*International specialized medium for agricultural mechanization in developing countries*

ISSN 0084-5841

# AMA

## AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.39, No.4, AUTUMN 2008

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

*International specialized medium for agricultural mechanization in developing countries*

ISSN 0084-5841

# AMA

## AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.39, No.4, AUTUMN 2008

*Edited by*

YOSHISUKE KISHIDA

*Published quarterly by*

Farm Machinery Industrial Research Corp.

*in cooperation with*

The Shin-Norinsha Co., Ltd.

and

The International Farm Mechanization Research Service

TOKYO

**ADVERTISING**
(Tel.+81-(0)3-3291-3672)
Yoshito Nakajima, Manager (Head Office)
Advertising Rate: 300 thousand yen per page

**CIRCULATION**
(Tel.+81-(0)3-3291-5718)
(Fax.+81-(0)3-3291-5717)
Editorial, Advertising and Circulation Headquarters
7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan
URL: http://www.shin-norin.co.jp
E-Mail: sinnorin@blue.ocn.ne.jp

SHIN-NORIN Building
7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan
Printed in Japan

This is the 137th issue since its maiden isue in the Spring of 1971

# EDITORIAL

A record-breaking financial crisis hit the United States, the world greatest economic power. In historical view, American economy has expanded along with the development of industries, from the primary industries to the secondary industries and further to tertiary industries. Meanwhile financial business has grown to have the mounting power even to lead the domestic and global economy. The collapse of that financial system has seriously affected the economy throughout the world.

In such insecure economic situations, we see that agricultural-related businesses maintain the economic stability because they are founded on food production that is essential to our life and, therefore, reflects substantial economy.

In order to prevent further recession, the U.S. administration started to make aggressive financial input as a measure to promote domestic consumption. China, the country with the largest population in the world, is expected to make a large investment in rural areas to revitalize rural economy in the face of the expanding economic gap between urban and rural areas. The governmental aid to farm machines and facilities will be much increased. Chinese farm machinery industries have grown to the most extensive scale in the world. Their total output reached 150 billion Yuan in 2007. The vast farmland, a large rural population and the financial support from the government will create a further demand for farm machines in China.

India and other countries that have a large population in rural areas are going to move to a more aggressive stance with regard to the investment in agriculture. In Thailand, where more than 2 million units of tillers are now in operation on farms under powerful economic growth, the demand for 4-wheel tractors is rapidly increasing and nearly 40 thousand brand-new 4-wheel tractors were sold this year. There is a good demand for rice in the international market. Since rice was sold out soon after being placed on the market, some of the farmers are trying to crop rice four times a year. Farm machines like transplanters, will be very helpful to them in saving cropping time. For farmers engaged in such intensified farming, farm machines are the highest priority items for investment.

As much more food production is needed in the world, it is expected that investment in agriculture will increase on a global basis. In the midst of financial crisis, the industries based on agriculture, especially the farm machinery industries in developing countries, seem to have a bright future. We owe much to agricultural machines in raising the productivity on the limited farmland because timely and accurate farming is needed to increase land productivity.

Among all developing countries, African countries have many difficulties in promoting agricultural mechanization. In Asia, it is required that the implements be developed that are suitable for each local faming situation, which is not good enough in many Asian countries. The research and the development of, not only tractors, but of the mechanization system to cover varied local situations are now in need there. The mechanization of agriculture will not be successful unless the machines to meet each local demand are developed. In this sense, we should strengthen more specific research and development on agricultural machines and develop the agricultural machinery industries based on the results from the research and development.

With much more attention being paid to agriculture, the situations involving agriculture have improved to the state that calls for new investment, which is welcomed for agricultural-related people. We have to take this excellent opportunity and make the effort for the progress of new agriculture. Worldwide cooperation and communications among the experts will be more and more significant in order to move ahead with the mechanization of agriculture in the world. AMA hopes to play an active part with its readers for this objective.

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

December, 2008

# CONTENTS

## AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

**Vol.39, No.4, December 2008**

# Biomass Heat-Emission Characteristics of Energy Plants

by
Jan Malaťák
Technical Faculty,
Czech University of Agriculture in Prague,
Prague
CZECH REPUBLIC

Gürkan A. K. Gürdil
Faculty of Agriculture,
Ondokuz Mayis University,
Samsun
TURKEY

Petr Jevic
Research Institute of Agricultural Engineering,
Prague
CZECH REPUBLIC

K. Çagatay Selvi
Faculty of Agriculture,
Ondokuz Mayis University,
Samsun
TURKEY

## Abstract

Biomass makes an important potential alternative to fossil fuel by the heating process. There is no possibility of using biofuels without a judgment of their influence on environment. Knowledge of biomass burning characteristics is also very important before its use. This study was mainly focused on gas emissions of briquette biofuels. Burned fuels were formed to brickets of a 65 mm diameter and $CO_2$, CO, $O_2$, NO, $NO_2$, $SO_2$, and HCl concentrations checked. Air surplus coefficient (n) of other values of heating characteristics were also measured. The highest ranges of value were achieved by combustion of energy sorrel.

## Introduction

Use of biomass as a renewable source of energy has many positive aspects. It also helps to solve ecological, agricultural and forestry problems (McBurney, 1995 and Malaťák, 2003). Biomass based fuel contains very little sulfide. Also, the other waste gases from phyto-fuels are more suitable in comparison with other fossil fuels. The ash remaining after burning can be used as a fertilizer with a high content of calcium, magnesium, potassium and phosphorus (Sladký, 1986; Sladký and Váňa, 2002).

The share of renewable and secondary sources of energy will be increased from the current 2.5 % to 3…6 % in 2010. This is also affected by entering of the Czech Republic to the EU and using of renewable sources of energy financial support. EU uses 12 % renewable sources of energy (Anonymous, 1999; Váňa, 2002).

According to current legislation, polluting substances are solid, liquid and gaseous that have a negative influence directly on the atmosphere or after the chemical or physical changes to the surrounded air. These substances also harm the human health and other organisms or property. The most important polluting substances are $SO_2$, CO, $CO_2$, NO and $NO_X$ (McBurney, 1995; Price, 1998; Pastorek et al., 1999; Hutla and Sladký, 2001; Malaťák, 2003).

Characteristics of fytomass and choosing the right type of burning equipment is important for biomass. Stechiometric analysis must be done for energy content. Stechiometric calculations for burning process are basic for any type of heat calculations. These calculations are also important for solving the whole problem and for controlling the burning equipment, as well (Pastorek et al., 1999 and Malaťák, 2003).

Determination of emission parameters of chosen biofuels is done by using compressed biofuels. These might be compressed to the different shapes by applying different pressures. Biofuels require a lot of space, and this increases shipping costs and storage if they are not compressed. Compressed biofuels also permit higher quality combustion.

## Material and Method

During measurement, the following concentrations were checked: carbon di-oxide $CO_2$, carbon mono-oxide CO, oxygen $O_2$, nitrogen mono-oxide NO, nitrogen di-oxide $NO_2$, sulfa di-oxide $SO_2$, and hydrogen chloride HCl. Measurements were obtained by using fireplace combustion equipment with an 8 kW power and briquette phytomass (65 mm diameter). The problem was basically solved by an element analysis of each element of the briquette phytomass, followed by stechiometry of the combustion processes. Their stechiometry were complemented by fuel characteristics. These are necessary for any heat concerned equation and setting of any emission concentration such as $SO_2$, CO, $CO_2$, NO and $NO_X$.

The first step within any stechiometry calculation of fuels and a thermal work of combustion equipment is the element analysis of fuel (Anonymous, 1998-a and Anonymous, 1998-b). Element analysis is very important for any stechiometry analysis, thermal effectiveness and losses of combustion equipment. It also influences a thermal work of combustion equipment. So-called elementary analysis is used during the detection of solid fuels. This element analysis is for finding the weight percentage of C, H, O, S, N and all of the water content in the fuel. Final elements compositions are given in **Table 1**.

The main point of the research was to set each of any stechiometry calculation for analyzed biofuels. Especially, a heating value of biofuel ($Q_n$) according to ČSN 44 1310 (Anonymous, 2001-b), theoretical amount of oxygen ($O_{min}$) and of the air ($L_{min}$) for an ideal combustion, theoretical volume amount of dry waste gases ($v^v_{spmin}$), percentage of volume amount of $CO_2$, $SO_2$, $H_2O$, $N_2$, $O_2$ and theoretical weight and volume concentration of ($CO_{2max}$) in dry waste gases were set by stechiometry calculation. Final chosen stechiometry parameter of phytomass is shown in **Table 2**, below.

GA-60 gauge was used for the setting of mass flows, emission factors and characteristics of solid particles by thermal use of phytomass briquettes. It is a multifunctional smoke gases analytical gauge. GA-60 gauge is also able to measure a temperature of surroundings ($t_{ok}$) and waste gases temperature ($t_{sp}$). By these temperatures, together with the chemical parameters, the gauge provided a calculation of heating characteristics such as; flue loss ($q_a$), thermal-technical effectivity of combustion ($\eta_{kor}$), air surplus amount (n) and other losses (Anonymous, 2001-a).

The measurement was focused on emissions ($CO_2$, CO, NO, $NO_2$, $SO_2$, and HCl) produced by combustion of mixed briquette phytomass. Carbon Dioxide was determined by

**Table 1** Elementary analysis of burned solid phytomass

| | | Wood ships fresh poplar | Wood ships dry poplar | Poplar bark | Energy sprrel (Rumex tianschanicus) | Canary grass (Phalaris arundinacea) |
|---|---|---|---|---|---|---|
| $W^r_t$ | Water content, % hm. | 42.73 | 8.86 | 53.57 | 7.95 | 9.12 |
| $A^r_t$ | Ash, % hm. | 1.43 | 1.64 | 2.61 | 4.45 | 6.74 |
| $C^r_t$ | Carbon - C, % hm. | 9.58 | 17.48 | 3.69 | 42.70 | 41.81 |
| $H^r_t$ | Hydrogen - H, % hm. | 27.17 | 44.02 | 0.2 | 5.42 | 4.85 |
| $N^r_t$ | Nitrogen - N, % hm. | 4.43 | 6.03 | 0.008 | 1.65 | 0.84 |
| $S^r_t$ | Sulphate - S, % hm. | 0.43 | 0.78 | 19.77 | 0.11 | 0.07 |
| $O^r_t$ | Oxygen - O, % hm. | 0.006 | 0.01 | 0.007 | 37.61 | 36.45 |
| $Cl^r_t$ | Chlorine - Cl, % hm. | 23.8 | 38.64 | 0.69 | 0.11 | 0.12 |

**Table 2** Final stechiometry parameters of phytomass

| | | Fuels | Wood ships fresh poplar | Wood ships dry poplar | Poplar bark | Energy sorrel | Canary grass |
|---|---|---|---|---|---|---|---|
| $Q^r_i$ | Heating value | 0.58 | 9.58 | 17.48 | 6.99 | 16.15 | 15.21 |
| $Q_{min}$ | Theoretical quantity of oxygen for ideal combustion process | 2.79 | 0.58 | 0.88 | 0.44 | 0.83 | 0.79 |
| $L_{min}$ | Theoretical air quantity for ideal combustion process | 7.34 | 2.79 | 4.21 | 2.105 | 3.97 | 3.78 |
| n | Overflow of the air ($O_2$ = 13 %) | 2.63 | 2.63 | 2.63 | 2.63 | 2.63 | 2.63 |
| $v^s_{spmin}$ | Theoretical cubical quantity of dry combination gas | $m^3N.kg^{-1}$ | 2.68 | 4.11 | 4.81 | 3.91 | 3.73 |
| $CO_{2max}$ | Theoretic cubical concentration of oxide carbonic in dry combustion gas | % | 18.76 | 19.85 | 18.5 | 20.26 | 20.76 |
| $CO_2$ | Carbon di-oxide | % | 5.90 | 6.69 | 5.54 | 6.90 | 7.10 |
| $SO_2$ | Sulfur di-oxide | % | 0.0 | 0.0 | 0.0 | 0.01 | 0.0 |
| $H_2O$ | Water | % | 15.36 | 9.99 | 19.18 | 9.71 | 9.75 |
| $N_2$ | Nitrogen | % | 66.82 | 70.7 | 63.88 | 70.78 | 70.72 |
| $O_2$ | Oxygen | % | 11.14 | 11.78 | 10.65 | 11.77 | 11.77 |

*All of the values obtain by measurement are counted to normal conditions. (Temperature t = 0 ºC and a pressure p = 101,325 kPa and for a referential amount of oxygen $O^r$ = 13 %

the measured concentration of oxygen and fuel's characteristics with respect to thermal parameters and emission conditions the fuel was then judged as combustion equipment.

Operation tests were made according to ČSN EN 13229 (Built in heat consumers and open fire place inserts for solid fuels - requirements and testing methods) (Anonymous, 1998-a). A tested heating was equipped with a closeable furnace. In order to obtain values, the convection pass (these were dependent on rated power) was in a restricted limit range 12 ± 2 Pa (values of static pressure in a measured area of emissions). An average concentration of Carbon Oxide during measurements and other gaseous emissions was counted to the value of 13 % ($O_2$). By the norm mentioned above, all of the average values of Carbon Oxide have to meet limit values for certain class of CO; the same as is mentioned in **Table 3**.

An efficient use of thermal energy by operation of the consumer in accordance with data provided by manufacturer and by the combustion of experimental fuels is judged by efficiency. Measured efficiency has to be in a accordance with limit values for certain class quoted in **Table 4**.

Combustion equipment was designed to burn any kind of wood or wooden briquettes. Its most important part was a steel palette or a part of iron with a thickness of 5-8 mm. It was covered on the sides and from the top by feolit bricks. These provide an accumulation of heat and radiate for a certain time after the end of heating process. The bricks were covered by a special made and shaped insulating layer of Calcium Silicate. Doors were equipped with a ceramic glass with resistance up to 750 ºC. Emissions were conveyed to the flue way of a 150 mm diameter (Anonymous, 1998-a).

## Results and Discussions

Biofuel stechiometry, mass flow and emission factors, along with air surplus coefficient and a total water content of biofuel are among the variable factors that influence thermal work of any combustion equipment, (McBurney, 1995; Malaťák, 2003). By the determination of basic stechiometry parameters of biofuels it is possible to effectively judge, design and check a work of observed combustion equipment (Malaťák, 2003). All water contained in a biofuel and the air surplus coefficient are primary factors that may influence thermal aspects of combustion equipment (McBurney, 1995; Pastorek et al., 1999; Malaťák, 2003). All of the calculated stechiometry values are then used in the calculation of thermal output and losses of combusting equipment.

Hydrocarbons and other incompletely burned products have the same characteristic features as a carbon oxide. This is an important indicator of a burning process quality. By the comparison of measured

**Table 3** Classes of CO emissions for solid fuel combustion (Anonymous, 1998-a)

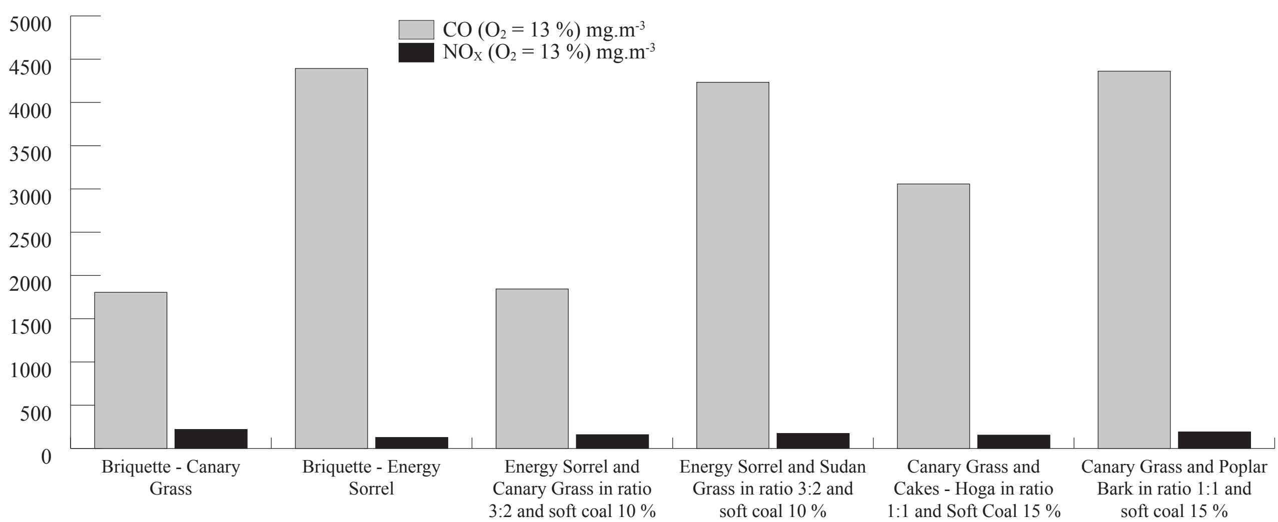
| Class of CO appliances | Appliances with close door<br>Limiting value of class emissions CO, % (at 13 % $O_2$) |
|---|---|
| Class 1 | ≤ 0.3* |
| Class 2 | > 0.3 ≤ 0.8* |
| Class 3 | > 0.3 ≤ 1.0* |

*1 mg.mN$^{-3}$ = 0.0001 %

**Table 4** Efficiency classes by rated heat power (Anonumous, 1998-a)

| Classes | Appliances with close door<br>Limiting value of class efficiency, % |
|---|---|
| Class 1 | ≥ 70 |
| Class 2 | ≥ 60 < 70 |
| Class 3 | ≥ 50 < 60 |
| Class 4 | ≥ 30 < 50 |

**Fig. 1** Final average values of CO and $NO_X$ (mg.m$^{-3}$) emissions of burned phytomass briquettes converted to 13 % amount of oxygen contained in waste gases



and worked values of CO with emission classes of CO by ČSN EN 13229 (Anonymous, 1998-a) (**Table 3**) all of the fuels are meet the criteria of class 2 where the limit is 10,000 mg.m$^{-3}$ by 13 % of referencial oxygen.

Values of $NO_X$ are easy to measure in the case of all observed fuels. There is no limited - restricted value of $NO_X$ because of its low heat power output. However, if a comparison is made for the limit value of $NO_X$ (250 mg.m N$^{-3}$ by 11 % $O_2$) by the regulation nr, 13-2002 MŽP ČR with requirements to get a certificate of "Ecologically safe product", concerned with water heating boilers for central heating systems with combusting of biomass up to 0.2 MW (Anonymous, 2001-c), that limit value was not overcome by the use of any fuel.

The air surplus coefficient (n) is a very important working parameter, which influences emissions as well as heating system efficiency. It determines the amount of oxiding parts and a furnace temperature. Optimal working temperature is possible to set for consumers of this class in a power range $1.4 \leq n \leq 2.6$. Values determined by this interval were obtained by burning of bricketed canary grass, bricketed mix power sorrel and canary grass in ratio of 3:2 and soft coal 10 % m/m, bricketed mix canary grass and gold-of-pleasure in ratio 1:1, soft coal 15 % m/m and bricketed mix canary grass a poplar bark 1:1 with additional 10 % m/m soft coal (**Table 5**).

More than 70 % technical-thermal effectiveness was achieved (class 1) by combustion of briquette mix of canary grass and briquette mix canary grass and gold-of-pleasure. For the class 2 (effectivity n 60 < 70 %), it was possible to place a briquette mix canary grass and poplar bark 1:1 + 10 % m/m soft coal.

Class 3 (effectivity n 50 < 60 %) was obtained with a briquette mix power sorrel and canary grass in ratio of 3:2 with additional 10 % m/m soft coal and briquette canary grass and briquette sorrel.

## Conclusion

There is a need to increase the percentage of biomass production for the betterment of national economy, efficient use of local funds, increase of employees and decrease of noxious emissions of $CO_2$, NO a $SO_2$.

Requirements for the quality of heating are increasing, along with the influence to the environment. For local heat consumers, consisting mostly of family houses, there is no way to solve a problem of emissions like that of big equipment. It is necessary to prefer standardized high quality fuels.

The currently produced plants, energy sorrel and canary grasses, have the highest production potential. They also have a large development perspective. As mentioned in the other works, emission parameters of fuels consisting of pure sorrel do not necessarily meet the standards and requirements demanded for use in certain combustion equipment.

Analyzed briquette fuels show good emission parameters given by class 2 and effectiveness in a range of classes 1 to 3. These might be suitable for similar local heating systems after the proving of other certificate requirements.

**Table 5** Results of working measurements of gaseous and heat-technical parameters

| | Temp. of gas | $O_2$ | n z $O_2$ | $CO_2$ | CO ($O_2$ = 13 %) | $SO_2$ ($O_2$ = 13 %) | HCl ($O_2$ = 13 %) | $NO_X$ ($O_2$ = 13 %) | Technical - thermal effect combustion |
|---|---|---|---|---|---|---|---|---|---|
| | °C | % | 0 | % | mg.m$^{-3}$ | mg.m$^{-3}$ | mg.m$^{-3}$ | mg.m$^{-3}$ | % |
| Bricketed - Energy sorrel briquettes diam. 65 | 361.22 | 14.90 | 3.67 | 5.33 | 4,392.80 | 0.00 | 103.34 | 127.66 | 59.56 |
| Energy sorrel and canary grass in ratio 3:2 and Soft Coal 10 % briquettes diam. 65 | 562.86 | 8.85 | 1.84 | 11.20 | 1,843.77 | 0.00 | 128.88 | 159.33 | 57.76 |
| Energy sorrel and sorghum in ratio 3:2 and soft coal 10% briquettes diam. 65 | 478.73 | 13.95 | 3.10 | 6.47 | 4,232.95 | 0.00 | 73.49 | 173.56 | 82.90 |
| Bricketed - Canary grass briquettes diam. 65 | 487.05 | 10.24 | 2.01 | 9.92 | 1,805.03 | 0.00 | 177.65 | 219.63 | 55.90 |
| Canary grass and gold-of-pleasure in ratio 1:1 and soft coal 15% briquettes diam. 65 | 554.41 | 7.10 | 1.54 | 12.83 | 3,057.32 | 227.29 | 125.11 | 154.60 | 85.40 |
| Canary grass and poplar bark in ratio 1:1 and soft coal 10% briquettes diam. 65 | 474.93 | 11.93 | 2.47 | 8.24 | 4,361.46 | 11.94 | 155.23 | 191.91 | 60.30 |

*All of the values obtained by measurement are counted to normal conditions. (by the temperature t = 0 °C and a pressure p = 101.325 kPa and for a referential amount of oxygen $O^r$, it's value is $O^r$ = 13 %

## REFERENCES


Anonymous. 1998-a. ČSN EN 13229: Vestavné spotřebiče k vytápění a krbové vložky na pevná paliva - Pożadavky a zkušební metody. ČNI Praha, Praha 1998, 66 s.

Anonymous. 1998-b. ČSN 83 4615: Stacionární zdroje emisí - Stanovení hmotnostní koncentrace a hmotnostního toku tuhých částic v potrubí - Manuální gravimetrická metoda. ČNI Praha, Praha 1998, 24 s.

Anonymous. 1999. CIGR Handbook of Agricultural Engineering, Volume V. Energy and Biomass Engineering. ASAE St. Joseph, Michigan, USA, 323 s

Anonymous. 2001-a. ČSN 83 4704: Stacionární zdroje emisí - Stanovení koncentrace emisí oxidů dusíku - Charakteristiky automatizovaných měřících metod. Praha, s. 51-55

Anonymous. 2001-b. ČSN 44 1310: Tuhá paliva - Označování analytických ukazatelů a vzorce přepočtů výsledků na různé stavy paliva. ČNI Praha, 65 s.

Anonymous. 2001-c. Smérnice č. 13-2002 s požadavky pro propůjčení ochranné známky "Ekologicky šetrný výrobek". Teplovodní kotle pro ústřední vytápění, na spalování biomasy. Praha, MŽP ČR, s. 5.

Hutla, P. and V. Sladký. 2001. Optimal drtiny of energetical wooden chips. Res. Agr. Eng. 47(3): 104-109.

Malaťák, J. 2003. Assessment of the Emission and Performance Characteristic at the Power Use of Solid Biomass in the Combustion Equipments with the Heat Output up to 100 KW. In.: International Congress on Information Technology in Agriculture, Food and Environment, Bornova - Izmir 2003, Turkey 2003, s. 633-639

McBurney, B. 1995. A Case Study of a Large Scale Wood Waste Power Generating Plant. Biologue - Regional Biomass Energy Program Report. The Official Publication of the National BioEnergy Industries Association. Vol.13. No.1, 1st Quarter 1995, s. 5-11

Pastorek, Z., J. Kára, P. Hutla, D. Andert, V. Sladký, A. Jelínek, and P. Plíva. 1999. Využití odpadní biomasy rostlinného původu. VÚZT Praha, Praha, 49 s.

Price, B. 1998. Electricity from Biomass. Financial Times Energy, G. Britain, 130 s.

Sladký, V. and J. Váňa. Biomasa pro vytápění v obcích i městech, 2002, příručka Státního fondu životního prostředí.

Sladký, V. Výroba sena v halových senících. Metodiky pro zavádění výsledků výzkumu do zemědělskě praxe. 1986, ÚVTIZ 16/1984, s. 74

Váňa, J. Problémy brzdící rozvoj energetického využívání fytomasy, 2002, ISBN:80-86555-16-X, s. 7


■■


*(Continued from page29)*


## Domestic Solar Geyser Cum Distiller

that the total gain in heat was about 3.02 kWh (Garg et al., 1998) and 3.40 kWh energy was required to evaporate the 5.17 kg of water. If electricity unit charge was taken as Rs. 3.00, then the cost of unit equivalent of electrical backup would be Rs. 19.00. Hence, per day saving of SGD would be Rs. 19.00.

## Conclusions

1. The maximum temperatures of hot water in winter and summer were 48.68 ºC and 52.28 ºC, respectively.
2. The yield of distilled water in SGD device was 5,007 ml $m^{-2}$ $day^{-1}$ in winter and 5,275 ml $m^{-2}$ $day^{-1}$ in summer.
3. The composite unit performed well and per day savings of SGD were Rs.19.

## REFERENCES


Garg, H. P., P. Avanti, and G. Datta. 1998. Development of monogram for performance prediction of integrated collector storage (ICS) solar water heating systems. Renewable Energy: An International Journal 14 (1-4): 11-16.

Hottel, H. C. and B. B. Woertz. 1992. Performance of flat plate solar heat collectors, Transaction of the American Society of Mechanical Enginering, 64:91 Journal of Energy Research. 16(5): 365-372.

Parampal Singh, S. S. Dhaliwal, and Singh Sukhmeet. 2004. Evaluation and development of integrated solar water heater. Annual Report 2002-2003, Thirteenth annual workshop at spreri vallabh vidya Nagar, Gujarat, January 7-10, 2004-IV1-IV14.

Sinha, S., G. N. Tiwari, and M. S. Sodha. 1992. Techno-economic analysis of solar distillation system. International Journal of Energy Research. 16(5): 365-372.

Tabor, H. 1958. Radiation, Convection and conduction coefficients in solar collectors, Bulletin of research Council of Israel, 6 C:155


■■

# Comparative Grain Supply Chain in Canada and China

by

L. Fan
Graduate Student
Dept. of Biosystems Engineering,
University of Manitoba,
Winnipeg, Manitoba, R3T 5V6
CANADA

D. S. Jayas
Distinguished Professor
Dept. of Biosystems Engineering,
University of Manitoba,
Winnipeg, Manitoba, R3T 5V6
CANADA

## Abstract

About 50 % of Canada's total production of grain is moved from farm to international grain market every year. In China, a significant amount of grain movement occurs every year to transport grain from surplus areas to deficit regions. Efficient grain supply chain plays an important role in grain economic development. This paper discusses and compares the current scenario of grain handling and transportation systems developed in Canada and China. In Canada, there are four levels of grain storage facilities (on-farm storage, primary elevator, terminal elevator and transfer elevator) that have evolved with the need to satisfy both domestic and international markets. Economic factors have driven the changes in Canada's grain supply chain. Canada's grain industry has worked toward achieving high efficiency at all levels. The grain handling and distribution system in China has developed rapidly during the last few decades. Four major grain distribution systems or grain transit corridors have been established, covering grain movement in the Yangtze river region, Northeast region, Southwest region, and Beijing to Tianjing region. Three major levels of grain storage facilities (primary depot, intermediate depot, and port terminal) have evolved in the grain distribution networks. The investments are aimed to achieve a significant reduction in grain distribution costs and losses in China.

## Introduction

Canada's grain industry plays a key role in its gross domestic product (GDP) and international trade. Canada is one of the main grain producing countries in the world. The grain export system, or the outbound system of grain movement in Canada, has played a significant role in national economic development. Bulk grain handling and transportation is practiced and has well developed in Canada. Canada has four basic levels in its grain storage system: on-farm bins, primary elevators, terminal elevators and transfer elevators. These share the same basic function of storing grain, but differ in the way each functions in Canada's overall grain supply chain. There were 382 primary elevators, 17 terminal elevators, and 13 transfer elevators in Canada as of 2002 (Canada Grain Commission, 2004 and Geary, 2004). Canada's primary elevator facilities create a critical interface between the farmers and world markets. The 17 terminal elevators provide a link between land and water. The majority of grain exported from Canada is handled through these terminal elevators. Another link in the chain of Canada's grain distribution system is the 13 transfer elevators which are located along the Great Lakes/St. Lawrence Seaway and along the Atlantic coast. Road, rail, and water modes are involved in Canada's transportation network to deliver grain from farm to foreign or domestic market.

China's bulk grain handling and distribution system has been developed through the implementation of the Grain Distribution and Marketing Project (GDMP), initiated in 1992 and completed in 1999. The major objectives of GDMP were to improve the efficiency of moving grain from surplus to deficit areas and to shift from bags to bulk handling. The concept of grain transit corridors was introduced to facilitate a structured approach. Four major grain transit corridors or grain distribution networks have been established in China, namely the Yangtze river corridor, Northeast corridor, Southwest corridor, and Beijing to Tianjing corridor.

The Yangtze river grain transit corridor mainly deals with the grain inflow and outflow for provinces along the Yangtze river. Six port terminals have been constructed to handle grain movement along the Yangtze river (Dekkers et al., 1999). The Northeast grain transit corridor plays an important role in dealing with grain movement into or out of Northeast provinces. Three grain storage levels are involved in the Northeast grain transit corridor, including 279 primary depots, 59 intermediate depots, and one port terminal (GDMP, 1992). Required grain in the Southwest region can be supplied via the Southwest grain transit system. One port terminal located in the Fangcheng port creates the link between the import and local consumption markets (Dekkers et al., 1999). Beijing to Tianjing grain transit corridor facilitates grain movement between these two major municipalities in China (Approval Report of GDMP 1993).

The objectives of this paper are to report on current grain distribution network that have been developed in Canada and China, including: (1) to discuss classification of grain storage facilities and major functions of each storage level in Canada and China, (2) to analyze grain flow and how grain is moved through the grain distribution network in Canada and China, and (3) to discuss the major changes in Canada's and China's grain handling and transportation system.

## Grain Supply Chain in Canada

**An Overview**

Canada's population, geography, and climate largely determine the nature of grain industry. The population of Canada is 31 million people and 90 % live along the border between Canada and the United States. Canada's agricultural production is concentrated in the western prairie region and southern areas of Ontario and Quebec. The agriculture region in eastern Canada is small and the population is large. The grain production in eastern areas concentrates on supplying the domestic market. Due to the small population and large land areas in Western Canada, these prairie areas focus on growing crops for export. A high level of productivity and low population enables Canada to export grains, oilseeds, pulses, and special crops at approximately 30 Mt each year, representing around 50 % of its total production (Agriculture and Agri-Food Canada, 2004). The efficient grain supply chain is remarkable in view of physical difficulties imposed by the geography and climate of Canada and has played an important role in Canada's grain economy. Usually the grain flows from producer to consumer involving four levels: on-farm storage, primary elevators, terminal elevators, and/or transfer elevators, using various transport modes at different levels (Geary, 2004 and Westdal, 2002).

**On-farm Storage Facilities**

More grain is being stored in on-farm storage than ever before due to the decrease in number and storage space in the Canada's commercial elevator system. The majority of on-farm storage structures in Western Canada have an average capacity of between 50 to 200 t each, while in Eastern Canada, the capacity is from 350 to 500 t (Geary, 2004). Galvanized steel bins are now the popular type on grain farms in Canada. Many farm storages are equipped with heated air drying, and/or near-ambient air drying equipment to reduce the high moisture content of harvested grain and aeration equipment to eliminate temperature gradients. For export, grain is unloaded from on-farm storage into trucks, e.g. a 40 t truck (Super B train), delivered to primary elevators, and through terminal elevators or transfer elevators to international markets.

**Grain Elevators**

***Primary Elevators:*** Primary elevators play an important role in Canada's grain supply chain and provide a link between producers and world grain markets. According to the Canada Grain Act (2000), a primary elevator receives grain directly from producers for storing and shipping to other destinations. The primary elevators in Canada are designed to receive grain from producer's farm trucks, store the grain in bulk lots in separate bins according to type and grade of grain, and transfer it quickly and efficiently into railcars for shipment to port elevators for export or to domestic markets.

Several changes or modifications have been made to primary elevator design. Better utilization of facilities occurs by continuing to consolidate small operations and replacing them with fewer but larger facilities in strategically located areas. Older wooden elevators are being replaced by concrete and steel elevators. Due to the great efficiency that has been achieved through economics of scale available at large facilities, and modernization of the primary elevator facilities, fewer elevators are able to handle more grain than earlier smaller elevators (Geary, 2004 and Berry, 1993). There were 2,843 licensed primary elevators in the year 1983-1984, 1,465 in the year 1993-1994, and only 382 in the year 2003 with a total storage capacity of 5 Mt. These primary elevators are located throughout Western Canada's vast grain production area, including 83 in Alberta, 7 in British Columbia, 90 in Manitoba, and 202 in Saskatchewan (Canada Grain Commission, 2004). The individual storage capacity of primary elevators ranges from 5,000 to 100,000 t (Geary, 2004). Most elevators are able to store many types and grades of grain at one time. Almost all primary elevators in Canada are constructed beside railway tracks (Tryon, 1993).

***Terminal Elevators***: In Canada, the principal uses of terminal elevators are the receiving of grain upon or after the official inspection and official weighing of the grain, cleaning, storing, and treating of the grain before it is moved forward (Canada Grain Act, 2000). The primary emphasis at terminal elevators is on grain collection and preparation for shipment to international or domestic markets. They receive grain arriving by rail from western Canada and load it into lakers or ocean going vessels destined for either export or transfer elevators in Eastern Canada. Trucks have not played an important role in moving grain to terminal elevators. Terminal elevators provide a link between land and water.

Grain destined for export from primary elevators moves principally to four Canadian ports. As of 2002, there were a total of 17 licensed terminal elevators with a total storage capacity of about 2.7 Mt, one at Churchill, MB; one at Prince Rupert, BC; nine at Thunder Bay, ON; and six at Vancouver, BC (Geary 2004) (**Fig. 1**). The majority of terminal elevators range in storage capacity from about 100,000 to 300,000 t. Grain is shipped to foreign customers from the west coast and the port of Churchill via the Pacific Ocean and Hudson Bay, respectively. Export grain loaded on lakers at Thunder Bay moves through the Great Lake/St. Lawrence Seaway system to one of the deep-water transfer elevators along the St. Lawrence Seaway and transfers to a large sea-going vessel heading to export markets or is directly shipped by ocean-going vessel from Thunder Bay to Atlantic ocean.

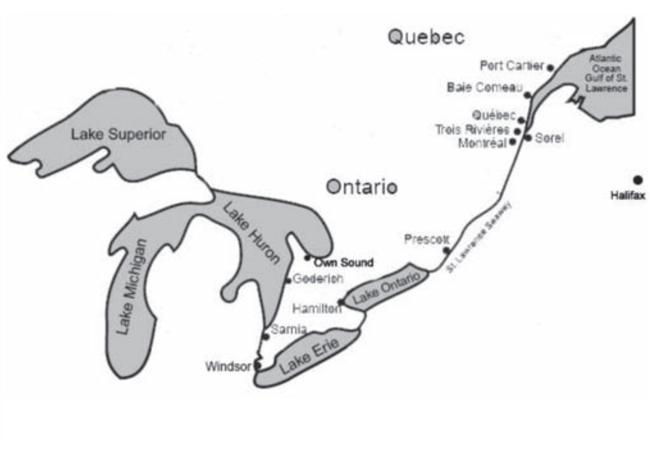
***Transfer Elevators:*** Another link in the chain of Canada's grain distribution system is the transfer elevators. Transfer elevators are defined as being elevators in the eastern region (Canada Grain Act, 2000). The principal use of transfer elevators is to transfer grain that has been officially inspected and officially weighed at another elevator, i.e. primary or terminal elevator, as well as receiving, cleaning, and storing of eastern grain or foreign grain. In 2002, there were 13 transfer elevators located along the Great Lakes/St. Lawrence Seaway system and the Atlantic Coast with total storage capacity of 2.3 Mt. One transfer elevator is located in Nova Scotia, six in Ontario, and six in Quebec (Geary, 2004) (**Fig. 2**). The storage capacity of transfer elevators ranges from 29,000 to 440,000 t. The design of transfer elevators is similar to terminal elevators (Thompson, 1993). Transfer elevators provide a number of services. They service both export and domestic markets. They are used as storage facilities for cleaned grain delivered by water from terminal elevators in Thunder Bay to be loaded onto ocean vessels (salties) for export. Some grain shipments are moved from primary elevators by rail directly to these transfer elevators by passing the terminal elevators at Thunder Bay. The majority of transfer elevators also handle some grain from the United States. The transfer elevators located along Lake Huron are primarily servicing domestic markets. They unload grain from lakers and also handle grain grown in Ontario and transfer it to domestic markets (Geary, 2004 and Tryon, 1993).

## Grain Transportation

***Railway Transportation:*** Rail transportation has played a critical role in Canada's grain industry. Once in the elevator system, Western Canadian grain moves forward from the production area to port terminals almost exclusively by rail. A smaller amount of grain is moved by rail or trucks to domestic users or into US markets. Grain destined for West Coast terminals or Churchill moves only by rail. Eastbound grain is generally unloaded and inspected at the terminals in Thunder Bay. At Thunder Bay the grain is sometimes loaded into ocean vessels, but more often put into lake vessels for transport to transfer terminals along the St. Lawrence Seaway. In addition, when the port of Thunder Bay is closed during the winter season, grain will be moved by rail farther down to the transfer elevators along the St. Lawrence Seaway to serve domestic and international markets (Westdal, 2004 and Transport Canada, 2003). For export markets, the majority of grain is transported by rail to four ports at Churchill, Prince Rupert, Thunder Bay, and Vancouver (Clegg, 1993). Some grain is directly transported to the transfer

**Fig. 1** Terminal elevator locations in Canada (Geary, 2004)


**Fig. 2** Transfer elevator locations in Canada



elevators along the St. Lawrence Seaway (**Fig. 3**). Most grain movement is handled by two major rail companies, i.e. Canadian National (CN) and Canadian Pacific (CP). OmniTRAX handles the movement of grain to the port of Churchill (Canada Transportation Agency, 2004 and Transport Canada, 2003). Grain movement by rail from primary elevators to four terminal elevators and eastern transfer elevators is in covered steel hopper cars (Canadian Wheat Board, 2004a).

***Great Lakes/St. Lawrence Seaway Transportation:*** The movement of grain to eastern ports is mostly carried out by water. The Great Lakes/St. Lawrence Seaway system is one of the main transportation networks serving Canada and U.S.A. The grain industry in Canada depends on the Great Lakes/St. Lawrence Seaway transportation system to handle about one-quarter of its yearly grain export. The Canadian Seaway begins at Thunder Bay, on the northwestern shore of Lake Superior, about 3,000 km from salt water and nearly halfway across Canada (Canada Wheat Board, 2004b). One of the world's largest concentrations of bulk grain storage is located at Thunder Bay, consisting of 9 terminals with a capacity for 1.4 Mt of grain (Geary, 2004). Each year large quantities of both domestic and export grain pass through these terminal elevators.

From Thunder Bay, grain shipment is carried out through the Seaway network via natural passageways and man-made canals and locks. Canals are built to provide links from Lake Superior to Lake Huron and from Lake Erie to Lake Ontario. Grain moves through Lake Superior via locks at Sault Ste Marie to Lake Huron, and through locks between Lake Erie and Lake Ontario. The St. Lawrence Seaway system provides ship access from Lake Ontario to the Atlantic Ocean.

The elevators located along the Seaway Lakes system serve domestic and world markets. Those elevators which are not serviced by rail are mainly involved in transferring export grain from lakers to ocean ships (Canada Wheat Board, 2004b and Tryon, 1993). The Great Lakes/St. Lawrence Seaway system, linking Thunder Bay with the Atlantic, provides an important access route for grain movement. The movement of grain east from Thunder Bay is a significant facet of the Canada grain distribution and handling system.

## Grain Handling and Distribution System in China

### An Overview

China is characterized by high density population and vast areas with imbalance in grain production and consumption. Northeast region is a major producer of corn. The major grain outflow from the areas along Yangtze river is rice. By comparison, the southern region of China is a major deficit region. A significant amount of grain movement occurs every year to transfer grain from areas of surplus to areas of high population concentration or deficit production or both. This movement requires the economical use of appropriate distribution networks. Before the implementation of China Grain Distribution and Marketing Project (GDMP), which was initiated in 1992 and completed in 1999, the grain handling and transportation system was underdeveloped. Insufficient capacity of grain storage facilities and inefficiency in the grain handling and distribution system were the major issues. Grain was stored, handled, and transported in bags. Congestion and queuing problems were due to lack of bulk handling equipment, transportation, and storage facilities. China's GDMP had been formed because of the need to satisfy efficient grain movement. The GDMP was developed following a major World Bank grain sector study. The investments allowed a major shift from bags to bulk handling and achieved a significant reduction in grain distribution costs and losses. The concept of "grain transit corridors" was introduced to facilitate a structured approach in GDMP.

