rice** | | | | | | | | |
| Dry seeding | 5.18 | 5.65 | 5.40 | 5.41 | 7.31 | 7.71 | 7.45 | 7.49 |
| Sprouted seeding | 4.91 | 5.50 | 5.19 | 5.20 | 6.82 | 7.83 | 7.55 | 7.40 |
| Manual transplanting | 5.23 | 5.44 | 4.81 | 5.16 | 7.16 | 7.62 | 6.73 | 7.17 |
| Mechanical transplanting | 5.15 | 5.35 | 4.47 | 4.99 | 7.36 | 7.21 | 6.25 | 6.94 |
| CD (P = 0.05) | NS | NS | NS | NS | NS | NS | NS | NS |
| **Wheat** | | | | | | | | |
| Dry seeding | 5.09 | 5.42 | 4.97 | 5.06 | 6.97 | 7.50 | 6.62 | 7.03 |
| Sprouted seeding | 5.30 | 5.77 | 5.44 | 5.67 | 7.61 | 7.96 | 7.83 | 7.80 |
| Manual transplanting | 5.02 | 5.28 | 4.64 | 5.01 | 6.94 | 7.29 | 6.50 | 6.91 |
| Mechanical transplanting | 5.06 | 5.47 | 4.82 | 5.04 | 7.13 | 7.62 | 7.03 | 7.26 |
| CD (P = 0.05) | 0.27 | 0.44 | 0.49 | 0.59 | 0.58 | 0.59 | 0.86 | 0.75 |

sowing. Since the amount of fuel required was about 60-70 % less in strip and zero till drilling, the profit margin of the farmers increased substantially. This was in conformity with the findings of Tripathi et al. (1999) and Sharma et al. (2002).

## Conclusions and Recommendation

Thus, on the basis of 3 years of experiment, it was concluded that the mechanical method was better for transplanting of rice in puddle fields for improving the productivity and profitability, followed by manual transplanting method. With wheat, strip till drilling produced higher yield and was more cost effective and energy efficient method, followed by zero till drilling and bed planting, and may be recommended for wheat sowing instead of conventional sowing. Therefore, the mechanical transplanting in rice and strip tilling in wheat are recommended for large- scale popularization among farmers.

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# Development of a Yam Pounding Machine


by

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## Abstract

A simple and easy to maintain kitchen size yam pounding machine was developed, constructed and tested. The machine, powered by a 600 W electric motor was tested with two replaceable hammers; T-shaped and closed C-shaped hammers. The machine performed satisfactorily with the T-shaped hammer on yam slices not more than 40 mm in thickness. The products compared favourably with pounded yam produced with the traditional method. On the other hand, samples produced with the closed C-shaped hammers were generally unacceptable because they were full of lumps and unbroken yam pieces. Generally, the machine produced hot pounded yam within 45 seconds; hence, it is suitable for the present day nuclear families in the cities. A higher wattage electric motor rating would enhance its capacity as the machine tends to get stuck as soon as the yam turns into a thick paste if additional water is not sprinkled on it.


**Fig. 1** Yam tubers

## Introduction

Yam belongs to the genus *Dioscorea* (Family *Dioscoreaceae*) Most of the world production is from Africa (about 96 %) with Nigeria alone accounting for nearly 75 % of the total world's production (FAO, 1975; FAO, 1990; Opara, 1999). The World production figures are as shown in **Table 1**. Yams are a staple crop accounting for over 20 % of the dietary calorie intake in most producing area especially Africa and the Oceania. The white fleshed yam which have firm texture mainly *Dioscorea rotundata* is the most popular in West Africa. Yam, a cylindrical tuber (**Fig. 1**) rich in carbohydrate and fibre, is a crop that originated in East Asia but now widely grown and consumed in Africa especially West Africa, which accounts for about 80 % of the output of the whole African continent (Scott et al., 2000). It is widely cultivated in Nigeria being the major producer and consumer.

It is mainly grown for direct consumption but common methods of preparation include boiling, baking, and frying. Various food forms produced from yam include boiled and fried yam slices eaten with oil, fried egg or vegetables; roasted yam, yam porridge produced from mashed boiled yam mixed with palm oil and other ingredients; yam balls or slices (fried, boiled and roasted) produced from mashed yam popularly known as *Akara ojojo* and *Ikokore* (*Yoruba*) in Nigeria. Yam flour produced from fresh yam (peeled, chipped, dried and milled into flour) when mixed with boiling water and turned into a thick paste is used to produce a popular food called *Amala* (*Yoruba*) and *Akwanaji* (*Ibo*) in South-Western and South-Eastern Nigeria respec-

**Table 1** World production of yam

| Year | 1975[1] | 1990[2] | 1995[3] | 2002[3] |
|---|---|---|---|---|
| Africa | 19,539 | 28,249 | - | - |
| Nigeria | 15,000 | 22,000 | - | - |
| Cote D'Ivoire | 1,700 | 2,528 | - | - |
| Ghana | 800 | 168 | - | - |
| Togo | 750 | 420 | - | - |
| Benin | 610 | 992 | - | - |
| North and South America | 291 | 350 | - | - |
| Asia and Oceania | 368 | 482 | - | - |
| World | 20,198 | 29,447 | 32,765 | 37,532 |

Source: [1]FAO, 1975; [2]FAO, 1991; [3]FAO/STAT, 2000 tively. However, pounded yam is by far the most common and popular of all the food obtainable from yam.

Pounded yam is a special staple food of royalty in West Africa with Togo having the highest per capita consumption figure followed by Cote D'Ivoire, Ghana, Benin Republic and Nigeria. Nigeria being the largest producer is fifth in consumption per capita of pounded yam because there are a number of other yam products (listed above) in Nigeria more than the other countries where pounded yam and boiled yam are the only products from yam. However, it is very popular among all the ethnic groups and still the most popular food from yam in Nigeria (Orkwor et al., 1978). At present it is becoming one of the staple food across the globe where West Africans, especially Nigerians, are resident.

Pounded yam is traditionally prepared by peeling the yam tuber, cut into pieces or slices and boiled until it is fairly soft. The pieces or slices are then fed into a wooden mortar and pounded with pestle(s) until a thick paste of uniform consistency is formed. This process is strenuous, time consuming and full of drudgery. This is evident in the profuse perspiration of the pounders and the blisters on their palms after pounding. Due to this strenuous process of production, its consumption in the cities where the elites want to spend more time on their job, earn more money and spend less time in the kitchen has been limited to special occasions, the restaurants and other local eating outlets.

Ngoddy and Unuoha (1983) reported pioneering efforts of some Nigerian Universities at removing the drudgery and reducing the preparation time involved in the production of pounded yam. Some of these include the development of instant yam flour that reconstitute into yam *fufu* upon mixing with boiling water. The quality could not compare favourably with the traditional pounded yam due to the resulting darkened colour, which makes it look more like *Amala* (another staple food from yam in Nigeria). There was an improvement over this when Ofi (1992) produced poundo-yam flour from parboiled, dried and milled yam slices, which gave a better product that resembles the traditionally produced pounded yam. However, this is only acceptable to the educated elites who are interested in fast food but not the masses who believe in the production of pounded yam only from boiled fresh yam pieces.

The only widely reported attempt at producing pounded yam directly from boiled yam using mechanical method, which resulted in the machine shown in **Fig. 2**, was by Makanjuola (1974). It was a successful attempt except that the resulting machine is very large, heavy and bulky. These make it unsuitable for the modern day kitchens especially in the multi-tenant houses, storey buildings and the high rises in the cities. The modified version, which is currently produced commercially (**Fig. 3**) is still considered too heavy and large, occupying a lot of space (See the size of the machine relative to the operator in **Fig. 3**). It is also not economical for home use for a relatively very small family. There is also a persistent problem in coupling the hammer to the inverted electric motor.

This paper, therefore, presents the development of a yam pounding machine that addresses all the associated problems, through redesigning, to produce a compact, portable and efficient machine that produces pounded yam comparable with that traditionally produced.