The four principal grain transit corridors had been planned and implemented in the Yangtze river

**Fig. 3** Grain movement by rail from primary elevators to export terminals

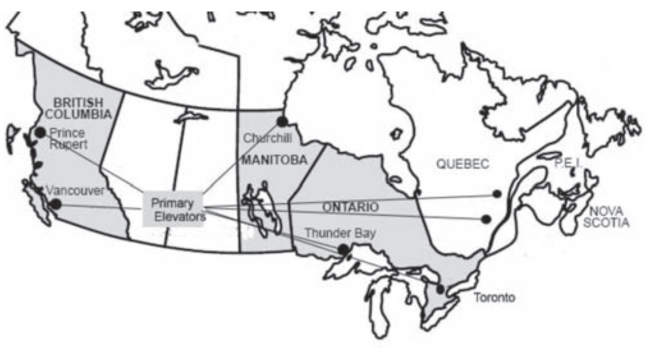



**Fig. 4** Map of China showing the principal provinces and locations of eight port terminals involved in the GDMP

region, Northeast region, Southwest region, and Beijing to Tianjing region. There are eight port grain terminals, 64 intermediate grain depots, and 279 primary depots that were constructed through GDMP. The provinces, autonomous region, and municipalities as well as locations of eight port grain terminals involved in GDMP are shown in **Fig. 4**.

Another important period in China's grain industry is the implementation of the State Grain Reserve Facility Project, which started in 1998. There are 1,273 grain reserve depots with a total storage capacity of 45 Mt that have been constructed throughout China's grain production area (China State Grain Administration, 2004). The grain reserve depots store grain for long periods with a focus on strategic and security purposes such as being prepared for famines, natural disasters, etc., and therefore they will have unique requirements for maintaining the quality of stored grain.

This paper mainly analyzes the grain distribution networks with focus on quick transfer purpose in China.

### Yangtze River Grain Transit Corridor

The Yangtze region includes five provinces (from east to west: Jiangshu, Anhui, Jiangxi, Hubei, Hunan) and one municipality (Shanghai). This grain transit corridor, along which grain flows beside the Yangtze river from downstream to upstream, was set up to establish an efficient grain distribution network through the Yangtze river district.

***Grain Flow:*** Rice, wheat, and corn are the main cereal grains grown in the Yangtze river region. The wheat produced in the Yangtze river region is soft wheat, requiring imports of hard wheat from overseas to mix with it to produce the required products. Grain inflows (corn, imported wheat, and soybean) into the provinces and major municipalities of the Yangtze river region are for local consumption. Grain flows outwards to provinces and municipalities within and outside the Yangtze river region.

The grain movement into and out of the provinces and major municipalities of the Yangtze river corridor via the Yangtze river do not all have to pass through Yangtze river terminals. Part of these grains may go directly by boat from Yangtze lakes or tributaries to out of Province or municipality destinations. Cross border grain movement is primarily taking place via the Yangtze river and also by rail. For the grain flows via the Yangtze river, Shanghai municipality is the major deficit area (wheat, rice, and corn) and Anhui province is the major surplus area (wheat and rice). An overview of origins and destinations of major grain of the Yangtze river corridor is shown in **Table 1** (Aalders et al., 1992).

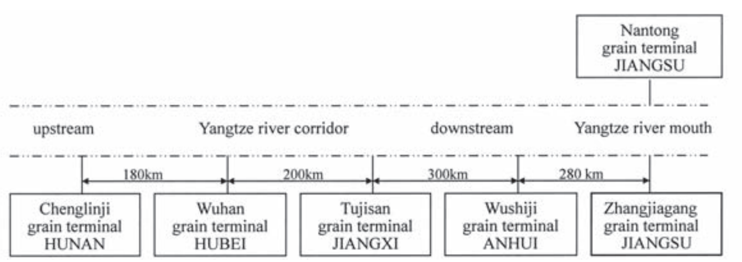
Port Grain Terminals: In planning port grain terminal locations, each of the entrances to the main Yangtze river lakes, which serve as major inland transport routes, and each major population and production center should have its own grain terminal. Other locations of port grain terminals along the Yangtze river should probably be between 100 to 300 km apart, depending on the density of the grain flows in that particular region (Roseeler, 1992). Six port grain terminals along the Yangtze river grain transit corridor have been designed and constructed (**Fig. 5**). Zhangjiagang and Nantong grain terminals are located near the mouth of the Yangtez river. With expected throughput increasing, the grain terminals in Zhangjiagang and Nantong were enlarged. The grain storage capacities reached 65,000 and 55,000 t, respectively (Dekkers et al., 1994a and 1994b). Another four port grain terminals, namely Tujishan grain terminal, Wushiji grain terminal, Wuhan grain terminal, and Chenglingji grain terminal are situated along the Yangtze river from downstream to upstream. These port grain terminals function as distribution centers. Grain is received from grain surplus areas, e.g. corn from the Northeast area of China or imported wheat from overseas and transferred to local processing plants, whereas local grain, e.g. rice, can be transferred via port grain terminals to other provinces or for export. Wheat, corn, and rice

**Table 1** An overview of origin and destination of major grain distributed via the Yangtze river corridor*

| Type of grain | Origin | Destination |
|---|---|---|
| Corn | Northeast | Yangtze river corridor |
| Soya bean | Northeast | Yangtze river corridor |
| Wheat (import) | Overseas | China |
| Wheat (local) | Yangtze river corridor | China |
| Coarse rice | Yangtze river corridor | China |
| Milled rice | Yangtze river corridor | China, oversea |

*Source: Aalders et al. (1992)

**Fig. 5** Six grain terminals within the Yangtze river grain transit corridor, China



are the main cereal grains transported in this corridor.

**Northeast Grain Transit Corridor**

The Northeast grain transit corridor covers the grain distribution and handling system in Liaoning, Jilin and Heilongjiang provinces, and Neimenggu autonomous region. The Northeast region is the major production area of corn. Each year amount of surplus corn will be moved to the other areas of China or for export. Grain inflow into the Northeast provinces for local consumption is mainly imported and domestic wheat.

The grain flows in the Northeast grain corridor involve three levels, i.e. primary depots, intermediate depots, and port terminals. There are 279 primary depots, 59 intermediate grain depots, and one port terminal that have been built in this grain transit corridor (GDMP, 1992). The port terminal, located on Dalian bay (**Fig. 6**), has been further modernized and enlarged during the process of implementation. At present, its total storage capacity reaches 1.5 Mt and annual throughput reached 10 Mt in 2003 (Dalian Beiliang Logistics Services Ltd., 2004). Dalian Beiliang port terminal has played an important role in moving grain into or out the Northeast provinces and has become the biggest grain export port in China (Ministry of Communication of China, 2004).

As shown in **Fig. 6**, the intermediate depots are concentrated in the Northeast region: 11 in Liaoning province, 17 in Heilongjiang province, 25 in Jiling province, and six in Nei Menggu autonomous region (GDMP, 1992). The main functions of the intermediate grain depots are the receiving of dried grain from primary depots or receiving imported grain from the port terminal, weighing, cleaning, and storing grain in readiness for forward movement to local processing plants or to a port terminal. The primary depots are located throughout vast grain production areas in Northeast provinces. The purposes of primary depots are to receive grain from farmers, clean, weigh, dry, and store the grain in readiness to transfer it to processing plants, intermediate depots, or to Dalian port terminal destined to the other regions of China or export. Through the implementation of GDMP, an effective grain distribution framework has been established in Northeast provinces.

**Fig. 6** Locations of one port terminal and 59 intermediate depots (ID) in the Northeast grain transit corridor of China


**Southwest Grain Transit Corridor**

The Southwest grain transit corridor mainly covers the grain distribution network within Guangxi autonomous region. Guangxi autonomous region is one of major grain deficit areas in China. The major grain inflow includes wheat and corn. Before the implementation of Southeast grain transit corridor project, these grains had been moved by rail from the Northeast of China as well as by ships through the ports of Fangcheng. Although wheat arrived at port in bulk, all transportation by rail and truck was in bags. The corn that had been moved to South by sea had been in bags for both the ship and inland transportation. The purpose of this corridor is to maximize the use of sea transport to the extent that is economical and to provide the physical infrastructure needed for all wheat and corn brought to the region by sea to be handled entirely in bulk to destination. Inland transportation was primarily by rail and truck for secondary distribution. The projected grain transit corridor includes bulk port terminal, intermediate depots, and small grain depots within Guangxi autonomous (Williams et al., 1992). Throughout the implementation of GDMP, one port terminal located in Fangcheng port was constructed with storage capacity of 50,000 t. The main function of this port terminal is to receive grain from other areas of China or from overseas by water and than transfer it to the destination points in an efficient manner. Four grain depots have been built in the inland areas of Guangxi autonomous, one each in Guilin, Liuzhou, Luzhai, and Nanning (Dekkers et al., 1999). The developed grain distribution network in Southwest is shown in **Fig. 7**.

**Fig. 7** Locations of one port terminal and four intermediate grain depots in the Sorthwest grain corridor, China


**Beijing to Tianjing Grain Transit Corridor**

To meet grain demands for the two large population municipalities, i.e. Beijing and Tianjing, one intermediate grain depot with a storage capacity of about 62,000 t was designed and constructed (Approval Report of GDMP, 1993). Grain supplied from other areas is distributed via this intermediate depot to processing plants located in these two municipalities.

## Discussion

In Canada, almost all the grains

are handled and stored in bulk. A small amount of grain is handled in containers to meet specific customer requirements. The four levels of grain storage facilities have played different roles in the overall grain handling and transportation system. The objective is to develop an efficient grain supply chain to achieve a competitive edge in international grain market. Economic factors have driven changes in Canadian grain storage facilities and the transportation system. In the transportation system, the grain movement from farm storage to primary elevator is handled by large truck configuration, i.e. 40 t super B train instead of 5-10 t small farmer truck. The use of commercial trucking is growing and trucking costs percentage in the total logistics costs is also expected to rise significantly due to the consolidation of rail and primary elevator network (Transport Canada, 2003).

Rail charges account to about 50 % of total grain logistics costs. This figure might reduce due to consolidation of primary elevator and increasing road hauling distance. However, the rail will continuously play an important role to move grain from primary elevators to foreign and domestic markets. The maximum carrying capacity of the covered hopper cars with 110 t are now popularly used in Canadian rail network. Because of their greater capacity and ease of loading and unloading, covered hopper cars have now replaced boxcars for movement of bulk grain (Canadian Wheat Board, 2004a; Transport Canada, 2003 and Clegg, 1993).

Canadian grain handling system worked to achieve a highly efficient system using 'elevator' system. High volume grain moving through the primary elevator requires a quick and efficient handling system. High through put elevators are now characterized by their high handling efficiency and are able to load and unload grain at same time. As in Canada's port elevator system, computerization and mechanized operations are increasing at primary elevator level. The primary elevators have been developed like inland terminals on prairies. Grain can be cleaned to meet export standard and destined to foreign market directly, e.g. the United States.

Port grain elevators are major intermodal interfaces. Highly complex handling system, automation and computerization represent the modern technology application in Canada's port elevator system. An information system has become an essential part in supply chain management and is applied to Canada's grain industry. Information and computer systems allow tracking grain movement through the entire terminal system to the final consumers. A computerized inventory control system monitors exactly what quantity, type, and grade of grain is being received, stored, and shipped (Geary, 2004).

In comparison with Canadian grain handling and transportation system, the concept of bulk grain handling and transportation system has been applied to China's grain industry in a relatively short period. Because there is no on-farm storage in China's grain depot system, the function of primary depot in China is like Canada's on-farm storage. The design of intermediate depot and port terminal in China's grain industry is similar to Canada's primary elevator and terminal elevator, respectively. A fully mechanized and computerized system has been applied in these two levels of storage facilities to enable grain to be handled quickly and efficiently. By comparison, the bulk grain transportation system is not well developed and has become a bottleneck issue in China's grain supply chain. Currently, the small truck is commonly used to transport grain for short distances. For long haul, 60 t not-covered boxcars are still a popular type in rail transportation. The use of large trucks and covered hopper railcar is expected to increase significantly in the future. Because of large population and vast areas of China, significant amount of intra-provincial, inter-provincial grain movement occurs every year. The developed bulk grain network only accounts for a small part of its total volume. Grain handled in bags still represents a large proportion and will co-exist together with bulk system for a certain period.

## Conclusion

Canada's grain distribution and handling system has developed to ensure the movement of large quantities of grain from the prairies to international and domestic markets. Four levels of grain storages and various transport modes (road, rail, and water) are involved in Canada's grain supply chain. The efficient bulk grain distribution and handling system is remarkable and has played an important role in Canada's grain industry. Mechanized and computerized modern elevators with high throughput are the new reality in Canada's grain distribution system.

China's Grain Distribution and Marketing Project (GDMP) structures the bulk grain supply chain in four grain transit corridors. Through the implementation of GDMP investment, throughput capacity and efficiency of the grain distribution system have been improved by a change from bag to bulk grain handling and by upgrading storage and handling system components. The GDMP and State Grain Reserve Facility Project aimed to facilitate the bulk grain storage, handling, and distribution system and will contribute to further development of a nation-wide grain distribution network in China.

## REFERENCES


Aalders, L., A. D. Hartog, and S. Roseeler. 1992. China grain distribution and marketing project, feasibility study report on Yangtze river corridor. Beijing, China: Ministry of Commerce.

Agriculture and Agri-Food Canada. 2004. Canada: crop production, consumption, and exports. In Grains & Oilseeds Handling, Marketing, and Processing, 5th edition. Winnipeg, MB: Canadian International Grains Institute.

Approval Report of GDMP. 1993. Beijing, China: Ministry of Commerce.

Berry, A. E. 1993. Canada's primary elevator system. In Grains & Oilseeds Handling, Marketing, and Processing, 4th edition, ed. A.W. Tremere, 139-164. Winnipeg, MB: Canadian International Grains Institute.

Canada Grain Act. 2000. http://www.grainscanada.gc.ca/Regulatory/CGCAct/2000/cgc2000-e.pdf (2004/08/07).

Canada Grain Commission. 2004. Grain Elevators. http://www.grainscanada.gc.ca/fag /elevdecr-e.htm (2004/07/24).

Canada Transportation Agency. 2004. http://www.cta-otc.gc.ca/rulings-decisions/decisions/2003/R/713-R-2003-ehtml (2004/08/05).

Canada Wheat Board. 2004a. The Canadian Wheat Board marketing system. In Grains & Oilseeds Handling, Marketing, and Processing, 5th edition. Winnipeg, MB: Canadian International Grains Institute.

Canada Wheat Board. 2004b. Grain and the Great Lakes Seaway System. In Grains & Oilseeds Handling, Marketing, and Processing, 5th edition. Winnipeg, MB: Canadian International Grains Institute.

GDMP. 1992. Feasibility study report on Northeast corridor. China Grain Distribution and Marketing Project. Beijing, China: Ministry of Commerce.

China State Grain Administration. 2004. Implementation News of State Grain Reserve Depots. http://www.chinagrain.goc.cn/ccyjs/20040721b.html (2004/07/25).

Clegg, C. 1993. Railways in Canada's grain transportation system. In Grains & Oilseeds Handling, Marketing, and Processing, 4th edition, ed. A.W. Tremere, 165-180.Winnipeg, MB: Canadian International Grains Institute.

Dalian Beiliang Logistics Services Ltd. 2004. http://www.dblc.com.cn/beiliang/zn-cn (2004/08/08).

Dekkers, J., M. Philip, and L. Fan. 1994a. China Grain Distribution and Marketing Project, preliminary design report on Zhangjiagang grain terminal. Rotterdam, Netherlands: GEM Consultant B.V.

Dekkers, J., M. Philip, and L. Fan. 1994b. China Grain Distribution and Marketing Project, preliminary design report on Nantong grain terminal. Rotterdam, Netherlands: GEM Consultant B.V.

Dekkers, J., E. Cevall, and L. Fan. 1999. China Grain Distribution and Marketing Project, supervision report on Southwest corridor and Yangtze river corridor. Beijing, China: Ministry of Domestic Trade.

Geary, A. 2004. Grain silos in Canada. In Grains & Oilseeds Handling, Marketing, and Processing, 5th edition. Winnipeg, MB: Canadian International Grains Institute.

Ministry of Communication of China. 2004. http://www.moc.gov.cn/news/2004-03 (2004/07/28).

Roseeler, S. R. 1992. Technical report on Yangtze river corridor. Beijing, China: Ministry of Commerce.

Thompson, M. R. 1993. Canada's terminal elevator system. In Grains & Oilseeds Handling, Marketing, and Processing, 4th edition, ed. A.W. Tremere, 199-232.Winnipeg, MB: Canadian International Grains Institute.

Transport Canada. 2003. Grain handling and transportation system. http://www.tc.gc.ca/plo/en/Report/grainMonitoringProgram/ghts_appendix.htm (2004/11/02).

Tryon, J. T. 1993. The evolution of Canada's grain handling and transportation system. In Grains & Oilseeds Handling, Marketing, and Processing, 4th edition, ed. A. W. Tremere, 115-139.Winnipeg, MB: Canadian International Grains Institute.

Westdal, P. 2002. Post farm food safety - strategic plan. Winnipeg, MB, Canada.

Westdal, P. 2004. Competitive wheat marketing systems. In Grains & Oilseeds Handling,

Marketing, and Processing. 5th edition. Winnipeg, MB: Canadian International Grains Institute.

Williams, B. S., D. Palko, and W. Gerrish. 1992. China Grain Distribution and Marketing Project, technical report on Southwest corridor. Beijing, China: Ministry of Commerce.


■■

# Investigation into Farm Mechanization Practices for Cassava and Yam in Rivers State, Nigeria

by
S. O. Nkakini
Dept. of Agricultural and Environmental Engineering,
Rivers State University of Science and Technology,
P.M.B. 5080, Port Harcourt
NIGERIA
nkakini@yahoo.com

O. Ceder
Dept. of Agricultural and Environmental Engineering,
Rivers State University of Science and Technology,
P.M.B. 5080, Port Harcourt
NIGERIA

## Abstract

The present state of farm mechanization practices for energy utilization in yam and cassava cultivation was assessed in Rivers State and is presented in this paper.

Field surveys were conducted in several farms, Ministry of Agriculture and Agricultural Development Project (ADP) in the 23 local government areas of the state. To ascertain data, a structured questionnaire, personal visits to farm and discussions with record holders were used. The state's current situation for energy utilization in tractorization operations for these two crops were highlighted and compared with their traditional operations. Within the period of 1986-2004 energy utilizations in the productivity of these crops were 2,738.87 MJ and 33.5 MJ for machine power and traditional operations respectively. Tractorization Intensity (IT) which described the use of the tractor as the pivot of agricultural mechanization in the state dropped from 0.352 hp/ha in 1986 to 0.345 hp/ha in 2004. This result was below the recommended 0.5 hp/ha (T.I) for efficient agriculture. This study identified the causes of these shortcomings and recommended that the right attitude towards use of farm machinery and the industrialization of all sectors should be encouraged.

## Introduction

In the pre-independence era, the dominant role of agriculture in Nigeria's economy was taken for granted. Rivers State in the Eastern Region was not exempted. The first decade after independence, was a period when the Regional Governments were involved in direct agricultural production activities to complement the output of the private sector, peasant farmers and fishermen (Meshach-Hart E. T., 2000).

At this time, the main agricultural development was mainly on export crops like Cocoa, in the Western Region, groundnuts and cotton in the Northern Region, palm produce and rubber in the Eastern Region. Within this period, self-sufficiency in food production seemed not to pose any problems worthy of public attention. Two decades after independence witnessed greater involvement of government in agricultural development, which was associated with rapid deterioration in the country's and state's agricultural situation. The situation was further worsened by the attention towards "Oil Boom", which created serious migration of labour from the agricultural sector. Prior to 1971, Rivers State practiced both subsistence and cash crop agriculture and relied solely on human beings as source of power and energy. Among the major crops grown in the state were rubber, oil palm, cassava, yam, cocoyam, and pepper. However, productivity was very low because as Liljedhal et al. (1979) stated, human beings are limited to less than 0.1 kW continuous output and were very ineffective and inefficient as power units or engines.

To remedy this ugly situation, the practices of agricultural mechanization in the state started. It began during the period of the first military administration (1967-1976) with the procurement of the first batch of tractors and farm implements in 1971. The state established several farms and programmes in different parts of the state, including tractor-hiring units in all the local government headquarters. The state also trained the requisite manpower at the Agricultural Mechanization Training Centre in Oyo State in 1971 to handle the machinery fleet. Thereafter, the successive military and civilian administrations in the state both procured various makes and models of tractors at different time of their regimes as the need arose, up to this present time.

In the State farm, holdings were very small. They ranged between 0.25 to 5 ha with an average of about 2.63 ha. They were owned and operated by the farmers and their households and were often widely dispersed spatially. A farmer and his household cultivated between 2 and 4 non-contiguous farm plots in a farming season. Hectarage cultivated in such a case was given by the total hectarage of all spatially dispersed farming plots (Allison-Oguru, 1995 and Allison-Oguru et al., 1998, 1999).

Tillage and cultivation were mechanical land preparation operations, which break and stir up the soil in readiness for crop planting (Odigbo, 1991). In this period, land preparation was predominantly manual operation. Hoes were the universally accepted implements for land preparation in the state.

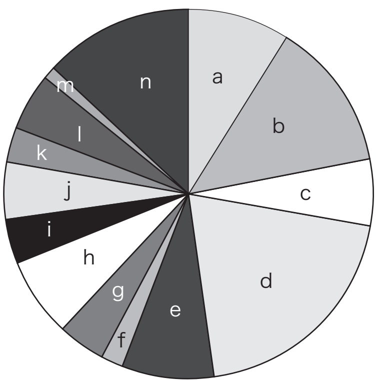
According to Kepner (1978), the increased production that had been realized during the past century must be credited to better crop varieties, the more effective use of fertilizers, improved cultural practices, and more essentially, the increased utilization of non-human energy and of the more effective machines and implements.

Thus, the objectives of this paper were to investigate and collect information on the present level of farm mechanization energy utilization and assessed tractorization intensity (TI) in the state. This would assist the government in looking into her deficit for updating and encourage farmers on profitable utilization of machine power.

## Materials and Methods

For this study, the main source of information was from the State Ministry of Agriculture, through personal visits to the farms and discussions with record holders. Field surveys were conducted in the 23 local government areas of the state and Agricultural Development Project (ADP) and farms. Further data were obtained by using a structured questionnaire to record information in agricultural mechanization practices, which covered farm sizes, cultivation practices, use of tractors and implements, labour utilization and requirements, energy utilization, timeliness of agricultural operations, availability of credit facilities, farmers social condition such as education, knowledge of farm machines, availability of repair facilities, makes, model, number, capacity and year of purchase of tractors.

**Fig. 1** Percent distribution of crops grown in Rivers State




a: Cassava ........................... 9 %
b: Plantain/Banana ............ 13 %
c: Maize .............................. 6 %
d: Sugar cane ..................... 20 %
e: Pineapple ........................ 8 %
f: Groundnut........................ 2 %
g: Melon.............................. 4 %
h: Sweet Potato .................. 7 %
i: Fluted Pumpkin ............... 4 %
j: Cocoyam ........................ 5 %
k: Pepper ........................... 3 %
l: Oil Palm........................... 5 %
m: Cocoa ........................... 1 %
n: Guava.............................. 13 %

**Table 1** Available tractors purchased by rivers state government (1971-2005)

| Month/year | Make | Model | Capacity, kW | Quantity |
|---|---|---|---|---|
| 1971 | Massey Ferguson | 135 | 48 | 11 |
| 1971 | Massey Ferguson | 105 | 60 | 3 |
| 1971 | Ford | 500 (D) | 48 | 2 |
| 1971 | Massey Ferguson | 135 | 48 | 9 |
| 1972 | Massey Ferguson | 165 | 60 | 8 |
| 1976 | John Deere | - | 60 | 12 |
| 1976 | David Brown | 1990 | 53 | 7 |
| 1977 | David Brown | 1990 | 60 | 3 |
| 1978 | Fiat | 80 (DT) | - | 10 |
| 1978 | Fiat | 640 (DT) | 82 | 15 |
| 1984 | Steyr | 8120A | 80 | 3 |
| 1984 | Steyr | 8080A | 52 | 10 |
| 1985 | Steyr | Fiat 666 | 52 | 5 |
| 1985 | Steyr | 768 | 52 | 15 |
| 1986 | Steyr | 768 | 97 | 5 |
| 1986 | Steyr | 8130 | 52 | 9 |
| 1986 | Steyr | 8075 | 52 | 9 |
| 1986 | Marshal/Leyland | - | 52 | 7 |
| 1986 | Marshal/Leyland | - | 52 | 3 |
| 1986 | Marshal/Leyland | - | 60 | 8 |
| 1986 | Steyr | 8075 | 52 | 50 |
| 1990 | Belorus | - | 60 | 50 |
| 1992 | Zetor | 7745 | 60 | 21 |
| 1996 | Fiat | 8066 (DT) | 60 | 20 |
| 1997 | Fiat | 8066 | 52 | 14 |
| 1997 | Fiat | 70.56 | 52 | 10 |
| 2001 | Fiat | 70.56 | 52 | 3 |
| 2002 | New Holland | 70.56 | 52 | 10 |
| 2003 | | - | - | - |
| 2004 | | - | - | - |
| | | | | ∑ = 332 |

**Data Collection and Processing**

Data collected in each of the 23 local government areas using both primary and secondary sources were analyzed. The primary data were obtained from the structured questionnaire, personal contact and oral interviews, while some physical inspections were also carried out.

By the secondary method relevant information were obtained from the agricultural documents, such as bulletins, workshop and seminar paper, etc.

The assessment of mechanization was done in two forms: The first was the simple percentage method used to analyze the data obtained in which the current tractorization intensity (TI) in the state was computed by using the equation proposed by Anazodo et al. (1986), as:

$T.I = P_u / A_c \ (\overline{hp}/ha)$ ....................(1)

$P_u = [(N)(\overline{hp})(\% \ OP) / 100]$

$T.I = [(N)(\overline{hp})(\% \ OP) / 100] / A_c$

$$\overline{hp} = \left( \frac{\sum_{j=1}^{m} n!h!}{\sum_{j=1}^{m} n!} \right)$$

where

$P_U$ = total tractor power in use (hp)

N = no of tractors available

%Op = percentage of operational tractors

$A_c$ = total land area mechanized (ha)

$\overline{hp}$ = weighted average size of tractor

m = 4 group range

n = no of tractors in the capacity range

h = corresponding average power in the range

The second assessment was on the energy basis. Suitable energy equivalents for human and tractor power were used to convert the man-hr and tractor-hr into (MJ) of energy (Ojha and Michael, 1998) as kWhr = 3.600 × $10^6$ J.

where

0.5 $\overline{hp}$/ha = 0.373 kW/ha.

∴Energy = day × 24 × 0.37 kW/ha to convert to kW hr/ha.

For the important crops grown in Rivers State, the energy utilized in the various operations namely land clearing, ridging, mould making, planting, weeding, harvesting were analyzed from the gathered information.

**Table 2** Numbers of tractors according to model purchased by Rivers State government (1971-2005)

| Tractor make | Number | % |
|---|---|---|
| Massey Ferguson | 31 | 9.34 |
| Ford | 2 | 0.60 |
| John Deere | 2 | 3.61 |
| David Brown | 10 | 3.10 |
| Fiat | 77 | 23.20 |
| Steyr | 101 | 30.42 |
| Marshall/Leyland | 18 | 5.42 |
| Belorus | 50 | 15.06 |
| Zetor | 21 | 6.33 |
| Fiat/New Holland | 10 | 3.01 |
| Total | 332 | 100.0 |

**Table 3** Numbers of tractors purchased within specific periods, in 10 years by Rivers State government

| Make | Number | % |
|---|---|---|
| 1971-1980 (1st decade) | | |
| Massey Ferguson | 31 | 9.34 |
| Ford | 2 | 0.60 |
| John Deere | 12 | 3.61 |
| David Brown | 10 | 3.10 |
| Fiat | 25 | 23.20 |
| 1981-1990 (2nd decade) | | |
| Steyr | 101 | 30.42 |
| Marshall/Leyland | 18 | 5.42 |
| Fiat | 5 | |
| Belorus | 50 | 15.06 |
| 1991-2000 (3rd decade) | | |
| Zetor | 21 | 6.33 |
| Fiat | 44 | |
| 2001-2004 | | |
| Fiat | 3 | |
| New Holland | 10 | 3.01 |
| Total | 332 | 100.0 |

## Results and Discussions

An appraisal of tractor acquisition (1971-2004) revealed the tractor

**Fig. 2** Energy utilization in cassava cultivation in Rivers State

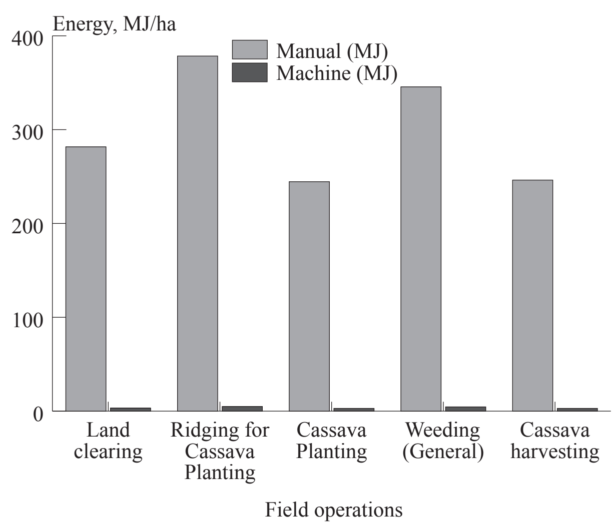
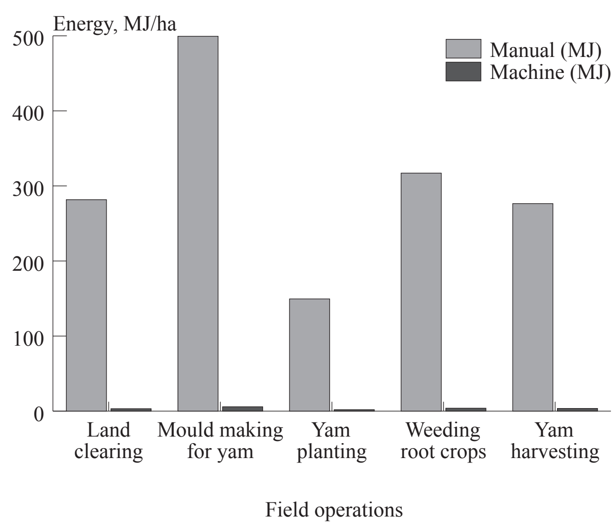



**Fig. 3** Energy utilization in yam cultivation in Rivers State



sources available for farming in Rivers State from 1971-2004, as shown in **Table 1**. A total of 332 tractors were procured by the state government. In the table, the variety of tractors by makes, model and capacity were also presented. Also from Table 1, it was observed that a total of 25 tractors were purchased in 1971 among which 22 had 48 kW while 3 had 60 kW. In 1972, 8 tractors bought were of 60 kW. There was no record of procurement of any model of tractor between 1973 and 1975.

In 1976, 1977, 1978 purchases were 12 tractors of 53 kW, 7 tractors of 53 kW and 3 tractors of 60 kW, respectively. The years between 1979 and 1983, no tractors was bought. In 1984, a total of 13 tractors were purchased. Among them were 3 tractors of 80 kW and 10 tractors of 25 kW. In 1985, 20 tractors of 52 kW were bought. And in 1986, a total of 41 tractors were bought, of which 5 were of 97 kW, 28 were of 52 kW, and 8 were of 60 kW. In 1987 and 1988, there were no tractors bought, while 50 tractors, all of 52 kW, were bought in 1989. In 1990, 50 tractors all of 60 kW were bought. There was no purchase made in the years 1991, 1993, 1994, 1995 and 1988. However, 21 ZETOR, all of 60 kW, were bought 1992. In 1997, total of 24 FIAT tractors all of 52 kW were bought, while 3 and 10 tractors of 52 kW were bought in 2001 and 2002, respectively. There were no purchases made in the years 2003 and 2004. **Table 1** further more indicated that 17 models of the tractors were used in the state.

**Table 2**, showed percentage distribution of purchasing according to models, from where it was observed that 30.42 % were STEYR, 23.20 % FIAT, 15.00 % BELORUS and FORD. Products accounting for only 0.6 % were the least purchased, it also showed that in the state a total of 10 different tractor makes were used.

The period of tractor procurement by the state government has been grouped into three decades in **Table 3**, 1971-1980, as 1st decade, and 1981-1990, 2nd decade and 1991-2000, 3rd decade. This was to assess tractor acquisition on a ten-year basis, based principally on the ten years service life of the tractor according to Culpin (1975). MASSEY-FERGUSON products ranked highest (38.75 %) in the 1st decade (1971-1980), STEYR product ranked highest (58.05 %) in the 2nd decade (1981-1990) and FIAT products ranked highest (67.70 %) in the 3rd decade (1991-2000). In the first four years of the fourth decade, NEW HOLLAND topped with 76.90 %. In all, FIAT-Products had the widest spread because the products were bought in all the decades. With this periodic purchase analysis, a drastic drop in the third decade was observed.

In **Table 4**, between 1971-2004 the actual tractor availability, makes, models, number of operational tractors, size of farm mechanization and staff strength in some farms in the state were shown. Only 16 tractors were reported to be available, of which 25 % were operational. When

**Table 4** Some farms in Rivers States and their levels of involvement in mechanization

| Name of farms | Type of owner management system (O.M.S.) | Size of farms mechanized, hr | No. of tractors available | Staff strength | No. of tractors in good condition | No. of operational tractors |
|---|---|---|---|---|---|---|
| School-to land authority farm, Irriiebe, Obio/Akpor L.G.A. | SGOMS | 150 | 6 | < 25 | 4 | 1 |
| Agricultural development programme farm, Okoro-odo, Obio/Akpor L.G.A. | SGOMS | 100 | 4 | > 25 | 2 | 1 |
| Nigeria prisons farm, Eleme, Ikwrre L.G.A. | FGOMS | 80 | 4 | > 25 | 1 | 1 |
| Zuru farm, Rumuigbo, Odo, Obio/Akpor L.G.A. | IOMS | 20 | Custom service | < 10 | - | - |
| Joel Nwala farm, Omuma, Omuma L.G.A. | IOMS | 30 | Custom service | < 10 | - | - |
| Chief N.U. Njoku farm, Etche, Etche L.G.A. | IOMS | 30 | Custom service | < 20 | - | - |
| Bionu Bangha farmers, Cooperative society ltd., Bionu Bangha, Khana L.G.A. | FCMS | 90 | Custom service | < 10 | - | - |
| Amadi electrical/farms, Igwurata, Ikwerre L.G.A. | IOMS | 20 | Custom service | < 10 | - | - |
| Antail farm Atali Obio/Akpor L.G.A. | SGOMS | 100 | 2 | > 25 | 1 | 1 |
| Rupheiza farms, Atali Obio/Akpor L.G.A. | IOMS | 15 | Custom service | < 10 | - | - |
| Areta farm, Atali, Odo, Obio/Akpor L.G.A. | IOMS | 20 | Custom service | < 10 | - | - |
| Total | | 655 | 16 | - | 8 | 4 |

SGOMS: State government owned management system, FGOMS: Federal government owned management system, IOMS: Individual owned management system, FCMS: Farmer's cooperative management system, the 16 tractors were compared with a total of 57 tractors bought between 1996 and 2004 in **Table 1**, it became obvious that, the 16 tractors available included the recent 13 tractors bought between 2001 and 2004 and perhaps 3 out of the 44 bought between 1996 and 1997. This could be attributed to poor maintenance and repair facilities.

### Tillage and Cultivation

In the state, the major and minor food corps cultivated by farmers, the average yield, yield and percentage distribution of crops are shown in **Table 5**. Yields for any of these crops were variable over space, the variability being influenced by fertility and management practices.

**Table 6**, shows a summary of comparison between the field operation rates by farmers using hand-tools and machine power in Rivers State. This involved nine different field operations as highlighted in the table. In the table, total of mean manual and machine field work of 317.0 man-days/ha and 1.04 machine days/ha, respectively were shown. The breakdown showed that 32.6 man-days/ha manual labour were used for land preparation and 0.10 machine days/ha was used for machine power. The ridging and cassava planting field work required 0.24 machine-days/ha using manual labour and 0.24 machine-days/ha using machine power. Mould making and yam planting required 75.1 man-days/ha manual labour and 0.24 machine-days/ha. The field work, which involved weeding (general and roots), used 40.0 man-days/ha, 0.14 machine-days/ha and 36.7 man-days/ha, 0.12 machine-days/ha for manual and machine power operations, respectively. Manual field work was time-consuming and required a lot of human power and expensive human labour. This was not ideal for Rivers State farmers who were mostly hand-tool farmers.

**Table 5** Avarage yield of selected crops cultivated in rivers state

| Crop | Yields, tons/ha | Avarage yield, ton/ha | % distribution of crops grown |
|---|---|---|---|
| Cassava | 10-14 | 12-50 | 31.50 |
| Plantain/Banana | 10-25 | 17-50 | 46.00 |
| Maize | 0.5-17 | 8-75 | 23.01 |
| Sugar cane | 15-40 | 27-50 | 72.34 |
| Pineapple | 8-15 | 11-50 | 30.25 |
| Groundnut | 1.5-3.0 | 2.25 | 5.92 |
| Melon | 3.0-8.0 | 5.50 | 14.46 |
| Sweet potato | 7.0-12 | 9.50 | 24.90 |
| Fluted pumpkin | 3.5-7.0 | 5.25 | 13.81 |
| Cocoyam | 5.0-8.5 | 6.75 | 17.75 |
| Pepper | 2.7-6.0 | 4.35 | 11.41 |
| Oil palm | 4.0-10 | 7.00 | 18.41 |
| Cocoa | 1.0-2.0 | 5.50 | 3.94 |
| Guava | 15-20 | 11.50 | 46.03 |
| Rubber | - | - | - |
| Cocoa nut | - | - | - |
| Mango | - | - | - |
| Pawpaw | - | - | - |
| Orange | - | - | - |

Source: Onuegbu and Zuofa (1999) and several rivers State ADP Annual Reports

**Table 6** A comparism of the energy utilization of manual production with the mechanized alternative in rivers state

| Fields operations | Mean manual work rate man-days/ha | Mean machine field work rate machine days/ha | Total energy, MJ/ha | |
|---|---|---|---|---|
| | | | Manual, MJ | Machine, MJ |
| Land clearing | 32.6 | 0.10 | 281.66 | |
| Riding for cassava planting | 43.8 | 0.15 | 378.43 | 4.83 |
| Mould making for yams | 57.8 | 0.18 | 499.39 | 5.80 |
| Cassava planting | 28.3 | 0.09 | 244.51 | 2.90 |
| Yam planting | 17.3 | 0.06 | 149.47 | 1.93 |
| Weeding roots crop | 36.7 | 0.12 | 317.09 | 3.87 |
| Weeding (general) | 40.0 | 0.14 | 345.60 | 4.51 |
| Cassava harvesting | 28.5 | 0.09 | 246.24 | 2.90 |
| Yam harvesting | 32.0 | 0.11 | 276.48 | 3.54 |
| Total | 317.0 | 1.04 | 2,738.8 | 33.5 |

### Energy Utilization in traditional and Machine Power Agricultural Technologies

Most of the traditional production technologies practiced in Rivers State were ineffective. A few that were effective and efficient could only handle low volume of output because they depended solely on primary human energy for manual operations. These facts were illustrated in **Table 6**, from which it was clear that cassava production per hectare used a total energy of about 1,467.93 MJ and 17.72 MJ of energy for manual and machine power, respectively. The production of yam per hectare utilized a total of about 1,524.09 MJ and 18.36 MJ for manual and machine power, respectively.

Also, **Fig. 2**, showed about 98.8 % and 1.2 % of manual and machine efforts were used for cassava and yam, respectively. The manual labour energy utilization was about 83 times than that of machine. In this table, energy utilization for tillage and cultivation operations in regards to land preparation, weeding and harvesting, it became clear that manual labour was much greater than that of machine.

Stout et al. (1979) reported specific human energy consumption for bush clearing as 40 KJ/min (1,680 MJ) and 19.4 man-day to prepare a hectare of land. He further reported machine power as 0.88 MJ energy utilization and 0.019 machine-day per hectare.

Energy utilization for manual weeding was 22 KJ/min (1,320 MJ) and 2.29 MJ for machine field operation and 32.6 man-day/ha and 0.015 machine effort was reported by (Stout et al., 1979). Energy-related data from a number of tropical cultivation systems and products for which cassava was one of them have been collected by Jentzach (1979) and Leach (1976) as 748 KJ (0.7488 MJ) for manual labour and 48.77 KJ (0.0487 MJ) machine power. There were no data for yam harvesting.

## Conclusion and Recommendation

The conclusion that could be drawn from this study was that farmers in Rivers State practiced a low level of mechanization. It was observed that these poor performances were due to poverty, ignorance and lack of incentive to the use of machinery in agricultural practices. There is no doubt that the traditional tools were cheap, simple and easily available to the farmer. However, they were time and energy consuming, and, therefore, required about 98.9 % when compared to about 1.2 % of machine power. The total energy utilization of the manual and machine power per hectare of the same work, was therefore, 2,738.8 MJ and 33.5 MJ of energy, respectively. The energy utilization was so much for manual methods that the farmers were reduced to subsistent level and, consequently, over populated the farm with labourers.

Again the tractorization intensity (TI) decreased from 0.352 hp/ha in 1986 to 0.345 hp/ha in 2003. This reflected that agricultural activity in the state was in recession. This was so because the 0.345 hp/ha tractor power utilization remained a far cry from the 0.5hp/ha, as recommended for efficient agriculture (Igbeka, 2002). Little wonder then that the much needed food security has continued to elude the state and, by extension, the entire country. Planting and harvesting of the major crops need to be mechanized in the state.

Also, there has to be a concerted effort towards standardization of the makes of tractors suited for the peculiar agro-physical and climatic conditions in the state, as this would ensure that tractors work efficiently throughout their service life. Agricultural lands should also be developed.

Presently, with a poverty alleviation programme, the effects of poverty could be taken care of. The issue of ignorance and lack of incentives could be tackled with the Government and Research institutions. Educating farmers on the right attitude towards the use of farm machinery could be the right step.

Certainly, data obtained in this study indicated that cultivation of these crops (yam and cassava) involved more energy utilization in manual than mechanical operations.

## REFERENCES

Allison-Oguru, E. A. 2001. Environmental Impact Assessment Report (Socio-economics sections) of Azuzuan Oil Field Development Project by Agip Oil Company Ltd. A Report Submitted to Jawura Environmental Service Ltd. Lagos.

Allisn-Oguru, E. A. 1995. A Report on Overview and Evaluation of Existing Data on Agronomy/Agroeconomics in the Niger Delta. Report Submitted to Eurconsult, Managing Consultants, Niger Delta Environmental Survey, Phase 1.

Allison-Oguru, E. A., K. Zuofa, and N. A. Berepubo. 1999. "Agriculture" in Alagoa E. J. (ed). Land and People of Bayelsa State: Central Niger Delta. Port Harcourt; Onyoma Research Publication. Pp 283-300.

Anazodo, U. G. N., T. O. Abinbola, and J. A. Dairo. 1986. "Agricultural Machinery Inventory, Type and Condition in Nigeria (1975-85)" Federal Department of Agriculture, Nigeria.

Culpin, C. 1975. Profitable Farm Mechanization, Granada Publishing Co., London, 307p.

Igoni, A. H. and R. N. Okparanma. 2003. "Cost Implication of Farm Mechanization in Rivers State of Nigeria". Journal of Science and Technology Research Press.

Igbeka J. C. 2002. Agricultural Engineering and the society: Nigerian Institution of Agricultural Engineers Quarterly (3) 3:3-11.

Kepner, R. A., R Bainer, and E. L. Barger. 1978. Principles of Farm Machinery (3rd edition) AVI Publishing Company Inc. Connecticut.

Liljedahi, J. B., W. M. Carition, P. K. Turuguist, and D. W. Smith. 1979. Tractors and their Power Units (3rd ed). John Wiley and Sons Inc., Canada.

Meshack-Hart E. T. 2000. Mechanized Agriculture for Sustainable Agricultural Development for Nigerians in the year 2010: A Journal South East Regional Chapter of the Nigerian Institution of Agricultural Engineers, 2000 p 39.

McColly, H. F. and J. W. Martin. 1995. Introduction to Agricultural Engineering McGraw-Hill Book Company Inc, New York.

Odigboh E. U. 1991. "Continuing Controversies on Tillage Mechanization" in Nigeria, J. Agric. Science Technology 41-49.

Ojah, T. P and A. M. Michael. 1988. Principles of Agricultural Engineering, Vol. 1 Jain Brothers Publishing Co., New Delhi. P. 623.

Stout, B. A., C.A. Myers, A. Hurand, and L. W. Faidley. 1979. Energy for World Agriculture-FAO-Agricultural Series No. 7, Rome.

■■

# Domestic Solar Geyser Cum Distiller

by

S. H. Sengar
Research Scholar
College of Technology and Engineering,
Dept. of Renewable Energy Sources,
Maharana Pratap University of
Agricultura and Technology,
Udaipur - 313 001
INDIA

A. K. Kurchania
Professor and Head
College of Technology and Engineering,
Dept. of Renewable Energy Sources,
Maharana Pratap University of
Agricultura and Technology,
Udaipur - 313 001
INDIA

## Abstract

A solar geyser cum distiller (SGD) device, having a capacity of 100 liters was designed, developed and performance evaluated. Overall efficiency of SGD for winter and summer was 36.70 % and 27.48 %, respectively. The yields of distilled water were 5,007 ml/m$^2$ day in winter and 5,275 ml/m$^2$ day in summer. The total cost of SGD device was Rs. 8,930.

## Introduction

The first detailed study of the performance of the flat plate collector was made by Hottel and Woertz (1942) and later modified by Tabor (1958). Many researchers have made performance evaluation as well as component-wise studies. Tiris et al. studied the storage tank and two flat plate solar collectors integrated with basin type solar still. Singh et al. made extensive performance study of integrated solar water heater having a solar collector and storage tank as separate unit.

**Plate 1** Solar geyser cum distillation unit

### System Description

The SGD device consisted of a flat plate collector with a net effective area of 2 m$^2$ as shown in **Plate 1**. It was fundamentally based on two processes; evaporation of water through the application of solar energy and subsequently condensation of vapors naturally that resulted in potable water.

The SGD unit consisted of solar collector (front glazing), metallic absorber, back insulation and collector box, insulated storage tank, water trough and piping. Water was heated with the solar energy and the same unit, also, distilled water. Evaporation took place from the water inside the storage tank that was heated through the solar collector. A conical cover (**Plate 2**) with cold water on the top of the storage tank was provided for maintaining the temperature difference for condensing the inside vapors of the storage tank. This temperature difference produced convection currents in the air, which was trapped inside the enclosure. These currents brought the humid air into the contact with relatively cool cover and resulted in condensation of some of the humidity on the surface of cover. This con-

**Acknowledgements:** The authors are highly thankful to Ministry of Non-conventional Energy Sources for providing the financial assistance to carry out the research work. They are also thankful to the Department of Renewable Energy Sources, College of Technology and Engineering, Udaipur for providing all sorts of required facilities for the study.

**Plate 2** Conical water trough

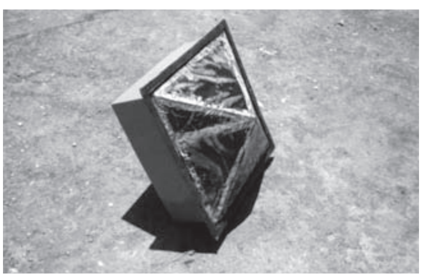
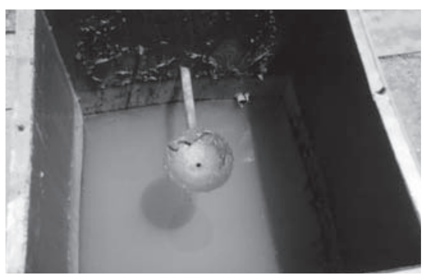


**Plate 3** Bowl inside storage tank



densation slid down the slope, collected in the distillation bowl (**Plate 3**) and drained out of the enclosure through the piping depicted in **Fig. 1**. The collector frame was mounted on steel angle bars, grouted on the roof having 40º inclinations from the horizontal facing south.

**Experimental Observation**

The study was conducted in February and April 2004. Temperature corrected electronic sensors with 0.1 ºC accuracy were used to measure the water temperature at different points of the SGCD. An insolometer was used to measure the instantaneous solar radiation on the surface of collectors. All measurements were made during the period of constant insolation.

**Performance Calculation**

***Solar water heater efficiency***

$\eta_{overall} = m\ s\ (T_f - T_a) / \Sigma\ I\ A_p\ \Delta t$, (Permpal Singh et al., 2004)

where,

$(T_f - T_a)$ is difference in temperature of water in the evening and ambient temperature at the subsequent morning, m is mass of water in the storage tank and s is specific heat of water, I is solar radiation, W/m$^2$ of aperture area, $A_p$ is aperture area and $\Delta t$ is Time.

***Distillation efficiency***

$\eta_{dist} = Q_e / Q_t$, (Sinha et al., 1992)

where,

$Q_e = Me \times f$

Me = Daily output of distilled water in kg m$^{-2}$ day$^{-1}$

f = Latent heat of vaporization of water in W kg$^{-1}$

$Q_t$ = Energy available, Wm$^{-2}$

## Results and Discussion

Experimental observations are shown in **Table 1**. Variation of solar radiation on collector surface during the measurement period was noted as 234-734 W/m$^2$ on 12 February 04 and 451-860 W/m$^2$ on 12 April 04, respectively. Overall efficiency of SGD for winter and summer was 36.70 % and 27.48 %, respectively. Temperature coming from the tank was 15-20 ºC more than the ambient temperature. Total distilled water in 24 hours produced from SGD in February 2004 and April 2004 was 5,007 ml m$^{-2}$ day$^{-1}$ and 5,275 ml m$^{-2}$ day$^{-1}$. During winter, the temperature in the water trough decreased while the temperature inside storage tank was more due to insulation but in summer temperature in the water trough was more due to higher ambient temperature. Hence, there was more condensation in February and consequently distillation was more. The output of the SGD was greater in February as shown in **Fig. 2**.

**Electrical Energy Saved**

Calculation of the electrical energy, saved by the SGD, was made during the observation. Temperature of cold water in the storage tank rose by about 24 ºC, which showed

*(continued on page13)*

**Table 1** Thermal performance of Solar Geyser (SG) in SGD for winter

| Time, hrs | Ambient temp., ºC | Inlet temp., ºC | Outlet temp., ºC | Storage temp., ºC | Inolation, W/m$^2$ | SG efficiency, % |
|---|---|---|---|---|---|---|
| 9:00 | 22.81 | 32.23 | 38.56 | 37.00 | 234.00 | |
| 9:30 | 23.80 | 33.06 | 40.70 | 37.39 | 399.33 | |
| 10:00 | 24.00 | 33.75 | 43.31 | 34.95 | 415.00 | |
| 10:30 | 24.13 | 34.33 | 49.65 | 36.99 | 535.18 | 36.70 |
| 11:00 | 25.14 | 34.31 | 43.15 | 38.75 | 586.91 | |
| 11:30 | 26.19 | 34.95 | 42.66 | 40.47 | 638.82 | |
| 12:00 | 26.99 | 35.78 | 45.41 | 41.88 | 697.91 | |
| 12:30 | 27.45 | 36.53 | 49.13 | 42.63 | 713.82 | |
| 13:00 | 28.27 | 38.21 | 49.80 | 44.75 | 733.27 | |
| 13:30 | 28.27 | 39.95 | 51.56 | 46.35 | 711.00 | |
| 14:00 | 28.52 | 41.11 | 52.83 | 46.72 | 680.00 | |
| 14:30 | 28.79 | 42.75 | 53.91 | 47.69 | 630.00 | |
| 15:00 | 28.47 | 44.00 | 56.41 | 48.29 | 547.91 | |
| 15:30 | 27.69 | 44.93 | 58.50 | 48.59 | 494.27 | |
| 16:00 | 26.15 | 45.75 | 60.33 | 48.50 | 407.00 | |
| 16:30 | 25.09 | 46.33 | 59.00 | 48.00 | 290.10 | |
| 17:00 | 24.05 | 46.91 | 53.75 | 48.00 | 182.55 | |

**Fig. 2** Performance of SGD for distillation during winter

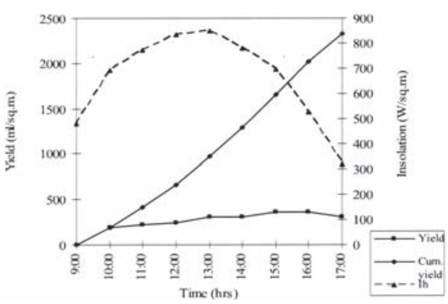
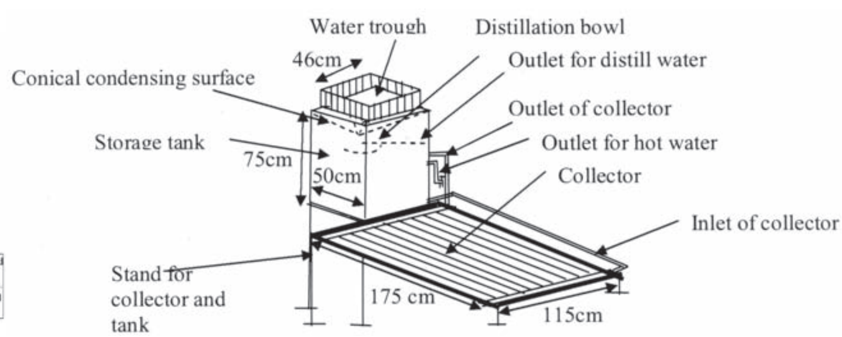
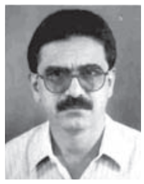



**Fig. 1** Solar water geyser cum distillation



# Laser Guided Land Leveler: Precession Leveler With Laser Technology for Land Preparation

by
B. Suthakar
Research Scholar
Dept. of Farm Power and Machinery,
Agricultural Engineering College
and Research Institute,
Tamil Nadu Agricultural University,
Coimbatore - 641003, INDIA
suthaameag@yahoo.co.in



K. Kathirvel
Professor and Head
Dept. of Farm Power and Machinery,
Agricultural Engineering College
and Research Institute,
Tamil Nadu Agricultural University,
Coimbatore - 641003, INDIA

R. Manian
Dean
Agricultural Engineering College
and Research Institute,
Tamil Nadu Agricultural University,
Coimbatore - 641003, INDIA

D. Manohar Jesudas
Professor
Dept. of Farm Power and Machinery,
Agricultural Engineering College
and Research Institute,
Tamil Nadu Agricultural University,
Coimbatore - 641003, INDIA

## Abstract

Unevenness of fields leads to inefficient use of irrigation water and also delays tillage, crop establishment and uneven maturing of crops, which in turn reduces the yield, grain quality and farm income. Hence, a precisely levelled field is a pre-requisite for an efficient surface irrigation system. The accuracy of leveling depends on skill and the judgment of the operator. But, in the laser system, the leveling of land is done precisely with the automatic functioning of the laser-operated scraper. So, the present study was conducted to find the feasibility of tractor operated laser guided land leveller. The study was carried out in the Research farms of Tamil Nadu Agricultural University, Coimbatore. A comparative evaluation of the laser guided land leveler with the existing system of leveling showed that the percentage reduction in standard deviation of reduced levels for before and after leveling was 92.55 % for laser leveling. For the conventional method, it was observed as 72.34 %, which was 20 % lower then the laser leveling. From contour charts, it was observed that considerably higher accuracy of grading was obtained when the fields were graded by use of laser leveler. The field capacity of the laser leveler and cost of operation were 0.08 ha/h and Rs 474/h and 0.098 ha/h and Rs 309/h for conventional leveler, respectively. The cost of leveling per hectare using laser leveler was 5,932.50 Rs/ha and 3,151 Rs/ha for conventional levelling.

## Introduction

Unevenness of the soil surface has a major impact on the germination, stand and yield of crops through nutrient water interaction and salt and soil moisture distribution pattern. Land leveling is an important operation for good agronomic, soil and crop management practices. Traditional methods of leveling land are not only more cumbersome and time-consuming but also more expensive. Most rice farmers level their fields very often under pounded water conditions. The other farmers dry level their fields and check level by pounding water. Thus, in the process of a having good leveling in fields, a considerable amount of water is wasted. It is a common knowledge that most of the farmers apply irrigation water until all the parcels are fully wetted and covered with a thin sheet of water. Studies have indicated that a significant (20-25 %) amount of irrigation water is lost during its application at the farm due to poor farm design and unevenness of the fields. Unevenness of fields leads to inefficient use of irrigation water and delays tillage and crop establishment options. Fields that are not level have uneven maturing of crops. All these factors tend to contribute to reduced yield and grain quality, which reduce farm income. Land leveling saves irrigation water, facilitates field operations and increases yield and quality of the produce. Leveled land also helps in mechanization of various field operations. Leveling of land may be done to obtain a perfectly level field as required for rice crop. For other crops and for efficient irrigation, a uniform grade is given to the land for faster advance of the waterfront. The grade or slope given is usually in one direction only. However, where drainage of water is required as is the case during rainy season, then grades are often given in both directions. So far, several types of land levelers such as bucket scrapers, drag scrapers, land smoothers and bull dozers are used for leveling both to obtain a perfectly level field (0 % slope) and to obtain a field with the desired slope. The selection of these implements is based on type of undulations in the field and the extent of leveling required. However, the accuracy of leveling depends on skill and the judgment of the operator. The amount of cut is controlled by the hydraulic system, controlled by the operator. Hence, a precisely levelled field is a pre-requisite for an efficient surface irrigation system. At present most of the fields are small and undulating, which result in waste of irrigation water and inefficient use of farm machinery. For an efficient irrigation system the level difference between high and low spots of a field should not exceed 20 mm whereas under actual field conditions, a difference of 50 to 100 mm is very common. The laser system is of quite recent origin. The levelling of land is done precisely with the automatic functioning of the laser-operated scraper. With the laser system the reference plane is generated above the ground with the help of a rotating transmitter. The scraper is controlled by the laser beam, through a control panel and a solenoid valve, to maintain a desired level by raising or lowering the cutting edge of the blade automatically, depending upon the field grades. The tractor operator constantly receives the signals regarding high or low spots as well as on grade information on the control box located in the cabin as well as on the light display fitted in front of operator. Hence, the present study is an attempt to find the feasibility of a tractor operated laser guided land leveller.

## Review of Literatures

Cook (1960) reported that a significant (20-25 %) amount of irrigation water was lost during its application at the farm due to poor farm designing and unevenness of the fields.

El-Gindy et al. (1994) evaluated the effect of precision land leveling with laser guided land leveler and three tillage treatments on the irrigation requirements and crop yield. They reported 20 and 22 % water saving for wheat and maize, respectively. Also, the crop yields increased by 30 % for wheat and 47 % for maize.

Xiang et al. (2000) evaluated the effectiveness of conventional and laser controlled land leveling procedures in the field for land preparation. They concluded that conventional land leveling technology could be used for primary earth moving process until the standard deviation of level of field surface approached 4 to 5 cm at which point laser controlled equipment should be used to achieve the required precision.

Rickman (2002) reported the yield of leveled fields was significantly higher (24.2 %) than the unleveled fields. He also reported that yield increased as land levelness increased. Highest yield of about 3.5 t/ha for field having about 20 mm land levelness was reported whereas the yields were in the range of about 2 to 2.3 t/ha when land levelness was about 40 mm or higher. He also reported the results of land leveling experiments done in Cambodia where the yield of rice increased to 2.72 t/ha as compared to 2.19 t/ha in unleveled fields.

Tarun Kumar and Maheshwari (2005) reported that the reduction from 21 to 5 labour-days per hectare was achieved using laser leveler for land levelling. They concluded that land leveling with laser was over 500 % more efficient and time saving than the traditional system of land leveling.

Mathankar et al. (2005) reported a yield of 10.7 % was obtained in the laser-leveled field. The yield of transplanted rice in India was about 4-5 t/ha and, assuming a 10 % increase in yield in the laser leveled field an additional 0.4-0.5 t/ha yield was achievable. The additional yield fetches the farmer an extra income of Rs. 2,500-3,000/-ha. The tractor operated laser guided land leveler improved the leveling accuracy by 50 % and saved irrigation water (16.7 %) with increased yield (10.7 %).

Chaudhuri et al. (2005) compared the performance of the laser guided land leveler with conventional methods. They found that standard deviation of reduced levels varied from 1.9 to 4.4 mm as compared to values of 25.0-30.2 mm for leveling without using laser system. The values of leveling index varied from

**Table 1** Particulars of the selected fields

| Parameters | Values | |
|---|---|---|
| | Field No. 1 | Field No. 2 |
| Length of the field, m | 80 | 70 |
| Width of the field, m | 70 | 70 |
| Area of the field, $m^2$ | 560 | 490 |
| Range of the elevation height, cm | 25.2 to -17.6 | 15.4 to -21.2 |
| Standard deviation, cm | 11.65 | 12.33 |

1.6 to 3.2 mm for laser guided grading as compared to 15.7-25.4 cm for grading without using laser systems. Field capacity varied from 0.09 to 0.12 ha/h for laser leveling as compared to 0.11-0.15 ha/h for grading without use of laser system.

## Materials and Methods

This study was carried out in the Research farm of Tamil Nadu Agricultural University, Coimbatore. Comparative evaluation of the laser guided land leveler with the existing system of leveling was made. In order to eliminate differences in leveler performance due to design of the drag scraper, the same leveler was used for both studies. For evaluating conventional leveling, the laser system was not used and the hydraulic system was actuated manually.

**Description of Laser Guided Land Leveler**

A commercial unit of laser guided land leveler was used for the study. The laser-controlled system consisted of (i) Laser transmitter, (ii) Laser receiver, (iii) Laser plane receiver, (iv) Control box, (v) Twin solenoid hydraulic control valve, (vi) Drag Scrapper.

***i. The Laser Transmitter***

The laser transmitter transmits a laser beam, which is intercepted by the laser receiver mounted on the leveling bucket. The control panel mounted on the tractor intercepts the signal from receiver and opens or closes the hydraulic control valve, which will raise or lower the bucket in order achieve the desired level. The laser transmitter (**Fig. 1**) mounts on a tripod stand, which allows the laser beam to sweep above the tractor unobstructed. With the plane of light above the field, several tractors can work from one transmitter.

***ii. Laser Receiver***

The laser receiver (**Fig. 2**) is a portable, battery-operated device that locates elevation of the rotating laser beam passed from the laser transmitter. This survey staff rod receiver indicates its position through Liquid Crystal Display or audible tones. The existing survey rod can be attached on the receiver through the universal clamp.

***iii. Laser Plane Receiver***

The laser receiver is an omni-directional receiver that detects the position of the laser reference plane and transmits these signals to the control box. The receiver mounts on a manual or electric mast attached to the drag bucket.

***iv. The Control Box***

The control box (**Fig. 3**) accepted and processed signals from the machine mounted receiver. The control box of the laser system had multiple functions. The main function was to receive the signals from the laser system and convey it to the hydraulic system. The control box took power for its operation and also for operation of receiver and solenoid

**Table 2** Surveyed readings in meters for the field no. 1 before leveling

| Sl. No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1.8 | 1.72 | 1.821 | 1.862 | 1.917 | 1.961 | 2.008 |
| 2 | 1.682 | 1.721 | 1.828 | 1.864 | 1.89 | 1.973 | 2.02 |
| 3 | 1.65 | 1.62 | 1.638 | 1.816 | 1.826 | 1.862 | 1.938 |
| 4 | 1.576 | 1.662 | 1.96 | 1.884 | 1.89 | 1.862 | 1.934 |
| 5 | 1.634 | 1.726 | 1.796 | 1.892 | 1.936 | 1.956 | 2 |
| 6 | 1.69 | 1.741 | 1.784 | 1.89 | 1.894 | 1.884 | 1.972 |
| 7 | 1.704 | 1.71 | 1.696 | 1.844 | 1.878 | 1.898 | 1.954 |
| 8 | 1.65 | 1.712 | 1.704 | 1.865 | 1.92 | 1.892 | 1.93 |

**Table 3** Surveyed readings in meters for the field no. 2 before leveling

| Sl. No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1.63 | 1.716 | 1.69 | 1.876 | 1.936 | 1.928 | 2.028 |
| 2 | 1.72 | 1.724 | 1.719 | 1.892 | 1.905 | 1.952 | 2.05 |
| 3 | 1.716 | 1.72 | 1.728 | 1.868 | 1.866 | 1.93 | 2.004 |
| 4 | 1.72 | 1.704 | 1.716 | 1.928 | 1.906 | 1.888 | 2.058 |
| 5 | 1.718 | 1.734 | 1.728 | 1.924 | 1.888 | 1.932 | 2.082 |
| 6 | 1.814 | 1.87 | 1.856 | 1.988 | 1.972 | 2 | 2.11 |
| 7 | 1.822 | 1.916 | 1.87 | 1.94 | 1.918 | 1.99 | 2.05 |

**Fig. 1** View of laser transmitter

**Fig. 2** View of laser eye receiver

**Fig. 3** View of the control box

valves from the tractor battery. Based on a signal from laser system, it actuated one of the two solenoids directional control valve, which was a part of the hydraulic system. The control box had indicator lights to indicate whether the existing level was higher, lower or at the desired level. It also had controls to operate the leveler in AUTO or MANUAL mode. The latter was used in case of accumulation of too much soil or when the leveler was to be operated without using the laser system. Another function of the control box was to actuate the electric mast.

***v. Hydraulic System***

The hydraulic system of the tractor was used to supply oil to raise and lower the leveling bucket. The oil supplied by the tractor hydraulic pump was normally delivered at 2,000-3,000 psi pressure. The solenoid control valve controlled the flow of oil to the hydraulic ram, which raised and lowered the bucket. The hydraulic system (**Fig. 4**) of the leveler consisted of a directional solenoid control valve, pressure relief valve, single acting hydraulic cylinder, hydraulic pipes, couplings and other adapters. When a low signal was received from the laser system, the corresponding solenoid directional control valve was actuated and hydraulic oil was sent to the hydraulic cylinder for lifting of the leveler blade. When a high signal was received, the second solenoid was actuated and the hydraulic cylinder oil returned to the hydraulic oil sump and the leveler blade was lowered due to weight of the blade. The leveling blade was 3.0 m in length and had a capacity of 1.7 cu m.

***vi. Drag Scrapper***

The drag scrapper is a bottomless structure with heavy-duty steel and has a replaceable cutting edge. It is pulled by the tractor drawbar. A set of wheels pivot on the back of the box. A hydraulic cylinder is linked to the wheel's frame; this cylinder raises and lowers the bucket. The tractor rear wheels maintain side to side stability as the tractor moves across the filed and helps the scrapper blade stay level while the tractor oscillates over rough ground.

**Table 4** Surveyed readings in meters for the field no. 1 after leveling

| Sl. No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1.811 | 1.82 | 1.826 | 1.828 | 1.829 | 1.832 | 1.836 |
| 2 | 1.821 | 1.824 | 1.827 | 1.828 | 1.828 | 1.83 | 1.833 |
| 3 | 1.825 | 1.827 | 1.828 | 1.828 | 1.828 | 1.828 | 1.831 |
| 4 | 1.827 | 1.828 | 1.828 | 1.828 | 1.828 | 1.828 | 1.828 |
| 5 | 1.826 | 1.828 | 1.828 | 1.828 | 1.828 | 1.828 | 1.829 |
| 6 | 1.825 | 1.827 | 1.828 | 1.828 | 1.828 | 1.829 | 1.831 |
| 7 | 1.82 | 1.824 | 1.827 | 1.828 | 1.829 | 1.83 | 1.834 |
| 8 | 1.81 | 1.821 | 1.825 | 1.828 | 1.83 | 1.835 | 1.837 |

**Table 5** Surveyed readings in meters for the field no. 2 after leveling

| Sl. No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1.84 | 1.85 | 1.86 | 1.876 | 1.88 | 1.89 | 1.9 |
| 2 | 1.845 | 1.869 | 1.87 | 1.881 | 1.882 | 1.884 | 1.89 |
| 3 | 1.866 | 1.872 | 1.874 | 1.868 | 1.869 | 1.883 | 1.885 |
| 4 | 1.871 | 1.877 | 1.871 | 1.87 | 1.882 | 1.881 | 1.871 |
| 5 | 1.866 | 1.871 | 1.872 | 1.872 | 1.888 | 1.881 | 1.884 |
| 6 | 1.855 | 1.86 | 1.868 | 1.872 | 1.886 | 1.883 | 1.892 |
| 7 | 1.833 | 1.854 | 1.87 | 1.87 | 1.884 | 1.89 | 1.901 |

## Methodology

In order to evaluate accuracy of the laser system, two treatments were taken: (a) leveling with laser-guided leveler and (b) leveling with same leveler and prime mover without using the laser control system, i.e. traditional land leveling. The reduced levels of grid points (10 × 10 m) were taken prior to and after the leveling operation, following standard surveying and leveling procedure. No grade (slope) was given to the land. The standard deviation of reduced levels of the grid points were calculated. The field was plowed using a disk plow in order to increase the topsoil volume. For a second working, a cultivator

**Fig. 4** Hydraulic control system

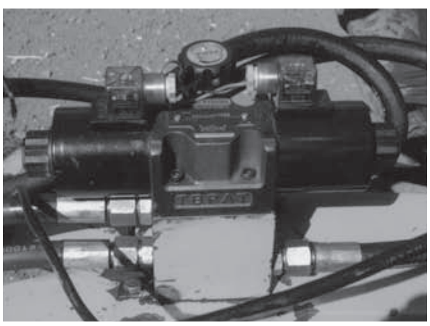


**Fig. 5** Operational view of laser leveller

**Fig. 6** View of the field after levelling

was used followed by rotovator to achieve the fine tilth of the soil to ensure smooth flow of soil in the leveler scrapper. All surface residues were cut and removed to aid soil flow from the bucket.

After the filed preparation, a topographic survey was conducted to record the high and low spots in the field. From the surveyed readings, the mean height of the field could then be established by taking the sum of all the readings and dividing by the number of readings taken. The laser surveying system was made up of a laser transmitter, a tripod, a measuring rod and a small laser receiver. A major advantage of laser surveying was the accuracy and simplicity of use. Also, only one person was needed.

**Procedure**

The plots were divided into two portions. In one portion, the grading operation was carried out using the laser guided land leveler, whereas, in the second portion, the control box switch was set to MANUAL and grading carried out by using judgment and skill of the tractor driver. In the latter case, for lowering and lifting of the leveler blade, the RAISE and LOWER switches of the control box were used. The reduced levels were taken at all grid points with the help of transmitter and the laser eye receiver at a spacing of 10 m × 10 m. At first, the laser beam was set at a level plane (0 % slope) in both directions and the readings taken at all grid points. The mean height of the field was determined by adding all measured points and dividing by the number of measurements. A new map was then drawn which showed the difference between the mean height of the field and recorded height. The average reduced levels and standard deviation of reduced levels of the grid points were calculated.

The laser controlled bucket was positioned at a point that represents the mean height of the field and the cutting blade should be set slightly above ground level (1-2 cm). The setting was changed to AUTO in control box. Next, the mast was moved up or down till the green light was displayed in the control box. The grading was started until all portions of the field showed green light. The tractor was then driven in a circular direction from the high areas to the lower areas in the field. To maximize working efficiency, as soon as the bucket was near filled with soil the operator drove toward the lower area. Similarly, as soon as the bucket was near empty the tractor was driven back to the higher areas. When the whole field has been covered in the circular manner, a final leveling pass was made in long runs from the high end of the field to the lower end. After the operation, mapping of field was again carried out using the laser eye receiver. As before, the average reduced levels and standard deviation of reduced levels of the grid points were again calculated. The standard deviation was used to obtain the accuracy of the reduced level. For a subjective assessment of accuracy of leveling, contour maps were plotted before and after leveling. The contour maps were plotted against a level field as the base. The cost of leveling per ha, for both the systems, were also calculated.

## Results and Discussion

The particular values such as length and width related to the selected field for this study are furnished in **Table 1**.

From **Table 1**, it is seen that the standard deviation of reduced levels corresponding to a level plane varied from 11.65 to 12.33 cm. The high value of standard deviation was mainly due to presence of a grade or slope in the field. The elevation height of the field at each

10 × 10 grid point for the laser leveling and conventional leveling, namely field No. 1 and field No. 2 is shown **Tables 2** and **3**, respectively.

The mean height was determined by adding all the measured points together and dividing by the number of the measurements. From the **Tables 1** and **2**, mean height of the surveyed reading was 1.828 m and 1.87 m for field No. 1 and field No. 2, respectively. For the field No. 1, the drag scrapper was placed at the grid point (2, 3) having a mean height of 1.828 m and leveled using laser technology as explained. The operational view of the laser guided land leveler and the view of the field after leveling is shown **Fig. 5** and **Fig. 6**, respectively. For field No. 2, the field was leveled with same leveler without using the laser technology, i.e. the control box switch was set to MANUAL and grading carried out by using judgment and skill of the tractor driver. The elevation height of the field observed at each 10 × 10 grid point after the laser leveling and conventional leveling is shown **Tables 4** and **5**, respectively.

From the **Tables 4** and **5**, the mean height of the surveyed reading was 1.827 m and 1.826 m for field No. 1 and field No. 2, respectively. To assess the accuracy of leveling, the standard deviation was calculated for surveyed readings of the each field before and after leveling and furnished in **Table 6**.

From the **Table 6**, the standard deviation of reduced levels before leveling was 11.65 cm and after leveling is 0.87 cm, using the laser

**Table 6** Standard deviation of surveyed readings

| Particular | Laser (Field No. 1) | Conventional (Field No. 2) |
|---|---|---|
| Standard deviation of reduced levels before leveling, cm | 11.65 | 12.33 |
| Standard deviation of reduced levels after leveling, cm | 0.87 | 3.41 |

leveler for leveling the field No. 1. The standard deviation of reduced levels before leveling was 12.33 cm and after leveling was 3.41 cm using the conventional leveler for leveling field No. 2. The 92.55 % standard deviation was reduced in the case of laser leveling, whereas, for the conventional method it was 72.34 %, which was 20 % lower then the laser leveling. Hence, the accuracy of leveling using laser leveler is higher with more precision than conventional methods since the standard deviation was less than one cm.

For a subjective assessment of accuracy of leveling, contour maps were plotted before and after leveling for both the fields using the SURFER 8.0 package. The latest version of the SURFER package facilitates creation of three-dimensional contour maps, which will be more useful for interpreting results. The contour maps for before and after leveling the field using laser leveler are shown in **Figs. 7** and **8**. The contour maps for before and after leveling the field using the conventional method are shown in **Figs. 9** and **10**.

All contour maps are presented with a contour interval of 2 cm. These maps have been developed with respect to a level plane. From **Figs. 7** and **8**, it was observed that accurate grading was possible using the laser guided land leveler as seen from parallel lines or evenness in the contour map. The grading was not so accurate at end of field since there was difficulty in effectively reaching the corners of the field due to larger turning radius. From the **Figs. 9** and **10**, it was observed that grading of the field without laser components was less accurate as compared to the laser system. From the contour maps it was also clear that similar trend of unevenness in grading was obtained in the field corners as observed in the case of laser leveled portion of the fields. However, the undulations on the filed are relatively more in conventional method. This further confirmed the results obtained from standard deviation of the surveyed readings.

The cost of operation of tractor and leveler combination was calculated both for laser guided land leveler and conventional leveler. The cost of operation of the laser guided land leveler was Rs. 474/h as compared to Rs. 309/h for the conventional leveler. The cost of operation was 53 % costlier for the laser guided land leveler as compared to the conventional leveler. The field capacity of the laser leveler was observed as 0.08 ha/h, whereas, without using the laser system, the field capacity of the leveler was 0.098 ha/h.

The fuel consumption of the tractor was 3.5 l/h for operation of the laser guided land leveler. When the laser system was not used the value was similar. From the above results it may be observed that the field capacity was slightly higher when the laser system was not used. This was due to the fact that there was continuous movement of the tractor and the operator adjusts the depth of cut as per his judgment. However, when the laser was system is used, the tractor had to stop when the scraper bucket was full and shifted to manual control. The cost of leveling was considerably higher when the laser guided land leveler was used. The cost of leveling per hectare using the laser leveler was 5,932.50 Rs/ha and 3,151 Rs/ha for conventional levelling. The cost of operation in terms of per unit area was considerably higher when the laser systems of the leveler were in operation in contrast to grading without use of laser systems. This was due to high initial cost of the laser guided land leveler.

**Fig. 7** The contour map for before leveling the field-using laser leveler

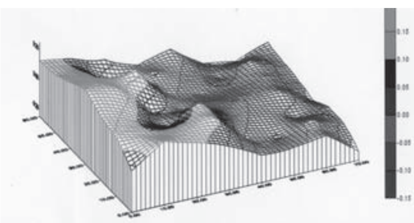


**Fig. 8** The contour map for after leveling the field-using laser leveler

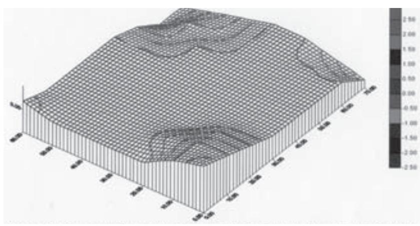


**Fig. 9** The contour map for before leveling the field-using conventional leveler

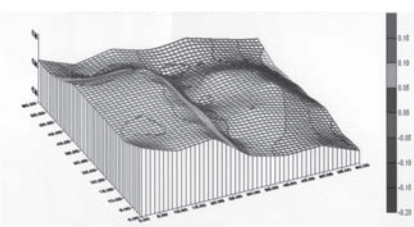
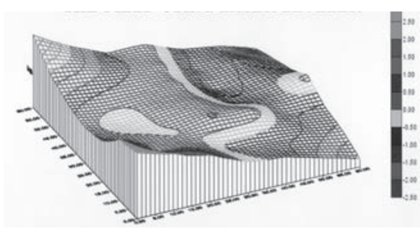


**Fig. 10** The contour map for after leveling the field-using conventional leveler



## Conclusions

- It was observed from contour charts and from values of standard deviation of reduced levels that considerably higher accuracy of grading were observed when the fields were graded by use of laser guided land leveler in comparison to using the leveler without laser systems.
- The field capacity of the laser leveler was observed as 0.08 ha/h whereas, without using the laser system, the field capacity of the leveler was 0.098 ha/h.
- The fuel consumption of the tractor was 3.5 l/h for operation of both laser guided land leveler and conventional levelling.
- The cost of grading was con-

siderably higher when the laser guided land leveler was used to grading in comparison to using the leveler without laser systems. The cost of operation of the laser guided land leveler was Rs. 474/h as compared to Rs 309/h for the conventional leveler. The cost of operation was 53 % costlier in case of laser guided land leveler as compared to the conventional leveler.

- The cost of leveling per hectare using laser leveler is 5932.50 Rs/ha whereas it was 3151 Rs/ha for conventional levelling.

## REFERENCES


Cook, R. L. and F. W. Peikert. 1960. A comparison of tillage implement. The Journal of American Society of Agricultural Engineers, Vol.31: 211-214.

Chaudhuri D., S. K. Mathankar, V. V. Singh, and N. A. Shirsat. 2005. Performance evaluation of Laser guided land leveler for land grading in vertisols of central india. Paper presented in the 39th annual convention of ISAE held at Acharaya N. G. Ranga Agricultural University, Hyderabad during, 9-11, March, 2005.

El-Guindy, A. A. M, Hasan El., G. Sayd, and El-Banna Osman. 1996. Effect of precision land leveling systems on wheat and maize production. Paper presented at 2nd International Conference on laser and Applications, 16-19 September, Cairo, Egypt

Mathankar, S. K., D. Chaudhuri, V. V. Singh, and N. A. Shirsat. 2005. Laser guided land leveling for rice crop production. Paper presented in the 39th annual convention of ISAE held at Acharaya N.G. Ranga Agricultural University, Hyderabad during, 9-11, March, 2005.

Rickman, J. F. 2002. "Manual for laser land leveling". Rice-Wheat Consortium Technical Bulletin Series 5. New Delhi-110 012, India: Rice ?Wheat Consortium for the Indo-Gangetic Plains, 24p.

Tarun Kumar and Maheshwari. 2005. Land preparation by Laser technology. Paper presented in the 39th annual convention of ISAE held at Acharaya N.G. Ranga Agricultural University, Hyderabad during, 9-11, March, 2005.

Xiang, Lu., Nong Fu, Di Xu, and Li Yi. 2000. Effectiveness evaluation and combined application of land leveling techniques. Transactions of Chinese Society of Agricultural Engineering 16(2), 50-53


■■

---

*(Continued from page29)*

# The Effect of Two Type of Plows With Four Speeds on the Field Capacity and Bulk Density

## REFERENCES


AL-Khafaf, A. M., H. AL-Rawi. 1970. Views on Agricultural Mechanization Assort study in the development of Agricultural Mechanization in the republic of Iraq between 1869-1969. AL-Najjaf publishing company, Bagdad, Iraq.

Baver, L. D., W. H. Gardner, and W. R. Gardner. 1972. Soil physics, John Wily and sons, Inc., Fourth Edition, New York, U.S.A.

Bukhari, S. B., J. M. Baloch, and A. N. Mirani. 1989. Soil Manipulation with Tillage Implements. Agricultural Mechanization in Asia. Winter, Vol. 20(1): 17-19.

Gill, W. R. 1959. Soil Compaction by traffic. Agricultural Engineering. July: 392-394.

Steel, R. G. D and J. H. Torric. 1960. Principles and procedures of Statistics McGrow-Hill Book Co., Inc. U.S.A.


■■

# Development and Testing of Engine Operated Pneumatic Cotton Picker

by
A. Tajuddin
Professor (Farm Machinery)
Agricultural Engineering College and Research Institute,
Tamil Nadu Agricultural University,
Kumulur - 621 712
INDIA

## Abstract

A pneumatic cotton picker operated by 3.3 kW, 3000 rev/min petrol start kerosene run engine coupled with a centrifugal blower was developed and tested. The pneumatic cotton picker developed an air suction force of 334 g. The machine could pick cotton at the rate of 3 kg/h. The machine-picked cotton required additional cleaning for removing the trash content. The break-even capacity of the machine was determined to be 7.2 kg/h.

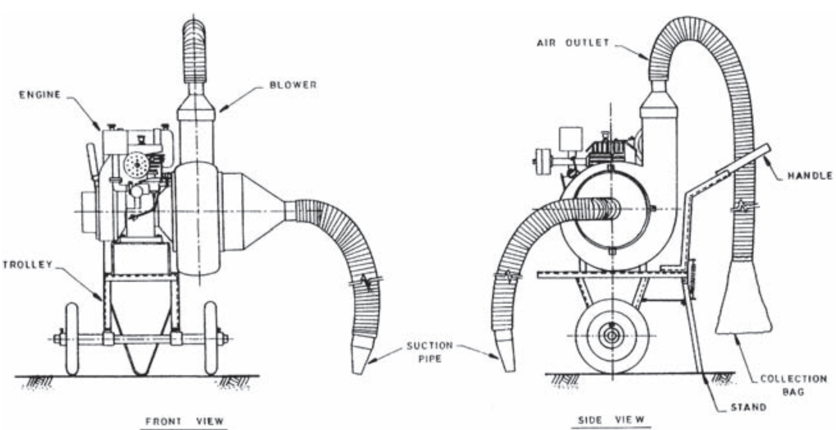
## Introduction

Cotton is one of the important fibre crops grown in India and the share of cotton is about 70 percent in the Indian textile industry (Anon., 1997). The cotton crop is cultivated in 8.87 million hectare with a production of 2.45 million tonnes at an average yield of 295 kg/ha in India (Swaminathan, 1999). India ranks third in cotton production in the world. In India, cotton is hand picked by human labourers, which is laborious and tedious work. Hand picking is ten and two times costlier as compared to irrigation and weeding operations, respectively. One adult person can pick only up to 70 kg of cotton per day as compared to 2180 kg/day capacity of a single row spindle type cotton picker (Prasad and Majumdar, 1999).

Manual picking of cotton is labour intensive, requiring 1560 man-hours per hectare (Sandhar, 1999). In recent years, labour shortage appears during peak periods of cotton harvesting. The use of a mechanical cotton picking machine will be useful in minimising the drudgery involved in hand picking. The mechanical cotton picking system will also be helpful in achieving timeliness of operation for the next crop. Attempts have been made to pick cotton using a vacuum created by knapsack engine operated blowers. However, a field machine is yet to be developed. Cotton harvesting being a selective, frequent and timely operation needs to be mechanised.