**Fig. 2** Pounded yam machine (Makamjuola, 1974)

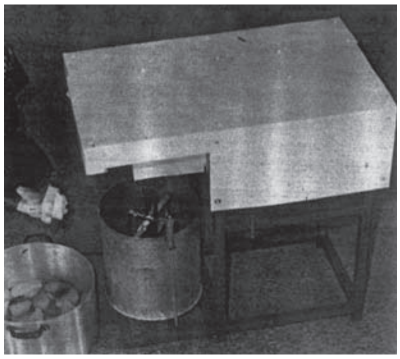
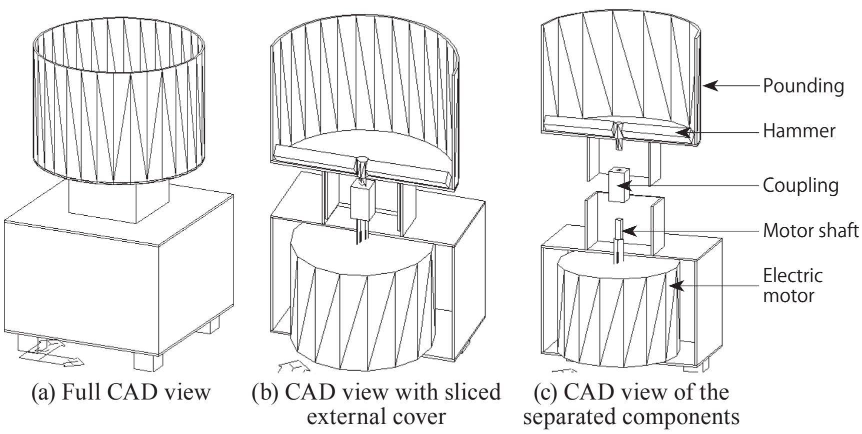


**Fig. 3** Modified pounded yam machine (left) with a user preparing yam for pounding (right)

**Fig. 4** CAD view of the pounding machine



## Materials and Methods

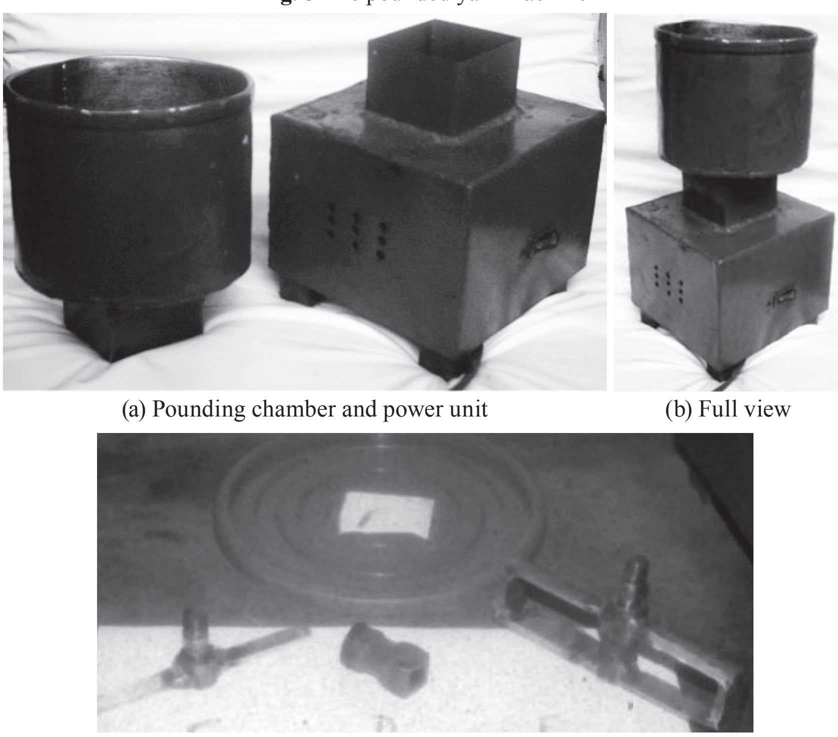
The determination of the shear force that would be required to bring about the shearing of the yam material on which the proposed machine is to work is very crucial and pertinent prior to the design. This is to aid the determination of the torque required to be applied to cause shearing of the yam pieces and, consequently, to serve as a guide towards designing for strength and size of the hammer and other component parts, as well as the selection of the prime mover.

Two yam species that are known for producing good quality pounded yam were used for the tests. These are yellow yam (*D. cayanensis*) and white yam (*D. rotundata*). Samples were subjected to shear tests under compression on an Instron testing machine with a data logger capable of displaying, recording and storing the load-deflection information on a computer connected to the machine. Samples of hot boiled yam slices of thickness between 10-80 mm were tested at two test speeds of 1 cm/sec (600 mm/min) and 0.25 cm/sec (150 mm/min). The load-deflection during loading was plotted while the peak load, yield stress and other parameters were automatically recorded and plotted with the computer attached to the test equipment. The maximum value obtained from all the values of the 'load at peak' was used as the shear force for design purposes.

## Design Considerations

The design of the yam pounding machine requires the consideration of some factors to ensure effective processing of the boiled yam into pounded-yam of acceptable quality. Some of the factors considered, especially during material selection for construction, include food contamination from corrosion and the strength of the materials. Also, safety was not sacrificed in the final specifications for the prime mover, other moving parts and power supply units while attempting to reduce the cost.

**Fig. 5** The pounded yam machine



(a) Pounding chamber and power unit (b) Full view

(c) Hammers and Chamber cover

**Design Features**

The machine is comprised basically of two detachable units, namely the pounding unit and the power unit (**Figs. 4a-c** and **5a**)

**The Pounding Unit**

This consists of the pounding chamber (hopper) which houses a replaceable hammer (**Figs. 4b-c** and **5c**), both of which are made of stainless steel to prevent corrosion and contamination. The chamber is a cylindrical cup of 150 mm diameter and 120 mm high made with 2 mm thick flat plate. A hole of 10.5 mm diameter by design was made at the bottom centre to accommodate the 10 mm diameter end of the shaft carrying the hammer.

Two hammers were designed and constructed for the purpose of this study; a closed C-shaped and a T-shaped. Each hammer consisted of three parts; the upper part, middle and lower parts. The upper part was made of a 16 mm diameter shaft and carried the functional unit, i.e. the pounding unit of the hammer. In the first hammer the upper part was 35 mm long with two C-Shaped structures formed from a 6 mm stainless steel bar welded to two opposite sides of the shaft. The upper part of the second hammer was of the same diameter but 20 mm long. A 6 mm thick rectangular bar was welded on top to form a T-structure. The bar was twisted to produce a screw effect. A ball bearing was force fitted onto the 100 mm diameter middle part of the shaft for easy rotation. The tail ends of the shafts were threaded to provide for the attachment of one end of a splined coupling, which meshes with the other end on the power unit to transmit power to the hammer. A rectangular guide was welded onto the lower part of the hopper and was force fitted to another rectangular guide on top of the power unit to ensure effective coupling. The components of the machine are shown in **Figs. 4** and **5**.

**The Power Units**

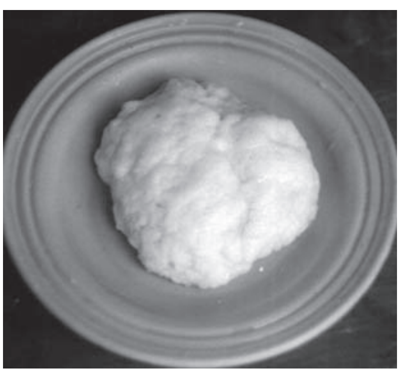
A 600 watt single phase electric motor supplied the power which was transmitted through a splined coupling to the shaft which rotated the hammer. The unit was protected by covering with a casing that has a control switch.

## Operational Principle

The hopper was placed and coupled with the power unit, then loaded with boiled yam slices and covered with the lid. The machine was operated by switching it on and off intermittently in order not to overload the electric motor. As the hammer rotated it pounded (i.e. shears, grinds and crushes) the yam against the wall of the hopper by impact until a thick drawing textural product was obtained. The twisted T-shaped hammer produced a screw effect that drew the yam pieces on top to the bottom and the ground pieces upward to ensure that all the products were handled. The pounded yam was discharged after about 45 to 180 seconds of operation by removing the hopper and turning the content into a bowl having obtained a thick drawing textural product that could be served hot and fresh.

**Fig. 6** Pounded yam obtained from yam cubes with the two hammers

(a) Closed C-shaped hammed



(b) T-shaped

## Performance Evaluation/ Tests

Performance evaluation tests included the effect of the materials of construction on the appearance of the pounded yam, the effect of the size of the yam slices on the performance of the machine and the effect of the shape of the hammer on the quality of food.

Pounded-yam samples were produced from 20 mm cubes of yam and whole yam slices of 20, 30, 40, 60 and 80 mm thick. The tests were performed using the two hammers and two different species of yam that are popular for producing high quality pounded-yam in West Africa. The products from each hammer and yam specie were coded and served to a 5-man panel for sensory evaluation. The evaluation was based on a scale of 1-9 in the order of 1 being dislike extremely to 9 being like extremely (most acceptable). The alphabet in the code represents the specie (A being *D.cyanensis* and B is *D.rotundata*) while the number represents the thickness.

## Results

The pounded yam obtained from yam cubes by the two hammers are shown in **Figs. 6** (**a** and **b**) while the products for T-shaped hammer for different yam thicknesses and yam species are as shown in **Fig. 7**.

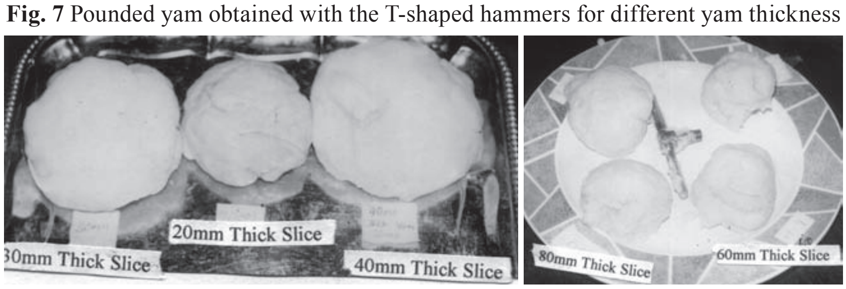
## Analysis and Discussion of Results

The physical nature of the samples of pounded yam produced with the two hammers shows that the initial white colour of the yam slices that were pounded was retained meaning that there was no contamination from the materials used for construction of the hammers and the hopper. This corresponds with the judgement of the evaluators as shown in **Table 2** with the appearance being 5 and above. The performance of the machine was better with T-shaped hammer adjudged with an average of 7 while the performance was poor with the closed C-shaped hammer having 6 and below.