A test rig was developed to assess airflow rate required to effect pneumatic picking of cotton. The picking force was determined for the bolls of ten cotton varieties. The 70E variety had the highest average picking force of 307.4 g and the 'Savitha' variety had the lowest (251.9 g). The picking force increased in direct proportion with the boll volume. The regression analysis revealed that the volume of boll has good lin-

**Fig. 1** Engine operated pneumatic cotton picker




**Acknowledgement:** The financial assistance provided by the Indian Council of Agricultural Research, New Delhi through the All India Coordinated Research Project on Farm Implements and Machinery to Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore is gratefully acknowledged.

ear relationship with picking force (Rangasamy et al., 2001).

A test rig was developed for measuring the cotton picking force. The five cotton varieties were CNH-36, Anjali, LRA-5166, AKA-8401 and AKH-4. The Anjali variety required the maximum picking force of 3.456 N. The average kapas weight of cotton varieties ranged from 2.31 g to 3.56 g and the average bract weight varied from 0.78 g to 1.33 g. Picking force varied with the variety of cotton and increased with increase in kapas weight (Murugesan and Manojkumar, 1999). In view of the above, an engine operated pneumatic cotton picker was developed and tested.

## Materials and Methods

Cotton is sucked by vacuum created by a centrifugal air blower driven by a 3.3 kW, 3000 rev/min petrol start kerosene run engine. A plastic hose is connected to the air inlet opening of the blower. A netted bag is tied to the outlet pipe. The engine-blower assembly is mounted on a two-wheeled trolley (**Fig. 1**). The picked cotton passes through the blower and collected in the netted bag at the blower outlet (Anon., 2002).

Velocity of air at the inlet end of the suction hose was measured by a hand held digital air anemometer. Air suction force (F) at the inlet end of the suction hose was determined by the following formula.

$F, kg = A v^2 \upsilon / g$

where,

A = area of cross section of air flow, $m^2$

v = air velocity, m/s

and,

$\upsilon$ = weight density of air at NTP (normal temperature and pressure - 0 ºC and 760 mm of mercury)

Weight density of air at room temperature of 27 ºC and 760 mm of mercury atmospheric pressure = 1.175 kgf/$m^3$ (from tables)

Weight density of air at 0 ºC and 760 mm of mercury =1.293 kgf/$m^3$ (using PV/T formula)

**Fig. 2** Engine operated pneumatic cotton picker in field operation

The engine operated pneumatic cotton picker was tested in the field. The machine was operated for one hour duration and the weight of seed cotton collected in the netted bag was determined. Three such readings were taken and the average cotton picking rate of the machine was found. The cost of picking cotton by the machine in comparison with manual picking was determined.

## Results and Discussion

Air suction force at the inlet end of the engine operated pneumatic cotton picker was determined to be 334 g which was more than determined by Rangasamy et al. (2001) and Murugesan and Manojkumar (1999). The pneumatic cotton picker could pick cotton at the rate of 3 kg/h (**Fig. 2**) whereas the rate of cotton picking by manual (women) labourers was 2 kg/labourer/h. The breakeven capacity of the machine was determined as 7.2 kg/h with 5 ha/yr break even point. The machine picked cotton contained 5.60 to 6.65 percent trash after ginning.

For the effective use of pneumatic the cotton picker, the following suggestions are made.

1. Number of cotton pickings should be minimized.
2. The cotton variety is to be evolved such that entire bolls burst at the same time preferably at the same height.
3. Defoliation may be done prior to picking by spraying ethrel at 3000 ppm or 20 percent potassium chloride solution.
4. To reduce the cost of cotton picking by the machine, the machine capacity needs to be increased by providing multiple picking heads.

## REFERENCES

Anonymous. 1997 Vision-2020. Central Institute for Research in Cotton Technology Perspective Plan, Indian Council of Agricultural Research, p 29.

Anonymous. 2002. Progress Report of Indian Council of Agricultural Research, All India Coordinated Research Project on Farm Implements and Machinery, Coimbatore Centre, Tamil Nadu Agricultural University, p 55.

Murugesan, R. and T. S. Manojkumar. 1999. Picking force measurement of some cotton varieties. Agricultural Engineering Today, 23(5-6): 56.

Prasad, J. and G. Majumadar. 1999. Present practices and future needs for mechanization of cotton picking in India. Agricultural Engineering Today, 23:1.

Rangasamy, K., C. Divaker Durairaj, and M. Muthamilselvan. 2001. Determination of picking force of some major varieties of cotton. Madras Agricultural Journal, 88(7-9): 414.

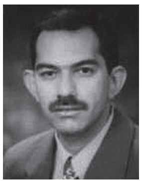
Sandhar, N. S. 1999. Present practices and future needs of mechanization of cotton picking/harvesting in India. Paper presented in Indo-Uzbek Workshop on Agricultural Research held at the Central Institute of Agricultural Engineering, Bhopal during November 15-16.

Swaminathan, M. S. 1999. Cotton and Rural Livelihoods. Indian Society for Cotton Improvement, Silver Jublilee Lecture Series, Mumbai, p 2.

■■

# The Effect of Two Type of Plows With Four Speeds on the Field Capacity and Bulk Density

by



Ali Mazin Abdul-Munaim
Assitant Instructor
Agric. Mechanization Dept.,
College of Agriculture,
University of Baghdad, Baghdad
IRAQ

Maysm Thamer Al-Hadidy
AAssitant Instructor
Civil Engineering Dept.,
College of Engineering,
University of Baghdad, Baghdad
IRAQ

## Abstract

A study was performed with the two essential types of plows most frequently used in Iraq, with four forward speeds.

The main aim of the study was to observe the effect of plow types and operational speed on field capacity and bulk density. The best type of plow and speed were identified along with interactions. The study used a split-plot, completely randomized block design in three replications.

The results showed that influence of speed was significant with field capacity and bulk density but the influence of type of plow had no significant influence on the field capacity or bulk density. The interaction between the type of plow and speed had no significant influence on the field capacity and bulk density. The highest field capacity was 0.592 ha/h at the fourth speed with the disc plow. The lowest bulk density was 1.21 g/cm$^3$ at the first speed with the moldboard plow.

**Table 1** The soil bulk density (g/cm$^3$) before the start of experiment

| Replicates | Depth (0-18 cm) |
|---|---|
| 1 | 1.44 |
| 2 | 1.47 |
| 3 | 1.45 |
| 4 | 1.47 |
| 5 | 1.46 |
| Average | 1.46 |

## Introduction

Archeological excavation in Mesopotamia has indicated that this land was the fountain of civilization and agriculture. These excavations also indicate that the tools used at that time were highly advanced.

Many examples can be found that show the skills of Sumerians in solving the most complicated agricultural problems, such as the Sumerian plows which could perform double functions; tillage and seeding at the same time.

The moldboard plow is considered one of the earliest modern agricultural plows in Iraq and is used in most middle Iraqi governorates. The disc plow is used in northern and southern governorates where it was introduced in Iraq after the moldboard plow.

Due to these considerations, the experiment was performed with two essential factors:

1. Type of plow - the two most frequently used types of plows in Iraq were used.
2. Forward speed - four speeds.

The primary aim of the study was to observe the effect of plow types and operational speed on the field capacity and bulk density. This study helped to know the best operational speed and the best type of plow and whether there was interaction between these two factors.

## Materials and Methods

An area of land for the experiment was 150 m long and 60 m wide (total area 0.9 ha). The land was plane and was not cultivated in the last season.

The field was bordered by ribbon and wedge. Samples were taken from five randomized locations in the field to depths of 5, 10, 15, 20, 25 cm in order to determine soil texture by the hydrometer method. The analysis of the soil samples showed that the texture of the soil was silty clay loam.

Soil samples were taken in another five randomized locations in the field to a depth of 18 cm in order to determine the soil bulk density. The results of soil bulk density analysis (**Table 1**) were available before the start of the experiment.

The study was carried out in a split plot design. The two types of plows (factor A), were assigned at random to the whole plots within each block. The four speeds of operation (factor B), were assigned at random to the subplots within each whole plot.

The whole-plot design was a randomized complete block with three blocks.

The two types of plows:

1. Iraqi moldboard plow (112) was manufactured by the state enterprise for mechanical industries. The plow had three bottoms with a nominal working width of 105 cm. The overall dimensions were 208 cm long, 120 cm wide and 113 cm high with a mass of 300 kg.
2. Iraqi disc plow (131) was manufactured by the state enterprise for mechanical industries. The plow had three bottoms with a nominal working width of 90 cm. The overall dimensions were 225 cm long, 115 cm wide and 135 cm high with a mass of 465 kg.

The tractor used was a CIRTA-C6806, two wheel drive with 50 kW power. The two types of plows used the same tillage depth (18 cm) and the soil moisture was fixed on 18 % during the study.

Speed of operation:

Four tractor gear speeds were used for evaluating the performance of tillage implements. The speed was determined by operating the implements between the staked distances of 30.5 m. The time required to cover this distance was obtained by the use of a stop watch and speed was calculated in km/h. The width of cut was measured in meters.

**Field Capacity**

Field capacity was calculated by the below equation:

C = SWE/10 = 0.0825 SW

where

C= field capacity, ha/h.

S= speed of operation, km/h.

W= width of plow, m.

E= field of efficiency of plows, decimal.

The time lost during the operation of implements as assumed to be 17.5 %.

**Bulk Density**

Bulk density is the ratio of soil mass to volume. It is usually expressed in terms of grams per cubic centimeter (g/cm³). The core technique was used to find the bulk density. Compaction of the soil into a smaller volume may be measured in terms of an increase in bulk density. Along with this bulk density increase, is an increase in the mechanical strength of the soil mass. This strength must be overcome by tillage implements.

## Results and Discussion

**Table 2** shows the mean of obtained results.

The results of statistical analysis are show in **Table 3**.

**Table 3** shows the influence of type of plow and the speed on field capacity. The influence of speed is significant with field capacity. When the speed increased, it caused an increase in field capacity. The importance of speed as one of the essential factors is shown in the field capacity equation. So, when speed increases, field capacity increases.

**Table 3** also shows that the type of plow had no significant influence on the field capacity or the interaction between the type of plow and speed. Also, the influence of the speed was significant on the bulk density of the soil. Therefore, as the speed increased the bulk density increased. There was no significance in the type of plow on the bulk density as well as the interaction between the two factors ( type of plow and speed).

## Conclusion

1. When applying the moldboard plow, the highest field capacity was 0.545 ha/h at the fourth speed. The lowest bulk density is 1.21 g/cm3 when the first speed was used.
2. When applying the disc plow, the highest field capacity was 0.592 ha/h when using the fourth speed. The lowest bulk density was 1.26 g/cm³ when the lowest speed was used.

*(continued on page36)*

**Table 3** Economics of solar-cum-gas fired dates drying system

| Implements | Speed, km/h | Width of cut, m | Field capacity, ha/h | Soil bulk density, g/cm³ |
|---|---|---|---|---|
| Mouldboard plow | 3,08 | 1.008 | 0.274 | 1.21 |
| | 3.68 | 1.017 | 0.308 | 1.34 |
| | 5.47 | 0.975 | 0.439 | 1.39 |
| | 6.94 | 0.955 | 0.545 | 1.46 |
| Disc plow | 3.15 | 1.007 | 0.261 | 1.26 |
| | 3.28 | 1.002 | 0.270 | 1.33 |
| | 5.91 | 0.989 | 0.480 | 1.40 |
| | 7.30 | 0.985 | 0.592 | 1.49 |

**Table 3** Statistical analysis of the field capacity and bulk density

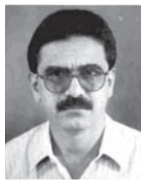
| S.O.V | d.f. | F cal | | F table | |
|---|---|---|---|---|---|
| | | Field capacity, ha/h | Bulk density, g/cm³ | 5 % | 1 % |
| Block | 2 | | | | |
| A | 1 | 1.675$^{n.s}$ | 6.857$^{n.s}$ | 18.51 | 98.50 |
| Error (a) | 2 | | | | |
| B | 3 | 139.033$^{**}$ | 10.148$^{**}$ | 3.49 | 5.95 |
| AB | 3 | 2.842$^{n.s}$ | 0.165$^{n.s}$ | 3.49 | 5.95 |
| Error (b) | 12 | | | | |
| Total | 23 | | | | |

A: Type of plow, B: Different speeds

# Development and Evaluation of Direct Paddy Seeder for Assessing the Suitability to Rural Women


by

D. Sirisha
Research Scholar
Dept. of Farm Power and Machinery,
Agricultural Engineering College
and Research Institute,
Tamil Nadu Agricultural University,
Coimbatore - 641003, INDIA
suthaameag@yahoo.co.in



K. Kathirvel
Professor and head
Dept. of Farm Power and Machinery,
Agricultural Engineering College
and Research Institute,
Tamil Nadu Agricultural University,
Coimbatore - 641003, INDIA

R. Manian
Dean
Agricultural Engineering College
and Research Institute,
Tamil Nadu Agricultural University,
Coimbatore - 641003, INDIA



## Abstract

Transplanting operation is performed by women in upright bending posture. A women has to dip her hand 6,000 to 7,000 times for transplanting paddy in standing water. This posture, when continued for years together results in Low Back Pain (LBP) and spinal disorders. This arduous operation can be made more comfortable by the use of direct paddy seeders. But a woman operated direct paddy seeder is non-existent. Hence three types of paddy seeders namely two row, three row and four row paddy seeders to reduce the drudgery of women and three types of material namely plastic galvanized iron (GI) and fiber reinforced plastic (FRP) for reducing the weight of the unit were selected for ergonomical evaluation. Ten female subjects were selected for the investigation based on the age. The parameters used for the ergonomical evaluation of the direct paddy seeders include heart rate and oxygen consumption rate, energy cost of operation, acceptable work load, work pulse, overall discomfort rating, body part discomfort score and force required for the operation of direct paddy seeder. A swinging type handle was developed for pulling the seeder to avoid the awkward posture of farm women.

The mean values of heart rate of the ten subjects for four row, three row and two row paddy seeders with plastic, GI and FRP materials varied between 124.43 and 152.50 beats $min^{-1}$ and the corresponding oxygen consumption values varied between 0.535 and 0.698 l $min^{-1}$. The field capacity for the four row, three row and two row paddy seeders with plastic, GI and FRP materials varied from 0.025 to 0.0625 ha $hr^{1}$. Based on the ergonomical evaluation and field capacity, the four row paddy seeders of three materials were chosen for performance evaluation and the four-row paddy seeder with plastic material was adjudged as the best seeder for rural women folk.


## Introduction

Transplanting of rice seedlings being labour-intensive and costly method could be substituted by direct seeding, which could reduce labour needs by more than 20 percent in terms of working hours. Direct seeded rice is an age-old practice of paddy cultivation in India, particularly in rain fed areas, where farmers totally eliminate the seedling preparation in nursery and transplanting. Drum seeder is becoming popular for wet seeding because of its less initial investment, easy operation, low repair and maintenance cost.

Transplanting operation is performed by women in upright bending posture. A woman has to dip her hand 6000 to 7000 times for transplanting paddy in standing water (Vatsala, 2002). This posture, when continued for years together results in Low Back Pain and spinal disorders. This arduous operation can be made more comfortable by direct paddy seeders. But a woman operated direct paddy seeder is non-existent. There are 200 million agricultural workers of which more than 35 percent are female workers.

These workers are exposed to all kinds of machine and environmental hazards. Therefore efforts should be made to blend the traditional technologies to suit the needs of the farm women and to increase the efficiency and work output at the same time to reduce the drudgery involved in performing the agricultural activities.

## Review of Literature

Borah et al. (2001) found that the average heart rate values of women for uprooting of seedlings were 126.6 beats min$^{-1}$ and 116 beats min$^{-1}$ for 25-35 years and 35-45 years respectively. Corresponding energy expenditure values vary between 9.85 to 11.41 kJ min$^{-1}$ for both the groups. Chauhan et al. (2004) determined the acceptable limits of physiological workload of Indian women based on the relationship between energy expenditure and relative load. Sivakumar (2002) reported that the force required pulling the four row Galvanized Iron (GI) drum seeder varied from 88.7 N to 116.1 N without furrow opener. Mrunalini (2001) reported the body part discomfort score of women in paddy cultivation and harvesting. Severe pain was reported by 100 percent of subjects at the lower back region followed by 95 percent in the shoulders, 50 percent at the neck during transplantation. Severe pain was also reported by about 45 percent in the calf muscles and ankles due to transplantation work. The subjects also reported similar responses for paddy harvesting. Susheela et al. (2001) evaluated the occupational workload of female agricultural workers in performance of selected agricultural activities like picking of stalks and stubbles, sowing, transplanting, interculturing, weeding and harvesting of wheat and jowar crop. They found that the mean heart rates were 101.0 ± 7.0, 118.6 ± 15.1, 131.0 ± 7.0, 109.1 ± 7.1, 126.0 ± 7.0 and 123.0 ± 5.0 beats min$^{-1}$ respectively for the selected agricultural activities. The physiological workload of interculturing, harvesting of wheat and jowar were classified as heavy. Vidhu (2001) conducted ergonomic evaluation of selected rice farming equipment and reported that the maximum aerobic capacity of selected three subjects varied from 1.69 to 1.92 l min$^{-1}$.

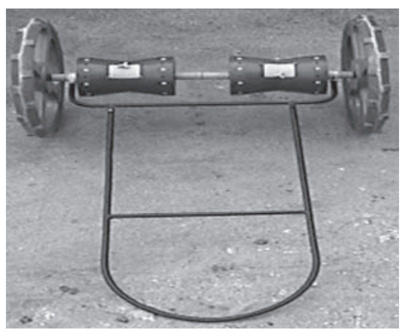
## Methods and Materials

Walking in the puddled field itself required 83 to 90 percent oxygen uptake for female workers and the physiological demands on human subject were very heavy. As the seeding operation needs to be done in a puddled field, the workers have to immerse their feet in mud (mid calf to knee cap) during their activities. In all the existing models of manually operated paddy seeders, the dry/wet seeds are drilled continuously at a higher seed rate than the recommended and without desired seed to seed spacing. An improved direct paddy seeder, which provides uniform seed distribution with respect to time, was developed. The existing manually operated improved direct seeder has 8 rows. To make the improved direct paddy seeder operational with the farm women the major factors viz. Weight of the unit, Force required to pull the unit in the puddled field and Harness to facilitate easy pulling and operation of the unit were considered.

The problem observed with the existing seeders is the awkward posture adopted by the operator, which adds to the fatigue component of the operator. An effective harness of ergonomic design will reduce the drudgery of the operator by eliminating the above-mentioned problems. Keeping in view the above mentioned functions three types of handles were developed viz. T-type handle, Shoulder strap type handle, Hip mounted handle. Based on the Overall discomfort Score (ODR), Body Part Discomfort Score (BPDS) and subjects feed back a swinging type handle was developed with the unit for pulling the seeder to avoid the awkward posture of farm women. For reducing the weight of the unit, material substitution was adopted. Hence three types of paddy seeders namely two row, three row and four row paddy seeders to reduce the drudgery of women and three types of material namely plastic galvanized iron (GI) and fiber reinforced plastic (FRP) for reducing the weight of the unit were selected for ergonomical evaluation. The four row paddy seeder with plastic material is shown in the **Fig. 1** and the operational view of four row paddy seeders with three materials is shown in the **Fig. 2**.

Ten women subjects were selected based on the age and screened for normal health for the investigation. The age of the selected subjects varied from 28 ± 2.49 to 35 ± 2.49 years as the maximum percentage of work could be expected from 25-35 years. To evaluate the physiological workload using heart rate, the relationship between heart rate and oxygen uptake must be determined for each subject. Both variables were measured in the laboratory at a number of sub maximal loads. This process is called calibration of subjects. With linear relationship of the heart rate and the oxygen consumption, the heart rate dur-

**Fig. 1** Four row paddy seeder (plastic material)



ing the field trials can be predicted from the calibration charts (Bridger, 1995). The heart rate was measured using Polar Vantage NV computerized heart rate monitor. This can be used in the field directly where the telemetry system cannot be used. This polar pacer has the following four basic components: chest belt transmitter, elastic strap, receiver unit, and interface. The oxygen consumption of the subjects while running on the treadmill was measured using Metamax-II. The Metamax II plus is a portable metabolic stress test system, which can be used as a mobile unit to measure pulmonary gas exchange under real conditions (e.g. off-site, at the work-site, in the field) or as a stationary system in the stress lab.

**Ergonomical Evaluation**

The ergonomic evaluation was carried out in puddled field of wetland of the Department of Agronomy, TNAU. The soil texture was 39.43, 9.2 and 51.37 percent clay, silt and sand respectively. For the ergonomic evaluation of the 2, 3 and 4 row paddy seeders, the field was disc ploughed and then it was flooded with water. The trials were conducted between 8.00 AM and 5.00 PM from the month of June to September 2004. The mean dry bulb temperature, wet bulb temperature and relative humidity were measured. The subjects were given information about the experimental requirements so as to enlist their full cooperation. They were asked to report at the work site at 7.30 AM in post-absorptive stage and have a rest for 30 minutes before starting the trial. The seeder was filled with CO 43 variety of paddy to be sown to its half of the capacity. The subject was allowed to operate the seeder in the field at a speed of 0.70 km $h^{-1}$ (Anon, 2000).

Each trial started with taking five minutes data for physiological responses of the subjects while resting on a stool under shade. The direct paddy seeder when filled to its half volume at start will be completely emptied within an average time of 20 minutes. But in actual practice, the drums are filled before it is fully emptied. So a trial time of 20 minutes was taken for the physiological measurement in 2, 3 and 4 row paddy seeders (with plastic, FRP and GI material each) operation.

**Parameters Used for the Egonomical Evaluation**

The values of heart rate at resting level and $6^{th}$ to $15^{th}$ minute of operation were taken for calculating the physiological responses of the subjects (Tiwari and Gite, 1998). From the values of heart rate (HR) observed during the trials, the corresponding values of oxygen consumption rate ($VO_2$) of the subjects for all the paddy seeders were predicted from the calibration chart of the subjects. The energy cost of operation of the implement was computed by multiplying the oxygen consumed by the subject during the trial period with the calorific value of oxygen as 20.88 kJ $l^{-1}$ (Nag et al., 1980) for all the subjects. The acceptable workload (AWL) for Indian workers was the work consuming 35 percent of $VO_2$ max (Saha et al., 1979). To ascertain whether the operation of all the paddy seeders is within the acceptable workload (AWL), the $VO_2$ maximum for each treatment was computed and recorded. To have a meaningful comparison of physiological response Δ values (Increase over resting values) for heart rate (work pulse) was calculated (Tiwari and Gite, 1998). For this, the average values of the heart rate at rest level and at working condition were used. For the assessment of overall discomfort rating a 10 - point psychophysical rating scale (0 - no discomfort, 10 - extreme discomfort) was used and a body map technique was used to asses the Body Part Discomfort Score which were an adoption of Corlett and Bishop (1976) technique. The effort required in pulling the implement was found using the Novatech load cell.

Based on the ergonomical evaluation and field capacity, the four row paddy seeders of three materials were chosen for performance evaluation. The paddy seeders were evaluated for its performance in the field in terms of agronomical parameters viz. growth attributes of rice such as plant population per square meter, number of tillers per square meter on 50 DAS and 75 DAS, yield at-

**Fig. 2** Four row paddy seeder in operation

Plastic | Galvanized iron | FRP

tributes like productive tillers per square meter, number of grains per panicle, 1000 grain weight and grain and straw yields of rice.

## Results and Discussion

The mean values for age, status and weight of all the ten subjects were 31.7 years, 156.4 cm and 52.2 kg, respectively. The mean dry bulb temperature, wet bulb temperature and relative humidity varied between 21 to 34.2 ºC, 19.0 to 25.0 ºC and 25 to 71 percent respectively during the period of evaluation. The selected ten subjects were calibrated in the laboratory by indirect assessment of oxygen uptake. The relationship between the heart rate and oxygen consumption of the subjects was found to be linear for all the subjects. The maximum aerobic capacity of the selected ten subjects varied from 1.214 to 1.386 l $min^{-1}$. A swinging type handle was developed with the unit for pulling the seeder to avoid the awkward posture of farm women.

The mean values of heart rate of the ten subjects for four row paddy seeders with plastic, GI and FRP material were 139.03, 152.50 and 140.21 beats $min^{-1}$ and the corresponding oxygen consumption values were 0.640, 0.743 and 0.646 l $min^{-1}$. The mean values of heart rate of the ten subjects for three row paddy seeders with plastic, GI and FRP material were 131.76, 145.62 and 133.64 beats $min^{-1}$ and the corresponding oxygen consumption values were 0.585, 0.698 and 0.601 l $min^{-1}$. The mean values of heart rate of the ten subjects for two row paddy seeders with plastic, GI and FRP material was 124.43, 138.89 and 125.11 beats $min^{-1}$ and the corresponding oxygen consumption values were 0.539, 0.635 and 0.535 l $min^{-1}$. The energy expenditure for the operations of four row paddy seeder with plastic, GI and FRP was computed as 13.43, 15.52, 13.51 kJ $min^{-1}$ and the operation of these seeders were graded as Heavy, Extremely heavy and very heavy. The energy expenditure for the operations of three row paddy seeder with plastic, GI and FRP was computed as 12.22, 14.43 and 12.52 kJ $min^{-1}$ and the operation of these seeders were graded as Heavy, very heavy and heavy. The energy expenditure for the operations of two row paddy seeder with plastic, GI and FRP was computed as 11.06, 13.38 and 11.17 kJ $min^{-1}$ and the operation of these seeders were graded as moderately heavy, heavy and heavy.

The over all discomfort rate for the four row paddy seeder with plastic, GI and FRP was 7.07, 8.10 and 7.15 whereas for three row paddy seeders the rating was 6.72, 7.25 and 6.87. Similarly for two row paddy seeder the rating was 6.37, 6.8 and 6.41. The body part discomfort score for the four row paddy seeder with plastic, GI and FRP was 47.73, 56.57 and 44.55 whereas for three row paddy seeders the discomfort score was 40.25, 50.02 and 41.82. While for two row paddy seeder the discomfort score was 37.76, 43.84 and 39.29. The force requirement for the four row paddy seeder with plastic, GI and FRP was 110.34, 195.98 and 124.43 N. whereas for three row paddy seeders the force requirement was 101.36, 165.84 and 103.34 N. While for two row paddy seeder the force requirement was 91.50, 124.16 and 96.71 N. The field capacity for the four row paddy seeder with plastic, GI and FRP was 0.0625, 0.0426 and 0.055 ha $hr^{1}$. Whereas for three row paddy seeders the value was 0.045, 0.031 and 0.039 ha $hr^{1}$. While for two row paddy seeder the field capacity was 0.028, 0.020 and 0.025 ha $hr^{-1}$. The comparative parameters measured for the 4, 3 and 2 row paddy seeders with plastic, GI and FRP materials are presented in **Table 1**.

The walking in the puddled field consumes 85 percent of the energy expenditure. The farm women has to walk 25 km to cover the area of 1 ha with two row paddy seeder. Based on the ergonomical evaluation and subjects feed back, the four row paddy seeders with three different materials are selected for intensive field evaluation and the four-row paddy seeder with plastic material was adjudged as the women friendly direct paddy seeder with improved ergonomic design features.

**Table 1** Comparison of parameters for the 4, 3 and 2 row paddy seeders with plastic, GI and FRP materials

| Parameters | Four row paddy seeder | | | Three row paddy seeder | | | Two row paddy seeder | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plastic | GI | FRP | Plastic | GI | FRP | Plastic | GI | FRP |
| Mean heart rate, beat $min^{-1}$ | 139.03 | 152.50 | 140.21 | 131.76 | 145.62 | 133.64 | 124.43 | 138.89 | 125.11 |
| Oxygen consumption, l $min^{-1}$ | 0.640 | 0.743 | 0.646 | 0.585 | 0.698 | 0.601 | 0.529 | 0.635 | 0.535 |
| Energy expenditure, kJ $min^{-1}$ | 13.43 | 15.52 | 13.57 | 12.22 | 14.43 | 12.52 | 11.06 | 13.38 | 11.17 |
| Grading | Heavy | Extremely heavy | Very heavy | Heavy | Very heavy | Heavy | Moderately heavy | Heavy | Heavy |
| ODR | 7.07 | 8.10 | 7.15 | 6.72 | 7.25 | 6.87 | 6.37 | 6.8 | 6.41 |
| BPDS | 47.73 | 56.57 | 44.55 | 40.25 | 50.02 | 41.82 | 37.56 | 43.54 | 39.29 |
| Force requirement, N | 110.34 | 195.98 | 124.43 | 101.36 | 165.84 | 103.34 | 91.50 | 124.16 | 96.71 |
| Coverage, ha $hr^{1}$ | 0.0625 | 0.0426 | 0.055 | 0.045 | 0.031 | 0.039 | 0.028 | 0.020 | 0.025 |

## Conclusion

Three types of paddy seeders namely two row, three row and four row paddy seeders to reduce the drudgery of women and three types of material namely plastic galvanized iron (GI) and fiber reinforced plastic (FRP) for reducing the weight of the unit were selected for ergonomical evaluation. Ten female subjects were selected for the investigation based on the age. The age of the selected subjects varied from 28 ± 2.49 to 35 ± 2.49 years as the maximum percentage of work could be expected from 25-35 years. The selected ten subjects were calibrated in the laboratory by indirect assessment of oxygen uptake. The maximum aerobic capacity of the selected ten subjects varied from 1.214 to 1.386 l min$^{-1}$. A swinging type handle was developed for pulling the seeder to avoid the awkward posture of farm women. The mean values of heart rate of the ten subjects for four row, three row and two row paddy seeders with plastic, GI and FRP materials varied between 124.43 and 152.50 beats min$^{-1}$ and the corresponding oxygen consumption values varied between 0.535 and 0.698 l min$^{-1}$. The over all discomfort rate for the four row, three row and two row paddy seeders with plastic, GI and FRP varied from 6.37 to 8.10 .The force requirement for the four row, three row and two row paddy seeders with plastic, GI and FRP varied in between 91.50 and 195.98 N. The field capacity for the four row, three row and two row paddy seeders with plastic, GI and FRP materials varied from 0.025 to 0.0625 ha hr$^{-1}$. Based on the ergonomical evaluation and field capacity, the four row paddy seeders of three materials were chosen for performance evaluation and the four-row paddy seeder with plastic material was adjudged as the best seeder for rural women folk.

## REFERENCES

Bridger, R. S. 1995. Introduction to Ergonomics. McGraw-Hill, Inc, New York: 205-210.

Brundke, J. 1984. Langzeitmessungen der Pulsfrequenz und Moglichkeiten der Aussage uber die Arbeitsbeansprunchung. In Pulsfrequenz und Arbeitsunchungen, Schriftenreihe Arbeitswissenschaft und Praxis, Band 28. Berlin: Beuth- Vertrieb.

Mrunalini, A. 2001. Women in paddy transplatation and harvesting - Physical and Physiological stresses. Humanizing work and work environment, 129-133.

Nag, P. K. and S. K. Chatterjee. 1981. Physiological reactions of female workers in Indian agricultural works. Human Factors, 23: 607-614.

Sivakumar, S. S., R. Manian, and K.Kathirvel. 2002. Investigation on the performance evaluation of drum seeder as influenced by machine, ergonomic and crop parameters. Ph D Thesis. Department of Farm Machinery, Tamil Nadu Agricultural University, Coimbatore, India.

Susheela P. Sawkar, M. A. Varghese, P. N. Saha, and K. V. Ashalatha. 2001. Ergonomic assessment of occupational workload and rest allowances for female agricultural labourers in Dharwad, Karnataka. Humanizing work and work environment, 140-144.

Tewari, P. S. and L. P. Gite. 1998. Human energy expenditure during power tiller operation. Paper presented at XXXIII annual convention of ISAE held at CIAE, Bhopal, Sept.21-23.

Vidhu, K. P. 2001. An investigation on ergonomic evaluation of selected rice farming equipment. Unpublished M.E.(Ag.) Thesis, Department of Farm Machinery, Tamil Nadu Agricultural University, Coimbatore, India.

■■

# Development and Evaluation of Farm Level Turmeric Processing Equipment

by

U. S. Pal
Assistant Process Engineer
AICRP on Post Harvest Technology,
College of Agricultural Engineering
and Technology,
Orissa University of Agriculture and Technology,
Bhubaneswar - 751003, INDIA
us_pal@lycos.com

K. Khan
Research Engineer
AICRP on Post Harvest Technology,
College of Agricultural Engineering
and Technology,
Orissa University of Agriculture and Technology,
Bhubaneswar - 751003, INDIA

N. R. Sahoo
Assistant Food Microbiologist
AICRP on Post Harvest Technology,
College of Agricultural Engineering
and Technology,
Orissa University of Agriculture and Technology,
Bhubaneswar - 751003, INDIA

G. Sahoo
Assitant Biochemist
AICRP on Post Harvest Technology,
College of Agricultural Engineering
and Technology,
Orissa University of Agriculture and Technology,
Bhubaneswar - 751003, INDIA

## Abstract

The post harvest unit operations of turmeric, i.e. cleaning, curing, drying, polishing, grading are carried out manually by conventional methods which are slow, tedious and labour-intensive. Attempts have been made to develop different post harvest equipment for turmeric such as washer (capacity- 200 kg/h), curing unit (capacity- 100 kg/h), polisher (capacity- 100 kg/h) and grader (capacity- 200kg/h) to reduce drudgery, labour cost and maintain the quality of the final product. During field testing, it was observed that all the equipment were operating satisfactorily and could be used in the farm level.

## Introduction

Turmeric is one of the main cash crops of India. The whole turmeric is a unique, colourful and versatile plant product combining properties of a spice or flavouring with added features being a colourant, a cosmetic and a drug useful in a number of diseases. India is the largest producer and exporter of turmeric with an annual production of 654,000 tonnes during 2000-01 (Vikas, 2003).

The post harvest unit operations of turmeric are cleaning, curing, drying, polishing and grading. After harvesting, turmeric is washed to remove the adhering earth from the harvested rhizomes. Then rhizomes are boiled to reduce the time of drying, ensure an even distribution of colour in the rhizomes and give a better quality product by gelatinisation of the starch (Purseglove et al., 1981). The boiled turmeric is dried under sun on the drying floor. Thoroughly dried turmeric is polished to remove the outer dirty skin, roots and soil particles and transformed into relatively smooth, bright and yellow rhizomes. Turmeric is graded into bulbs and fingers in different fractions, based on their size.

Most of these farm operations are carried out manually by conventional methods which are slow, tedious and labour-intensive. There is a mechanization gap in the field

**Acknowledgement:** Authors are thankful to Indian Council of Agricultural Research for providing necessary financial support and Orissa University of Agriculture and Technology, for providing the infrastructure for the research work.

**Table 1** Physical properties of turmeric

| Physical property | Primary finger, raw | | Primary finger, dried | |
|---|---|---|---|---|
| | Range | Average value | Range | Average value |
| Length, cm | 8.94-9.55 | 9.25 | 5.15-7.50 | 6.3 |
| Diameter, cm | 1.47-1.69 | 1.58 | 1.0-1.4 | 1.2 |
| Bulk density, kg/m$^3$ | 678-710 | 694 | 470-496 | 483 |
| True density, kg/m$^3$ | 1,295-1,317 | 1,306 | 1,136-1,164 | 1,150 |
| Porosity, % | 46-47 | 46.5 | 57-58 | 57.5 |
| Angle of repose, º | 30-32 | 31 | 35-37 | 36 |

of farm level primary processing activities of turmeric after harvest. The adaptation of mechanized and improved technique can reduce drudgery, labour cost and maintain the quality of the final product. Attempts have been made to develop different post harvest equipments for turmeric such as washer, curing unit, polisher and grader to make the job easier and labour-saving.

The improved turmeric boiler developed at the Department of Agricultural Processing, TNAU, Coimbatore, India consists mainly of two rectangular shaped perforated containers placed inside an outer metallic container provided with lid. The capacity is 150 kg per batch with operating cost of Rs. 4/- per quintal and only two labourers for loading, unloading and fixing the container (Sreenarayanan and Viswanathan, 1989). A mechanical polisher for turmeric has been developed in the Agricultural University at Andhra Pradesh, India. It consist of 880 mm diameter mild steel drum with meshes wrapped one above the other which rests on ball bearings at the two ends on a rectangular stand. It is operated by a 2 hp electrical motor. The drum speed is maintained at 30-32 rpm. It can polish about 600-700 kg/h (Sukumaran and Satyanarayana, 1999). A reciprocating type grader has been developed by the Agricultural University at Andhra Pradesh, which has a capacity of 400 kg/h, with a grading efficiency of 95 %. It can grade into four grades, viz. bulbs, fingers (30 mm length and above), polishable nail (20 to 30 mm length) and un-polishable nail (less than 20 mm length) in a single pass (Varshney, 2004).

**Table 2** General information on hand and power operated turmeric washer

| Name of the equipment | Hand operated turmeric washer | Power operated turmeric washer |
|---|---|---|
| Function | Washing of turmeric | Washing of turmeric and ginger |
| Overall dimension | 90 × 50 × 82 cm | 82 × 82 × 67 cm |
| Weight | 24 kg | 56 kg |
| Cost | Rs. 2,000/- | Rs. 12,000/- |
| Power source and requirement | Manual | 1.0 hp single phase electric motor |
| Speed of operation | 120 rpm | 120 rpm |
| Rated capacity | 200 kg/h | 300 kg/h |

**Table 3** General information turmeric washer and grader

| Name of the equipment | Pedal operated turmeric washer | Tturmeric grader |
|---|---|---|
| Function | Polishing of turmeric | Washing of turmeric and ginger |
| Overall dimension | 115 × 70 × 125 cm | 150 × 102 × 170 cm |
| Weight | 55 kg | 86 kg |
| Cost | Rs. 4,000/- | Rs. 10,000/- |
| Power source and requirement | Manual | 1.0 hp single phase motor |
| Speed of operation | 45 rpm | 90 rpm |
| Rated capacity | 100 kg/h | 200 kg/h |

## Materials and Methods

**Determination of Physical Properties of Turmeric**

Physical properties of turmeric such as shape, size, bulk density, true density and angle of repose were determined which are required for design of different equipment for turmeric. The length and diameter of fingers were measured by vernier calipers. The bulk density was measured by weighing a known volume of turmeric and true density was measured by toluene displacement method. The angle of repose was measured by a tilting top drafting table. The dimension of turmeric was required for selecting proper sieve size required for design of turmeric grader, bulk density was required for design of drum volume of a polisher or storage structure for a given capacity and angle of repose for design of the hopper and discharge chute.

## Construction Features of the Equipment

**Hand Operated Turmeric Washer**

A hand operated washer was

**Fig. 1** Hand operated turmeric washer

**Fig. 2** Power operated turmeric/ginger washer

**Fig. 3** Turmeric curing unit

developed which consisted of a perforated drum (40 cm dia × 60 cm length) rested on the stand (**Fig. 1**). Below the drum, there was a water tank so that the bottom portion of the drum submerged inside the water in the tank. Turmeric was loaded in the perforated drum through the door provided on the drum surface. When the drum was rotated, the adhering earth on the rhizomes was washed away and collected in the water tank. After the operation, the drum was unlocked and the turmeric was then unloaded by opening the door. The capacity of the washer was 40 % of the volumetric capacity of the drum as less than half of the drum was submerged inside the water tank.

Dimensions of perforated drum: Diameter- 40 cm, Length- 60 cm
Water tank dimensions: 73 cm × 20 cm × 20 cm

**Power Operated Turmeric Washer**

A power operated turmeric washing machine was also developed and tested in the field. It was a vertical cylindrical container having rotating base (diameter 77 cm), as shown in **Fig. 2**, and having provision for water spray through a perforated pipe fitted at the inside surface of the container. The holding chamber height was 25 cm. It was operated by 1.0 hp motor at a speed of 240 rpm. Provision was made for loading the uncleaned turmeric at the top opening and discharging the washed product at the side opening of the cylindrical casing. Two projections were provided on a rotating base to impart mild mixing action of the rhizomes during operation. The water with mud was collected at the bottom through an extended pipe. The actual capacity was taken as 50 % of the inside volumetric space so as to facilitate turning of rhizomes during washing and to avoid load on the motor. The same machine could also be used for washing of ginger.

**Turmeric Curing Unit**

The improved low cost turmeric curing/boiling unit consisted of two aluminium cooking containers of different size with a covering lid. The outer container was 75 cm diameter and 50 cm deep, whereas the inner perforated container was of 65 cm diameter and 45 cm deep (**Fig. 3**). The inner container was placed inside the outer container over two stands and taken out by means of two 'S' shaped hooks, rope and poles. The capacity was 100 kg per batch. The outer container with water was placed over a fire. The inner container full of rhizomes was placed inside outer container and then the outer container was covered with a lid. After the curing operation the inside container was taken out. The capacity per batch of curing was generally taken as the volumetric capacity of the inside container.

**Pedal Operated Turmeric Polisher**

A hexagonal drum having six polishing plates of size 30 cm × 60 cm made of inner expanded wire mesh (2.5 cm × 2.5 cm) and outer oven wire mesh (0.5 cm × 0.5 cm size) rested on ball bearings at the two ends of the stand. The polishing drum was rotated by pedal through

**Table 4** Field performance data of hand and power operated turmeric washer

| | Hand operated turmeric washer | Power operated turmeric washer |
|---|---|---|
| Material processed | Raw turmeric | Raw turmeric |
| Amount processed | 200 kg | 400 kg |
| Operating time | 1 h | 80 min |
| Capacity | 200 kg/h | 300 kg/h |
| Power consumption | Manual | 0.3 kWh/q |
| Labour requirement | 1 man.h | 1 man.h |
| Breakdown of equipment | - | No |
| Cost of operation | Rs. 4.50/q | Rs. 6.50/q |
| Test result | 12 % loss in weight due to washing. Water consumption 150 l/h | 16 % weight loss was observed with some peel loss. Water consumption 150 l/h |
| Overall performance | Satisfactory | Satisfactory |
| Remark | Useful for on-farm washing job | This unit can be installed in the processing yard where electric power is available. This unit is also suitable for washing green ginger |

**Fig. 4** Turmeric polisher (pedal operated)

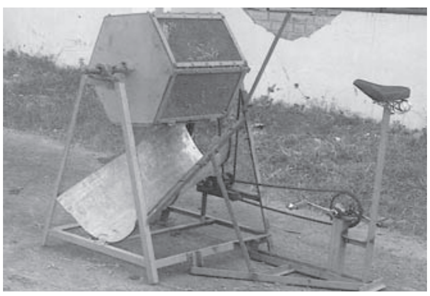


**Fig. 5** Hexagonal drum

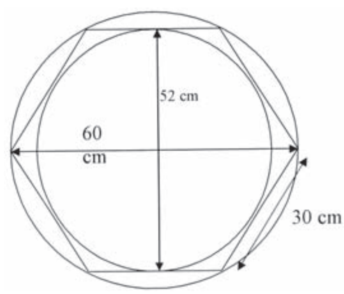



**Fig. 6** Turmeric grader

chain and sprocket arrangement (**Fig. 4**). There was a seating arrangement for operator comfort during pedaling the polisher. Spikes in the polishing plates and baffles on the shaft were provided for thorough mixing of turmeric and imparting additional rubbing action. For loading and unloading of turmeric, one polishing plate was used as the door on the drum surface. Due to rotation of the drum, turmeric was rubbed against the inside expanded wire mesh surface and polishing was achieved. The outer skin rubbed off by polishing fell through the perforation of the drum. The capacity of the polisher was generally 75 % of the drum volume to facilitate turning and mixing of dried rhizomes during polishing.