The summary of the opinion of the judges during the sensory evaluation test are as presented in **Table 2**.

The texture of the outputs from the machine when the C-shaped hammer was used, were full of lumps and unbroken yam pieces (**Fig. 6a**). This was observed to be due to the nature of the hammer. Yam pieces get stuck in the space in between the loops in the C-shaped hammer, and more importantly the hammer had no screw effect that could move the already pounded yam mass to the upper part and replace them with the yet to be broken yam pieces. As a result, the few yam pieces that were pounded during

**Fig. 7** Pounded yam obtained with the T-shaped hammers for different yam thickness

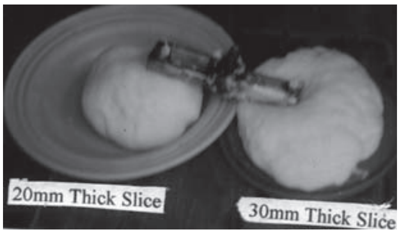


the first few rotations of the hammer remain stuck to the bottom of the pounding unit while the rest of the yam slices remain at the top, unbroken. It was also noticed that the size of the lumps of unbroken yam pieces increased with the size of the yam slice used for pounding.

The quality of the pounded yam samples produced with T-hammer, on the other hand was satisfactory and generally acceptable for all the sizes of yam tested (**Table 1**) except that one or two pieces of unbroken yam were found on the pounded yam mass when yam slices of 80 mm were used. This could easily be removed by hand before being served. However, addition of water by sprinkling and further pounding accomplished the full pounding with no lumps left behind. However, this resulted in a low quality product since the viscosity of the food reduced and the texture was slightly unacceptable until its temperature became low (**Fig. 8**). The pounded yam became too soft when a large quantity of water was added as shown in **Fig. 8** with a simple depression test under the self weight of the C-shaped hammer. Also the better performance of the T-shaped hammer was due to the screw effect which was lacking in the other hammer.

It was, however, observed that as the pounded yam became thicker, the machine tended to get stuck and required addition of water by sprinkling for further pounding, suggesting that an electric motor of slightly higher rating would enhance its overall efficiency. There was also a need to increase the gap between the hammer and the floor of the pounding chamber to reduce the quantity of pounded mass within the gap hence reducing the pressure that must be overcome. This could create another problem of very small yam lumps not being pounded but remaining in the wider gap.

**Fig. 8** Simple depression test for pounded yam with different water contsnt




## Conclusion

The following conclusions were made. An inexpensive, compact machine with about the same bowl size as that of Makanjuola (1974), which is simple to construct, operate and maintain was successfully designed. The machine performance varied with the type of hammer, size of the yam slices, and the duration of pounding. However, the newly designed hammer with a screw effect proved to be a better design. It, also, had a better coupling and the product compared favourably with the product from the traditional pestle and mortar.

Instant production of pounded yam comparable with those prepared traditionally and enough for 2 to 3 adults was made possible with ease. Hence, the drudgery involved in the traditional yam pounding method was eliminated at an affordable price.

The machine could successfully handle yam slices not more than 40 mm thick for excellent performance.

**Table 2** The sensory evaluation test result

| Specie | T-shaped hammer | | | C-shaped hammer | | |
|---|---|---|---|---|---|---|
| | Texture | Appearance | General acceptability | Texture | Appearance | General acceptability |
| A20 | 7 | 8 | 8 | 4 | 6 | 3 |
| A30 | 7 | 7 | 7 | - | - | - |
| A40 | 6 | 7 | 7 | 4 | 6 | 4 |
| A60 | 7 | 7 | 8 | 6 | 6 | 5 |
| A80 | 7 | 7 | 7 | - | - | - |
| B20 | 8 | 7 | 7 | 6 | 5 | 6 |
| B30 | 7 | 7 | 7 | - | - | - |
| B40 | 7 | 7 | 8 | 6 | 6 | 6 |
| B60 | 8 | 8 | 7 | 4 | 6 | 5 |
| B80 | 6 | 5 | 5 | - | - | - |

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# Possession, Knowledge and Operational Status of Farm Machinery with Surveyed Farm Woman in Vindhya Plateau Agro-climatic Zone of Madhya Pradesh

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## Abstract

Bhopal and Sagar districts were purposively selected from Vindhya plateau agro-climatic zone of Madhya Pradesh to generate the information on possession, knowledge and operation of improved farm machinery (tractor and manually-operated improved machinery) with various categories (landless, marginal, small, semi-medium, medium and large) of farm women. Of the total surveyed households (1,528) from 44 villages of both the districts, 18.5 %, 20.4 %, 20.7 %, 20.4%, 10.3 % and 9.7 % households were from landless, marginal, small, semi-medium, medium and large categories of farmers, respectively. Tractor, cultivator, seed drill, thresher and wheel hoe were commonly possessed and known by all the categories of farmers including landless. Tractors were owned by 0.4 % landless, 4.8 % marginal, 12.0 % small, 27.7 % semi-medium, 47.5 % medium and 60.4 % large categories of farmers. All categories of farm women had knowledge about the tractor and tractor operated cultivators, seed drills and threshers. Pedal cum power operated cleaner-grader was also known by 8.1 % farm women. Knowledge of farm women about manually-operated farm equipment like, wheel hoe, seed treatment drum, groundnut decorticator and maize sheller was 69.0 %, 23.0 %, 17.9 % and 14.6 %, respectively. It is found that 22.8 % of farm women worked with wheel hoes whereas 14.2 % worked with threshers, 8.2 % with groundnut decorticators, 5.1 % with hand maize shellers, 2.4 % with seed treatment drums, 1.2 % with cleaner graders and 0.7 % with tractors. There is a need to prepare a category wise set of tools/implements for farm women to reduce their drudgery in agricultural operations and also to increase their farm income. There is also need to develop and popularize the women friendly improved farm tools and equipment among them.

## Introduction

Madhya Pradesh is the largest state in India with a total population of over 60 million, a large concentration of tribal population (34.26 %), and great regional and cultural diversity. It covers an area of 307.55 thousand km$^2$, of which, 14.766 million hectare area (48.01 % of total geographical area) is under agriculture (Agricultural Statistics, 2001). On the basis of operational holdings, 60.9 % farmers belong to the marginal and small categories (1995-1996). On the basis of rainfall patterns, temperature and soil types, the state has been classified into eleven agro-climatic zones, namely: Zone-I: Chhattisgarh plains, Zone-II: Northern hill region of Chhattisgarh, Zone-III: Kymore plateau and Satpura hill, Zone-IV: Central Narmada valley, Zone-V: Vindhya plateau, Guna, Zone-VI: Gird zone, Zone-VII: Bundelkhand, Zone-VIII: Satpura plateau, Zone-IX: Malwa plateau, Zone-X: Nimar valley, and Zone XI: Jhabua hill.

A number of studies have been conducted on possession of tractors with farmers, utlisation of tractor, demand of tractor and repair-maintenance in the various parts of country (Singh and Tandon, 1987; Singh et al., 1991, Pannu et al., 1992; Shyam, 1992; Guruswamy et al., 1992, and Balishter et al., 2000). In the changing economy scenario of the country, it is necessary to get the information of possession of various types of farm machinery with various categories of farmers, viz., landless, marginal, small, semi-medium, medium and large categories to make future planning in terms of mechanisation for reducing drudgery of farmers particularly farm women as they are involved in all the agricultural operations. Keeping in view the pivotal role of farm women in agriculture, the present paper has made an attempt identify the possession of improved farm machinery, knowledge about the machinery and their handling by the farm women of above mentioned categories. Keeping this fact in mind, under project "Involvement of Farm Women in Agriculture and Allied Activities in the State of Madhya Pradesh" the category-wise above-mentioned information was collected. The paper presents the same under various categories of farmers of two districts of Vindhya plateau agro-climatic zone of Madhya Pradesh.

## Materials and Method

Vindhya plateau zone consists of Bhopal, Sagar, Damoh, Vidisha, Sehore (except Budni tehsil), Raisen (except Bareli tehsil) and Guna (part of Chanchaura, Raghogarh and Aron tehsils) districts. The zone is characterized by black soils mostly medium in depth. About 60 % of the zone has medium black soils 30-60 cm depth and about 20 % deep black soil (more than 60 cm depth) and shallow soils (30 cm depth). It experiences sub-tropical climate and an annual average rainfall of 1,000-1,500 mm is received mostly concentrated during the months of July and August (Singh, G., 2000).

Based on minimum and maximum female agricultural labourers, female cultivators, female population and net sown area, Bhopal and Sagar districts were selected to carry out the present study. Bhopal is a capital of the Madhya Pradesh. The district had a net sown area of 153,157 ha and is surrounded by Vidisha, Sehore, Raisen, Shajapur, Rajgarh and Guna districts of the state. The female agricultural labourers and female cultivators were nearly 31 thousand and 22.8 thousand, respectively. The district had two blocks namely, Phanda and Berasia. The average annual rainfall varied from 1,000-1,200 mm.

Raisen, Vidisha, Guna, Tikamgarh, Chhatarpur, Damoh and Narsinghpur districts of the state surround the Sagar district. The net sown area in the district is 526,167 ha. The female agricultural labourers and female cultivators were nearly 84.59 thousand and 47.5 thousand, respectively. The district is having 11 blocks namely, Keasli, Deori, Rehli, Khurai, Bina, Jaisinagar, Shahgarh, Malthone, Rahatgarh, Sagar and Banda. About 26 % of cropped area was under irrigation. The average annual rainfall varied from 1,200 mm to 1,500 mm.

To identify the locations of survey sites in the selected districts, the stratified multistage sampling technique was adopted for selecting villages. To get true representation of the district, block-wise villages were grouped. Further villages were cat-

**Table 1** Possession of improved tools and equipment by households of various categories of farmers of Bhopal and Sagar districts in Vindhya plateau agro-climatic zone of Madhya pradesh

| Improved implements | Possession of Improved implement with households of various categories, % | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Landless | | Marginal | | Small | | Semi-medium | | Medium | | Large | | % | |
| | Bh | Sa | Bh | Sa | Bh | Sa | Bh | Sa | Bh | Sa | Bh | Sa | Bh | Sa |
| Wheel hoe | 3.3 | 13.8 | 25.4 | 17.1 | 34.9 | 28.7 | 49.2 | 38.6 | 48.6 | 47.8 | 51.3 | 56.5 | 33.5 | 29.6 |
| Tractor | | 0.6 | 7.6 | 3.1 | 17.1 | 8.5 | 31.1 | 25.4 | 45.9 | 48.8 | 55.0 | 66.7 | 22.8 | 17.9 |
| Cultivator | | 0.6 | 7.6 | 3.1 | 17.1 | 8.5 | 31.1 | 25.4 | 45.9 | 48.8 | 55.0 | 66.7 | 22.8 | 17.9 |
| Thresher | 2.5 | 1.3 | 8.5 | 3.1 | 11.6 | 11.2 | 33.6 | 25.4 | 44.6 | 59.5 | 55.0 | 71.0 | 22.6 | 19.9 |
| Seed drill | | 0.6 | 6.8 | 3.1 | 14.7 | 8.5 | 31.1 | 23.3 | 45.9 | 48.8 | 55.0 | 66.7 | 22.2 | 17.4 |
| Maize sheller | | 1.9 | 1.7 | 0.5 | 0.8 | 5.9 | 3.3 | 10.6 | | 10.7 | 6.3 | 18.8 | 1.9 | 6.5 |
| Seed treatment drum | | 0.6 | | 2.6 | | 3.2 | 4.9 | 9.0 | | 10.7 | 2.5 | 11.6 | 1.2 | 5.2 |
| Groundnut decorticator | | 0.6 | 0.8 | 0.5 | | 4.3 | | 6.3 | | 2.4 | 5.0 | 1.4 | 0.8 | 2.8 |
| Cleaner-grader | | | | 0.5 | | 2.1 | | 3.2 | | 3.6 | 7.5 | 2.9 | 0.9 | 1.8 |

Bh: Bhopal, Sa: Sagar

egorised based on household population into six groups, namely, less than 100, 101-200, 201-300, 301-400, 401-500 and more than 501 households. After that, four villages from each household population group were randomly selected using Fisher and Yates random table. Thus, 24 villages from Sagar and 20 villages from Bhopal district were selected. Ten percent of households from the selected village of the category were surveyed. Hence, it was planned to conduct a survey of 10, 20, 30, 40, 50 and 70 households from villages having less than 100, 101-200, 201-300, 301-400, 401-500 and more than 501 households, respectively. In selected villages, the households were selected from landless and landholding, viz., marginal (< 1 ha), small (1-2 ha), semi-medium (2-4 ha), medium (4-6 ha) and large (> 6 ha) categories of farmers. Of the total surveyed households from a village, 77-80 % of households were from landless to semi-medium categories on almost equal basis and the rest from medium and large categories of households. The distribution of households for the survey was kept almost as per the operational holdings by major size groups as per the Agricultural census, Ministry of Agriculture, New Delhi of 1995-96. A total of 1,528 respondents (farm women) were surveyed in both the districts during December, 2003 to March, 2004. The pre-tested pro-forma was used to collect the data through the survey method. The information of possession, knowledge of selected improved farm machinery about its utility like, tractor, tractor-operated cultivator, tractor-operated seed drill, thresher, wheel hoe, seed treatment drum, cleaner-grader, maize sheller and groundnut decorticator was collected from selected households under various categories. Category-wise data were analysed. The selected improved farm machinery was grouped in two categories, viz., power operated (tractor, tractor-operated cultivator, tractor-operated seed drill and power-operated thresher) and manually-operated (seed treatment drum, wheel hoe, maize sheller, cleaner-grader and groundnut decorticator) farm machinery.

## Results and Discussion

### General Information about Household Survey

Mean age of surveyed respondents was 39 years varying from 17 years to 76 years. Mean literacy percentage of the respondents was 35.1 %. Nearly 33.3 % households had more than one female worker for agricultural work in their family. Out of surveyed villages in both the districts, 75 % of villages had a village panchyat. The education facilities in Bhopal and Sagar districts were 100 % and 87.5 %, respectively. Of total 1,528 surveyed households from both the districts, the share of Bhopal and Sagar districts was 42.2 % and 57.8 %, respectively. Major crops grown in the Bhopal and Sagar districts of the zone during kharif and rabi seasons were soy bean-wheat. Average operational land holdings of marginal, small, semi-medium and large categories of surveyed respondents were 0.75 ha, 1.62 ha, 3.04 ha, 5.12 ha and 8.8 ha, respectively. About 45.0 % of households of the landless category were doing lease-in type farming.

Of the total surveyed households, landless, marginal, small, semi-medium, medium and large categories of farmers in the zone were 18.5 %, 20.4 %, 20.7 %, 20.4 %, 10.3 % and 9.7 %, respectively. In taking land on lease-in for cultivation, it was 41.8 % for landless households followed by marginal (14.5 %), small (9.5 %), semi-medium (5.1 %), medium (4.5 %) and large (3.3 %) categories of farmers. Bullock carts were owned by 13.5 % households. Nearly 22.3 % households had metallic bins for storage of food grains. Biogas and solar gadgets were owned by 6.7 % and 0.8 % households, respectively. About 26.3 % women visited agricultural fairs whereas about 66.4 % farm women showed interest in taking training on agricultural related activities.

### Possession Status of Improved Farm Machinery

Possession of selected improved

**Table 2** Knowledge of improved farm machinery by the surveyed farm women of various categories in Vindhya zone

| Improved implements | Mean value of category-wise women's knowledge about improved farm machinery, % | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Landless | | Marginal | | Small | | Semi-medium | | Medium | | Large | | Overall | | Mean |
| | Bh | Sa | Bh | Sa | Bh | Sa | Bh | Sa | Bh | Sa | Bh | Sa | Bh | Sa | |
| Tractor | 100.0 | 100.0 | 99.2 | 100.0 | 99.2 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Cultivator | 100.0 | 100.0 | 99.2 | 100.0 | 99.2 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Seed drill | 100.0 | 100.0 | 99.2 | 100.0 | 99.2 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Thresher | 100.0 | 100.0 | 99.2 | 100.0 | 99.2 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Wheel hoe | 63.9 | 43.8 | 99.2 | 56.0 | 99.2 | 44.7 | 100.0 | 52.4 | 100.0 | 64.3 | 100.0 | 56.5 | 93.2 | 51.4 | 69.0 |
| Seed treatment drum | 0.0 | 39.4 | 0.9 | 37.3 | 0.0 | 45.7 | 0.0 | 36.5 | 0.0 | 41.7 | 10.0 | 26.1 | 1.4 | 38.8 | 23.0 |
| Groundnut decorticator | 9.0 | 11.9 | 30.5 | 16.1 | 22.5 | 21.8 | 13.9 | 15.3 | 23.0 | 19.0 | 11.3 | 27.5 | 18.4 | 17.6 | 17.9 |
| Maize sheller | 1.6 | 21.9 | 14.4 | 13.5 | 0.8 | 14.9 | 3.3 | 28.0 | 0.0 | 38.1 | 6.3 | 29.0 | 4.5 | 22.0 | 14.6 |
| Cleaner-grader | 0.0 | 15.0 | 0.8 | 13.0 | 2.3 | 6.9 | 3.3 | 8.5 | 4.1 | 13.1 | 5.0 | 29.0 | 2.3 | 12.3 | 8.1 |

Bh: Bhopal, Sa: Sagar

farm machinery with surveyed households of various categories of farmers in both the districts is given in **Table 1**. It is clear from the table that wheel hoes and threshers were possessed by all the categories of farmers in both the districts. Tractor, cultivator, seed drill and thresher were also owned by all the categories of farmers in Sagar district whereas in Bhopal district marginal to large categories of farmers owned these. Among selected households in Sagar district, the highest percentage of tractors was owned by the large category of farmers (66.7 %) followed by medium (48.8 %), semi-medium (25.1 %), small (8.5 %), marginal (3.1 %) and landless (0.6 %) category farmers. A similar trend was also observed in Bhopal district from large to marginal categories of farmers. It is observed that the aim of keeping tractor by households of landless to semi-medium categories was mostly for custom hiring. Among manually-operated farm tools/implements, wheel hoes, seed treatment drums, hand maize shellers and groundnut decorticators were also owned by all categories of surveyed farmers in Sagar district, whereas only wheel hoe was owned by all the categories of selected farmers in Bhopal. Surveyed farmers of marginal to large categories owned cleaner-graders in Sagar district, whereas only large category farmers in Bhopal district owned it.