**Critical Speed of Polishing**

During rotation inside the drum, the speed above which centrifuging occurred was called the critical speed. The rpm of the polishing drum must be less than this critical speed otherwise proper polishing of the rhizomes will not take place.

From theoretical consideration:

$N_c = 30/\pi \ \mathrm{sqrt}\,[g/(R - r)]$

where,

$N_c$ = Critical speed, rpm

g = acceleration due to gravity, 9.81 m/s$^2$

R = Radius of the drum, m

(For hexagonal drum 'R' is taken as the average radius of circumscribing and inscribing circle as given in **Fig. 5**)

r = radius of turmeric, m

Since r <<<< R, hence r = 0

For proper stirring, critical speed is taken as 80 % of Nc

The critical speed is calculated to be 45 rpm.

**Turmeric Grader**

The grader consisted of frame, hopper, two sets of sieves, electric motor and rocking arrangement (**Fig. 6**). The frame (size 102 cm × 82 cm × 115 cm) of M.S. angle housed one upper sieve of 1.2 cm dia hole and one lower sieve of 1.0 cm dia hole 100 cm × 74 cm with individual discharge outlets. The inclination of both the sieves was 13° with the horizontal. The frame reciprocated on a stand by a rocking mechanism. The sieve assembly was connected eccentrically to a fly wheel (25 cm) which was powered by a 1 hp electric motor through a belt and pulley arrangement. On top of the frame, a feed hopper 102 cm × 40 cm with a sliding chute was provided for uniform loading of turmeric to the upper sieve.

**Table 5** Field performance data of turmeric polisher and grader

| | Pedal operated turmeric polisher | Turmeric grader |
|---|---|---|
| Material processed | Dried turmeric | Dried turmeric |
| Amount processed | 100 kg | 400 kg |
| Operating time | 60 min | 120 min |
| Capacity | 100 kg/h | 200 kg/h |
| Power consumption | Manual | 0.4 kWh/q |
| Labour requirement | 1 man.h | 1 man.h |
| Breakdown of equipment | Slipping of chain | No |
| Cost of operation | Rs. 12.70/q | Rs. 8.80/q |
| Test result | 6 % polishing achieved | Discharge at the three outlets were observed to be 68 % , 25 % and 7 % |
| Overall performance | Satisfactory | Satisfactory |
| Remark | Useful for on-farm polishing job | This unit was appreciated by the processors |

**Fig. 7** Field testing of turmeric washer

**Fig. 8** Graded fractions obtained from turmeric grader

## Results and Discussion

**Determination of Physical Properties of Turmeric**

The physical properties of both raw (81 % moisture content) and dried turmeric fingers (10 % moisture content) were determined and given in **Table 1**.

**Hand and Power Operated Turmeric Washer**

From field testing of the turmeric washer (**Fig. 7**), the capacity of the washer was 2 q/h with 20 kg per batch. The water consumption was 75 lit per 100 kg of washed turmeric. Performance of the machine was satisfactory. This machine can be used conveniently for washing of turmeric in those regions where electricity is not available.

From the field trial of the power-operated washer, the capacity was 40 kg/batch. It took 8 min for washing a batch of turmeric and 16 % of weight including peels was lost during washing. Capacity of the washer was 300 kg/h. The cost of operation of hand and power operated washer was Rs. 4.50 and Rs. 6.50 per quintal, respectively. The speed of the base was 120 rpm. The general information, field performance data and cost of operation of hand and power operated turmeric washer are given in **Tables 2** through **4**.

**Turmeric Curing Unit**

The improved curing unit required 50 min for curing a batch of 100 kg of rhizomes with 2 labourers. The improved method of curing took less time and the fuel consumption was also found to be less compared to the traditional method of curing due to the lid covering. The overall performance was found to be satisfactory and comfortable to the worker due to the provision of easy unloading system by means of a wooden handle. In the improved unit, the perforated inner container with turmeric was to be lifted leaving the hot water in the outer container which could be reused in the subsequent batches. Aluminum cooking containers of different sizes were easily available in the local market and needed no special fabrication. Only by purchasing two aluminium containers of different sizes and making perforations in the inner smaller container, these could be used for turmeric curing.

**Pedal Operated Turmeric Polisher**

It took 30 minutes to polish a batch of 50 kg turmeric in the polisher to achieve 6 % polishing (percentage loss of weight). The drum was rotated below the critical speed of 45 rpm to avoid centrifuging. The cost of polishing was Rs 12.70/- per quintal. The field-test data of the turmeric polisher are given in **Table 5**. The farmers expressed their satisfaction over performance of the polishing machine.

**Turmeric Grader**

The capacity of the grader was 200 kg/h. The turmeric was graded into 3 fractions. The output in the 3 discharge spouts was 68, 25 and 7 %, respectively (**Fig. 8**). The speed of vibrator was 90 rpm with stroke length of 20 cm for satisfactory operation. General information and field performance data of the turmeric grader are given in **Tables 3** and **5**. The cost of operation was Rs. 8.80 per quintal of turmeric.

## Conclusion

The post harvest unit operations of turmeric like cleaning, curing, drying, polishing and grading were carried out manually by conventional methods, which are slow, tedious and labour-intensive. Attempts were made to develop different post harvest processing equipment such as washer, curing unit, polisher and grader to reduce drudgery, labour cost and maintain the quality of the final product. All the equipment developed were simple, easy to operate and techno-economically feasible for farm level processing. Performance of all the equipment was found quite satisfactory and,therefore, can be used for carrying out tedious post harvest operations easily.

## REFERENCES


Sreenarayanan, V. V. and R. Viswanathan. 1989. An improved turmeric boiler. Spices India, 2(10): 15-16.

Sukumaran, C. R. and CH. V. K. Satyanarayana. 1999. Souvenir-cum-Proceedings of the national seminar on Food Processing: Challenges and Oppurtunities, Gujrat Agricultural University, Anand.

Vikas, S. 2003. Indian Agriculture, Indian Economic Data Research Centre, New Delhi.

Purseglove, J. M., E. G. Brown, C. L. Green, and Robbin, S. R. J. 1981 Spices, Vol. 2. Longman group Ltd., London, New York.

Varshney, A. K., S. N. Garala, and S. H. Akbari. 2004. Status of post harvest technology of turmeric. Agricultural Engineering Today, 28(1-2): 13-19.


■■

# Effect of Threshing Cylinders on Seed Damage and Viability of Moongbean (*Vigna radiate*. (L.) Wilezee)


by

Shiv Kumar Lohan

Dept. of Seed Science and Technology,
CCS Haryana Agricultural University,
Hisar - 125004
INDIA
shivkumarlohan@hau.ernet.in



## Abstract

An experiment was conducted to compare hammermill, spike tooth and raspbar threshing cylinders with respect to cylinder speed and concave clearance for damage free seeds, maximum threshing, high germination and less electrical conductivity of moongbean. The minimum seed damage (1.1 %) and maximum germination (89 %) was found with the use of a raspbar threshing cylinder which resulted in less threshing efficiency (91.5 %) under lower cylinder speed (400 rpm) and higher concave clearance (15 mm). With the spike tooth threshing cylinder, minimum seed damage (3.6 %), maximum germination (87 %) and minimum electrical conductivity (1.06 ms) was found under lower cylinder speed (400 rpm) and higher concave clearance (15 mm). In the hammermill cylinder, minimum seed damage (3.8 %), maximum germination (86 %) and minimum electrical conductivity (1.02 ms) was observed under lower cylinder speed (400 rpm) and higher concave clearance (15 mm).

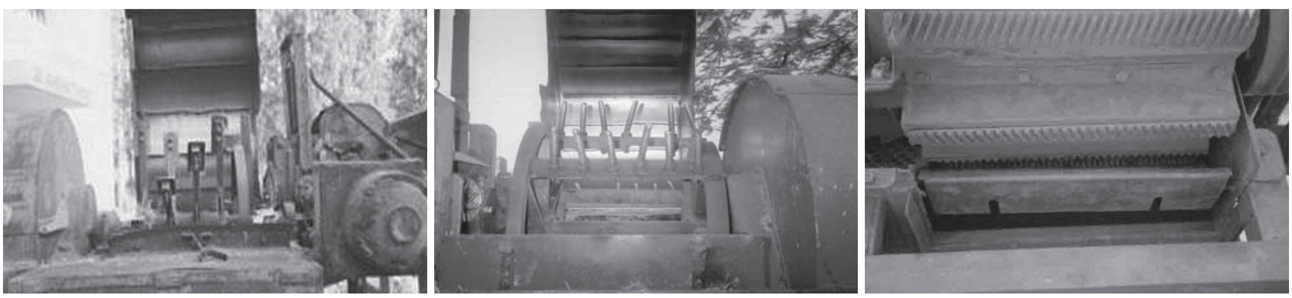

## Introduction

Threshing involves the detachment of seed from the panicles/pods. It is one of the most important post-harvest operations for most of the agricultural crops especially for oilseed and pulses. Basic principles employed in threshing are shear, rubbing, impact and their combination. The force applied by threshing cylinders usually results in splitting of dicot seeds, such as Chickpea (*Cicer aeritinum.* L), Moongbean (*Vigna radiate.* (L.) Wilezee) and Soybean (*Glycine max.* (L.) Menill) and the seed damage may go up to 20 to 25 percent, which is a big loss to the seed sector and the farmers (Kamble and Panwar, 1984). Threshing performance and damage of seeds is affected by several parameters, viz. type of threshing cylinder, moisture content of crop, cylinder speed, feed rate, concave

**Table 1** Optimum combination of threshing cylinder, cylinder speed and concave clearance for minimum seed damage and maximum percent germination

| Threshing cylinder | Cylinder speed, rpm | Concave clearance, mm | Seed damage, % | Threshing effiiciency, % | Germin -ation, % | Electrical conducti-vity, $ms^{-1}$ |
|---|---|---|---|---|---|---|
| Hammer mill | 400 | 15 | 3.8 | 94.7 | 86 | 1.02 |
| Spike tooth | 400 | 15 | 3.6 | 93.8 | 87 | 1.06 |
| Raspbar | 400 | 15 | 1.1 | 91.5 | 89 | 1.07 |

**Plate 1** Threshing cylinder



Hammer mill Spike tooth Raspbar

clearance, blower speed, aspirator speed and laborer's skill. Therefore, evaluation was done to quantify the effect of influence of the most important factors, viz. threshing cylinders, cylinder speed and concave clearance on seed damage and viability of moongbean seeds.

## Material and Methods

The present study was conducted in the Research Farm and Seed Testing Laboratory of Department of Seed Science and Technology, CCSHAU, Hisar during the season of kharif 2005. The moongbean (Vigna radiate. (L.) Wilezee), (cv.c. Asha) crop was harvested at maturity, and sun-dried up to a moisture content of 10.5 percent. The dried pods were then threshed using three types of threshers having three types of threshing cylinders, viz. hammer mill (Hadamba thresher), spike tooth (Hadamba thresher) and raspbar (axial flow thresher). Three levels of cylinder speed (400, 450, 500 rpm) and three levels of concave clearance (5, 10, 15 mm) with three replications were selected. Every care was taken to ensure constant feed rate. The threshed seeds were collected from the main outlet of thresher. The parameters for cylinder performance and seed quality, viz. seed damage (%), threshing efficiency (%), standard germination (%) and electrical conductivity (ms) were determined with each run.

## Results and Discussion

**Effect on Seed Damage**

Seed damage increased with the increase in cylinder speed and de-

**Fig. 1** Effect of cylinder speed and concave clearance on seed damage

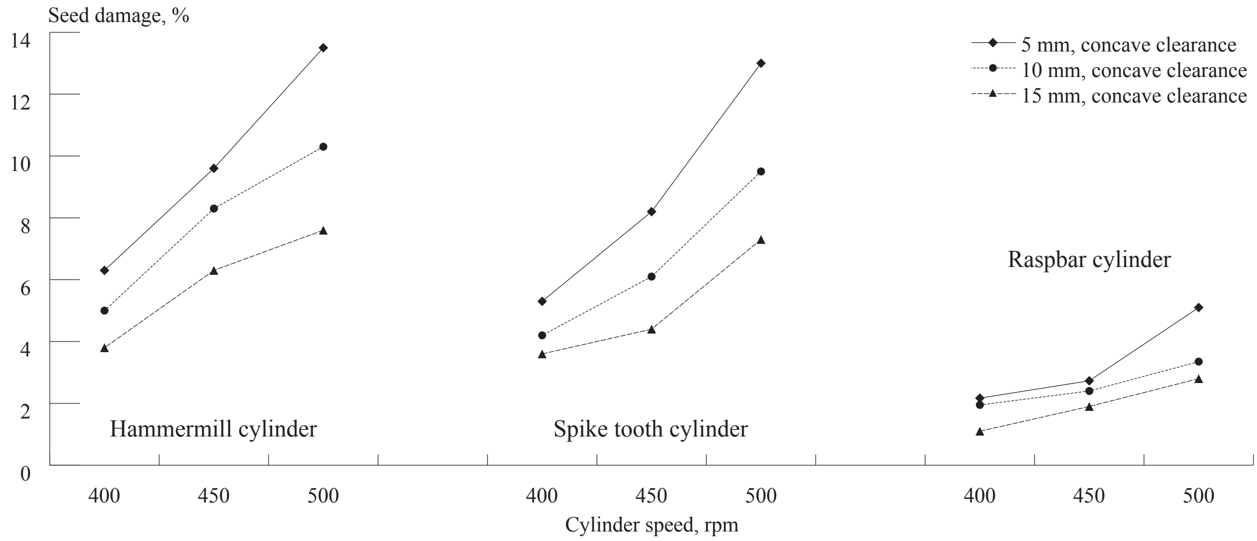
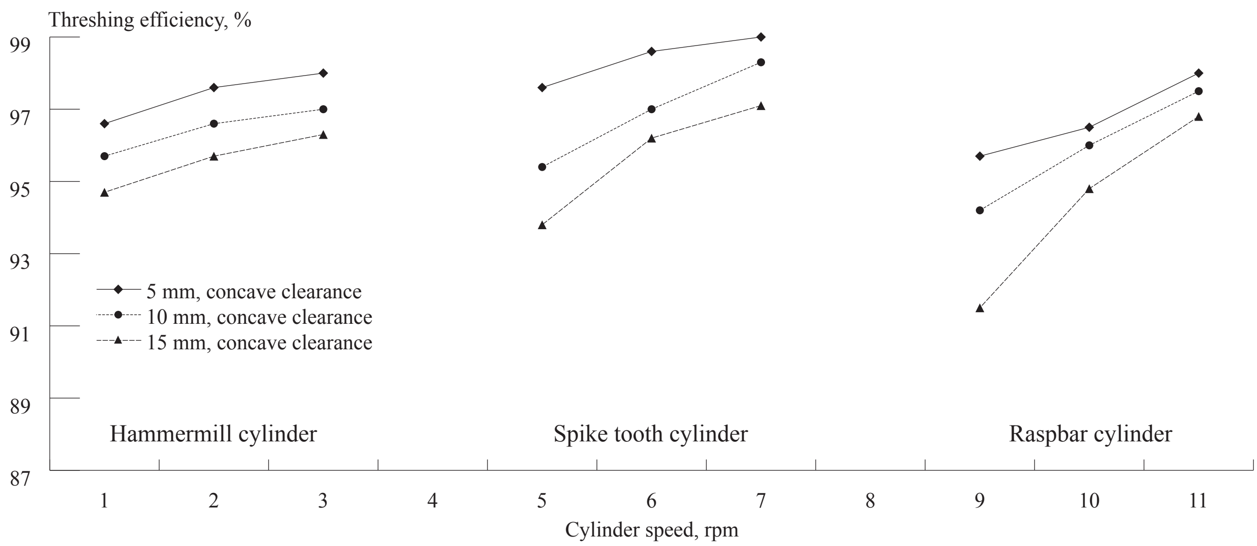



**Fig. 2** Effect of cylinder speed and concave clearance on threshing efficiency



creased concave clearance in all the three types of threshing cylinders. The data in **Fig. 1** revealed a significant effect on extent of damage to the seed. The minimum seed damage (1.1 %) was observed with a cylinder speed of 400 rpm and concave clearance of 15 mm when the threshing was done with a raspbar cylinder. A maximum damage of 13.5 % and 13 % was obtained with a higher cylinder speed of 500 rpm and concave clearance of 5 mm when threshing was done by hammermill and spike tooth cylinder, respectively. The higher seed damage at higher speed may be due to the increased effect of impact and rubbing force at higher speed (Neeaj and Singh, 1998). The results confirmed with the findings of Anwar et al., 1991.

### Effect on Threshing Efficiency

Threshing efficiency was maximum (99 %) with the use of spike tooth threshing cylinder at a cylinder speed of 500 rpm and concave clearance of 5 mm; however, the seed damage was maximum (13 %) at this cylinder speed and concave clearance. At higher threshing efficiency, the seed damage was also higher. The rubbing effect between cylinder and concave was also reduced which resulted in minimum seed damage and poor threshing efficiency. The threshing efficiency decreased with decreasing cylinder speed from 500 to 400 rpm and increasing the concave clearance from 5 to 15 mm (**Fig. 2**). This may be due to the resistance of pods, as well as decrease in impact force and frictional force.

### Effect on Standard Germination

The standard germination was

**Fig. 3** Effect of cylinder speed and concave clearance on germination

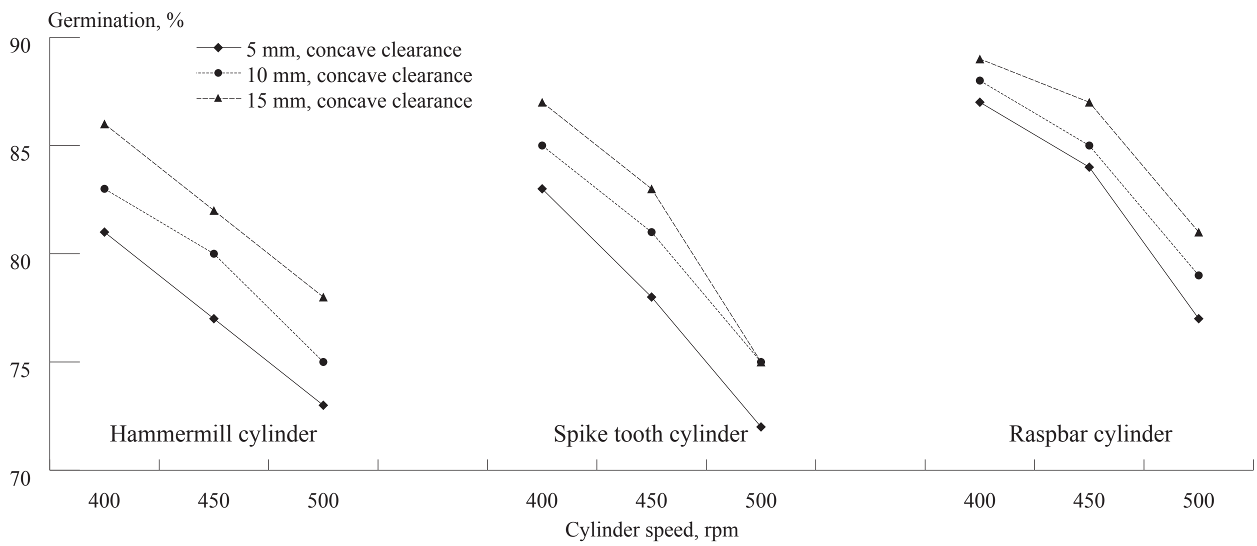
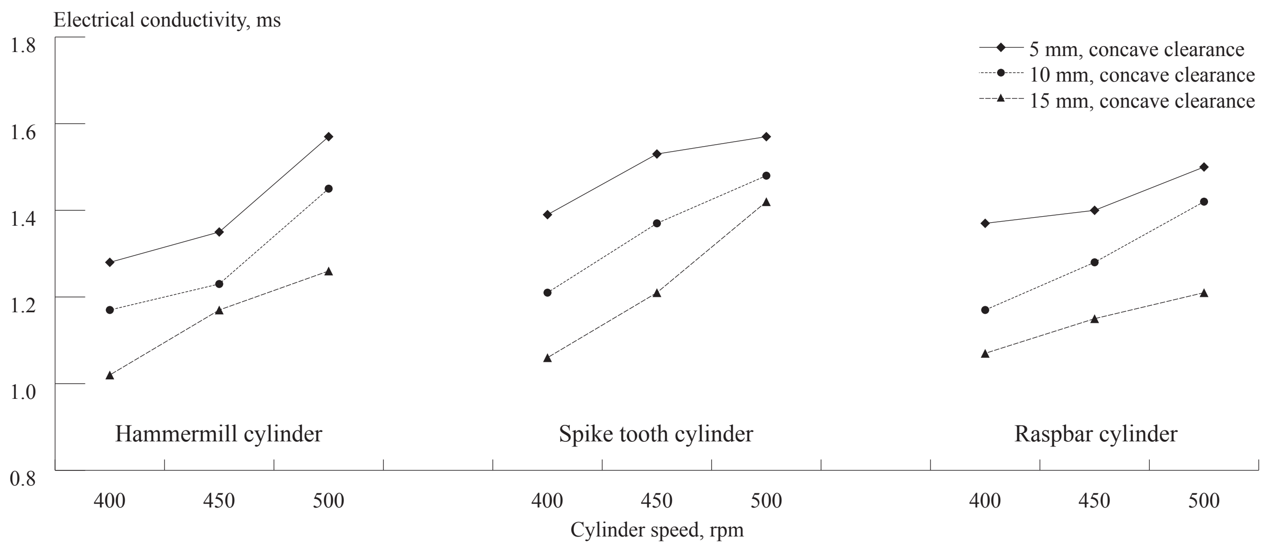



**Fig. 4** Effect of cylinder speed and concave clearance on electrical conductivity



maximum (89 %) at higher concave clearance (15 mm) and lower cylinder speed (400 rpm) when the spike tooth cylinder was used. It decreased to 72 % as cylinder speed increased from 400 to 500 rpm with concave clearance of 5 mm with the use of hammermill threshing cylinders. The results shown in **Fig. 3** revealed that the standard germination was on a decreasing trend with the increase in both cylinder speed (400 to 500 rpm) and concave clearance (5 to 15 mm) in all the three types of threshing cylinders. The minimum seed damage and maximum germination was found under low cylinder speed and high concave clearance, which could be attributed to the reduced impact force to detach the seed from the pod that resulted into poor threshing efficiency (Sinha and Pandita, 2002).

Effect on Electrical Conductivity

The seed leachate electrical conductivity increased as the cylinder speed increased and concave clearances decreased in the rasp bar type cylinder (**Fig. 4**). The reduction in seed leachate (electrical conductivity) with increase of concave clearance may be because, at higher concave clearance, the rubbing effect was reduced, which resulted in less invisible seed damage that resulted in low seed leachate (electrical conductivity).

## Conclusions

The optimum combination for different independent variables, viz. threshing cylinder, cylinder speed and concave clearance for minimum seed damage and maximum percent germination are represented in **Table 1**. Hence, it can be concluded that the minimum seed damage (1.1 %) and maximum germination (89 %) was found under lower cylinder speed (400 rpm) and higher concave clearance (15 mm) which resulted into less threshing efficiency (91.5 %) with the use of a raspbar threshing cylinder. In the spike tooth threshing cylinder, minimum seed damage (3.6 %), maximum germination (87 %) and minimum electrical conductivity (1.06 ms) was found under lower cylinder speed (400 rpm) and higher concave clearance (15 mm). In the hammermill cylinder, minimum seed damage (3.8 %), maximum germination (86 %) and minimum electrical conductivity (1.02 ms) was observed under lower cylinder speed (400 rpm) and higher concave clearance (15 mm).

## REFERENCES

Anwar, M. Tahir, Abdul Waheed and Nadeem Amjad. 1991. Development and field performance of a chickpea thresher. AMA 22(3): 73-78

Jagadish, G. V. and K. G. Shambulingappa. 1984. Relationship between seed damage and germinability in sunflower (Helianthus annuus L.). Seeds & Farms 10(6): 25-27

Kamble, H.G. and J. S. Panwar. 1984. Studies on machine crop variables for threshing of moong. J. Agric. Engg. Res. 21(4): 1-7

Neeraj and Bachchan Singh. 1998. Performance and evaluation of pigeon pea threshing mechanism, J.Agric. Engg, ISAE. 25 (4) 9-17

Sinha, J. P. and V. K. Pandita. 2002. Effect of threshing methods on seed damage, germinability and seedling vigour in okra. Seed Res. 30(1): 161-163

■■

# Engineering the Application of Grain Protectants on F1 Hybrid Rice Seeds: The Philippine-HRCP Experience

by

Ricardo F. Orge
Supervising Science Research Specialist/Head
Seed Production and Health Division,
Philippine Rice Research Institute,
Central Experiment Station,
Maligaya, Science City of Muñoz, Nueva Ecija
PHILIPPINES

John Eric O. Abon
Science Research Specialist I
Seed Production and Health Division,
Philippine Rice Research Institute,
Central Experiment Station,
Maligaya, Science City of Muñoz, Nueva Ecija
PHILIPPINES

## Abstract

In 2002, when the commercialization of the hybrid rice technology in the Philippines started and was carried out nationwide through the Hybrid Rice Commercialization Program (HRCP), quality deterioration of stored and distributed F1 hybrid rice seeds due to storage pest infestation was a widely experienced problem. In order to prevent further seed quality losses, the Philippine Rice Research Institute (PhilRice), at that time being the agency in-charge of the procurement, storage and distribution of the hybrid rice seeds nationwide, decided to treat the seeds with grain protectants (insecticides) prior to storage starting with the 2003 dry season harvest.

Although there were available information on the right kind and amount of insecticide that could effectively control such kind of pest infestation, the urgent problem encountered at hand was how to accurately and uniformly apply the insecticide solution to the seeds at a recommended low volume application of 1-2 liters per ton of seeds. Low volume application was necessary since a significant increase in the seed moisture content could be another threat in maintaining the quality of the seeds. At that time, there was no locally available technology developed and marketed for the purpose.

The need was urgent and there was not much time available to come up with a seed treatment technology that could be used by the HRCP. This paper presents the experiences and the process of developing a low cost seed treating machine as a prompt answer to a serious need of the Program.

## Introduction

The Philippines need an increased supply of rice because of its increasing population and decreasing land and water resources Realizing this fact, the Philippine government launched the Hybrid Rice Program in 1998 using hybrid rice technology as a new approach for increasing rice production, farmers' productivity, and competitiveness, to mitigate the negative effects of the El Nino phenomenon over the short term and to attain national food security over the long term (Obien, 1998). Hybrid rice is known to have a yield advantage of 15-20 % against the best commercial varieties (Barona, 2002).

In 2002, with the implementation of the Hybrid Rice Commercialization Program (HRCP), commercialization of hybrid rice technology became Philippine agriculture's banner program for attaining self-sufficiency and increasing productivity and profitability in rice, and generating rural employment (Redoña, et al., 2004). Since the implementation of the HRCP, more and more farmers are convinced that hybrid rice can indeed increase their yields and incomes. In Northern Luzon, survey showed that farmers get an average net profit that is P16,069/ha higher than what they get from inbred rice (Pablico, 2004).

However, although there had been a lot of success stories told about hybrid rice cultivation, some problems were also encountered which resulted to slow adoption of hybrid rice in some areas. One of these problems was the susceptibility of hybrid rice, particularly PSB Rc72H or Mestiso I, one of the most popular and widely grown hybrid rice varieties in the Philippines, to storage pest (rice weevil/lesser grain borer) infestation. If left uncontrolled, this infestation could cause significant damage on seeds such that the seeds' capacity to germinate would be affected.

Because of this problem, PhilRice, being the agency in-charge of the procurement, storage and distribution of the hybrid rice seeds nationwide, decided to treat the seeds with insecticides (admixture treatment) as a preventive measure against such infestation beginning with the 2003 dry season harvest. Admixture treatment is a seed treatment procedure wherein liquid insecticide solution is applied uniformly at low volume and appropriate dosage directly to seeds. The Bureau of Postharvest Research and Extension (BPRE) conducted research on admixture treatment of paddy rice and came up with recommended kind and amount of active ingredients to control storage pests of rice (**Appendix Table 1**).

The major problem encountered at that time, however, was the need for a machine that could uniformly and accurately apply the insecticide solution at low volume application. Moreover, the machine reqyired a relatively high throughput capacity considering the large volume of seeds that were to be treated by PhilRice. The need was urgent such that the plan was to acquire a commercially available seed treating machine. However, after surveying the market and contacting farm equipment suppliers and manufacturers, it was found that there was no locally available seed treating machine. If ever seed treatment was to be done, as in the case of one seed company, insecticide solution at predetermined volume, was sprayed directly on seeds that are thinly scattered on the ground using a lever-operated knapsack sprayer. Even the local animal feed industry which also suffers losses due to storage pest infestation had no machine technology currently for admixture treatment (Villanueva, 2005).

This was an action research conducted to locally develop a machine for applying insecticide solution, that satisfied certain requirements and restrictions, to F1 hybrid rice seeds.

## Materials and Methods

**Design Criteria**

The seed treating machine (STM) was designed to apply liquid insecticide solution at an application rate of 1 to 2 liters per ton. A low volume requirement was strictly imposed since some batches of seeds to be treated may have a moisture content (MC) that was already at the borderline for safe storage and any significant increase in the MC could lead to seed quality deterioration (Cameron, 1999). The following criteria, adopted from Halmer (1994) and McGee (1995), were considered in the design of the machine:

1. Accuracy and uniformity of application. The machine must be able to apply the target dose of active ingredient and distribute the insecticide solution uniformly on each individual seed;
2. Ease of operation
3. Could also be used to treat other seeds or products (not only rice)
4. Allows only minimal damage to seeds
5. Easy to clean so as to prevent cross-contamination of products
6. Safe to use so that operators are protected from health hazards

**Fig. 1** Relationship between droplet-seed ratio and size of droplets at different application rates

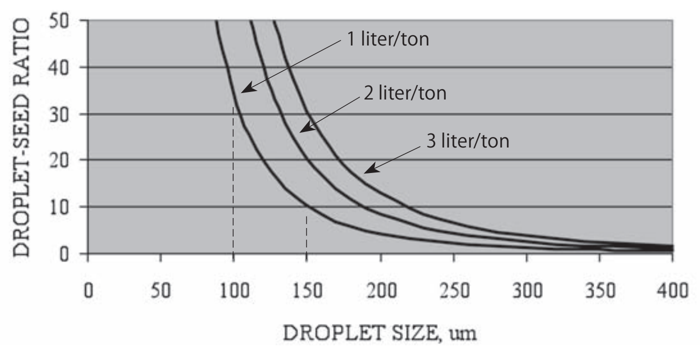



**Fig. 2** The basic working component (BWC) of the designed STM

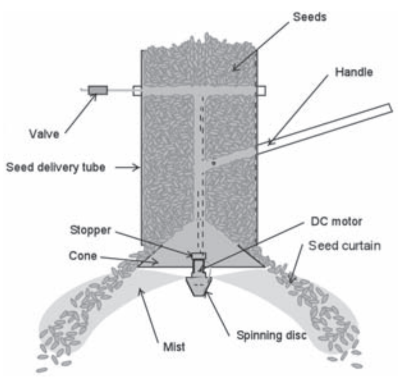
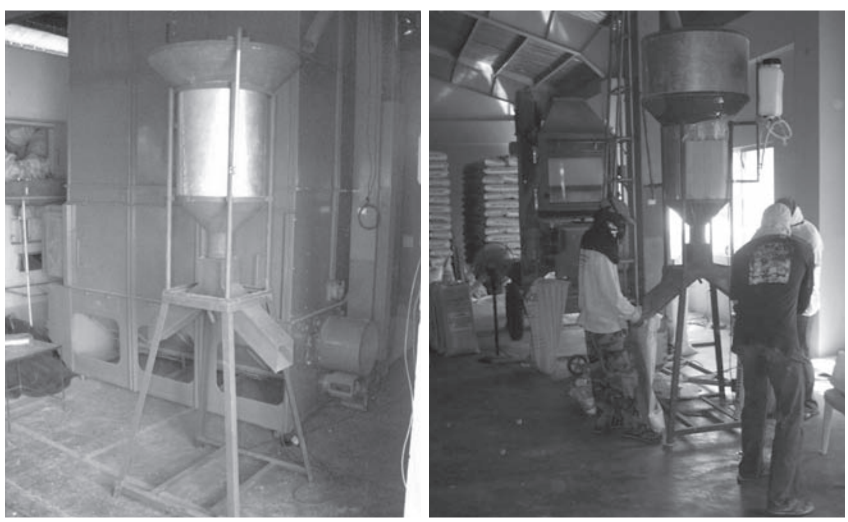



**Fig. 3** The first prototype of the STM



7. With relatively high throughput capacity
8. Low cost to make the machine affordable to hybrid seed growers who, after the implementation of the HRCP, may become its ultimate end user.

**Designing Machine Components**

The first criterion (accuracy and uniformity of application) was the most difficult to satisfy, hence, design efforts were focused on the component parts that do the distribution of the liquid (insecticide solution) onto the seed as well as the control of liquid and seed metering.

***Distribution of the Liquid onto the Seed***: This concerned the design of the applicator, the part of the STM that distributed the insecticide solution onto the seeds. To attain a low volume and uniform application, the applicator must be able to transform the liquid into fine droplets prior to application. Two existing designs were available and considered for adoption, namely, the hydraulic nozzle such as the one accompanying a lever-operated knapsack sprayer and the spinning disc such as the one employed in the battery operated Ultra Low Volume (ULV) sprayer. Evaluation of each option led to the selection of the spinning disc because of the following reasons:

1. The spinning disc could easily satisfy the low volume requirement unlike the hydraulic nozzle which has much higher discharge rate. Moreover, the spinning disc is not difficult to adopt since most of the hybrid seed growers, who are the ultimate end users of the STM, also have ULV sprayers which are commonly used in applying gibberellic acid (GA3), one important operation in the hybrid rice seed production.
2. The spinning disc produces finer and more uniform size of droplets as compared to the hydraulic nozzle (Bateman, 2003). As long as operator contamination due to drifting droplets could be prevented, a smaller droplet size is more advantageous to use than the coarse one since finer droplets would also mean more droplets produced per unit volume of liquid.

This relationship could be best described using **Fig. 1**, which shows an estimated ratio of the number of droplets available for application to each single seed at any given droplet size and application rate. The graph was constructed based on the assumption that a single seed of PSB Rc72H weighs 0.018 g (on the average) and that all of the droplets are equally distributed onto each individual seed. If a spinning disc, with an average size of droplet of approximately 100 um (Bateman, 2003) is to be used, one can assume that a single seed can get as much as 34 droplets for an application rate of 1 liter per ton of seed. If for example, a hydraulic nozzle, having an average droplet size of 150 um, is to be used, then one can only expect around 10 droplets per seed for the same application rate. One strategy to increase the droplet-seed ratio is to use a higher application rate. However, there is also a corresponding risk of increasing the moisture content of the seeds.

***Seed Metering:*** The selection of the spinning disc for the applicator influenced the design of the seed metering and distributing mechanism. Using a spinning disc as the applicator required a layer of seeds flowing in a cylindrical form since the droplets generated by the spinning disc traveled radially, originating from the spinning disc's rim. To

**Fig. 4** The STM'S BWC attached to the hopper of seed processing plant

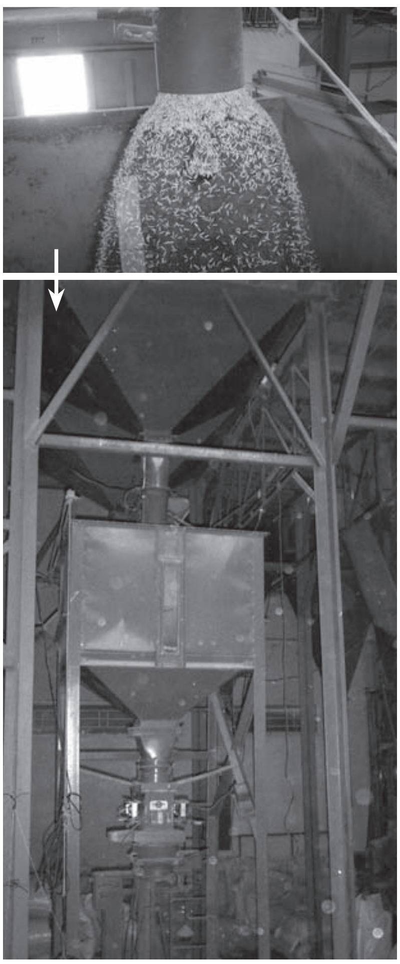


**Table 1** Performance of the designed STM in terms of applying the target dose

| Observation no. | Applied volume, liters | No. of bags treated, 20kg/bag | Application rate, l/ton | Variation, % |
|---|---|---|---|---|
| 1 | 4.3 | 200 | 1.08 | 8 |
| 2 | 5.5 | 250 | 1.10 | 10 |
| 3 | 6.5 | 332 | 0.98 | 2 |
| 4 | 5.5 | 268 | 1.03 | 3 |
| 5 | 4.5 | 205 | 1.10 | 10 |
| 6 | 5.5 | 265 | 1.04 | 4 |
| 7 | 8 | 384 | 1.04 | 4 |
| 8 | 5 | 242 | 1.03 | 3 |
| 9 | 6.5 | 323 | 1.01 | 1 |
| 10 | 5 | 259 | 0.97 | 3 |

attain this, a cylindrical seed delivery tube paired with a cone at the base (**Fig. 2**) was used as the medium for creating a cylindrical seed curtain as the seeds were discharged from the hopper. Underneath this cone was the spinning disc where the stream of droplets were produced and where the seeds were subjected to as they fell down from the base of the cone. The stopper set the outlet opening or the clearance between the seed delivery tube and the cone. The handle, on the other hand, controlled the movement of the cone during the opening and closing of this clearance, which was usually done during calibration. For best performance, the outlet opening should be adjusted to attain an optimum thickness of seed curtain; just enough to enable each seed to get an equal chance of being hit by the droplets. If this opening was set above the optimum, the droplets could hardly penetrate through the thickness of the seed curtain such that the seeds at the outer side received less droplets as compared to those at the inner side. On the other hand, if the opening was set below the optimum, there would be a lot of empty spaces in the seed curtain and the probability that some of the droplets would not land on target (seeds) was high.

***Liquid Metering:*** The requirement was to deliver the insecticide solution at an application rate not exceeding 2 liters for every ton of seeds. To attain this, the liquid (insecticide solution) flowed by gravity with the flow regulated with the mechanism normally used in dextrose application.

**Performance Evaluation**

The performance of the prototype STM was evaluated in terms of its following basic functions:

***a. Ability to apply the target dose:*** This was done by monitoring the flow rates of the seed and the insecticide solution during actual seed treatment operation;

***b. Ability to uniformly apply the insecticide solution on individual seeds:*** This was done during free time when actual seed treatment operations had been completed and enough time was already available for laboratory testing. The purpose was to check/confirm the quality of work performed by the machine.

## Results and Discussion

**The Prototype**

The first prototype was fabricated in the second quarter of 2003, almost a month after the need to come up with a STM was urgently felt. As shown in **Fig. 3**, it was made mostly of galvanized iron (GI) sheet, GI pipe and steel bars. It had a cylindrical hopper at the base of which was the BWC. Installed below the BWC was a receptacle where seeds were collected, after passing through the stream of droplets, and discharged to facilitate bagging. A GI sheet cover for the BWC was installed to protect the operator from being contaminated by the drifting droplets. Attached at the side of the hopper was the tank for the insecticide solution. The prototype made use of a bucket elevator of an old batch recirculating dryer to facilitate filling of the hopper with seeds.

During operation, seeds coming from the hopper entered the seed delivery tube and slid through the side of the cone. As the seeds fell, they were exposed to a stream of droplets coming from the spinning disc, which was installed underneath the cone. These droplets were produced by the centrifugal action as the insecticide solution came in contact with the fast rotating (approximately 6000 rpm) spinning disc, which was driven by a direct current motor.

Because of immediate need, performance testing and evaluation of the prototype was done side by side with actual use. Using the prototype in actual seed treatment operation provided an opportunity to identify weak points of the design when exposed to actual operating conditions, thus, necessary improvements were made immediately.

**The STM as an Integral Part of a Seed Processing Plant**

An urgent need to fabricate additional units of the designed STM was felt because of the increasing volume of hybrid rice seeds that continued to arrive during the third quarter of 2003. However, since PhilRice-Central Experiment Station (CES) had an existing seed processing plant, the idea of fabricating the machine's BWC and attaching it on one of the hoppers of the processing plant was conceived. The idea proved feasible and since then seed treatment has become an integral component of the seed processing plant at PhilRice-CES (**Fig. 4**). Another unit was also fabricated and installed in the same facility in its branch station in Midsayap, Cotabato, which also handled the seed

**Fig. 5** Schematic diagram showing the effect of the receiving funnel's placement on seeds' exposure to the spray of droplets

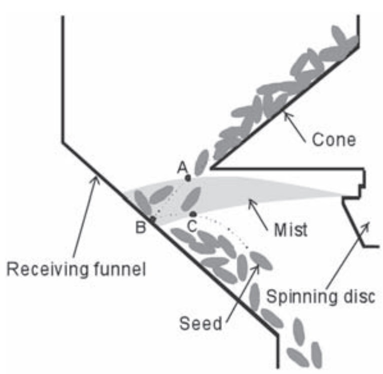
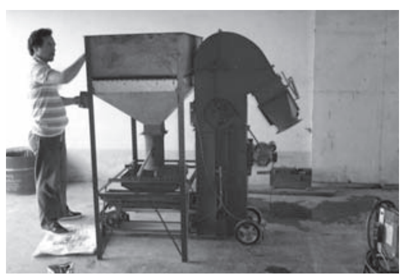



**Fig. 6** The coop model of the STM



treatment operation for the Mindanao-produced hybrid rice seeds.