On an overall basis, the status of possession of the farm machinery with various categories is shown in **Fig. 1**. It is clear from the figure that possession percentage of the selected farm machinery increased order as increase in size of landholdings except in the case of seed treatment drums, hand maize shellers and groundnut decorticators. It was found that 31.2 % households had a wheel hoe whereas 21.1 %, 20.0 %, 20.0 %, 19.4 %, 4.5 %, 3.5 %, 2.0 %, and 1.4 % households had threshers, tractors, tractor-operated cultivators, tractor-operated seed drills, hand maize shellers, seed treatment drums, groundnut decorticators and cleaner-graders, respectively. Category-wise, 0.4 % landless, 4.8 % marginal, 12.0 % small, 27.7 % semi-medium, 47.5 % medium and 60.4 % large categories of farmers owned tractors. Most of the tractor owners had cultivators, seed drills and threshers.

**Knowledge of Improved Farm Machinery**

**Table 2** shows that nearly all the surveyed farm women of landless to large categories had knowledge about the tractor, cultivator, seed drill and thresher in both the districts. Based on mean values obtained from both the districts, for rest of the selected improved farm equipment, 69.0 %, 23.0%, 17.9 %, 14.6 %, and 8.1 % farm women had knowledge of wheel hoes, seed treatment drums, groundnut decorticators, hand maize shellers, and cleaner-graders, respectively. The table also shows that some respondents of marginal and large categories had knowledge of all the listed

**Fig. 1** Owning percentage of farm machinery with various categories of surveyed households in Vindhya Plateau zone of M.P.

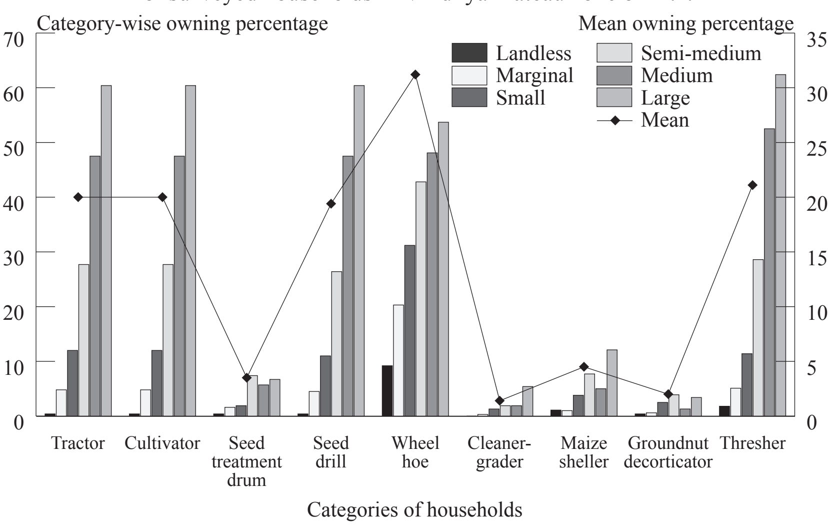


**Table 3** Operation of selected farm machinery by the surveyed farm women of various categories in Vindhya zone

| Improved implements | Mean value of category-wise women's knowledge about improved farm machinery, % | | | | | | | | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Landless | | Marginal | | Small | | Semi-medium | | Medium | | Large | | Overall | | |
| | Bh | Sa | Bh | Sa | Bh | Sa | Bh | Sa | Bh | Sa | Bh | Sa | Bh | Sa | |
| Wheel hoe | 11.5 | 26.3 | 55.1 | 23.3 | 17.1 | 25.0 | 9.8 | 16.9 | 21.6 | 20.2 | 31.3 | 15.9 | 23.9 | 22.0 | 22.8 |
| Thresher | 53.3 | 4.4 | 21.2 | 15.5 | 20.2 | 11.2 | 0.0 | 6.9 | 20.3 | 13.1 | 0.0 | 5.8 | 20.3 | 9.7 | 14.2 |
| Groundnut decorticator | 13.9 | 1.3 | 24.6 | 4.7 | 20.9 | 3.7 | 12.3 | 2.1 | 8.1 | 2.4 | 6.3 | 4.3 | 15.3 | 3.1 | 8.2 |
| Maize sheller | 0.0 | 3.8 | 0.0 | 5.2 | 0.8 | 9.6 | 9.8 | 16.9 | 0.0 | 11.9 | 0.0 | 15.9 | 0.6 | 8.4 | 5.1 |
| Seed treatment drum | 0.0 | 0.6 | 0.0 | 5.2 | 0.0 | 4.3 | 0.0 | 3.7 | 0.0 | 7.1 | 0.0 | 5.8 | 0.0 | 4.1 | 2.4 |
| Cleaner-grader | 0.0 | 1.9 | 0.0 | 2.1 | 0.0 | 2.1 | 0.0 | 1.1 | 0.0 | 0.0 | 0.0 | 7.2 | 0.0 | 2.0 | 1.2 |
| Tractor | 0.0 | 0.0 | 0.8 | 1.0 | 0.8 | 0.5 | 0.8 | 1.1 | 0.0 | 1.2 | 2.5 | 0.0 | 0.8 | 0.7 | 0.7 |

Bh: Bhopal, Sa: Sagar

improved farm machinery in Bhopal district whereas in Sagar district and some respondents from all the categories had knowledge of all the listed farm machinery.

**Operation of Improved Farm Machinery**

**Table 3** shows that wheel hoes and groundnut decorticators were operated by 23.9 % and 15.9 % farm women of all categories in Bhopal district, whereas in Sagar district, 22.0 %, 9.7 %, 8.4 %, 4.1 % and 3.1 % of farm women operated wheel hoes, threshers, maize shellers, seed treatment drums and groundnut decorticators, respectively. In Bhopal district, a maximum percentage of farm women of marginal category operated wheel hoes whereas it was operated by farm women of landless category in Sagar district. A maximum percentage of farm women of landless categories had worked with a thresher in Bhopal district whereas in Sagar district, farm women of marginal category worked with it. Nearly 9.8 % of farm women of semi-medium category worked with maize shellers in Bhopal district whereas it was operated by 15.9 % farm women of large category in Sagar district. In Sagar district, cleaner-graders and groundnut decorticators were maximum utilized by 7.2 % and 4.7 % farm women of large and marginal categories, respectively. Seed treatment drums were utilized by a maximum of 7.1 % of farm women of medium category.

It can be seen from the table that 22.8 % of farm women worked with wheel hoes whereas 14.2 % worked with threshers, 8.2 % with groundnut decorticators, 5.1 % with maize shellers, 2.4 % with seed treatment drums, 1.2 % with cleaner graders and 0.7 % with tractors. During the survey, it was observed that farm women needed women friendly improved tools and equipment for various farm operations for increasing their productivity with reduced drudgery.

## Conclusion

Among selected improved farm machinery was the tractor, cultivator, seed drill, thresher and wheel hoe that were commonly possessed and known by all the categories of farmers including landless. Wheel hoes were owned by a maximum 31.2 % of households followed by 21.1 % threshers, 20.0 % tractors, 20.0 % tractor-operated cultivators, 19.4 % tractor-operated seed drills, 4.5 % hand maize shellers, 3.5 % seed treatment drums, 2.0 % groundnut decorticators and 1.4 % cleaner grader. Nearly 14.5 % of farmers of all categories were engaged in taking land on lease-in for farming. Of this, about 53.0 % of farmers were of the landless category. Based on the analysis following suggestions are presented.

1. There is a need to popularize women friendly, manually operated, improved farm machinery among all the sections of the farming community so that they can be aware of the developed tools and equipment.
2. The study also felt the need to prepare a category-wise set of tools/implements to reduce the drudgery of farm women and also it may help in planning for reduction of drudgery based on land holdings.

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# ABSTRACTS

The ABSTRACTS pages is to introduce the abstracts of the article which cannot be published in whole contents owing to the limited publication space and so many contributions to AMA. The readers who wish to know the contents of the article more in detail are kindly requested to contact the authors.

**504**

**Study on the Indigo Production in Bangladesh**: **Daulat Hussain**, Professor, Dept. of Farm Power and Machinery, BAU, Mymensingh, Bangkadesh; **A. K. M. Rafiqul Islam**, Lecture, Graduate Training Institute, same; **A. P. Roy**, Graduate Student, same.

The experiment was carried out at Pirgachha indigo processing center, Madhupur, Tangail during the period from April to August 2004. From laboratory test, it was observed that the river water contains the highest value of pH (8.2) and supply water contains the lowest value of pH (7.3). It was also observed that before and after adding NaOH (caustic soda) solution electric conductivity (EC) and TDS in different types of water were increased and pH values decreased with increasing time. For field test 4 processing units were selected. In processing unit-1, the highest values of pH, EC and TDS were found 10.8, 2.00 and 2078, respectively. In this unit, 0.04 % NaOH solution and 400 kg raw materials were used for indigo processing and 1.961 kg indigo was obtained. In other 3 processing units indigo production was low due to small amount of NaOH was added and lower pH values. The average yield of indigo was 0.485 kg per 100kg plants and leaves. The average yield of raw materials per acre was 3.5 tones (3500 kg) which include plants and leaves. 1 kg of indigo was obtained from 206 kg of raw materials (plants and leaves together) and the average production of indigo per acre was 17 kg. It was observed that the cost benefit ratio of indigo production was 1: 4.055 and it is more then the conventional crops grown in Bangladesh.