The incorporation of the STM into the seed processing facility had significantly improved PhilRice's capability to perform seed treatment operation on all hybrid rice seeds it had procured nationwide. This had also further enhanced the quality of the distributed hybrid seeds since, by using the seed processing plant, the seeds were first cleaned (to remove impurities and weevils in case the infestation has already started) prior to seed treatment in just one operation.

**Design Refinements**

Although the first prototype (including the one installed in the seed processing plants) performed satisfactorily during actual use, some points for improvement in the overall design of the STM were noted as follows:

a. The dextrose hose used to convey the insecticide solution from the tank to the spinning disc did not last long. The hose material reacted with the insecticide solution and softened such that it needed replacement every after 3 days of use;

b. The discharge rate of insecticide solution was significantly affected by the content of the tank. Because the liquid flows by gravity, the discharge rate was relatively high when the tank was full as compared to that when the tank was half empty. Hence during actual operation, there was a need to regularly monitor the volume of insecticide solution consumed as well as the corresponding amount of seeds being treated. As the seed treatment operation progressed, however, the operators were able to acquire skill in setting the desired insecticide flow rate based on the appearance of the flowing liquid as seen from the viewing chamber (enlarged portion) of the dextrose hose.

c. Some droplets that did not hit the target (seeds) accumulated at the side of the receiving funnel. This caused rewetting of the seeds.

After identifying these problems, the following improvements on the design of the STM were made:

a. The delivery tube was replaced with a chemical resistant hose normally used for agricultural sprayers. This replacement however affected the choice for the flow regulator since the one commonly used for the dextrose hose was no longer applicable. After looking for and evaluating other substitutes, a cut-off valve designed to control the flow of kerosene fuel in household stoves was found to be appropriate. This valve was made of brass material making it resistant to the corrosive effect of the insecticide solution.

b. To minimize the effect of the tank content on the metering of the insecticide solution, the tank's vertical distance from the spinning disc was increased. Moreover, a simple flow indicator was designed and fabricated utilizing the same concept employed in dextrose application. The appearance of the liquid flow when the tank was full significantly varied with that when the tank was ¾ full or less. Hence, maintaining a constant flow rate could be done by just taking note of the initial appearance of the liquid flow inside the device when the tank was full.

c. Improvement of the receiving funnel. Originally, the receiving funnel was designed merely to perform two basic functions, namely, 1) as a shield to prevent the operator from being exposed to the stream of droplets, and 2) to receive the seeds and divert them into the container beneath for final bagging. However, further analysis showed that, if properly designed and installed in the right location, it could further increase the seeds' exposure to the stream of droplets, thus the possibility of increasing the seeds'

**Fig. 7** Relationship between outlet opening and seed flow rate of the designed STM

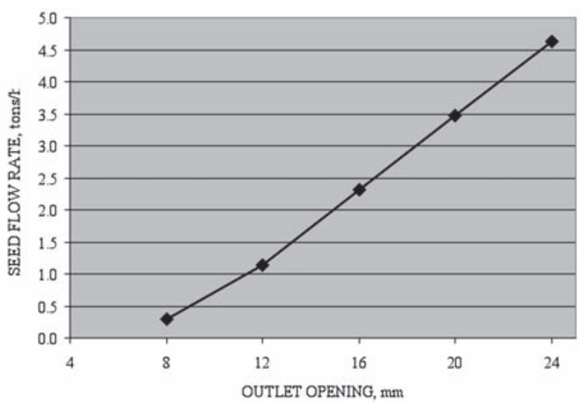
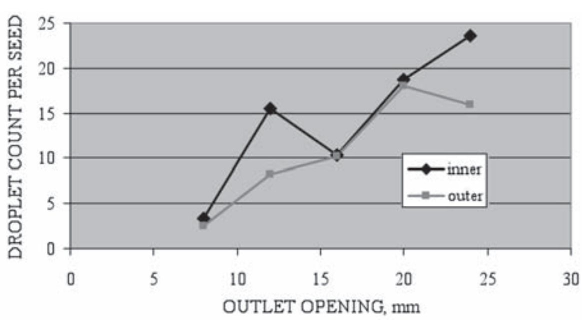



**Fig. 8** Droplet count of seed samples representing the inner and outer layer of the seed curtain



droplet count. The idea was to design an appropriate size and inclination of the receiving funnel and install it in such a way that the inclined surface would pass through a point where the stream of droplets and the flow of seeds intersect (point B, **Fig. 5**). Under this condition, the seeds' exposure to the stream of droplets (time for the seed to travel from point A to point C) would be increased since each individual seed will have a bouncing point B before it finally exits the stream of droplets at point C.

**The Coop Model of the STM**

The coop model (**Fig. 6**) was designed to fit the requirements of the hybrid rice seed growers' cooperatives who are the key players of the HRCP. This model was designed and fabricated after observing the performance of the first prototype as it was extensively used in the treatment of F1 hybrid seeds for almost 2 years (2003-2004). Although the BWC was basically the same, it incorporated some solutions to the problem encountered in the first prototype. The model was equipped with a bucket elevator, which was actually an optional part (depending on the budget of the user) that facilitated bagging operation after the seed treatment process.

**Optimizing Machine Settings**

Due to the urgent need of the HRCP to treat thousands of bags of F1 hybrid rice seeds that already had accumulated at the time the fabrication of the first prototype was completed, there was no thorough laboratory testing done except calibration of the seed and the liquid metering mechanisms. The selection of the optimum size seed outlet (clearance) was purely based on the visual appearance of the seed curtain. Later a laboratory test was conducted to check and verify/confirm the optimum seed outlet opening. This was done by counting the number of droplets in each set of 20 seed samples - one set representing those that were in the inner surface of the seed curtain and another set representing those in the outer surface. Making the droplets visible was made possible with the use of seeds that had been coated with white paint and a dye solution (approximately 20 sachets of black dye in 1 liter water) that was used as substitute for the insecticide solution. Counting of droplets on each seeds sample was done with the use of a microscope.

Results of calibration tests showed that the seed flow rate and the size of the seed outlet had the following linear relationship:

$$y = 0.27526x - 2.032$$

$(8 \leq x \leq 24; r = 0.97)$

where:

y = seed flow rate, tons/h

x = seed outlet size or the perpendicular distance between the side of the cone and the base of the seed delivery tube, mm

At 8 mm opening, occasional clogging was observed such that manual tapping of the seed delivery tube had to be done from time to time. This could have caused the slight deviation in the straightness of the calibration line (**Fig. 7**). Smooth flow of seeds was observed starting at 12 mm outlet opening.

The optimum size of the seed outlet was 20 mm. As shown in **Fig. 8**, it was at 20 mm opening where the highest seed flow rate and the least difference in seed droplet count between the inner and outer side of the seed curtain was observed. This opening was also the one selected based on the visual appearance of the seed curtain. At this opening, one could partially see the spinning disc even with the presence of the flowing seeds. At 24 mm, there was already a decrease in the number of droplets in seeds at the outer surface of the seed curtain. This meant that the seed curtain was already too thick such that the seeds at the outer side receive fewer droplets as compared to those in the inner side.

**Machine Performance**

In general, the ability of the machine to accurately and uniformly apply the insecticide solution could be evaluated by looking at the result of a separate study conducted by Abon, et al. (2005) which compared the quality of stored seeds that had been treated with insecticide solution (using the machine) with that of

**Fig. 9** Droplet count of 20 randomly collected seed samples taken at the inner and outer layer of seed curtain

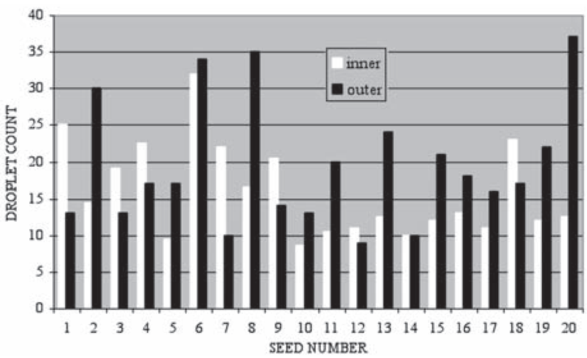
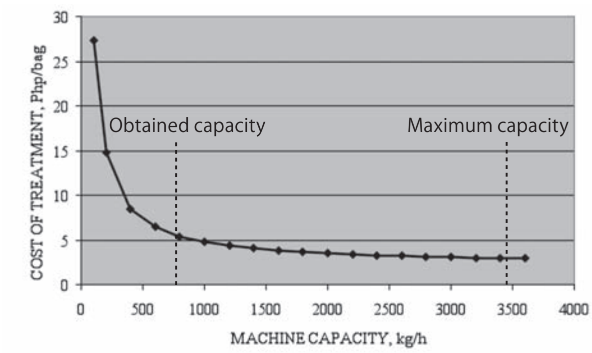



**Fig. 10** Seed treatment cost as affected by amchine capacity (Data and assumptions in Appendix Table 3)



the untreated seeds. Results of the study showed that treating the seeds with the recommended active ingredients (**Appendix Table 1**) provided protection against storage pest infestation for at least six months and a reduction in pest population (rice weevil and lesser grain borer) by 71 % for one year storage under ambient condition.

***Ability to Apply the Target Doze:*** Monitoring of the actual amount of insecticide solution applied per unit weight of seeds revealed that the machine could apply the target doze at a maximum variation of 10 % or an average of 4.8 % (**Table 1**). This relatively low variation from the target dose was made possible because of the independent control of metering of the seeds and insecticide solution as well as regular monitoring the amount of the insecticide solution to the corresponding amount of seeds being treated.

***Ability to Uniformly Apply the Insecticide Solution on Individual Seed:*** Results of a laboratory test conducted to determine the number of droplets that are deposited on each individual seed showed that all of the 20 randomly collected seed samples taken from the inner and outer layers of the seed curtain received sufficient amount of droplets (**Fig. 9**). For the inner layer, the number of droplets deposited on each seed ranged from 8 to 32 (an average of 16). On the other hand, those collected at the outer layer ranged from 9 to 37 (an average of 20). Because of lack of sufficient equipment, the size of droplet was not measured. As observed visually, the range in size of droplets was relatively wide - the largest was approximately 10 times larger in diameter than the smallest.

**Appendix Table 1** Active ingredients and their recommended dosages for the control of rice storage pests

| Active ingredient | Recommended dose, g/ton seed |
|---|---|
| Pirimiphos methyl | 7 |
| Deltamethrin | 0.75 |

Source: PRPC, 2003

**Appendix Table 2** Amount of F1 hybrid seeds (PSB Rc72H) treated by the designed STM from 2003-2005 at PhilRice-Central Exeriment Station

| Year | Amount of seeds treaded | |
|---|---|---|
| | Bags* | Tons |
| 2003 | 6,552 | 131.04 |
| 2004 | 17,422 | 348.44 |
| 2005 | 11,280 | 225.60 |

*at 20 kg/bag

**Machine Capacity and Cost of Seed Treatment**

Although the machine, based from the results of the calibration test (**Fig. 7**), can treat seeds up to 3.5 tons per hour, actual use of the machine from 2003 to 2005 (**Appendix Table 2**) yielded only a capacity of around 250 to 300 bags (20 kg/bag) per day, equivalent to 625-750 kg/h. This is because the hybrid seeds, which came in different locations and sources, had to be treated on per lot basis so that around 25 % of the time was lost in segregating seed lots. Other time was spent on the opening of the bags (12 %), closing/sewing of the bags after filling with treated seeds (19 %), and piling (6 %). Actual seed treatment operation (use of machine) only accounted 38 % of the total time spent for the whole operation. It was obvious that, during that period of actual use, the machine's maximum capacity was not attained because the seeds being treated were not homogenous.

The cost of seed treatment was highly influenced by machine capacity (**Fig. 10**) and, as earlier discussed, machine capacity was also highly influenced by the homogeneity of the seeds being treated. At a capacity of 300 bags (750 kg) per day, the cost of treating the seeds using the machine was Php 5.58/bag (Php 0.28/kg). If seeds to be treated are only homogenous (i.e. coming from one source and no segregation needed) the machine could perform close to its maximum capacity thus lowering the cost of seed treatment to as low as Php3/bag.

## Summary and Conclusion

With the development of the STM in 2003, seed (admixture) treatment became an important and a prerequisite postharvest operation prior to storage at PhilRice. It yielded significant improvement on the viability of stored F1 hybrid rice seeds which resulted to more seeds utilized starting 2004 dry season planting as compared to that in the previous seasons.

Realizing these advantages, the government required the hybrid rice seed growers to treat their own hybrid seeds with the recommended active ingredients. The Department of Agriculture, through the Administrative Order No. 29 series

**Appendix Table 3** Assumptions used in computing for the cost of seed treatment using the designed STM

| Parameter | Value |
|---|---|
| Machine acquisition cost, Php | 10,000 |
| Life span, years | 10 |
| Salvage value, % of original cost | 10 |
| Repair and maintenance cost, % of acquisition cost | 5 |
| Machine capacity, bags of seeds treated per day (@ 20 kg/bag) | 200 |
| Number of workers involved | 4 |
| Cost of labor, P/day | 250 |
| Cost of insecticide | |
| Insecticide A (with 250 g Pirimiphosemethyl/L), Php/liter | 2,457.28 |
| Insecticide B (with 25 g Deltamethrin/L), Php/liter | 1,435.20 |
| Cost of treating 1 bag (20 kg/bag), Php/bag | 7.26 |

of 2004, issued the Implementing Guidelines on Seed Treatment of F1 Hybrid Rice Seeds which was based from the experiences gained on seed treatment operations at PhilRice.

Being designed to fit to local conditions, particularly the requirements of our hybrid rice seed growers, the STM could be easily fabricated at local welding shops and does not require special skills to operate. With a capital of around Php 10,000, a cooperative can acquire this machine for use in the treatment of its produced rice seeds, either hybrid or inbred.

The key to an accurate application of the target dose using the designed machine is regular monitoring of the seed and liquid flow rates. Any deviation in the actual dose with that of the targeted dose requires corresponding adjustment of the flow regulators and this has to be constantly monitored until this deviation would fall within acceptable limits.

## REFERENCES


Abon, J. E. O., R. F. Orge, and A. C. Ismael. 2005. Quality preservation of Mestizo I (PSB Rc72H) seeds through seed treatment and controlled storage. Paper presented during the 55th Philippine Society of Agricultural Engineers (PSAE) Annual National Convention held on April 18-22, 2005 at the Family Court Hotel and Conveñntion Center, General Santos City.

Baroma, L. J. 2002. The Hybrid Has Two Faces. Office of the Alumni and Public Affairs, University of the Philippines Los Baños. Retrieved from http://www.pinoy-farmer.com/ news.cfm?id=378

Bateman, R. P. 2003. Rational Pesticide Use: spatially and temporally targeted application of specific products. Pages 129-157 in M. Wilson, ed. Optimizing Pesticide Use. John Wiley & Sons Ltd., UK.

Cameron, A. G. 1999. Seed Storage in the NT Tropics. In Agnote. 785. No.C35. September 1999. Agdex No.: 139/61. ISSN No. 0157-8243.

Halmer, P. 1994. The development of quality seed treatments in commercial practice objectives and achievements. Pages 363-374 in seed treatment: Progress and Prospects Mono. 57, BCPC, Thornton Health, UK.

McGee, D .C. 1995. Advances in seed treatment technology. Paper presented at ASIAN SEED ’95. New Delhi, India, 27-29 September 1995

Obien, S. R. 1998. Hybrid Rice Technology for Rice Self-Sufficiency. Pages 2-7 in E.D. Redona, ed. Advances and Challenges in Hybrid Rice Technology in the Philippines. Philippine Rice Research Institute. Maligaya, Munoz, Nueva Ecija, Philippines.

Pablico, M. S. 2004. Hybrid rice a boon to farmers in North Luzon. The Manila Times. June 21, 2004

Philippine Rice Postproduction Consortium (PRPC) and Japan Grain Inspection Association (KOKKEN). 2003. Rice postproduction technology - a technical reference guide. First Ed. Philippine Rice Postproduction Consortium. NFA, Quezon City.

Redoña, E. D., L. M. Perez, L. R. Hipolito, V. E. Elec, I. A. Pacada, L. M. Borines, R. O. Solis, S. A. Ordoñez, and J. Agarcio. 2005. Harnessing molecular markers in hybrid rice commercialization in the Philippines. In K. Toriyama, K.L. Heong, and B. Hardy, eds. Rice is life: scientific perspectives for the 21st century. Proceedings of the World Rice Research Conference held in Tokyo and Tsukuba, Japan, 4-7 November 2004. Los Ba?os (Philippines): International Rice Research Institute, and Tsukuba (Japan): Japan International Research Center for Agricultural Sciences.

Sebastian, L. S. 2001. Foreword. In E. D. Redona and M. G. Gaspar, eds. Hybrid Rice in the Philippines: Progress and New Horizons. Food and Agriculture Organization of the United Nations (UN) and Philippine Rice Research Institute. Maligaya, Science City of Munoz, Nueva Ecija, Philippines.

Villanueva, E. 2005. Personal communication.


■■

# Development and Performance of a Solar-Cum-Gas Fired Dates Dryer

by

Munir Ahmad
Principal Engineer/PSO
Farm Machinery Institute,
National Agricultural Research Centre,
Parkload, P.O. NIH, Islamabad
PAKISTAN
mahmad11@hotmail.com

Asif A. Mirani
Assitant Engineer/SO
Farm Machinery Institute,
National Agricultural Research Centre,
Parkload, P.O. NIH, Islamabad
PAKISTAN

## Abstract

Dates are the third most important fruit of Pakistan. It is grown on an area of about 78,000 ha, and its annual production is 625,000 tonnes. Sun drying of dates is the common practice prevailed in Pakistan. Sun dried dates have a short life and are not free from contamination and aflatoxins. Therefore, these cannot be presented in the international market for better return. About 22 % of the total dates produced in the country are wasted every year due to unavailability of proper drying/processing, and storage facilities. To overcome these problems, a solar-cum-gas fired dates dryer was developed at the Farm Machinery Institute, National Agricultural Research Centre, Islamabad. It consisted of eight flat-plate solar collectors, a drying chamber, and an axial flow fan. A gas burning system was also developed as a supplement source of heat.

This dryer was installed and evaluated at Mitra Abad, Dhaki, D. I. Khan in August 2003. Experimental results indicated that the system was capable of drying/processing about 544 kg of fresh dates within 5 days. The seasonal drying capacity of the dryer was predicted at about 4 tonnes, with a value addition of Rs. 72,116. It was a small scale on-farm dates drying technology, and was well suited to produce quality dates in order to present them into the international market.

## Introduction

World date production is about 5 million tones of fruit, whereas date production in Pakistan is about 0.625 million tones. This constitutes about 12.5 % of the world date production. Pakistan follows Iran, Egypt, Iraq, and Saudi Arabia on the list of the top date producing countries (Quraishi and Zia, 1997). About 22 % of the total dates produced in the country are wasted every year due to unavailability of the proper drying, processing and storage facilities (Iqbal, 1996).

The traditional method of dates drying is sun drying, in which dates are spread on date leaf mates. In most cases the drying yard is not properly fenced. Thus, birds, insects, and wild animals move around and contaminate the dates. Heavy losses may occur because of untimely rains. Dew accumulates on the surface of fruit and causes mold growth if the fruit is not covered properly at night. Colour change occurs, and drying becomes slow (Bajoi, 1996). Finally, the quality of the dried dates is likely to be variable with some of the dates over dried and with possible contamination by dust and infestation by insects. The dates dried in this manner have a short shelf life and may not be free from contamination and aflatoxins, thus, making these dates unhygienic from health point of view. Also, such dates can not be marketed in international markets in order to earn handsome foreign exchange.

As compared to sun drying, solar drying provides higher air temperature and lower relative humidity, which are conducive to improved drying rates and lower final moisture contents of the dried dates (Ahmad and Khan, 1997). As a result, the risk of spoilage is reduced, both during the actual drying process and in subsequent storage. The higher temperatures attainable are also deterrent to insect and microbial infestation. Protection against rain, dust, insects and other animals is enhanced by drying in an enclosed structure. Therefore, this research work was carried out with the following specific objectives:

a. To develop a solar-cum-gas fired date dryer.
b. To evaluate the performance of newly developed date dryer.
c. To perform the economic analy-

sis of this dryer.

## Literature Review

The date goes from one extreme of moisture content (85 % at the early Kimri stage) to another (5 to 10 % in dry desert dates). In between, there are several levels of importance, i.e. about 50-60 % for sweet khalal, about 35 to 4 % for rutab, around 24 % for entering the zone of self preservation, and 20 % at which a large amount of dates are marketed because they are safe to store but still retained a pliable and attractive texture (Internet material). Experience in most date producing countries showed that a well matured Rutab, handled with care, is one, if not the most, appreciated form in which the date is consumed and which gives the grower the highest rate of return. However, Rutab has three serious setbacks: it is produced in comparatively short periods with the tendency of production peaks; it is highly perishable; and it is delicate, which makes handling, packaging, and transport difficult and expensive. At Tamar stage (below 25 % down to 10 % and less), the fruit has undergone the process of ripening and drying on the palms. Fruit at the Tamar stage is ideal for marketing as “dried” dates. This fruit is used for year round consumption. It should be noted that the climatic conditions of dates growing areas of Pakistan does not allow the fruit to reach at Rutab or Tamar stage on the palms (Verbal Communication). Therefore, fruit is usually harvested at Khalal stage, and then dried to reach the Tamar stage. Artificially dried Khalal at 55 ºC and a relative humidity of not less than 70 % resulted in a well-ripened fruit after 72 hours (Internet material).

Three types of solar dryers have received the most attention and seem the most practical propositions (Trim, 1982).

a. Direct dryers employing natural convection with the separate collector and drying chamber.
b. Direct dryers employing natural convection with combined collector and drying chamber.
c. Indirect dryers employing forced convection with separate collector and drying chamber.

The direct dryers employing natural convection with separate collector and drying chamber were developed at Asian Institute of Technology (AIT), Bangkok, Thailand (Excell and Kornsakoo, 1978; Excell et al., 1979 and Excell, 1980). This dryer was successfully used to dry paddy in the monsoon season, but this was not tested for drying fruit and vegetable. A version of direct dryers employing natural convection with a separate collector was also developed by the New Mexico Solar Energy Association, 1978. The drying chamber contained a tier of perforated trays. Fruit, vegetable, and

**Fig. 1** Three commonly used configrations for air-type solar collectors

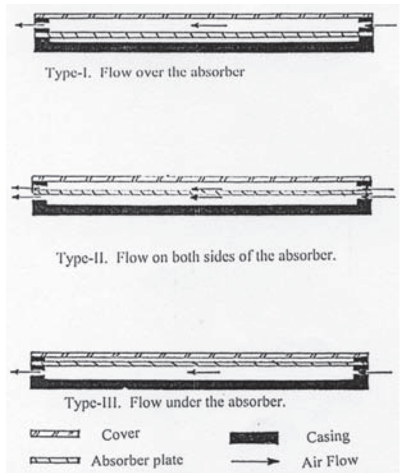



**Table 1** Hourly performance of the solar-cum-gas fired dates drying system

| Date | Time | $T_a$, ºC | $T_{co}$, ºC | $T_{dco}$, ºC | $RH_a$, % | $RH_{co}$, % | Remarks |
|---|---|---|---|---|---|---|---|
| 20/08/03 | 08:30 | 35.0 | 57.0 | 37.5 | 72.0 | 74.0 | solar + gas |
| 21/08/03 | 09:30 | 36.0 | 61.0 | 38.5 | 66.0 | 70.0 | solar + gas |
| 22/08/03 | 10:30 | 36.5 | 66.0 | 40.0 | 64.5 | 68.0 | solar + gas |
| 23/08/03 | 11:30 | 38.5 | 68.0 | 41.0 | 62.0 | 67.0 | solar + gas |
| 24/08/03 | 12:30 | 38.0 | 66.0 | 42.0 | 59.0 | 65.0 | solar |
| | 13:30 | 39.0 | 72.0 | 43.0 | 57.5 | 66.0 | solar |
| | 14:30 | 39.0 | 66.0 | 43.0 | 56.0 | 60.0 | solar |
| | 15:30 | 39.0 | 60.5 | 43.0 | 55.0 | 56.5 | solar |
| | 16:30 | 38.0 | 54.0 | 43.0 | 59.5 | 56.0 | solar |
| | 17:30 | 37.0 | 53.5 | 43.0 | 61.0 | 52.0 | solar |
| | 18:30 | 36.5 | 58.0 | 43.5 | 53.5 | 56.0 | gas |
| | 19:30 | 35.0 | 57.0 | 44.5 | 73.0 | 58.0 | gas |
| | 20:30 | 34.0 | 54.0 | 44.5 | 76.0 | 56.5 | gas |
| | 21:30 | 33.5 | 54.0 | 45.0 | 82.0 | 58.0 | gas |
| | 22:30 | 34.0 | 54.0 | 45.0 | 83.0 | 56.0 | gas |
| | Average | 36.5 | 60.2 | 42.5 | 65.3 | 61.2 | |

$T_a$ is ambient temperature, ºC, $T_{co}$ is collector outlet temperature, ºC, $T_{dco}$ is drying chamber outlet tempreature, ºC $RH_a$ is ambient air relative humidity, %, and $RH_{co}$ is chamber outlet relative humidity, %

**Fig. 2** An isometric view of a flat-plate collector develoed for dates drying system

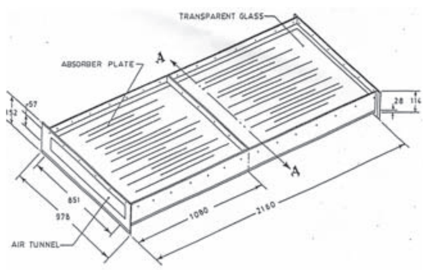
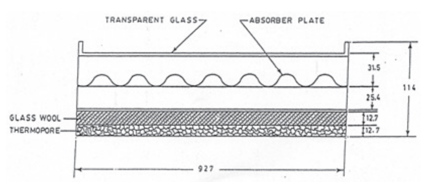



**Fig. 3** A cross-section of a flat-plate collector develoed for dates drying system




All dimensions in mm

herbs could be dried in this dryer. The loading capacity of this dryer was about 20 to 25 kg. Another successful new solar tunnel dryer was designed and developed at the University of Hohenheim, Germany, to meet the drying requirement of small farmers and small co-operatives (Esper et al., 1994). Instead of forcing the air through a depth of crop, it was just directed over the crop spread in a thin layer. A study was conducted at AIT, Bangkok to evaluate the solar tunnel dryer for drying chillies (Mastekbayeva et al., 1998). The length of this dryer and its collector length were half of the tunnel dryer designed by the University of Hohenheim, Germany. They loaded it with 19.5 kg of chillies at 75 % moisture content, and after three days the moisture content of the chillies was less than 10 %. The solar tunnel dryers are being used in most of the developing countries, however their drying capacity is too low.

**Fig. 4a** An isometric view of drying chamvber

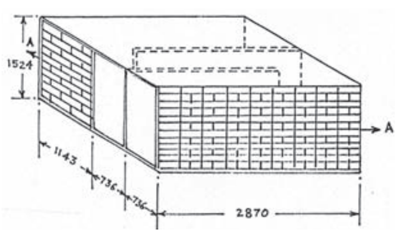
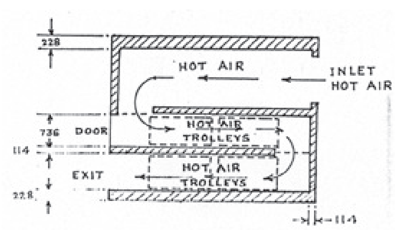



**Fig. 4b** Cross sectional view of the drying chamber




All dimensions in mm

**Fig. 5** A typical view of solar collectors with the drying camber at Mitra Abad, Dhaki. D. I. Khan

Under the category of direct dryer with natural convection combined collector and drying chamber, the most widely accepted is the cabinet dryer pioneered by the Brace Research Institute (Anonymous, 1965). The basic design consisted of a rectangular container perfectly insulated and covered with a roof of glass or clear plastic. The cabinet dryers have been found good for drying fruit and vegetable on a small scale.

Indirect dryers employing forced convection with separate collector and drying chamber have inherent tendency towards greater efficiency, as both units can be designed for optimum efficiency of their respective functions. Therefore, this design was selected to be incorporated in this development work.

## Material and Methods

### Development of Solar-cum-Gas Fired Dryer

The solar-cum-gas fired date dryer was developed with the following key requirements:

i. Low cost construction using local material and manufacturing technology.
ii. More simple and durable.

The key components of the solar-cum-gas fired date drying system are flat-plate solar collectors, drying chamber, axial flow fan, jet gas burner and cylinder for supplement source of heat.

### Development of Flat Plate Solar Collectors

Air-type solar collectors could be constructed mainly in three configurations (**Fig. 1**): (i) flow over the absorber (Type-I), (ii) flow on both sides of the absorber (Type-II), and (iii) flow under the absorber (Type-III). Each of these collector flow paths differs in thermal performance as well as construction requirements, construction material, and construction cost. Thermal performance tests of these three types of solar air-type collectors revealed that average efficiency of Type-II and Type-III collectors was slightly higher than the average efficiency of the Type-I collector (Parker et al., 1993). It was observed that the Type-II collector performed better

**Table 2** Hourly moisture removal from solar-cum-gas fired dates drying system

| Date | Time | Ambient absolute humidity, g/kg | Chamber outlet absolute humidity, g/kg | Moisture removal, kg/hr |
|---|---|---|---|---|
| 20/08/03 | 08:30 | 26.3 | 31.0 | 1.86 |
| 21/08/03 | 09:30 | 25.3 | 31.0 | 2.26 |
| 22/08/03 | 10:30 | 25.2 | 32.5 | 2.90 |
| 23/08/03 | 11:30 | 26.4 | 33.4 | 2.77 |
| 24/08/03 | 12:30 | 25.0 | 35.5 | 4.15 |
| | 13:30 | 25.2 | 39.9 | 5.82 |
| | 14:30 | 25.0 | 33.2 | 3.25 |
| | 15:30 | 27.0 | 31.8 | 1.90 |
| | 16:30 | 25.8 | 31.1 | 2.10 |
| | 17:30 | 24.9 | 29.1 | 1.66 |
| | 18:30 | 27.0 | 31.6 | 1.82 |
| | 19:30 | 27.0 | 35.0 | 3.17 |
| | 20:30 | 26.0 | 37.0 | 4.35 |
| | 21:30 | 28.0 | 36.1 | 3.20 |
| | 22:30 | 29.0 | 36.0 | 2.77 |
| | Average | 26.2 | 33.61 | 2.93 |

at high air flow rate, whereas the Type-III collector performed better in the colder environment (low ambient temperature). For the sake of better efficiency Type-II collector was incorporated in the date dryer.

The Type-II collector had an absorber, transparent cover and back plate. The absorber was between the transparent cover and back plate, and air passed on both sides of the absorber. Convection heat loss due to wind blowing across the surface of the collector was reduced by the glass cover. It acts as barrier between the wind and absorber plate (**Figs. 2** and **3**). Eight such modules were required to meet the system heat demand. These modules were connected in series, and an axial flow fan was placed in the centre of the eight modules. The fan was employed to draw the hot air from the collector air-duct and force it to the drying chamber. An experimental study was conducted to measure the efficiency of these solar collectors in Nalkot, Swat and was found to be 44 % (Ahmad, 2001).

**Construction of Drying Chamber**

The drying chamber was designed into three tunnels (**Figs. 4a** and **4b**). An axial flow fan was employed to force the hot air from the solar collectors into the first tunnel, where the air stream was mixed and moved to the second tunnel. The chamber was designed and developed in such a way that it could easily accommodate four trolleys filled with fresh dates in the second and the third tunnels. The hot air moved over the dates, and became moist, and then the moist air escaped from the door at the end of the third tunnel. The drying chamber was constructed with ordinary bricks. Each trolley accommodated 34 trays, and each tray accommodated 4 to 5 kg of fresh dates. Hence, the drying chamber could accommodate about 544 kg to 600 kg of fresh dates during full load operation.

**Performance of Solar-cum-Gas Fired Dates Dryer**

The performance of the solar-cum-gas fired dates dryer was evaluated at Mitra Abad, Dhaki, D. I. Khan in August 2003 (**Fig. 5**). The key parameters measured were:

(i) ambient temperature, outlet temperature from the collectors(inlet temperature to the drying chamber), and outlet temperature from the drying chamber;
(ii) relative humidity of the ambient air, and relative humidity of the escaped air from the drying chamber;
(iii) moisture content of the dates before and after drying.

**Instrumentation and Methodology**

A T-type digital thermometer was used to measure ambient air temperature, outlet temperature from the collectors (inlet temperature of the drying chamber), and exit temperature from the drying chamber. However, the relative humidity of ambient and outlet air of the drying chamber was measured with "MANNIX" digital thermo hygrometer. The air mass flow rate was measured using a velometer. The measured air mass flow rate was 0.11 kg/s, through the solar collectors. The data were recorded manually from 8.30 A.M. to 10.30 P.M., with an interval of an hour. The heat for drying dates was generated from solar-cum-gas fired system from 8:30 A.M. to 11:30 A.M., then from solar system from 11:30 A.M. to 18:30 P.M., and then from gas fired system alone from 18:30 P.M. to 22:30 P.M. Data were recorded for 5 days (20/08/03 to 24/08/03), and then the average of these values were taken.

## Results and Discussion

**Table 1** shows the hour-by-hour

**Fig. 6** Plots of dry-bulb temperature against the hours of the day

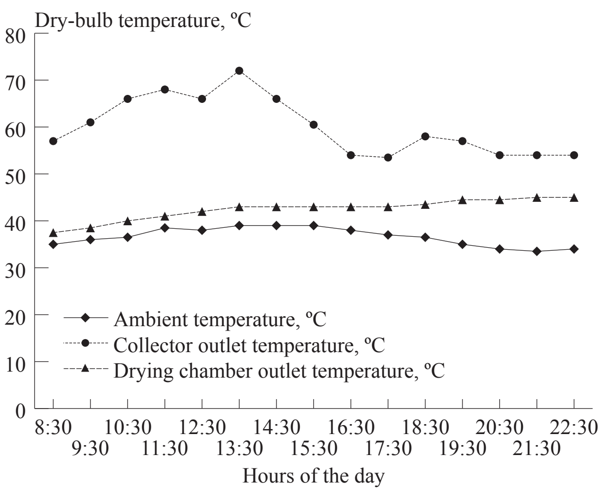
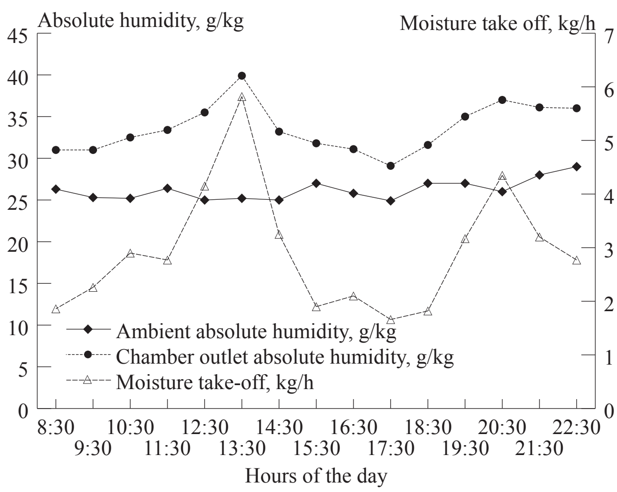



**Fig. 7** Plots of ambient and chamber outlet absolute humidity and moisture take-off against the hours of the day



ambient temperature, collector outlet temperature, drying chamber outlet temperature, ambient relative humidity and chamber outlet relative humidity. The plots of these data against hours of the day are presented in **Fig. 6**. When this data were taken, the drying chamber was loaded with 544 kg of dates. It can be seen from **Fig. 6** that at 8:30 A.M, ambient temperature was 35 ºC, which was raised to 39 ºC at 13:30 hours and then fell to 34 ºC at 22:30 hours. The collector outlet temperature at 8:30 A.M was 57 ºC, which was raised to 72 ºC at 13:30 hours. From 8:30 A.M to 11:30 A.M both solar and gas firing systems were in operation. From 11:30 A.M to 6:30 P.M only solar system was in operation. At 6:30 P.M. again the gas firing system was switched on that remained in operation till 10:30 P.M. At 10:30 P.M. the gas firing system was switched off, because the relative humidity of the ambient air increased to 80 %, consequently the drying rate was decreased. Hence, it was not favourable to run the dryer from 10:30 P.M. to 8:30 A.M. It is also clear from **Fig. 6** that the drying chamber temperature was 37.5 ºC at 8:30 A.M, 43 ºC at noon and 45 ºC in evening hours.

It can also be seen from **Table 1** that the relative humidity of the ambient air was 72 % at 8:30 A.M., which was decreased to 55 % in afternoon hours, and then again increased to above 80 % at 22:30 hrs. The chamber outlet relative humidity was 74 % at 8:30 AM, and it was about 56 % in afternoon and evening hours. On average, the ambient temperature during the test period was 36.5 ºC, the collector outlet temperature was 60.2 ºC, and drying chamber outlet temperature was 42.5 ºC. The average relative humidity of the ambient air, and chamber outlet air was 65.3 %, and 61.2 %, respectively during the test period.

**Table 2** shows the hour-by-hour ambient air absolute humidity, chamber outlet air absolute humidity, and moisture take off from the drying chamber. The average absolute humidity of the ambient air was 26.2 g/kg during the test period, whereas the average absolute humidity of the chamber outlet air was 33.61 g/kg. The average moisture removal was 2.93 kg of water/h. **Fig. 7** shows that at 8:30 A.M the moisture removal was 1.86 kg/h, it raises to 5.82 kg/h at 13:30 hours, and then decreased to 1.82 kg/h at 18:30 hours. At 18:30 hours, again, the gas firing system was switched on and the moisture removal increased to 3.17 kg/h. The air flow rate used in the calculations was 0.11 kg/s. The system was shutdown at 22:30 hours. During the test period (20/8/03, 21/8/03, 22/8/03, 23/8/03, and 24/8/03) the dryer was in operation for 75 hrs. This meant the moisture removal was 219.75 kg (75 hrs × 2.93 kg/hr). This moisture removal could be improved by insulating the inner side of the drying chamber. The final moisture content of the dried dates was about 22 to 24 %, at the end of the drying period.

**Table 3** Economics of solar-cum-gas fired dates drying system

| Cost parameters | Values |
|---|---|
| Purchasing cost (PRS) | 150,000 |
| Useful life (Years) | 20 |
| Salvage value (5 % of purchase price, PRS) | 7,500 |
| Annual fixed charges | |
| Depreciation (SLM) | 7,125 |
| Interest on average Investment (9 %) | 7,088 |
| Repair & maintenance cost (2 % of purchase price per annum) | 3,000 |
| Total annual fixed cost (PRS) | 17,213 |
| Annual dates drying capacity of the system (tons/year) | 4 |
| Fixed cost of dates drying (PRS/ ton) | 4,303 |
| Variable cost (PRS/ ton) [Labour charges etc] | |
| Electricity cost (24 kwh/ton, Rs 7/kwh) | 168 |
| LPG cost (40 kg/ton, Rs 40/kg LPG) | 1,600 |
| Labour cost (Rs/ton) | 1,500 |
| Total variable cost (PRS/ton) | 3,268 |
| Total (fixed + variable) cost of dates drying (PRS/ton) | 7,571 |
| Cost of one ton of fresh dates (PRS) | 15,000 |
| Cost of 0.58 ton of dried dates (PRS) | 40,600 |
| Value addition per ton of fresh dates | 18,029 |
| Value addition for 4 ton of (annual drying capacity) fresh dates (PRS) | 72,116 |

Sale price of the dried dates is assumed PRS 70,000/ton

## Economic Analysis of Solar-Cum-Gas Fired Dates Dryer

The economic analysis of the solar-cum-gas fired dates dryer is important, particularly for the dates processors and growers in order to understand the benefit they can gain by adopting this innovative technology. **Table 3** presents the economics of the solar-cum-gas fired dates dryer. The various assumptions and the input data to perform this economic analysis has already been presented (Ahmad and Mirani, 2005). The fixed and variable costs were predicted using the methodology given by Kepner et al. (1978). The purchase price of the new solar-cum-gas fired dates dryer was considered to be PRS 150,000/- and the useful life of the system was assumed 20 years based on our experience. It is revealed from **Table 3** that the total (fixed + variable) cost of drying one ton of fresh dates using solar-cum-gas fired dates dryer was PRS 7,571.

During the dates harvesting season, the cost of one tonne of fresh dates (dung doka) is about Rs. 15,000. After drying one tonne of fresh dates, only about 0.58 ton of dried dates can be obtained. The sale price of the 0.58 ton of dried dates is about PRS 40,600, by assuming the sale price of the dried dates as PRS 70,000/tonne. By deducting the cost of drying the one tonne of fresh dates (Rs. 7,571), and the cost of fresh dates from the sale price of the 0.58 tonne of the dried date, one can easily determine the value addition in one tonne of fresh dates. This comes around PRS 18,029/tonne. The seasonal drying capacity of the dryer is 4 tonnes. Hence, one may earn about PRS 72,116/season by adopting this technology.

## Conclusions and Recommendation

A solar-cum-gas fired dates dryer has been developed at the National Agricultural Research Centre, Islamabad. The experimental results indicated that about 544 kg fresh dates can be loaded in a batch. The dryer takes about 75 hours to dry these dates up to moisture content of 24 %. The dryer is normally operated from 8:30 AM to 10:30 PM, and 5 days are required to process one batch of dates up to the desired moisture content level.

The economic analysis revealed that the cost of drying dates using solar-cum-gas fired dates dryer is Rs. 7,571 per tonne, and one may earn Rs. 72,116 per season by adopting this dryer.