**506**

**Work Potential and Physiological Responses of Donkeys at Different Sets of Pressures During Water Lifting at Constant Suction Head**: **B. Anuraja**, All India Coordinated Research Project on Utilization of Animal Energy, College of Agricultural Engineering, Raichur - 584 101, India; **S. S. Kumathe**, same; **Jag Jiwan Ram**, same; **P. S. Kannannavar**, same; **T. Guruswamy**, same.

The study was conducted using two pairs of donkeys to lift water from 3 m suction head. Three discharge pressure heads (I.0, 1.5 and 2.0 kg/cm$^2$) were created using a 38 mm x 32 mm reciprocating pump. The donkeys worked for 5 hrs, 4 hrs and 3 hrs respectively at the above pressure heads before they were fatigued. The pump discharged 5,056.66 ± 58.ll to 4,316.66 ± 60.90, 4,953.33 ± 37.ll to 4,036.66 ± 44.09 and 4,726.66 ± 53.64 to 4,066.66 ± 88.19 liters of water per hour at the corresponding pressures. The corresponding power developed by the animals, to obtain the above discharge was 0.72 ± 0.01 to 0.49 ± 0.01, 0.78 ± 0.02 to 0.45 ± 0.06 and 0.83 ± 0.02 to 0.56 ± 0.04 kW, respectively. The walking speed of the donkeys, power developed and water discharged showed a decreasing trend over the duration of work. Calculations showed that pressure of 1.5 and 2.0 kg/cm$^2$ was suitable for drip irrigation for appropriate widely spaced horticultural crops on small scale. The pulse rate (PR), respiration rate (RR) and body temperature (BT) increased with the duration of work. As the pressure increased the animals showed early fatigue symptoms.

**507**

**Development and Evaluation of Woman Friendly Groundnut Stripper with Ergonomic Design Features**: **D. Sirisha**, Research Scholar, Dept. of Farm Machinery, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore - 641 003, India; **K. Kathirvel**, Professor and Head, same; **R. Manian**, Dean, same.

Groundnut in view of its importance, as the most popular dry land and garden land crop, and as the most common oil seed, fits well with the prevailing choice of crop rotation opted by the farmer. Labour intensive stripping operation hither to being carried out at farm is not only uneconomical, but also is of slow pace. The groundnut stripper is used for stripping or detaching the pods from the groundnut vines. The equipment consists of a square frame having vertical support legs and a horizontal ship of expanded metal fixed on each side of the frame in the form of comb. The stripping of the pods is accomplished by drawing a handful of vines across the comb with a slight force. This operation is generally done by farm women. Hence the available groundnut stripper was ergonomically evaluated for assessing its suitability to farm women labours. Ten women subjects were selected and screened for normal health for the investigation. The mean work heart rate and oxygen consumption were 99.04 beats min$^{-1}$ and 0.346 l min$^{-1}$, respectively. The energy expenditure for the groundnut stripping was computed as 7.02 kJ min$^{-1}$ and classified as light. The mean energy cost of operation in terms of the maximum aerobic capacity was 27.76 % of VO2 max, which is well within the Acceptable Work Load of 35 % of VO2 max. The work pulse value was l9.46 which was also well with in the Limit for Continuous Performance (LCP) value of 40. The Overall Discomfort Rating (ODR) and Body Part Discomfort Score (BPDS) were found to be 6.27 and 58.30, respectively. Based on the evaluation and subjects feed back, a small adjustable stool was fabricated for the operator to sit and perform the stripping operation and the frame of the stripper was provided with telescopic support legs. The groundnut stripper with ergonomic design features enhanced the comfort of the subject with 6.6l, l5.26, 23.l3 and 31.l5 percent reduction in head rate, oxygen consumption, Overall Discomfort Rating and Body Part Discomfort Score respectively when compared to the available model.

**508**

**Effect of Soil, Crop and Tool Parameters on Harvesting Efficiency of Groundnut Digger**: **S. H. Suryawanshi**, Research Scholar, Dept. of Farm Machinery, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore - 641 003, India; **B. Shridar**, Professor, same; **K. Kathirvel**, Professor and Head, same.

An investigation was carried out to find the effect of soil, crop and tool parameters on the harvesting efficiency of power tiller operated groundnut digger shaker. Three types of digging tools viz., straight, inverted V and crescent shaped tool geometry were developed for harvesting of CO 1 and TMV 2 groundnut varieties. The effect of tool and operational parameters were evaluated in terms of draft and harvesting efficiency at different levels of factors namely, rake angle (10, 15 and 20 deg), tool geometry (straight, inverted V and crescent), forward speed (1.5, 2.0 and 2.5 kph) and soil moisture (10.5, 12.5 and l5.5 percent). The maximum harvesting efficiency of 99.99 percent was achieved at a combination of 15 deg rake angle, l5.5 percent soil moisture and 2.0 kph forward speed for the straight shaped tool. The draft requirement at this combination was 158.33 kg.

**509**

**Effect of Operating parameters and Pesticide Flow Characteristics on Performance of Air Assisted Spraying**: **D. Dhalin**, Ph.D Scholar, Dept. of Farm Machinery, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore - 641 003, India; **K. Kathirvel**, Professor and Head, same; **T. V. Job**, Professor, same; **R. Manian**, Dean, same.

The safe and efficient application of pesticides requires, among other things, the definition of an appropriate droplet size spectrum. The ideal spectrum will maximize spray efficiency for depositing and transferring a lethal dose to the target, while minimizing off-target losses such as spray drift and user exposure. The effect of spray fluid discharge rate, height and orientation of nozzle and operational speed depositional characteristics of spray on both artificial plants (plastic leaves) and potted plants was quantified to ensure for maximum spray coverage. Laboratory experimental set up consisted of blower assembly, fluid flow regulator, nozzle height and orientation adjustments were developed for the study. The trace wash procedure with methylene blue dye as tracer was used for sample extraction and the amount of deposition was calculated by Spectrophotometer. Filter paper of size 5 x 5 cm was used for sample collection. The droplet size (VMD) was measured by 'IMAGE ANALYSER' software from the samples collected on bromide paper of size 5 x 5 cm.

The deposition efficiency of spray reduced with the increment in discharge rate of spray fluid at slow forward speeds (1.0 and 1.5 $kmh^{-1}$) and increased with the increment in discharge rate of spray fluid at higher forward speed (2.0 $kmh^{-1}$). It shown a declining trend as the forward speed increased. It was maximum at 50 cm of nozzle height from the canopy and shows declining trend on both upper and lower heights. The deposition efficiency at nozzle orientation of 60 degree with vertical shows the maximum for all the combinations discharge rate of fluid and height of nozzle and forward speed of operation. As the discharge rate increased the droplet size also increased irrespective of height and orientation of nozzle. The effect was considerably high at a nozzle height of 25 cm. The size of droplets formed was at the recommended level (100 to 200 μm). The droplet size was minimum (150 to 175 μm) at nozzle height of 50 cm.

**512**

**Aqua Ferti Seed Drill for Dryland Areas**: **A. K. Dey**, Dept. of Biosystems Engineering, University of Manitoba, Winnipeg, MB, Canada; **Indra Mani**, Division of Agricultural Engineering, IARI, New Delhi - 110 0012, India, **J. S. Panwar**, same.

This study investigates the design values of a tractor drawn aqua ferti seed drill suitable for sowing and simultaneous application of nutrients in aqueous form at root zone depth for initial root and shoot development of the winter crops in dry land areas. The machine consists of a peristaltic pumping unit, for metering and dispersing the required amount of aqueous fertilizer, and seeding unit for placing seeds at appropriate position. The selected design values of the pumping system included reel diameter 30 cm; rotational speed 150 rpm; roller spacing 15.7 cm; aqueous fertilizer head 51 cm, and tube diameter 0.96 cm. The pumping system was test evaluated for discharge rate and its uniformity for the above different combinations of the design variables. The machine gave a discharge of 5,800 l/h. It was mounted on a 9-tyne commercially available seed drill modified to accommodate and match the pumping system. The discharge from different tubes for selected levels of design values was uniform. The tubes used in this study showed very good physical properties and remained inactive and unaffected in tests with different acids and bases. The developed aqua fertilizer seed drill was powered from a power take-off shaft of a 58.5 hp tractor. The row spacing of the seed drill was kept adjustable to suit different crop locations and the aqueous fertilizer tube was mounted in a manner to allow almost no choking with soil. The gravity flow type seed metering mechanism was used, which could be adjusted to accommodate different crops and seed rate. The developed aqua fertilizer seed drill was able to meet the required rate of aqueous fertilizer at the time of sowing for major dry land crops like wheat, mustard, and gram.

**515**

**Effect of Curing and Drying Methods on Quality of Turmeric (Curcuma longa L.)**: **S. H. Akbari**, Dept. of Agricultural Process Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh - 362 001, India; **A. K. Varshney**, same; **S. N Garala**, same.

Studies on drying characteristics of turmeric rhizomes (Sugandham) were conducted using sun drying and solar drying methods at Junagadh (Gujarat). Before drying, the rhizomes were cured at different pressures (0.50, 0.75 and 1.00 kg-cm$^{-2}$). The drying parameters (drying time and drying constants) and quality parameters (volatile oil curcumin content and oleoresin content) were also studied. It has been concluded from the research findings that the rhizomes should be cured at 0.75 kg-cm$^{-2}$ pressure and dried under solar cabinet dryer at 74 ºC to get good quality of product in terms of volatile oil curcumin and oleoresin contents with the drying time 56 h.