The solar-cum-gas fired dryer is suitable for on-farm dates drying, and there is a need to demonstrate and commercialize this technology in dates growing areas of Pakistan.

## REFERENCES


Ahmad, M. and A. S. Khan. 1997. Design and construction of solar grain and fruit drying system. Agricultural Mechanization in Asia, Africa, and Latin America. 28(4): 62-66.

Ahmad, M. 2001. Performance of solar fruit drying system. Journal of Engineering and Applied Sciences, July-December. 20(2): 45-52.

Ahmad, M. and A. A. Mirani 2005. Development and evaluation of a solar-cum-gas fired dates drying system. Research Report No. 01/2005. Farm Machinery Institute, National Agricultural Research Centre, Islamabad.

Anonymous 1965. How to make a solar cabinet dryer for agricultural produce. Do-it-yourself, Leaflet L 6, Brace Research Institute, Ste Anne de Bellevue, Canada: 9

Bajoi, A. H. 1996. Post harvest aspects of date cultivation in Baluchistan. In: Proceedings of the National Conference on Post harvest Technology of Horticultural Commodities (Edited by: W. A. Farooqi). Held at Quetta, September 10-12.

Esper, A., O. Hensel and W. Muhlbauer. 1994. PV-driven solar tunnel drier. Agricultural Engineering Conference, Bangkok, December: 6-9.

Excell, R. H. B. and S. Kornsakoo. 1978. A low cost solar rice dryer. Appropriate Technology, Vol. 5(1): 23-24.

Excell, R. H. B., S. Kornsakoo, and S. Thiratrakoolchai. 1979. A low cost solar rice dryer for farmers in south east Asia. Agricultural Mechanization in Asia. Autumn, 75-78.

Excell, R. H. B. 1980. Basic design theory for a simple solar rice dryer. Renewable Energy Review Journal. Vol. 1(2): 1-14.

Internet material. Whole dates, file://E:\Whole%20Dates.htm

Iqbal, M. 1996. Financial implications of post harvest losses in horticulture commodities in Pakistan. In: Proceedings of the National Conference on Post harvest Technology of Horticultural Commodities (Edited by: W. A. Farooqi). Held at Quetta, September 10-12.

Kepner, R. A., R. Bainer, and E. L. Barger. 1978. Principles of farm machinery. AVI publishing company, Inc. Westport, Connecticut.

Mastekbayeva, G. A., M. Augustusleon, and S. Kumar. 1998. Performance evaluation of a solar tunnel dryer for chilli drying. Paper presented at the ASEAN Seminar and Workshop on Drying Technology, held at Phitsanulok, Thailand, June 3-5.

New Mexico Solar Energy Association. 1978. How to build a solar crop dryer. Santa Fe, USA; NMSEA: 10

Parker, B. F., M. R. Lindley, D. G. Colliver, and W. E. Murphy. 1993. Thermal performance of three solar-air heaters. Solar energy. 51(6): 467-479.

Quraishi, M. A. A. and M. A. Zia 1997. Pakistan agricultural resources. A-one Publishers, Lahore.

Trim, D. S. 1982. Solar crop dryers. Presented at the Arab Conference on Solar Energy Utilization in Agriculture, at Amman, Jordan, December.

Verbal Communication with Professor Abdul Ghafoor, Department of Horticulture, Gomal University, D. I. Khan.


■■

# Formulation of Generalized Experimental Models for Double Roller Gin


by

P. G. Patil
Ph. D. Scholar (VNIT), Scientist (SG)
Central Institute for Research on Cotton Technology,
(Indian Council of Agricultural Research)
Nagpur - 440023
INDIA

P. M. Padole
Head and Professor
(Mech. Engg.)
Visveswaraya National Institute of Technology,
Nagpur - 440011
INDIA

J. F. Agrawal
Workshop Superindendent and Assistant Professor
(Prod. Engg.)
Yeshwantrao Chavan College of Engineering,
Nagpur - 441110
INDIA

A. B. Dahake
(Agric. Engg.)
Central Institute for Research on Cotton Technology,
Nagpur - 440023
INDIA



## Abstract

To optimize the processing parameters of double roller (DR) gin for cotton ginning, it was necessary to establish the generalized models. An experimental study on performance of machine was carried out to study the influence of leather roller speed, beater speed, seed cotton moisture on ginning rate, lint quality and power consumption during ginning. Seed cotton of different staple lengths and three levels of RPM of roller for two replications were utilized for the experiment. Experiments were conducted on an especially designed experimental setup, which recorded roller RPM, energy consumption and roller temperature. The highest roller speed of 120 RPM coupled with 7 % moisture content seed cotton showed highest ginning rate with maximum saving in electrical energy. The highest ginning rate and maximum energy saving were observed for higher staple length as compared to lower staple length. The ginning rate ranged from 8.37 to 15.75 g/m of roller length as the power requirement varied from 2,577 to 3984 W, respectively. Roller surface temperature rise due to frictional heating was -in the range of 0.5 to 19.6 ºC. According to Duncan's Multiple Range Test ($p > 0.05$), process parameters (roller and beater speed) and moisture content of cotton did not significantly affect lint quality like 2.5 % span length, micronaire, fibre tenacity, uniformity ratio, maturity ratio, short fibre content, neps and seed coat neps. Generalized experimental models for power, roller temperature, staple length and ginning percentage were developed using MATLAB and were validated using students t-test.



**Acknowledgements:** The authors would like to acknowledge Dr. S. Sreenivasan, Director and Dr. K. M. Paralikar, Central Institute for Research on Cotton Technology (ICAR), Govt. of India for providing facilities in our experiments. The authors would also like to acknowledge Bajaj Steel Industries Ltd., Nagpur 440018, India for their help in experimentation.


## Introduction

Ginning is the process by which seed cotton is separated into lint (fibres) and seed and the machine used for its separation is called a ginning machine. Thus, ginning is the first engineering activity that cotton undergoes on its way from cotton field to textile mills. The gin stand is the heart of the ginning plant (Wright et al., 1977). Most of major cotton producing countries like the USA, China, Uzbekistan and Australia use saw gins for ginning the cotton. In India, the third largest producer of cotton in the world, the double roller gin was used for 3.3 million tones of fiber in 2004-2005 (80 % of the total cotton production). Ginning rate in the DR gin is far less than in the saw gin but it is far gentler to the fibre and preserves the quality of lint as compared to the saw gin. However, the slow ginning rate of the roller gin has made it expensive to maintain and operate. A technical survey (Cotton Ginning and Pressing Factories in India: A Census Based Techno-Economic study, 2003) revealed that 43,585 ginning machines (4,245 single roller gin stands, 38286 double roller gin stands, and 1,054 saw gin stands) are presently working in India. The rotary knife roller gin is not used in India.

The process of ginning cotton is a complex phenomenon. In a double roller gin, two spirally grooved leather rollers, pressed against a fixed knife (stationary knife) with the help of adjustable dead loads, are made to rotate in opposite directions at a specific speed. The three beater arms are inserted in the beater shaft and two knives are then fixed to the beater arms with proper alignment. This is known as beater or moving knife, which oscillates by means of a crank or eccentric shaft, close to the leather roller. When the seed cotton is fed to the machine in action, fibres adhere to the rough surface of the roller and are carried in between the fixed knife and the roller such that the fibres are partially gripped between them. The oscillating knives beat the seeds from top and separate the fibres, which are gripped from the seed end. This process is repeated a number of times and the fibres are separated from the seeds, carried forward on the roller and dropped out of the machine. The ginned seeds drop down through the slots provided on the seed grid that is part of the beater assembly, which also oscillates along with the moving knife.

The ginning performance in the DR gin depends on the length and diameter of roller, speed of roller, beater oscillations per second, initial staple length and moisture content, which are all considered as independent variables. Power required for ginning, lint output, quality of lint, roller temperature and ginning percentage are the dependent variables. Indian double roller ginning machines are operated at a roller speed of 100 RPM. Very few data are available on performance of the double roller gin with reference to factors such as roller RPM, variety (type) of cotton and moisture content of cotton. To optimize the processing parameters in the double roller ginning machine, extensive experimentation is essential. This study will also help generate design data for a more efficient machine. The main objective of this research is to optimize the process parameters to improve the design of the DR gin and establish approximate generalized models for estimation of important design parameters. The approach proposed by Schenck (1961) is used for planning and execution of experiment and data is validated by students t-test and Duncan's multiple range test (DMRT) to check its significance.

**Fig. 1** Battery of DR gins in factory and experimental set up

## Review of Literature

Leonard and Gillum (1974) studied the effect of fibre moisture on rotary knife roller gin having 1016 mm (40 inch) wide and 381 mm (15 inch) diameter of roller and found that that the optimum range of fibre moisture content for roller ginning and lint cleaning ranged from 5 to 6 percent. Johnson et al. (1977) studied the ginning performance by varying the crank and roller speeds on Pima and SXP varieties on a 1016 mm (40 inch) roller gin. The study revealed that by increasing the speed of the crank from 650 to 840 revolutions per minute (29 %), the amount of lint ginned per hour increased from 18.2 to 22 kg (i.e. 40 to 48.3 pounds) (21 %). It was further revealed that

**Table 1** Test range, test points and test sequence

| Independent variable | Test envelope | Test points | Test sequence | |
|---|---|---|---|---|
| | | | Level 1 | Level 2 |
| Roller length, 1,360 mm | Constant | Constant | Constant | Constant |
| Roller speed (RPM) | 80 to 100 | 80, 100, 120 | 2, 3, 1 | 2, 3, 1 |
| Beater speed (OPM) | 800 to 1200 | 800, 1000, 1200 | 2, 3, 1 | 2, 3, 1 |
| Roller diameter (Chrome leather) | 170 mm | 170 mm | Constant | Constant |
| Staple length | Constant | Constant | 1, 2, 3 | 1, 2, 3 |
| Moisture, % | 5 to 9 | 5, 7, 9 | 3, 1, 2 | 1, 3, 2 |
| Roller-stationery knife pressure, 10.5 kN/m$^2$ | Constant | Constant | Constant | Constant |
| Acceleration due to gravity, 9.81 m/s$^2$ | Constant | Constant | Constant | Constant |
| Moment of inertia, 0.9735 kg/m$^2$ | Constant | Constant | Constant | Constant |

by increasing the speed of the roller from 110 to 150 revolutions per minute (36 %), the amount of lint ginned per hour was stepped up from 18.8 to 22.5 kg (41.5 to 49.5 pounds) (19 %). The staple length of cotton was not affected by increasing the roller speed and indicated differences in grade steps were insignificant. Gillum (1974) studied performance of different roller gin covering materials and found that for walrus leather roller, power in watts per inch (25.4 mm) length of roller required to drive roller while ginning and not ginning was 33.5 and 35 W/inch, respectively.

Agrawal et al. (2005) studied the effect of moisture content and weight of cotton on force of compression of lint cotton on mechanical press, which is the need of cotton ginnery to decentralized ginning and pressing industry. Schenck (1961) methodology has been used for developing experimental models for force of compression using MATLAB and further was checked using ANN software. Models were validated using students t-test.

## Materials and Methods

### Identification of Variables

The independent variables of process were roller RPM (ν), roller-stationary knife pressure (P), beater oscillations per second (ω), roller length (L) and diameter (D), variety (Lh), moisture content (M), total moment of inertia of mechanical power transmission system (MI), acceleration due to gravity (g) and instantaneous roller temperature (Tr). The dependent variables were power required for ginning (W), ginning percentage (GP), roller temperature (T) and quality of lint (Ls). The extraneous variables were the voltage fluctuations during the test, small errors in gear train of power transmission system because of wear and an error of instrumentation because of warming up of electric motor.

Unless all independent variables were varied over the widest possible range during experimentation, the developed model was not a generalized one (Schenck, 1961). Some of these independent variables could not be varied during the experimentation because of time and expense. Hence, some of the independent parameters remained constant like roller length, roller diameter, roller-stationary knife pressure, total moment of inertia of mechanical power transmission system and acceleration due to gravity. Thus, models were approximate generalized models.

### Dimensional Equations

The dimensional equations for dependent variables were established as given below:

$$\log_{10}(W\omega^2/P\nu^3) = a + b\ \log_{10}(L\omega/\nu) + c\ \log_{10}(D\omega/\nu) + f\ \log_{10}(Lh\omega/\nu) + g\ \log_{10} M + h\ \log_{10}(I\omega^5/P\nu^3) + i\ \log_{10}(g/\omega\nu) \quad \text{.........................(1)}$$

$$\log_{10}(Tr/T) = a + b\ \log_{10}(L\omega/\nu) +$$

**Fig. 2** Roller speed vs electric units

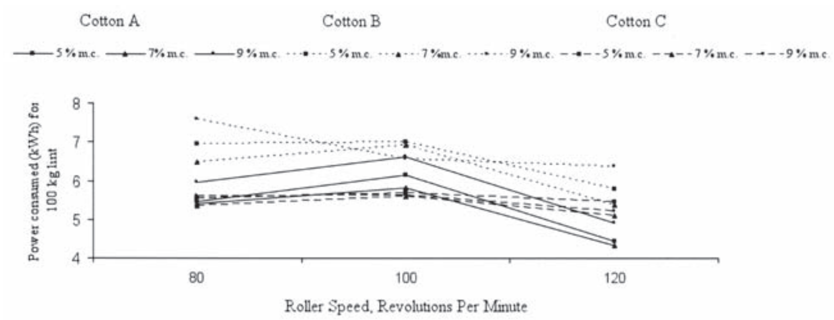



**Table 2** Double roller gin lint output, power requirement and lint quality data

| Roller RPM | Lint output*, kg/h | Power requirement* kWh for ginning 100 kg lint | 2.5 % SL*, mm | UR*, % | MIC* | Tenacity*, g/tex | NEPS*, cnt/gm | SCN*, cnt/gm | MR* | IFC*, % |
|---|---|---|---|---|---|---|---|---|---|---|
| **Cotton A** | | | | | | | | | | |
| 80 | 45.1 a | 5.617 a | 30.27 a | 47.8 a | 3.9 a | 23.4 a | 141.3 a | 32.8 a | 0.84 a | 8.2 a |
| 100 | 52.5 b | 6.205 b | 30.25 a | 47.3 a | 4.0 a | 22.9 a | 164.5 a | 33.5 a | 0.83 a | 8.7 a |
| 120 | 86.2 c | 4.573 c | 30.35 a | 48.0 a | 4.1 a | 23.7 a | 138.3 a | 37.0 a | 0.84 a | 8.4 a |
| **Cotton B** | | | | | | | | | | |
| 80 | 36.5 a | 7.00 a | 30.5 a | 47.8 a | 3.9 a | 24.7 a | 104.0 b | 33.8 a | 0.89 a | 6.8 a |
| 100 | 45.8 b | 6.96 a | 30.6 a | 47.3 a | 3.9 a | 24.3 a | 119.2 a, b | 51.8 a | 0.89 a | 6.6 a |
| 120 | 68.2 c | 5.85 b | 30.4 a | 48.2 a | 4.0 a | 24.2 a | 138.8 a | 57.3 a | 0.89 a | 6.7 a |
| **Cotton C** | | | | | | | | | | |
| 80 | 48.2 a | 5.512 a | 23.5 a | 47.8 a | 5.5 a | 16.2 a | 90.7 a | 12.0 a | 0.92 a | 5.8 a |
| 100 | 60.6 b | 5.642 a | 23.7 a | 47.3 a | 5.5 a | 15.7 a | 88.7 a | 14.6 a | 0.92 a | 5.8 a |
| 120 | 76.6 c | 5.257 a | 23.9 a | 48.2 a | 5.6 a | 15.8 a | 84.3 a | 11.2 a | 0.92 a | 5.6 a |

* Means with the same letter not significantly different based on Duncan's Multiple Range Test at 5 % significance level
+ Based on 5 set of measurements of two replications and three moisture contents

$c \log_{10}(D\omega / \nu) + d \log_{10}(Lh\omega / \nu) + g \log_{10} M + h \log_{10}(I\omega^5 / P\nu^3) + i \log_{10}(g / \omega\nu)$ ..............................(2)

$\log_{10}(Ls\omega / \nu) = a + b \log_{10}(L\omega / \nu) + c \log_{10}(D\omega / \nu) + f \log_{10}(Lh\omega / \nu) + g \log_{10} M + h \log_{10}(I\omega^5 / P\nu^3) + i \log_{10}(g / \omega\nu)$ ..........................(3)

$\log_{10}(GP) = a + b \log_{10}(L\omega / \nu) + c \log_{10}(D\omega / \nu) + f \log_{10}(Lh\omega / \nu) + g \log_{10} M + h \log_{10} (I\omega^5/ P\nu^3) + i \log_{10}(g / \omega\nu)$ ................................(4)

where a, b, c, f, g, h and i are constants and were to be determined by MATLAB.

### Test Planning

Test envelope, test points and test sequence were decided on the basis of some of the known ranges of variation of some of the independent variables and are shown in **Table 1**.

### Experimental Set Up

The laboratory experimental set up was specially designed to conduct experimentation (**Fig. 1**). The desired speed of roller was achieved by A.C. drive (X 4 C 40 100 C 1 P 66, 10 hp, Input volts: 380 − 460 ± 15 %, Input Ampere: 19.7/16.3, Output volts: 0 - 380/460, 3 phase, Output Ampere: 15.6/14 A) by varying frequency. The temperature of the roller was recorded by temperature sensors (DS 1621, Dallas calibrated).

Roller RPM was measured by 1 R slot sensor and recorded. The power input of the machine was measured by a specially designed system interface with computer through an analog digital card (20 A. 100 mA current transformer). The required hardware like V potential transformer, current transformer, temperature sensor and software for interfacing were prepared. The experimentation was conducted as per test plan. Measurements were made at 1.4 seconds interval. The measurements made during the first 200 seconds were discarded to avoid non-equilibrium temperature of roller results.

Important fibre properties such as 2.5 % span length, micronaire, fibre tenacity and uniformity ratio were determined using High Volume Instrument HVI-900 of Uster Technologies (Switzerland), and maturity ratio, short fibre content, neps and seed coat neps were determined using the Advanced Fiber Instrumentation system (AFIS) of Uster Technologies. All these tests were performed at standard conditions of humidity and temperature (65 ± 2 % RH and 27 ± 2 ºC). The ginning rate (g/m/s) was obtained by dividing the quotient of lint weight and roller length by the ginning time.

### Conduct of Experiment

Different levels of fibre moisture content were obtained by moisture conditioning the seed cotton before it was ginned. The fibre moisture content at the time of ginning was intentionally varied to determine its effect upon the roller gin operation and lint quality. Seed cottons of different staple lengths (Cotton A: 29.1-31.8 mm, Cotton B: 30-31 mm and Cotton C: 23-24 mm) were subjected to three levels of revolutions per minute (RPM) of roller (80, 100, and 120) and three levels of moisture contents (5, 7 and 9 %). However, it may be noted that the ratio of roller RPM and beater oscillations per minute (OPM) remained constant at 1:10. The tests were conducted and

**Fig. 3** Roller speed vs lint output

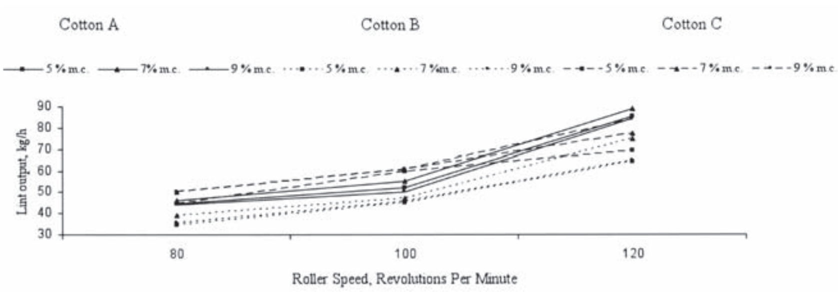



**Table 3** Model values and experimental values for the dependent pi terms

| Roller RPM | Power, $W\omega^2/P\nu^3$ | | Temperature, Tr/T | | Staple length, $Ls\omega/\nu$ | | Ginning percentage, GP | |
|---|---|---|---|---|---|---|---|---|
| | Model Value | Experimental value | Model Value | Experimental value | Model Value | Experimental value | Model Value | Experimental value |
| **Cotton A** | | | | | | | | |
| 80 | 118.2 | 117.9 | 1.0376 | 1.0238 | 0.12536 | 0.56836 | 35.9455 | 36.0166 |
| 100 | 119.6 | 120.2 | 1.0422 | 1.0227 | 0.78978 | 0.56490 | 35.9098 | 35.9833 |
| 120 | 120.8 | 120.8 | 1.0391 | 1.0205 | 2.83081 | 0.56728 | 35.8685 | 35.9833 |
| **Cotton B** | | | | | | | | |
| 80 | 118.0 | 118.9 | 1.0371 | 1.0421 | 0.12369 | 0.52276 | 36.0920 | 36.0166 |
| 100 | 119.5 | 118.0 | 1.0418 | 1.0504 | 0.78036 | 0.57366 | 36.0422 | 35.9833 |
| 120 | 120.7 | 121.9 | 1.0387 | 1.0546 | 2.79695 | 0.56915 | 36.0012 | 35.9833 |
| **Cotton C** | | | | | | | | |
| 80 | 122.5 | 122.0 | 1.0424 | 1.0420 | 0.18296 | 0.44156 | 32.0130 | 31.9833 |
| 100 | 123.9 | 126.3 | 1.0561 | 1.1075 | 1.15201 | 0.44410 | 31.9871 | 31.9 |
| 120 | 125.3 | 123.8 | 1.0529 | 1.0672 | 4.1320 | 0.44650 | 31.9436 | 31.9666 |

analyzed as completely randomized design replicated two times. In all, 54 experiments were conducted to ensure an adequate response in ginning rate, power consumption and quality of lint. A lot of 20 kg of seed cotton was used in each ginning trial. The crops were raised in selected farmers' fields. The seed cotton was not processed through mechanical pre-cleaner, but was carefully hand opened and cleaned before ginning.

The gin machine adjustments were made according to the manufacturer's specification (Spare parts Catalogue and Operating Instructions, 2005, M/s Bajaj Steel Industries Ltd., Nagpur, India). The edges of the fixed knife were set to 85 mm from the seat on the knife rail throughout. The moving knife was set parallel to the fixed knife throughout at a distance 1.5 mm to 2 mm. The selection of seed grid was important in double roller gins. The grid slots should be slightly bigger than the seed size. Seed size was calculated by formula (Mohsenin, 1978) as seed size = (length × breadth × thickness)$^{1/3}$. Seed size for cotton A, cotton B, and cotton C was 5.8, 6.4 and 5 mm, respectively, and grid sizes selected as 7.1, 7.1 and 6.3 mm, respectively.

## Results and Discussion

The important parameter that influences the ginning rate and electrical power consumption in ginning is the speed of rotating roller. The effect of roller speed with different moisture contents on ginning rate and electrical power consumption is shown in **Figs. 2** and **3**, respectively.

Lint output, power requirement, quality parameters like 2.5 % SL, UR, micronaire, tenacity, neps, SCN, MR and IFC are presented in **Table 2**. There was a significant difference in lint output in kg/h with the increase in roller RPM for all types of cottons. Power requirement in kWh for ginning 100 kg lint varied significantly with roller RPM for long staple (30 mm) cotton like cotton A and B but for short staple (24mm) cotton C, difference in power requirement was not significant between roller RPMs. Duncan's Multiple Range Test ($p > 0.05$) on HVI and AFIS data showed no significant difference among three RPMs. However, difference between cottons were common in HVI and AFIS results.

### Computer Simulation and Derivation of Experimental Model and Its Validation

Based on the observations, the constants for the dimensional equations for dependent variables were identified from MATLAB. The experimental models developed are given in equations (5) to (8) are as follows:

$$\log_{10}(W\omega^2 / P\nu^3) = 0.44754 + 1.34 \log_{10}(L\omega / \nu) + 2.7827 \log_{10}(D\omega / \nu) - 0.15084 \log_{10}(Lh\omega / \nu) + 0.13614 \log_{10} M - 0.594 \log_{10}(I\omega^5 / P\nu^3) - 0.6301 \log_{10}(g / \omega\nu) \quad .....(5)$$

$$\log_{10}(Tr / T) = 5.0939 - 3.4142 \log_{10}(L\omega / \nu) - 24.511 \log_{10}(D\omega / \nu) - 0.055411 \log_{10}(Lh\omega / \nu) - 0.061772 \log_{10} M + 3.9804 \log_{10}(I\omega^5 / P\nu^3) + 4.046 \log_{10}(g / \omega\nu) \quad .....(6)$$

$$\log_{10}(Ls\omega / \nu) = - 443.54 + 531.92 \log_{10}(L\omega / \nu) - 1461.3 \log_{10}(D\omega / \nu) - 1.5889 \log_{10}(Lh\omega / \nu) - 3.6245 \log_{10} M + 142.29 \log_{10}(I\omega^5 / P\nu^3) + 140.51 \log_{10}(g / \omega\nu) \quad .....(7)$$

$$\log_{10}(GP) = 1.7332 - 0.54012 \log_{10} (L\omega / \nu) - 2.908 \log_{10}(D\omega / \nu) + 0.48691 - \log_{10}(Lh\omega / \nu) - 0.0083231 \log_{10} M + 0.711 \log_{10}(I\omega^5 / P\nu^3) + 0.71424 \log_{10}(g / \omega\nu) \quad .....(8)$$

Equations (5) to (8) are approximate generalized models. Model values and experimental values for the dependent pi terms are given in Table 3. Model values for power, ginning percentage, roller temperature and staple length were in close proximity of experimental values.

Each set of data for ginning cotton for roller RPM 80 to 120 and moisture content in the range of 5 to 9 % was subjected to two-tailed students t-test with null hypothesis and the fit between the experimental data and model value was excel-

**Table 4** Results of students t-test for ginning cotton

| Roller RPM | Estimated t-test value | | | | Standard tabulated t-values for two-tailed test at 5 % SL | Degrees of freedom |
|---|---|---|---|---|---|---|
| | Power | Temp | Staple | GP | | |
| **Cotton A** | | | | | | |
| 80 | -0.12095 | -1.2746 | 2.1739 | 0.83794 | 2.571 | 5 |
| 100 | 0.24925 | -1.8725 | -0.73425 | 1.1354 | 2.571 | 5 |
| 120 | -0.04883 | -1.7054 | -1.5666 | 1.6098 | 2.571 | 5 |
| **Cotton B** | | | | | | |
| 80 | 0.42761 | 0.42948 | 2.1742 | -0.87987 | 2.571 | 5 |
| 100 | -0.51335 | 0.45845 | -0.6904 | -0.80686 | 2.571 | 5 |
| 120 | 0.53714 | 0.87519 | -1.5695 | -0.25986 | 2.571 | 5 |
| **Cotton C** | | | | | | |
| 80 | 0.21217 | -1.2114 | 1.9115 | -0.87442 | 2.571 | 5 |
| 100 | 0.76302 | 1.0332 | -1.3508 | -1.7529 | 2.571 | 5 |
| 120 | -0.48211 | 0.60589 | -1.6556 | 0.31027 | 2.571 | 5 |

lent. The estimated t values for each set of data were within the range of standard tabulated values of t at 5 % level of significance and corresponding degrees of freedom as shown in **Table 4**.

## Conclusions

An experimental database and approximate generalized models for power, ginning percentage, roller temperature and staple length were obtained. Model values for power, ginning percentage, roller temperature and staple length were in close proximity to experimental values. The models were approximate generalized and standard tabulated student's test t-values of for two-tailed test at 5 % significance level were higher than the estimated t-values, hence models developed showed good results. Duncan's Multiple Range Test for lint output showed that there was a significant increase in output with increase in roller RPM. Power requirement varied significantly with roller RPM for long staple (30 mm) cotton like cotton A and B. For short staple (24 mm) cotton C, power requirement did not vary much with roller RPMs. DMRT ($p > 0.05$) for lint quality parameters showed that quality was not affected by increasing the roller (120 RPM) and beater speed (1200 oscillations per minute) to attain higher ginning rate.

## REFERENCES


Agrawal J. F., R. D. Askhedkar, P. M. Padole, J. P. Modak. 2003. Formulation of generalized experimental model for compressing lint cotton to form a bale with a view to generate design data for mechanical press. INCARF 2003, IIT Delhi, Paper No. 228, Technical Session IV B.

Agrawal, J. F., S. L. Pandharipande, R. D. Askhedkar, P. M. Padole. 2006. Modeling of Compression of Lint Cotton to Form a Bale Using Artificial Neural Network. Paper shortly publishing in International Journal of Advances in Modeling and simulation techniques in enterprises, France.

Johnson, Arvind J., J. S. Townsend, T. C. Walton. 1977. American-Egyptian Cotton Quality and Ginning, U. S. Department of Agriculture, Agriculture Handbook, 503.

Cotton Ginning and Pressing Factories in India, A Census Based Techno-Economic study. 2003. Textiles Committee, Ministry of Textiles, India. 39.

Gillum, M. N. 1974. Properties of Roller Gin Roller Covering Materials, U. S. Department of Agriculture, Technical Bulletin No.1490, 13.

Schenck H. Jr. 1961. Theories of Engineering Experimentation" McGrew Hill Book Co., New York.

Leonard C. G. and M. N. Gillum. 1974. Effect of Fiber Moisture on Roller Ginning, Ginner' Journal & Yearbook, 40-46.

Mohsenin, N. N. 1978. Physical properties of plant and animal materials. Gorden and Breach Science Publishers. Second Edition, New York.

Spare parts Catalogue and Operating Instructions. 2005. Bajaj Steel Industries Ltd., Nagpur, India.

Wright, J .E. and V. P. Moore. 1977. Gin stands. In Cotton Ginners Handbook. U .S. Department of Agriculture, Agriculture Handbook 503, 29-35.


■■

# Preservation and Storage of Perishable Fresh Fruits and Vegetables in the Lowlands of Papua New Guinea

by
Surya Nath
Associate Professor
Department of Agriculture
PNG University of Technology
Private Mail Bag
LAE
Papua New Guinea

Simon Sil
Ex-Post Graduate Student
Department of Agriculture
PNG University of Technology
Private Mail Bag
LAE
Papua New Guinea

## Abstract

The temperature and humidity is very high in most part of the country except in the highlands. As a result vegetables and fruit loose their freshness very quickly. An evaporative cooling system, (ECS) was developed at the Agriculture Department of the Papua New Guinea University of Technology, Lae, which is very humid with high temperature throughout the year. Three kinds of fruits namely pawpaw, banana and oranges and other vegetables like cabbage, broccoli and lettuce were stored in the ECS and subjective measurements were taken.

Chemical analysis were conducted in the lab on the stored produce to determine vitamin A and C.

The self-life of cabbage was observed to be nine days while broccoli and lettuce maintained their shelf life for four and five days, respectively. For the samples left outside at the prevailing ambient condition, cabbage remained good for four days and broccoli and lettuce for two and three days, respectively. The ECS system maintained 2 to 5 ºC lower temperature compared to the outside temperature. A regression analysis showed that as the independent variable increased, the shelf life of the produce stored in the ECS was reduced. When the temperature in the model was increased to a higher level, it gave a negative value. This meant that at that temperature produce will loose its marketable value. The same was true for humidity. It was anticipated that if this technology was applied in rural areas at a larger scale, it would go a long way in enhancing the shelf life of fruits and vegetables in the lowlands of Papua New Guinea.

## Introduction

The production of fruits and vegetables has been continuously increasing in the lowlands of Papua New Guinea. The losses during post harvest operations both at the village and commercial level are extremely high in case of perishable products. The production of fruits and vegetables suffers from severe handicaps including poor harvesting and handling, transport, storage and marketing. The cultivation of fresh fruits and vegetables is labour intensive in PNG but quite remunerative for small and marginal farmers. Storage facilities at rural farmer level is nonexistent in PNG; however, if it is made available, the farmer will soon have capacity to avoid distress sale of the commodities immediately after harvest.

If the losses are reduced, more commodities will be available in the market and consumers will pay less for the same commodity. Debney, (1980) pointed out that a partial alternative to increased agricultural production as a means of increasing food availability is provided by improved storage and conservation leading to reduced post harvest loss. According to FAO (1988) the post harvest losses in fresh fruits and vegetables among developing countries stands at 70 percent. Hence,strategy for preservation and storage of perishables has to be evolved so that all the farmers can reap the benefits.

**Acknowledgements**: Numerous individuals have helped in their own way to make this project a success and they need special mention. First of all, Australian Centre for International Agricultural Research, (ACIAR) in collaboration with Professor Barry Nortan of the University of Queensland of Australia is thanked for the financial support without which this project would have not been undertaken. The sympathetic attitude and constructive advice of Professor Abdul Halim warrant special mention. Special thanks are also due to Mr. Cliff Wep and Mr. Kepo Yari of Lae Technical College for their help in the construction of the evaporative cooling system. Finally thanks are also due to Ms. Geraldine Kapipi for typing the manuscript and Mr. Frank Vidinamo for editing the Figures.

As a result, research funded by the ACIAR (Australian Centre for International Agricultural Research) in collaboration with the University of Queensland and the University of Technology, LAE was undertaken in the agriculture department of the University of Technology, LAE, Papua New Guinea.

A small-scale evaporative cooling system was developed with 1 $m^3$ space available for storage. The evaporative cooling system consisted of two brick-walls separated by a column of normal sand on which water was continuously sprinkled so that it provided cooling effect inside the chamber. The cover of this structure was made of thatch so that cross ventilation helped lower the temperature inside the chamber. Wooden racks were fitted in the chamber on which baskets of fruits and vegetable were stored. Pawpaw, banana, orange, cabbage, broccoli and lettuce were the subjects of studies. Banana and pawpaw stored very well for seven days whereas orange stored up to nine days. Similarly, broccoli and lettuce stored well for only four and five days, respectively. Cabbage stored up to nine days. The vegetables kept outside as control lasted only for two days. This showed that the evaporative cooling system worked and, if this technology is spread among villagers, it would go a long way in improving the well being of rural farmers in the low lands of Papua New Guinea.

## Review of Literature

Fruits and vegetables are important sources of essential minerals and vitamins in the human diet. Vegetables and fruits a contain significant amount of calcium, iron and some other minerals. Vitamins are essential for the control of chemical reactions in the body. Fruits and vegetables play major role in Papua New Guinea because subsistence farmers can trade it for other substances which they do not have. This, in turn, improves their living standards and nutritional status of children and people (FAO, 1988). The government of Papua New Guinea established a Food Marketing Corporation in 1976 where in the producers wishing to sell fruits and vegetables were helped by improving the market facilities in urban centres. Now, it has been replaced by the Fresh Produce Development Agency.

Mechanical damage during harvesting and handling can result in defects on the produce and permit invasion of microorganism causing diseases (Friedman, 1960). Produce can overheat and rapidly deteriorate during temporary storage. According to Jenny (2000) failure to sort or discard immature, overripe, undersized, misshapen, blemished or otherwise damage produce creates problem in the subsequent handling and marketing of the produce. The harvested produce, if transported on bumpy roads, will be bruised due to shaking action. The produce may become overheated at high temperature if there is inadequate shade, ventilation and cooling (Irving, 1984).

Poor control of storage conditions, storage for too long and inappropriate storage conditions for a particular commodity will also result in a poor quality product (Kalman Peleg, 1985). Fruits and vegetables are living biological systems and they deteriorate after harvest. The rate of deterioration varies greatly between individual produce depending on their overall rate of metabolism (Kader et al., 1985). On the other hand, many volatile compounds evolved by the produce may accumulate in the storage atmosphere. Janet and Richard (2000) stated that ethylene is the most important of these compounds and its accumulation above a certain critical level may reduce storage life.

Therefore, it is important to avoid storing sensitive produce with those producing high level of ethylene (Jones and Moody, 1993).

**Fig. 1** Evaporative cooling system storage facility

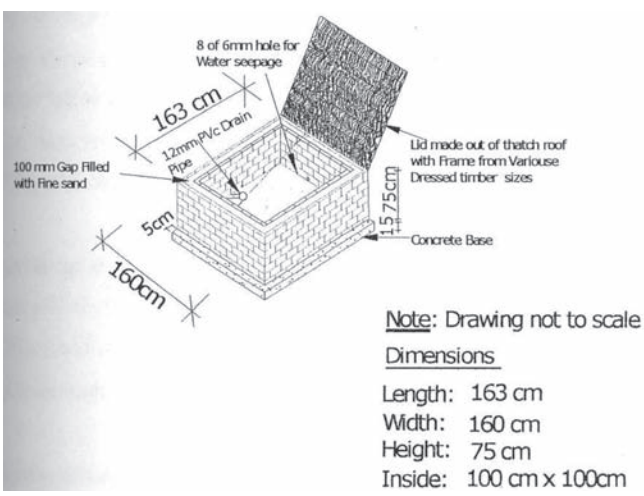
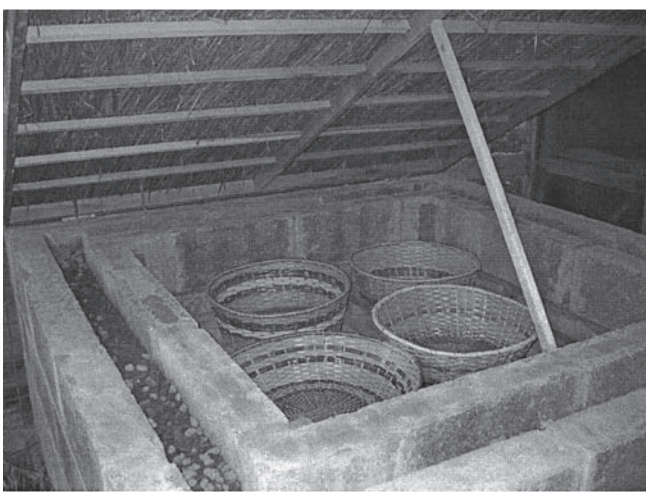



**Fig. 2** The lid made of impereta cylinderica and gap filled with sand



Temperature management is one of the most important factors affecting the quality of fresh produce. There is an optimum storage temperature for all products. The ideal temperature often depends on the geographical origin of the product. Most fruits from tropical regions must be stored above 12 ºC (Jenny, 2000). Another important factor in the storage of fresh fruit and vegetables is the humidity. The relative humidity in storage facility should be kept at 90 to 100 % although maintaining high humidity close to 100% may cause excessive growth of micro-organisms. As the temperature is lowered, the required concentration of oxygen is also reduced. The addition of a few percent of carbon dioxide to the storage system can have a marked effect on respiration of the stored product. Hardenburg, et al. (1986) reported that post harvest handling is the final stage in the process of producing high quality fresh produce, thus, the required type of storage could reduce high losses of fresh produce.

Evaporative cooling is a very economical way to store fresh fruits and vegetables in PNG conditions. This method is not very costly and is easy to manage. A well designed evaporative cooler produces air with a relative humidity greater than 90 percent (Thompson, 1996). Its main limitation is that it cools air only to the wet bulb temperature of the outside air. Quality is an increasingly important factor in the production and marketing of fresh fruits and vegetables. The limit to which an evaporative cooling system can maintain the quality of product is a matter of concern because quality assessment is very subjective and depends on the individual's viewpoint and preferences. According to the ISO 1900 standard, quality is defined as the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs. Kader (1985) defines it for fruits and vegetables as the combination of attributes or properties that give them value in terms of human food. Eating quality can be assessed most accurately by using taste panels, which consist of a selection of customers who are trained to assess the quality attribute being examined.

Bakker-Arkema (1999) outlined that the post harvest loss or wastage can be controlled by cultural methods. No post harvest treatments or miracle chemical exist which can overcome inferior quality resulting from poor production practices or improper handling. Quality and condition of fresh fruits and vegetables are major factors in market inspector's determination of grades and standards. Bruising is a major component of these factors. The key to damage reduction is simply TLC, tender loving care (Jenny, 2000). PNG's post harvest industry has several constraints. Among others, wide economic gaps between farmers and businessmen has significantly placed a large division among the rich and poor in Papua New Guinea. Information on improved technologies is not usually available to small farmers resulting in non-adoption of profitable practices in PNG.

## Materials and Methods

The evaporative cooling system was built inside the screen house of the department of agriculture, University of Technology, Lae which has an elevation of 65 m above mean sea level. The screen house had transparent plastic roofing and sidewalls made of arch mesh wire and black shade cloth to allow air ventilation. The experiment was conducted during 2005 when the produce was harvested. The storage facility was built with interior and exterior walls made of concrete blocks. The base of the storage was made of concrete and the interior dimensions were such that it had approximately 1 $m^3$ volume. The gap between the exterior and interior walls was filled with ordinary sand, which was kept wet by spraying water. The dimensions are shown in **Fig. 1** and interior in **Fig. 2**. Six-inch nail size holes were made at the base of the four interior walls for water to seep on the base floor of the storage area. A PVC pipe was laid at the base for draining excess water. There were two shelves made of dressed timber on which baskets full of produce were kept. The roof was made of a timber frame covered with Kunai grass (Imperata cylinderica) which provided good ventilation.

The samples of fruits and vegetables were sprinkled with water and were allowed to cool for two hours before placing them in the basket inside the cooling system. The inside chamber was disinfected before samples were placed inside. The wet and dry bulb thermometers were placed inside and outside the storage structure. The initial weight and subjective measurements were recorded. Temperatures were recorded at 9:00 AM and 3:00 PM on a daily basis and at 3:00 PM their weight loss and physical changes were recorded until they reached their termination point. Chemical analyses of Vitamin A and C of each of the fruit and vegetable samples were made in the laboratory before and after the storage in order to compare the vitamin A and C content of the stored samples to that of fresh samples. A regression analysis was made of the cumulative weight loss of each of the stored samples. The coefficient and intercept values from the analysed data were used to identify the expected shelf life of the samples. Thereafter, these values were substituted in the model, $Y = a + bx$, to estimate the effect of independent variables on the shelf life of each sample stored. The notations in the model are:

y = expressed in days (product)
a = intercept, b = coefficient, and
x = independent variable to mea-

sure.

## Results and Discussion

Subjective measurements: The evaporative cooling system, ECS, storage facility gave significant results on the storage of perishable fresh fruits and vegetables. The environment, degree of freshness, mode of post harvest handling and bacterial and fungal infections had a significant influence on the shelf life and Vitamin A and C. Each produce sample lost different amounts of weight at different days while in storage (**Table 1**).