**604**

**Study of Selected Engineering Properties of Dry, Soaked and Sprouted Rice (Pant-4 Variety) Seeds and Experimental Soil**: **S. C. Sharma**, Ex-PG Scholar, Dept. of Farm Machinery and Power Engineering, College of Technology, G.B. Pant University of Agriculture and Technology, Pantnagar - 263 145, India; **T. P. Singh**, Associate Professor, same.

The physical properties of dry, soaked and sprouted rice seed such as size of seed, weight of seed, germination percentage, bulk density, angle of repose, sprout length and moisture content was determined in the department of Farm Machinery and Power Engineering, College of Technology, G.B.P.U.A. & T., Pantnagar. It was found that the average length, width and thickness were 9.2, 3.05 and 2.0 mm respectively with mean dimension of 3.83 mm for dry rice seed, 9.1, 3.03 and 1.98 mm with mean dimension of 3.79 mm for soaked seed. These dimensions for sprouted seeds were 9.36, 2.77 and 2.49 mm at 1.03 mm sprout length, 9.28, 2.86 and 2.01 mm at 3.48 mm sprout length, 9.67, 2.94 and 2.04 mm at 4.64 mm sprout length and at 9.47 mm sprout length it was found as 9.88, 2.97 and 2.03 mm respectively. The average weight of 1000 seeds for dry, soaked and sprouted seed was found as 31.6, 35.1 and 36.6 g respectively. The germination percentage was found as 89.4 percent for the rice seed (Pant-4). The average bulk density was found to be 0.602 g/cc for dry 0.601 g/cc for soaked and 0.601g/cc, 0.547 g/cc, 0.502 g/cc and 0.457 g/cc for sprouted rice seed at different sprout length of 1.03, 3.48, 4.64 and 9.47 mm respectively. Angle of repose of rice seed was also determined and was found to be 35.98 degree for dry, 42.53 degree for soaked and 43.29, 51.60, 52.60 and 54.22 degree at sprout length of 1.03, 3.48, 4.64 and 9.47 mm, respectively. Sprout length was also measured at different incubation period and it was found as 1.03, 3.48, 4.64 and 9.47 mm at 24, 36, 44 and 52 hours of incubation periods respectively with moisture content of 34.53, 39.02, 42.22 and 46.65 percent for sprouted seed and 10.24 and 31.45 percent for dry and soaked seed respectively. The physical properties of the soil were also determined and it was found that the average moisture content, bulk density, and angle of repose were 16.35 percent, 1.17 g/cc and 46.27 degree respectively.

**613**

**Development of a Pedal Pump**: **Toufiq Iqbal**, Dept. of Agronomy and Agricultural Extension, Faculty of Agriculture, University of Rajshahi, Rajshahi - 6205, Bangladesh.

A pedal pump (**Fig. 1**) was developed in a local workshop. Two pistons of an ordinary two-cylinder treadle pump were connected with a crankshaft having a flywheel on one end and a chain sprocket on the other. The crankshaft is powered through a chain sprocket from the pedal of the bicycle and is rotated by the foot of the operator seating on the seat. The discharge of the designed pedal pump is between 60 to 100 liters per minute, average command area is 0.50 acre for 8 hours per day operation, and it can lift water from seven-meter depth. The pedal pump was also used for lifting surface water.

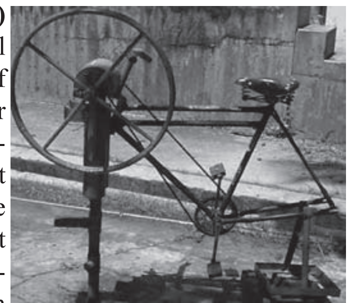

**Fig. 1** Pedal pump

**629**

**Effect of Puddling Levels and Transplanting Methods on Weed Dynamics, Growth and Productivity of Rice in Rice-wheat System**: **K. K. Singh**, Senior Scientist (FMP), Project Directorate for Cropping Systems Research, Modipuram, Meerut - 250 110, India; **A. S. Jat**, Research Associate, same.

An experiment was conducted at the research farm of the Project Directorate for Cropping systems Research, Modipuram, Meerut (U.P.) during kharif 2000 to rabi 2003-04, to evaluate the effect of puddling levels and transplanting methods on weed dynamics, growth and productivity of rice (Oryza sativa L.) in rice-wheat cropping system. Results indicated that puddling levels and transplanting methods significantly affected the weeds growth and yield of rice. Three passes of puddler recorded lower density (17 to 30 %) and dry matter of weeds (14 to 30 %); produced taller plants (5.9 %) and higher plant dry matter (9.1 %), effective panicles/m$^2$ (11.8 %), grain (11 %) and straw (8 %) yields, and gross (11.2 %) and net (11.2 %) returns of rice, compared to one pass of puddling. However, one and passes of puddling of puddling remained at par with each other in respect of all the parameters. Mechanical transplanting recorded lower density (16 %) and dry matter of weeds (13 to 16 %); and produced higher plant dry matter (10.1 %), effective panicles/m$^2$ (14.7 %), grain (12.3 %) and straw (11.7 %) yields, and gross (12.4 %) and net (39.4 %) returns, compared to manual transplanting, respectively.

**707**

**Effect of Seed Soaking Duration on the Germination, Growth and Yield of Cotton**: **S. D. Tunio**, Professor, Dept. of Agronomy, Sindh Agricultural University, Tandojam, Pakistan; **M. A. Ansari**, Lecture, same; **G. H. Jamro**, Professor, same; **H. R. Memon**, Lecture, same.

A field trial was carried out to determine the effect of seed soaking on the germination, growth and yield of cotton at Sindh Agriculture University, Tandojam during the year 2005-2006. The treatments were, $T_1$ = No soaking (control), $T_2$ = seed soaking for 6 hrs, $T_3$ = seed soaking for 12 hrs, $T_4$ = seed soaking for 18 hrs. $T_5$ = seed soaking for 24 hrs, $T_6$ = seed soaking for 30 hrs, in a four replicated Randomized Complete Block Design. The results revealed that seed germination, bolls plant$^{-1}$, seed cotton yield ha$^{-1}$ were highly significantly affected due to different seed soaking durations. However there was a non significant effect of the seed soaking duration on the monopodial and sympodial branches plant$^{-1}$, staple length and G.O.T. percentage. However, almost all the characters were more or less superior when seed soaked for a 12 hrs and under this treatment the crop had 19.25 m$^{-2}$ germination, 110.87 cm plant height, 2.18 monopodial branches plant$^{-1}$, 12.36 sympodial branches plant$^{-1}$, 18.65 bolls plant$^{-1}$, 28.70 mm staple length, 70.76 g seed cotton weight plant$^{-1}$, 2,972.59 kg ha$^{-1}$ seed cotton yield and 36.71 percent G.O.T. From yield point of view, treatment where seed was soaked for 18 hrs ranked second with 12.62 m$^{-2}$ germination, 117.38 cm plant height, 2.02 monopodial branches plant$^{-1}$, 12.63 sympodial branches plant$^{-1}$, 18.59 bolls plant$^{-1}$, 28.70 mm staple length, 70.38 g seed cotton weight plant$^{-1}$ and 26,060.63 kg ha$^{-1}$ seed cotton yield and 36.27 percent G.O.T. The treatment where seed was soaked for 6 hrs ranked third in yield, had 10.37 m$^{-2}$ germination, 115.81 cm plant height, 2.25 monopodial branches plant$^{-1}$, 24.24 sympodial branches plant$^{-1}$, 18.88 bolls plant$^{-1}$, 28.49 mm staple length, 69.59 g seed cotton weight plant$^{-1}$, 2289.57 kg ha$^{-1}$ seed cotton yield and 35.40 percent G.O.T. The lowest seed cotton yields and values for its associated characters were recorded from the treatment where seed was sown without soaking (control). From the results it was suggested that for getting positive cotton production, seed may be soaked for 12 hrs before sowing.

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# NEWS

## International Conference on Automotive Technologies

**Hyatt Regency Hotel, November, 13-14, 2008, Istanbul, Turkiye**

Today, automotive industry is facing not only fierce competition but also stringent limits and regulations regarding emission reduction. In order to meet today's global market requirements and tomorrow's emission restrictions, it has been recognized by the both academic and industrial environments that the introduction of new technologies is crucial for a competitive automotive industry. Since 2000, ICAT Conferences have undertaken a task of discussing, evaluating and sharing future and recent developments in automotive technologies with the industry.

The fourth of this series, International Conference on Automotive Techonology - ICAT 2008 will be held on 13-14 November, 2008 at Hyatt Regency Hotel in Istanbul. The main theme of this conference will be "Alternative Technologies for the Reduction of CO2 Emissions".

The aim of this ICAT 2008 is bringing people of different disciplines and involved in automotive industry together to present and share new developments and advanced technology outcome from resent studies. This two-day conference is focused on the latest advancements and economics in,

• Hybrid Vehicle Technology
• Alternative Powertrains and Powertrain Control,
• Alternative Fuels and Hydrogen Technologies,
• Advanced Materials, Fluids and Lubricants in Automotive Applications

The format of the ICAT'08 will be arranged with the following major elements as general papers presented in oral sessions, keynote papers by invited speakers, and panel discussion.

Authorities, industry and R & D actors join their strength and vision for common future transportation understanding and actions. Browse conference website www.icatconf.org for more information, paper submission and registration.

## The International Rice Research Institute (IRRI) News

**Rice Research Community Seeks to Reach 18 Million Households with Improved Rice Varieties, Increase Yields by 50% within 10 Years**

Los Baños, Philippines - The International Rice Research Institute (IRRI) is receiving significant new funding to harness major scientific advances and address some of the biggest unsolved problems in agriculture. IRRI's new project will help develop and distribute improved varieties of rice that can be grown in rainfed ecosystems-where farmers have little or no access to irrigation-and withstand environmental stresses such as drought, flooding, and salinity.

The Bill & Melinda Gates Foundation today announced a grant to IRRI for US$19.9 million over three years to initially help place improved rice varieties and related technology into the hands of 400,000 small farmers in South Asia and sub-Saharan Africa. Farmers are expected to achieve a 50 percent increase in their yields within the next 10 years.

The grant to IRRI was part of a package of agricultural development grants announced today by Bill Gates, co-chair of the foundation, at the World Economic Forum in Davos. All of the grants are designed to help small farmers boost their yields and increase their incomes so they can lift themselves out of hunger and poverty.

IRRI will draw on its past success in improving incomes for millions of poor farmers to reach its ultimate goal: more than 18 million households benefiting from improved rice varieties that will generate income increases and help lift farmers out of poverty. IRRI will work closely with other national and international agricultural research centers, including the Africa Rice Center (WARDA). In addition, the project will build the capacity of researchers and seed producers in poor rice-dependent countries.

The success of the Green Revolution in the 1960s and '70s-which sharply boosted production, causing rice prices to steadily fall-helped lay the foundation for the economic growth and prosperity in Asia in the two decades that followed. The new funding comes at a vital time for rice farmers, who are now facing major production pressure and rising prices that threaten Asia's continued economic growth.

The project is underpinned by IRRI's new strategic plan, Bringing Hope, Improving Lives. With its focus on reducing poverty, the plan, which gives fresh impetus to research at the Institute, is now attracting support that will help some of the world's poorest people.

"If we are serious about ending extreme hunger and poverty around the world, we must be serious about transforming agriculture for small farmers-most of whom are women," said Gates. "These investments-from improving the quality of seeds, to developing healthier soil, to creating new markets-will pay off not only in children fed and lives saved. They can have a dramatic impact on poverty reduction as families generate additional income and improve their lives."

The grant to IRRI is part of a package totaling $306 million that nearly doubles the foundation's investments in agriculture since the launch of its Agricultural Development initiative in mid-2006. The initiative, part of the foundation's Global Development Program, is focused on a range of interventions across the entire agricultural value chain-from planting the highest quality seeds and improving farm management practices to bringing crops to market. The foundation believes that with strong partnerships and a redoubled commitment to agricultural development by donor- and developing-country governments, philanthropy, and the private sector, hundreds of millions of small farmers will be able to boost their yields and incomes and lift themselves out of hunger and poverty.

Rice is a food staple for 2.4 billion people and provides more than 20 percent of their daily calorie intake, and up to 70 percent for the poorest of the poor. In order to meet the projected global demand for rice production in the 21st century, the world's annual rice production must increase by nearly 70 percent-from 520 million tons today to nearly 880 million tons in 2025. With nearly all irrigated rice-growing lands already in production, there is considerable potential to increase rice yields on rainfed lands.

IRRI's project will target the poorest rice farmers in Africa and South Asia, who have little or no access to irrigation and who are totally reliant on sufficient, timely rains. These farmers are regularly exposed to drought, flooding, or salinity-conditions that reduce yields, harm livelihoods, and foster hunger and malnutrition. The development and distribution of new rice varieties tolerant of these environmental stresses can help avert hunger and malnutrition while improving livelihoods for millions of farmers and their families. With minimal access to irrigation and fertilizer, these farmers, who own small plots on marginal land, are inevitably most exposed-and most vulnerable-to poor soils, too much or too little rain, and environmental disasters.

IRRI Director General Robert S. Zeigler emphasizes that, with climate change threatening to worsen the frequency and severity of these problems, the need for insurance-in the form of stress-tolerant crops-is growing ever urgent.

"Scientists have been confounded by the challenges of stress tolerance for decades," said Dr. Zeigler. "But the rice-science community in general and IRRI in particular have recently taken significant steps forward through precision breeding to develop stress-tolerant varieties. As a world-class scientific facility with links throughout the rice-consuming world, we are uniquely positioned to produce crop varieties that can-and have, and will-benefit the poor."

A team co-led by IRRI scientists made a key breakthrough in 2006 with the discovery of a gene that allows rice to survive up to two weeks' flooding with minimal yield loss. Varieties without this gene that are subjected to more than a few days' flooding can be completely ruined.

The gene, known as Sub1, has been bred into several popular varieties-which in the absence of submergence behave exactly as the original variety-and these are already being tested in farmers' fields in India and Bangladesh.

A United States National Public Radio report in October 2007 visited a field of Sub1 rice grown by Bangladeshi farmer Gobindra, the only person in his village who planted the seed before an 8-day flood hit. After the water subsided, his crop recovered and now every other farmer in Gobindra's village plans on planting the flood-tolerant variety. A striking time-lapse video showing the relative effects of 10 days' flooding on a Sub1 rice variety and its non-floodproof counterpart is available at www.irri.org/timelapse.asp.

Even Bangladeshi farmers who were devastated by Cyclone Sidr in November last year -which was so fierce that no rice crop could fully withstand it-can benefit from new varieties with sufficient tolerance of submergence, salinity, and stagnant flooding. Such varieties can mitigate the immediate effects of severe storms and offer yields that will avert hunger until the next harvest.

Several other major donors have signaled their confidence in IRRI's research. A series of significant grants has recently come from the government of Japan (¥499.5 million-$4.7 million-for flood tolerance in Southeast Asia), Germany's Federal Ministry for Economic Cooperation and Development in combination with the Eiselen Foundation ($1 million-$1.45 million-for salinity tolerance), and the International Fund for Agricultural Development ($1.5 million for sub-Saharan Africa, in partnership with the Africa Rice Center).

The International Rice Research Institute (IRRI) is the world's leading rice research and training center. Based in the Philippines, with offices in 13 other countries, IRRI is an autonomous, nonprofit institution focused on improving the well-being of present and future generations of rice farmers and consumers, particularly those with low incomes, while preserving natural resources. IRRI is one of 15 centers funded through the Consultative Group on International Agricultural Research (CGIAR), an association of public and private donor agencies (www.cgiar.org).

**About the Gates Foundation**

Guided by the belief that every life has equal value, the Bill & Melinda Gates Foundation works to help all people lead healthy, productive lives. In developing countries, it focuses on improving people's health and giving them the chance to lift themselves out of hunger and extreme poverty. In the United States, it seeks to ensure that all people-especially those with the fewest resources-have access to the opportunities they need to succeed in school and life. Based in Seattle, the foundation is led by CEO Patty Stonesifer and co-chair William H. Gates Sr., under the direction of Bill and Melinda Gates and Warren Buffett.

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## The Second International Conference on Computer & Computing Technologies in Agriculture (CCTA2008)

**October 18th-20th, 2008, Beijing, China**

We are pleased to inform you that the Second International Conference on Computer and Computing Technologies in Agriculture (CCTA2008) will be held in Beijing, China in October 18-20, 2008. The URL Address is http://www.iccta.cn.

The conference will focus on Computer and Computing Technologies in Agriculture and targeted participants are from universities, institutes, research organizations, government, large companies, and regional development agencies and consultants all over the world. The conference will provide a forum for original research contributions and practical system design, implementation, and applications of computer and computing technologies in agriculture.

All accepted papers will be published in the Proceedings of CCTA 2008. Selected best papers will be published in a special issue of the http://www.rsnz.org/publish/nzjar/International Journals (we have applied, and will let you know the results as soon as possible). Other papers will be published in the IFIP Series in Spinger Press in USA, which was listed in ISI Proceedings.

All abstracts should be submitted to the Secretary of the Conference at ccta2008@sina.com, by not later than February 29, 2008.

**Topics and areas of interest include, but are not limited to the following Technologies in Agriculture:**

- Applied Mathematics
- Numerical Analysis
- Simulation, Optimization, Modeling
- Systems Theory
- Circuits and Systems
- Neural Networks
- Fuzzy Systems
- Optimization
- Multidimensional Systems
- Computing & Computational Science
- Statistics
- Telecommunications
- Signal Processing
- Computer Science
- Multimedia
- Wireless and Optical Communications
- Agricultural Decision Support System and Expert System
- GIS, GPS, RS and Precision Farming
- Agricultural System Simulation
- Intelligent Monitoring and Control
- ICT applications in Rural Area

**Important Dates**

Deadline for submission of abstract: February 29, 2008

Deadline for abstract acceptance: March 14, 2008

Deadline for submission of full paper: May 19, 2008

Deadline for submission of full paper (after revision): July 28, 2008

Conference: October 18th to 20th, 2008

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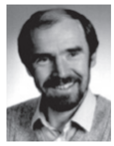
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