Pawpaw stored well for seven days with a daily percentage weight loss of 0.38, 1.9, 2.3, 3.9, 4.2 and 5.4 %. Bananas were also stored for seven days with a percentage weight loss of 3.3, 4.4 5.6 and 6.7 % and oranges stored for nine days with a relative percentage weight loss of 10.8 % in the third day and 11, 11.5, 12.5, 11,10 and 11 %. Broccoli and lettuce stored well in the ECS storage for only four and five days, respectively. Broccoli had a percentage weight loss of 0, 6.7, 10, 11.7 and 13.3 % and lettuce had a weight loss of 0, 10.6, 11.1, 11.3, 12.9 and 15.3 %, respectively. Oranges and cabbage stored longer than other produce, which was for Nine days, were stored in the open for only two days. **Table 2** and **Fig. 4** illustrate this argument.

(**Fig. 3**).

Regarding the control samples, banana had a high percentage weight loss of 24.4, 28.8 and 33.3 % in the first three days of storage in open air and pawpaw had percentage weight loss of 1.2, 3.5 and 5.9 %. Oranges stored well for five days with a percentage weight loss of 0, 4, 13, 36, 36 and 39.2 % and cabbage remained for five days and had a weight loss of 0, 1.2, 1.2, 3.5, 4.7 and 4.7 %. Broccoli and lettuce both

**Vitamin A and C analysis**

Chemical analysis of vitamin A and C were done on the samples stored in the ECS and compared with the samples purchased from the market. The analysis result of β-carotene (µg/100g) of the food sample is given in **Table 3** and illustrated in **Fig. 5**.

**Table 1** Percentage weight loss of fruits and vegetables stored in the evaporative cooling system storage

| Day | Temperature, ºC | Pawpaw, % | Banana, % | Orange, % | Cabbage, % | Broccoli, % | Lettuce, % |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 20 | 0.38 | 3.3 | 0 | 0 | 6.7 | 10.6 |
| 3 | 21 | 1.9 | 4.4 | 10.8 | 0 | 10 | 11.1 |
| 4 | 22 | 2.3 | 4.4 | 10.8 | 0 | 11.7 | 11.3 |
| 5 | 23 | 2.3 | 5.6 | 11 | 1.1 | 13.3 | 12.9 |
| 6 | 24 | 3.9 | 5.6 | 11.5 | 1.1 | | 15.3 |
| 7 | 25 | 4.2 | 5.6 | 12.5 | 2.2 | | |
| 8 | 26 | 5.4 | 6.7 | 11 | 2.2 | | |
| 9 | 27 | | | 10 | 3.3 | | |

**Table 2.** Percentage weight loss of fruits and vegetables stored in the open air (control)

| Day | Temperature, ºC | Pawpaw, % | Banana, % | Orange, % | Cabbage, % | Broccoli, % | Lettuce, % |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 24 | 1.2 | 24.4 | 4 | 1.2 | 3.6 | 13.6 |
| 2 | 25 | 3.5 | 28.8 | 13 | 1.2 | 34.5 | 30.3 |
| 3 | 26 | 5.9 | 33.3 | 36 | 3.5 | | |
| 4 | 27 | 5.9 | 33.3 | 36 | 4.7 | | |
| 5 | 28 | | | 39.2 | 4.7 | | |

**Fig. 3** Percentage weight loss against days of storing

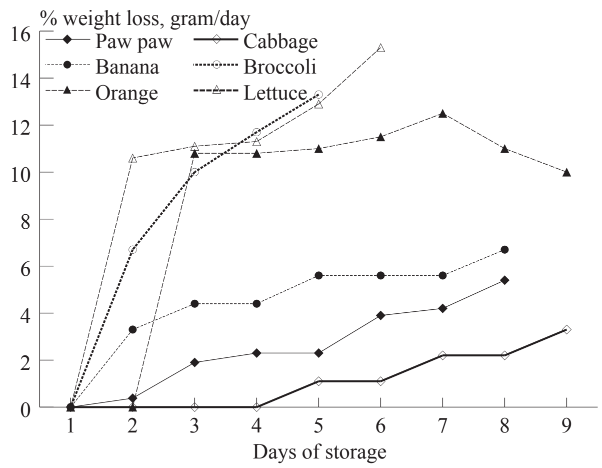
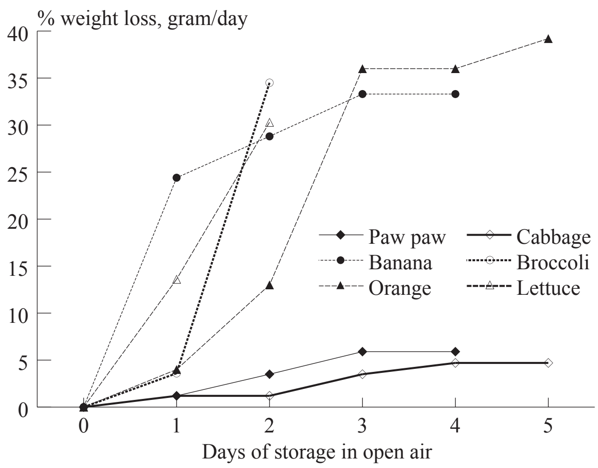



**Fig. 4** Percentage weight loss of produce against days of storing in open air



Fresh pawpaw from the market contained 0.05 µg per 100 gram and pawpaw stored in the ECS contained 0.12 µg per 100 grams of vitamin A after seven days of storage. That means there was an increase of 58 % vitamin A in the stored pawpaw. However, in the case of banana there was no difference. Fresh oranges contained 0.12 µg/100 grams of vitamin A and those stored in ECS contained 0.17 µg/100 gram of vitamin A after 10 days of storage. The increase of vitamin A in the stored fruits are acceptable because carotenees are coloured derivatives of carotenoids (Eilati et al., 1969) and they cause the yellow colour. Fresh cabbage from the market contained 0.2 µg/100 gramg of Vitamin A whereas stored cabbage contained only 0.008 µg. Similarly fresh broccoli and lettuce contained 0.06 and 0.19 µg/100 gram and those stored in ECS contained only 0.01 and 0.08 µg/100 gram. Hence, vitamin A reduced during storage, but ECS storage prolonged the shelf life of the fruits and vegetables.

Vitamin C analysis is presented in **Table 4** and illustrated in **Fig. 6**. The vitamin C in pawpaw, banana and orange were found to be 42, 36 and 28 mg/100 grams in fresh samples but after seven days of storage of pawpaw and banana and 9 days for orange, the vitamin C was 30, 46 and 18 mg/100 grams. Banana had an increase in vitamin C by 27 % in mg/100 grams to that of banana. Fresh cabbage, broccoli and lettuce had 70, 36 and 44 mg/100 grams of vitamin C, which reduced to 50, 24 and 24 mg/100 grams, respectively. Macnish et al. (2000) reported that temperature is a big factor on the rate of metabolism of the products. Other environmental factors which may have caused the loss of vitamin C in fruits and vegetables are gaseous content of the atmosphere and humidity. Hardenburg, et al. (1986) stated, that fresh produce is alive, living and breathing in which metabolism is an on going process inside all living organisms. This means when the temperature rises in products with deficient stored reserves like leafy vegetables where carbohydrate can become limiting (Story and Simons, 1997). More simply they run out of food, as a result the shelf life and quality rapidly reduces.

**Regression Analysis**

The regression analysis was done on the cumulative weight loss of each fresh fruit and vegetable to determine how long the samples would sustain their shelf life in the evaporative cooling system. When a lower independent variable value was substituted into the equation, the shelf life was higher.

For example, using pawpaw (papaya) and broccoli for the fruit and vegetable,

say

$y = a + bx$

where

**Table 3.** Chemical analysis result of β - carotene (µg/100 g) of various food samples

| Sample | Fresh sample | Stored sample | Difference | Loss % |
|---|---|---|---|---|
| Pawpaw | 0.05 | 0.12 | -0.07 | 58 |
| Banana | 0.03 | 0.03 | 0 | 0 |
| Orange | 0.12 | 0.17 | -0.05 | 42 |
| Cabbage | 0.2 | 0.01 | 0.19 | 95 |
| Broccoli | 0.06 | 0.01 | 0.05 | 83 |
| Lettuce | 0.19 | 0.11 | 0.11 | 58 |

**Table 4**. Chemical analysis result of ascorbic acid or vitamin C in fresh and stored food samples (mg/100 g)

| Sample | Fresh sample | Stored sample | Difference | Loss % |
|---|---|---|---|---|
| Pawpaw | 42 | 30 | 12 | 29 |
| Banana | 36 | 46 | -9.89 | 27 |
| Orange | 28 | 18 | 10 | 36 |
| Cabbage | 70 | 50 | 20 | 29 |
| Broccoli | 36 | 24 | 12 | 33 |
| Lettuce | 44 | 24 | 20 | 45 |

**Fig.5**. Comparison of vitamin A in fresh and stored fruits and vegetables

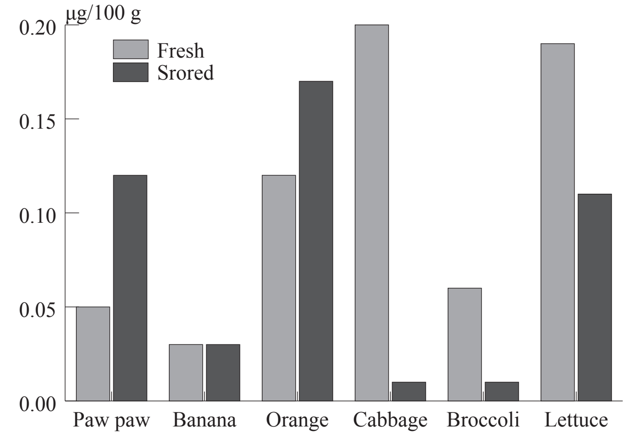
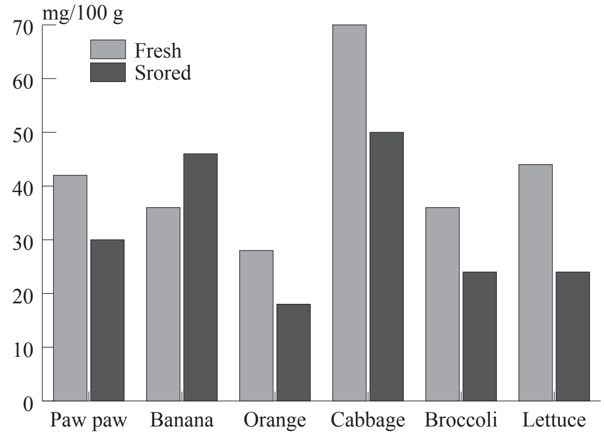



**Fig 6.** Comparison of vitamin C in fresh and stored fruits and vegetables



y = 7 days (papaya)
a = 0.05
b = 0.34, then x was found to be 20

Substituting this value in the equation y = 0.34(20) + 0.05 = 7 this means the produce remained fresh for seven days with a temperature is 23 ºC. Similarly, for broccoli when the temperature was 28 ºC, y = 0.34(28) + 0.05 = 9.57 and for Y =4 days, a =95, b = −50 and x was 1.82. By substituting this value of x, y = 4. Hence, the shelf life determined from values obtained from regression analysis coincided with those recorded number of days from the experiment.

## Conclusions

The evaporative cooling system facility successfully sustained the shelf life of the fresh fruits and vegetables for a prolonged period of time compared to the control, i.e. stored outside. The most important factors that control the shelf life in the lowlands of Papua New Guinea were the temperature and relative humidity. The vitamin A and C in the fruits and vegetables can remain intact for a longer period of time if they are stored in the evaporative cooling system.

## Recommendations

1. The evaporative cooling system of storage especially for fruits and vegetables should be propagated in the coastal areas of Papua New Guinea.
2. As there is no energy requirement in this system, it is most suitable in the rural areas where there is no electricity.
3. This technology translated into a larger volumetric capacity can provide storage security for fruits and vegetables at community level.

## REFERENCES


Bakker-Arkema, F. W. 1999. CIGR. Hand book of Agricultural Engineering. Agro-processing and Engineering. The Society for Engineering in Agricultural food and biological systems, 2950 Niles Rood, St Joseph MI 49085-9659 USA.

Debney, H. G. et al., 1980. Handing and storage practices for fresh fruits and vegetables -product manual. Brishane, Australia. Australian United for fresh fruit and vegetable Association (C/O Committee of Direction of Fruit Marketing).

Eilati, S. K, S. P. Monselize, and P. Budowski. 1969. Seasonal Development of External color and carotenoid content in the peel of ripening, "Snamouti" orange. Westport. USA.

FAO, Database. 1988. Food loss Prevention in Perishable Crops. FAO Agriculture Service, Bul, 43, United Nations Food and Agriculture Organization, Rome, Italy.

Friedman, B. A. 1960. Market diseases of Fresh fruits and vegetables, Department of Agriculture and Hortic. University of Bristol, Long Ashton Research Station. England.

Hardenburg Robert, E., A. E. Watada, and C. Y. Wang. 1986. The Commercial Storage of Fruits and Vegetables, and Florist and Nursery stocks. US Department of Agriculture, Agriculture Handbook - 66-16.

Irving, A. R. 1984. Transport of horticultural produce under modified atmospheres Food Research Department of Hortic., College of Agriculture, Alexandria University, Shatbi, Alexandria, Egypt.

Janet Bachmann and Richard Earles. 2000. Post harvest handling of fruits and vegetables. ATTRA - National Sustainable Agriculture Information Service, Fayetteville, AR. 72702.

Jenny Jobling 2000. Correct Cool Chain management is essential for all fruit and vegetables. Sydeny @ http://www.postharvest. com.au/

Jones, R. and H. Moddy 1993. Agmendia, Department of Agriculture Victoria, East Melbourne, Australia.

Kader, Adel. A., Robert. F. Kashmir, F. Gorden Mitchell, Michael S. Reid, Noel F. Sommer, and James F. Thompson. 1985. Post Harvest Technology of Horticultural Crops. Division of Agriculture and Natural Resources. University of California, Berkely. P 139-143.

Kalman Peleg. 1985. Produce Handling, Packaging and Distribution. Department of Agriculture Engineering Technion, Israel Institute of Agriculture.

Macnish, A., D. Joyce, P. Hofman, and D. Simons. 2000. Fruit, vegetable and fresh produce storage expert system. SCIRO Publishing, Collingwood Vic, Australia.

Story, A. and D. H. Simons. 1997. Fresh produce manual. Australian United Fresh fruit and Vegetables Association, Ltd, Sydney Australia.

Thompson, A. K. 1996. Post harvest Technology of fruit and vegetables. Oxford. Blackwell UK.


■■

# Annual Costs of Mechanizing With Tractors in Tanzania

by
Sylvester Mpanduji
Dept. of Agricultural Engineering
and Land Planning,
Sokoine University of Agriculture,
P.O Box 3003, Morogoro
TANZANIA

Baanda Salim
Dept. of Agricultural Engineering
and Land Planning,
Sokoine University of Agriculture,
P.O Box 3003, Morogoro
TANZANIA

## Abstract

The level of utilization and annual costs of using 2WD and 4WD tractors under Tanzanian conditions were investigated using data collected from large-scale farms. The results showed- that the mean annual level of utilization of 2WD tractors was 880 hours, whilst the annual use of 4WD tractors was 640 hours. The predicted minimum annual cost of 2WD tractor utilized for 1000 hours per year was Tshs. 15,000/= per hour and for the same annual use for 4WD tractors was Tshs 23,000/= per hour. These values were found to be 1.1 to 1.6 times higher than the minimum values of using a tractor in Germany.

## Introduction

Agriculture in Tanzania is essentially rain-fed because less than 4 % of the cultivated land is under irrigation (Kalinga, 2001). However rainfall seasons in many places are characterised to be short. This necessitates that the completion of key farming tasks such as ploughing, planting and weeding to be carried out in a short time span. When using hand tool technology to accomplish these tasks only a small area of less than one ha can be handled.

Tanzania has a big potential in terms of available arable land (MALDC, 1991). In order for the country to use her agricultural potential, there is a need to expand and improve mechanised agriculture at all levels of power application. However, agricultural mechanisation with tractors has been a controversial issue. On one hand, there is no question about the need for higher agricultural production through the increased use of mechanical power. On the other hand, the contribution of mechanical power in agricultural production has been observed by Tanzanian agricultural planners (mainly economists) to be unreliable, costly and inefficient. These observations have caused the government in the past to adopt cautious policies regarding the promotion of this technology. However, when examining the green revolution that has turned Asian countries from importers of food to exporters (IITA, 1992; Anderson, 1992), a number of reasons have been advanced for the change. Amongst other things, the increased utilisation of tractors has played an important role. The statistical data on tractor use in Asian countries in the last 50 years (**Table 1**) shows that the number of tractors in use in India has increased from less than 10,000 in 1950 to more than 1.4 million in 1997. Asian farmers would not be buying these tractors if they were not using them economically and making profit.

Additionally, the increase of rural to urban migration is found to be critical to the change. In Tanzania, urban population is increasing at a rate of 6.9 % per annum and doubling every 10 to 12 years (IBRD 2000). Since the urban dwellers rely

**Table 1** Growth of tractor population used for agricultural production in different countries (1950-1997)

| Year | India | Malaysia | Morocco | Tanzania |
|---|---|---|---|---|
| 1950 | 9,000 | | | |
| 1960 | 31,000 | | | 1,500 |
| 1970 | 148,000 | 7,776 | 24,684 | 17,000 |
| 1980 | 393,000 | 12,500 | 32,000 | 15,898 |
| 1990 | 1,063,012 | 26,000 | 39,155 | 6,000 |
| 1995 | 1,400,000 | 43,295 | 41,000 | 7,000 |
| 1997 | 1,450,000 | 43,300 | 43,226 | 7,600 |

Source: FAO Production Year Books 1958-1997 on food supply from rural areas, this increases the pressure on the rural areas to produce even more food. However, it is the educated and young people who migrate from rural to urban areas to liberate themselves from the drudgery associated with the hand-tool technology agriculture leaving aged people in the villages. Data collected in 1990 in Tanzania shows that more than 50 % of heads of rural households are 45 years old or above (URT, 1992). For a country with a life expectancy of 42 years (IBRD 2000), it is indeed facing the problem of aged rural population. The older people remaining in the rural areas cannot be expected to increase the agricultural productivity for the country.

According to the recommendation of the World Bank, (1994), an average income of about 70 times the present annual income is needed for a family of six people in order to have their basic requirements covered. All that money has to come from the farmers pocket regardless of the government contribution in social services. In that case, the farmer has to cultivate an estimated area of about 30 hectares per year for subsistence and for family development needs. A farm of that size cannot be cultivated by use of hand hoes or draft animals when using family labour. The use of animal draft technology and hired labour for such an area will be too expensive. The only way to handle such an area is to use a tractor; either own or hire.

Considering all the mentioned cases, it is obvious that the area under-cultivation in Tanzania could be increased substantially if tractor technology were encouraged and promoted by the government. The user of the technology cannot be the small-scale peasant farmer who is aged as we have seen. These must be the young and educated people who can perform agricultural activities as medium scale commercial farmers. This argument is also in agreement with the Tanzania Vision Agriculture 2025 (URT, 1999), which states that, if agriculture in Tanzania is to be expanded, the current farming community (80 % of the population) needs to change from small peasant dominated farmers to commercial medium scale holder farmers.

Tractor technology is considered inappropriate in Tanzania because very subjective criteria are used to decide when and how to operate a tractor profitably. There is no data published indicating the required level of tractor utilisation in terms of hours per year or minimum farm sizes required to be cultivated per year. Additionally, the annual costs of owning and using tractors are unknown and information on how farmers can best minimise the costs in Tanzania is unavailable. Had this information been available, the users of tractor technology could be advised accordingly based on objective facts that could help them increase the probability of utilising the technology profitably. This paper, therefore, intends to minimize some of the said problems.

## Objectives of The Study

The main objective of this study was to provide the costs information for tractor use under Tanzanian conditions necessary for good decision management.

The specific objectives of the study were:

1. To determine the average level of tractors utilization in Tanzania.
2. To determine annual costs of 2WD and 4WD tractors for different levels of utilisation
3. To suggest some measures to be used to reduce the annual cost of tractors.

## Materials and Methods

Data for this study were collected from large-scale farms, namely Tanganyika Planting Company, Mringa Estate, Tanganyika Wattle Compa-

**Fig. 1** Annual costs of 2WD tractors at different levels of utilization

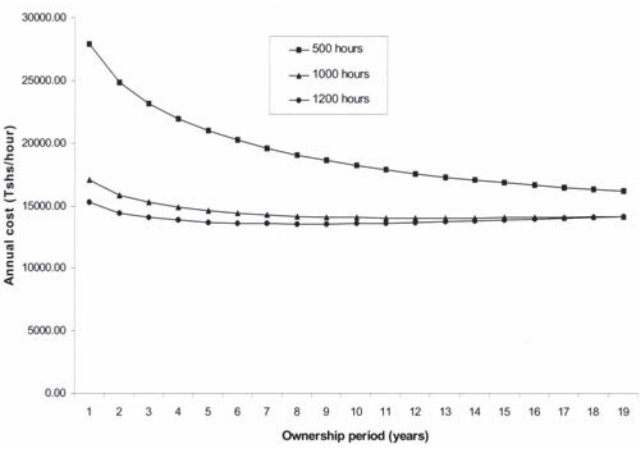
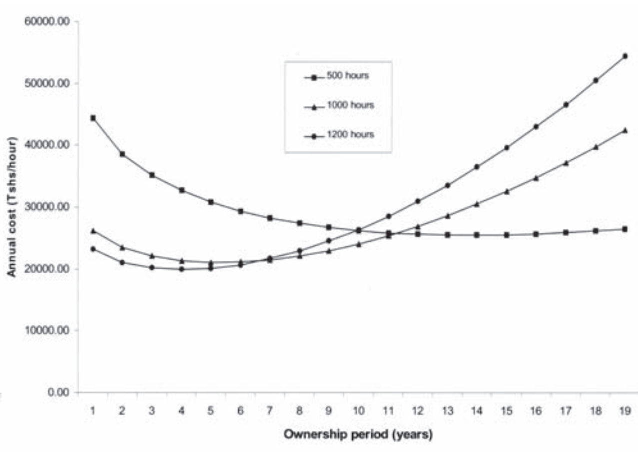



**Fig. 2** Annual costs of 4WD tractors at different levels of utilization



ny, Mwera Sisal Estate and Mtibwa farms. Data were obtained from companies' records and files. The data collected include tractor type, model, power, initial purchase price and tractor use in terms of hours.

In total, data for 108 tractors were collected of which 2WD tractors were 83 and the remaining tractors were 4WD. The tractor types include Massey Ferguson, Ford and Case International. Other secondary data included bank interest rates, inflation rates, price of fuel and labour costs that were obtained from secondary sources.

The annual tractor use was recorded as the performance of the tractor in hours. The annual performance was obtained by adding the recorded monthly tractor hours for each year under the study. In case the level of perfomance was not recorded, the estimation method was used for determination of the values The method used was either by dividing the total quantity of fuel consumed in that year with the standard amount of fuel consumption of the tractor or by the average use of the tractors in the same group. It was difficult to get the exact hours of use for each separate activities carried out by the tractor because the available recorded data were for all activities done by tractors in a month.

All costs involved in the analysis were adjusted to the base year of 2002 to remove the effect of the inflation. The real Tanzanian shillings were converted to actual Tanzanian shillings by multiplying by the factor $(1 + i_{f1})(1 + i_{f2})(1 + i_{f3})$ ........$(1 + i_{fn})$ for all costs before 2002 and by a deflation factor $1 / [(1 + i_{f1})(1 + i_{f2})(1 + i_{f3})$ ........$(1 + i_{fn})]$ for cost obtained after 2002 as suggested by Morrris (1988). The year 2002 was chosen as a base year because this research work was carried out in that year.

The equation developed by Witney and Saadoun (1989) was used to analyse the annual ownership cost of the tractor. However the equation was modified to include the annual costs of labour, fuel and oil. The tax component was eliminated from the equation because, in Tanzania, tractors are not directly charged tax. The final form of the equation used for determination of annual ownership costs was expressed as:

$$A_t = \sum_{n=1}^{N} NPV_m + NPV_r - NPV_s + F_c + C_o + C_L$$

where,

$A_t$ = Annual ownership cost

$NPV_m$ = Annual repayment of loan capital and interest

$NPV_r$ = Annual repair costs and insurance charges

$NPV_s$ = Income from selling the tractor

$F_c$ = Annual fuel cost

$C_o$ = Annual oil cost

$C_L$ = nnual labour cost

The repair costs models for 2WD and 4WD tractors developed by Mpanduji et al. (2001) were used to determine the repair costs. The resale function developed by Witney and Soadoun (1989) was used for determination of salvage values because it fits more to the Tanzania situation. The bank rates used in the calculation were 10 % for the investment interest rate and 22 % for the loan interest rate. The 9 % inflation rate was also used as this was the average inflation rate at the time of analysis. To simplfy the analysis, a computer software programme was developed using a quick basic language (Q-basic).

## Results and Discussion

### Level of Utilization

**Table 2** shows the results of the annual tractor utilization levels in Tanzania. The level of utilization ranges from 550 hours to 1100 hours per year per tractor. These results show that the levels of utilization differ little when compared to the levels of utilization reported in other African countries. In Nigeria, for example, Kolawole (1974) reported that the annual utilization of government tractors (hire services) was about 500 hours, while the annual use of privately owned tractors was about 786 hours.

The mean annual level of utilization of two wheel drive (2WD) tractors was about 880 hours per tractor. The average annual use of four wheel drive tractors was 640 hours. This showed that 2WD tractors were utilized more than 4WD tractors under large scale farm ownership in Tanzania. This was attributed to the fact that 2WD tractors under large scale ownership were regarded as multipurpose tractors, therefore, they were assigned frequently into a range of activities, that included ploughing, spraying, planting, and transportation, whereas the 4WD tractors were regarded as special tractors. Thus, 4WD tractors were restricted only to heavy-duty tasks, such as uprooting, sub-soiling and ploughing. On the other hand, 4WD tractors were bigger machines than 2WD tractors, therefore, they tended to accomplish their tasks at a faster rate than their counterpart 2WD tractors. This idea is also in

**Table 2** Annual utilization levels of tractors in Tanzania

| Tractor group | Unit | Range of annual use, h | Mean annual use, h |
|---|---|---|---|
| 2 WD | 83 | 700-1,100 | 880 |
| 4 WD | 25 | 550-700 | 640 |

**Table 3** Average purchase price of tractors in Tanzania

| Tractor type | Average tractor power, kW | Purchase price, Tshs |
|---|---|---|
| 2 WD | 60 | 31,000,000.00 |
| 4 WD | 90 | 48,000,000.00 |

Note: US$ 1 = Tshs 1,020

line with the trend in agriculture in USA, where farmers tend to own bigger farms than before and use bigger 4WD tractors to complete all agricultural activities in less time.

**Annual costs of tractors**

The results of the analysis of the annual ownership cost per hour at different ownership periods were carried out for three different levels of utilization, namely, an annual use of 500, 1000 and 1200 hours. These levels were chosen because tractors in Tanzania were found to operate within these ranges (**Table 2**). The ownership period of tractors was considered to be to 19 years. The choice of the period was based on the information obtained from the field survey because, during data collection, it was found that some tractors had been in operation for that period. The average purchase price of the 2WD and 4WD tractors are as shown in **Table 3**. The difference in prices were mainly influenced by the average power of the tractors rather than by the tractor makes.

The results of the analysis of the annual ownership cost per hour at different ownership periods for both 2WD and 4WD tractors are shown in **Table 4**. These results were then plotted in **Fig. 1** for 2WD tractors and in **Fig. 2** for 4WD tractors. The Figures demonstrate that the annual ownership costs of different tractors declined rapidly in the first few years but after some time the annual cost curves became flatter. When the ownership period was extended further, the total cost curves increase with the increased of tractor age. This kind of trend was a typical result of the annual ownership costs one could expect (Herderson and Guericke,1985: Witney and Saadoun, 1989). In the early life, tractors usually experienced a decrease in capital costs. Whereas in later stages, when the curve was on the increase, tractors were generally suffering from the increase in repair costs due high rate of wear and tear.

The results of the annual costs at different levels of utilisation indicated that 2WD tractors with annual use of 500 hours have higher annual cost than 2WD tractors performing about 1000 or 1200 hours annually. However, in the case of 4WD tractors, the results in **Figure 2** show that the annual cost of tractors used for 500 hours per year was higher within the first 10 years of ownership than that of tractors used for 1000 or 1200 hours. Above 10 years of ownership, 4WD tractors with annual usage of 1200 hours were found to have higher annual costs followed by tractors used for 1000 hours.

The increase of annual use from 1000 hours to 1200 hours for the tractors in the first few years of ownership decrease the annual costs. However, the decrease in cost is small with a maximum decrease of about 11 %. At later stages of tractor ownership the annual costs of tractors operated for 1200 hours per year tended to increase more than tractors with annual usage of 1000 hours.

Therefore, these results suggested that it is more economical for most of the 2WD tractors to be used annually at average hours between 1000 and 1200 than to be operated below that figure. Whereas in the case of 4WD tractors it is more economical to be operated at an average annual use of about 500 hours if the tractor owner intends to use the tractor for more than 10 years. But otherwise it was economical to operate the tractor at 1200 hours for 5 years of ownership and it was recommended that the tractor be utilized for 1000 hours if the owner intends to use the tractor for 10 years.

The result of the annual costs of 2WD tractors indicates that the minimum annual cost of these tractors is about Tshs 15,000 per hour if the tractor will be used for 1000 hours per year. The minimum annual ownership cost of 4WD tractors is about Tshs 25,000 per hour for 500 hours annual utilization and

**Table 4**. Annual ownership costs (Tshs/hour) of 2WD and 4WD tractors at different period of ownership

| Period of ownership (year) | Annual hours of use of 2WD | | | Annual hours of use of 4WD | | |
|---|---|---|---|---|---|---|
| | 500 h | 1000 h | 1200 h | 500 h | 1000 h | 1200 h |
| 1 | 27,911.25 | 17,055.90 | 15,315.30 | 44,402.85 | 26,192.70 | 23,182.20 |
| 2 | 24,882.30 | 15,856.20 | 14,449.95 | 38,550.60 | 23,472.45 | 21,060.00 |
| 3 | 23,192.10 | 15,271.65 | 14,116.95 | 35,125.65 | 22,107.60 | 20,167.65 |
| 4 | 21,969.90 | 14,890.50 | 13,849.20 | 32,667.30 | 21,370.50 | 19,901.70 |
| 5 | 21,014.10 | 14,620.50 | 13,710.15 | 30,801.60 | 21,074.85 | 20,102.85 |
| 6 | 20,239.20 | 14,425.20 | 13,626.45 | 29,355.75 | 21,132.90 | 20,700.90 |
| 7 | 19,597.50 | 14,283.90 | 13,581.45 | 28,229.85 | 21,493.35 | 21,652.65 |
| 8 | 19,057.95 | 14,182.65 | 13,566.15 | 27,357.75 | 22,122.45 | 22,928.40 |
| 9 | 18,598.50 | 14,113.35 | 13,572.90 | 26,690.85 | 22,995.90 | 24,506.55 |
| 10 | 18,203.40 | 14,067.90 | 13,596.75 | 26,194.05 | 24,094.80 | 26,372.25 |
| 11 | 17,860.05 | 14,041.80 | 13,633.20 | 25,843.05 | 25,404.30 | 28,510.65 |
| 12 | 17,559.45 | 14,031.00 | 13,680.90 | 25,616.25 | 26,914.95 | 30,912.30 |
| 13 | 17,294.85 | 14,031.90 | 13,735.35 | 25,498.80 | 28,614.60 | 33,567.75 |
| 14 | 17,059.05 | 14,042.70 | 13,795.65 | 25,477.20 | 30,496.50 | 36,471.60 |
| 15 | 16,848.00 | 14,062.05 | 13,860.90 | 25,542.00 | 32,555.25 | 39,614.40 |
| 16 | 16,658.10 | 14,085.90 | 13,929.30 | 25,686.45 | 34,785.45 | 42,993.45 |
| 17 | 16,485.75 | 14,116.05 | 14,000.40 | 25,901.10 | 37,180.35 | 46,602.00 |
| 18 | 16,328.25 | 14,149.35 | 14,072.85 | 26,181.90 | 39,737.25 | 50,434.65 |
| 19 | 16,185.15 | 14,186.70 | 14,146.65 | 26,524.80 | 42,452.10 | 54,490.05 |

Tshs 23,000 per hour for 1000 hours of annual use. The explanation for the difference in annual cost per hour between these two groups of tractors could be explained by the difference in the initial purchase price and repair costs regime of the tractor concerned.

The comparison of the minimum values of annual ownership costs established in this study with the annual costs of owning tractors in Germany (**Table 4**) showed that the annual cost of using tractors in Tanzania was higher by almost 1.1 to 1.6 times the annual costs in Germany.

**Measures to Reduce Annual Ownership Cost of Tractors in Tanzania**

As per **Table 4**, it can be concluded that the annual costs of owning and using tractors in Tanzania are higher than those of a developed country. These costs can however be reduced if necessary measures can be taken by Tanzanian farmers. The measures include the possibility of using tractors of low initial purchase price, reducing repair costs of the tractors and avoiding unecessary ownership of the tractor after the optimum period of use.

The purchase price of the tractor has a significant effect on the annual cost. If this can be reduced then the annual ownership cost of the tractor can also be substantially decreased. In Tanzania, this can be achieved by the use of imported second hand tractors. In Morocco for example, where the mechanisation degree is still low like that of Tanzania, a considerable number of second hand tractors are used for agricultural activities (Bourarach et al., 1999). More than 50 % of the estimated 43,000 tractor units in Morocco are imported second hand tractors. Their experience with these tractors has shown that even though modifications on the imported second hand tractors are carried-out at the beginning, the purchase costs of second hand tractors are far below the purchase price of the new tractors. This idea is also supported by Ward (1990) who suggested that second hand tractors of less than 4 years are the best option for farmers with annual use of about 400 to 900 hours.

Reducing repair costs of the tractor can also be another feasible measure to decrease the annual costs of ownership. Actual repair costs can be reduced by maintaining a tractor carefully. This could be achieved by employing educated and well trained tractor operators in the field of tractor operations, service and maintenance. Currently in Tanzania, this is not the case (Mpanduji, 2000).

Another important method, which can be used to reduce the ownership costs is that of replacing a tractor within the optimum period of ownership. Operating a tractor above this point results in unnecessarily additional costs that make agricultural mechanization with a tractor unattractive. As far as this study is concern, 2WD tractors used annually for 1000 hours are recommended to be replaced at the age of 8 years, whereas 4WD tractors are recommended to be replaced at the age of 14 years if the annual use is 500 hours. Otherwise it is very important to establish the optimum replacement time of a machine once it is bought, as there are other factors that need to be taken into account.

**Table 5** Comparison of annual ownership costs of tractors in Germany and Tanzania

| Tractor type | Tanzania | Germany |
|---|---|---|
| 2WD (60-74 kW) | 15,000/= | 9,300/= |
| 4WD (75-92 kW) | 23,000/= | 19,500/= |

Source of Germany data: KTBL, 1999/2000

## Conclusion and Recommendation

The level of utilization and annual costs of using 2WD and 4WD tractors under Tanzanian condition were investigated. In total, data for 108 tractors were collected from large-scale farms. Of the data collected, 2WD tractors were 83 and the remaining 25 tractors were 4WD. The average power rating of the 2WD tractors was 60 kW and 89 kW for the 4WD tractors.

The results showed that the level of annual tractor utilization ranged from 550 to 1100 hours. The mean annual level of utilization of 2WD tractor was 880 hours, whereas for 4WD tractor was 640 hours.

The results of the annual costs at different levels of utilisation indicated that 2WD tractors with annual use of 500 hours had higher annual cost than 2WD tractors performing about 1000 or 1200 hours annually. However, in the case of 4WD tractors the results showed that the annual cost of tractors used for 500 hours per year was higher within the first 10 years of ownership than that of tractors used for 1000 or 1200 hours. Above 10 years of ownership, 4WD tractors with annual usage of 1200 hours were found to have high annual costs followed by tractors used for 1000 hours.

The 2WD tractor utilized for 1000 hours per year had a minimum annual cost of Tshs 15,000/= per hour. The minimum annual ownership cost of 4WD tractors were Tshs 25,000/= per hour for 500 hours utilization and Tshs 23,000/= per hour for 1000 hours of annual use and costs about Tshs. 42,000 per hour to own an 18 year old 4WD tractor.

The comparison of the minimum values of annual ownership costs established in this study with the annual costs of owning tractors in Germany showed that the annual costs of using tractors in Tanzania was higher by almost 1.1 to 1.6 times the minimum annual costs of owning tractors in Germany.

The annual costs in Tanzania could be significantly reduced if the initial purchase price of the tractor could be reduced, mainly by the use of second hand imported tractors, and through the use of trained tractor operators. Another measure suggested to reduce the cost is that of using a tractor only up to optimum period of ownership.

## REFERENCES


Anderson, J. R. 1992. Difficulties in African agricultural systems enhancement? Ten hypotheses in agricultural systems 38, pp 387-409.

Bourarach, H., H. Baali, and H. Reijmil. 1999. The importation of second hand tractors in Morocco. VDI prospectus pp. 347-350.

FAO. 1958-1997. Production year books, Rome Italy, Vol. 12 (1958); Vol. 19 (1965); Vol. 25 (1971); Vol. 40 (1986); Vol. 45 (1990) Vol. 49 (1995); Vol. 51 (1997).

Henderson, H. D. and W. Guericke. 1985. Economics of tractor operation in Swaziland. Agricultural Mechanization in Asia, Africa and Latin America 16(4) pp. 11-17.

IBRD. 2000. Sub-Sahara Africa: From crisis to sustainable development. A long term perspective. The World Bank Washington D.C.

IITA. 1992. Sustainable food production in Sub-Sahara Africa. IITA's contribution. IITA Oyo Road Ibadan, Nigeria, pp 195.

Kalinga, G. 2001. Irrigation development plan. Irrigated Agriculture for Food Security and Poverty Eradication. Conference document.

Kolawole, M. I. 1974. Economic aspects of private tractor operation in the Savannah zone of Western Nigeria. Journal of Agricultural Engineering Research 19(4) pp. 401-410.

KTBL. 1999/2000. Taschen Landwirtschaft. Daten fuer die Betriebskalkulation in der Landwirtschaft, Darmstadt Germany pp. 12.

MALDC. 1991. National agricultural mechanization programme. Agricultural Planning and Marketing Division, Ministry of Agriculture, Livestock Development and Co-operatives, Dar es Salaam Tanzania.

Morris, J. 1988. Estimation of tractor repair and maintenance costs. Journal of Agricultural Engineering Research, Vol. 41, pp. 191-200.

Mpanduji, S. M. 2000. Repair costs of tractors and comparison of mechanization strategies under Tanzanian conditions.

Mpanduji, S. M., G. Wendl, H. O. Dihenga, and E. L. Lazaro. 2001. Investigation on tractor repair costs under Tanzanian conditions. Agricultural mechanization in Asia, Africa and Latin America 32(4) pp. 71-75.

Mrema, G. C. and M. Y. Mrema. 1993. Draught animal technology and agricultural mechanization in Africa; Its potential role and constraints. NAMA Newsletter Vol. 1 No. 2 pp 12-33.

URT. 1999. United Republic of Tanzania. Tanzania development vision 2025, Dar es Salaam Tanzania.

Ward, S. M. 1990. Tractor ownership costs. Agricultural Mechanization in Asia, Africa and Latin America 21(1).

Witney, B. D. and T. Saadoun. 1989. Annual costs of farm machinery ownership. Journal of Agricultural Engineers pp 3-11.

World Bank. 1994. Adjustment in Africa; reforms, results and the Road ahead. World Bank policy research report, Oxford University Press.


■■

# 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.

### 570

**Tractor in Gedarif Rainfed Agriculture Eastern Sudan:** **Lotfie A. Yousif,** Agric. Engineering Researcher, Agric. Research and Technology Corporation Gedarif Res. Station Gedarif, Sudan; **El Hag H. Shanto,** Faculty of Agric. and Environmental sciences University of Gedarif, Gedarif; **Rehab M. Rehan,** same; **Hanan I. Adam**, same.

**I: Current Condition, Utilization and Failure:** This research work aiming at highlighting on farm tractors been used in rainfed agriculture in Gedarif area, Eastern Sudan. With special considerations to tractors make, age, usage, performance, failure and repair. A questionnaire was conducted during the 2004/2005 growing season. Seventy farmers and tractor-owners were surveyed. Tractor of Massey Ferguson and Ford makes were the most used tractors in the rainfed agriculture Eastern Sudan. More than fifty percent of the studied tractors were over ten years old and their current condition is below the average. Tractor rehabilitation and replacement strategies are required. All tractors use drawbar power, few of them (11%) use hydraulic power and 25% use PTO. More different implements are needed to promote tractor use efficiency. Seventy one percent of the tractors have different levels of break and failure. Most of the tractors repair and maintenance (71.5%) were carried out at Gedarif town and the repairing and maintenance takes many hours. The establishment of workshops and services centers near the farmer fields can save time. Spare part represents the major factor causing defect and restricts repair and maintenance. The availability of genuine spare parts at suitable cost is of great necessity. The majority of tractor drivers (96%) either illiterate or has primary education only. Educated and well-trained or skilled operators are required for efficient and safety use of tractors.

**II: Repair and Spare Parts:** The purpose of this research is to assess farm tractor being used in the rainfed area Eastern Sudan regarding repair and spare part. Two questionnaires were conducted during the 2004/2005 growing season. Forty-five persons of tractor servicemen specialist were asked about most common repair that had been done to the tractor operating system. On the other hand, 30 of spare part traders were asked about the available spare part (type, makes and specifications) in their shops. In addition, they were asked about the rate and methods of sale as well as factors affecting spare part availability.

Results showed that, tractors of Massey Ferguson and Ford make were the most used tractors in the rainfed agriculture in Eastern Sudan. Both tractors makes received different levels of repair at different parts. Regardless of tractor make, these repairs were at Engine, Transmission system, Fuel pump, Atomizer, Magneto, Starter and Tire. The most troublesome parts in the engine were rings, crankshaft and piston.

The majority of the available spare parts were of commercial type (not genuine), and the customers have tendency to bay second hand type. Lack of money is the major factor restricting availability of spare parts that followed by technical and management factors. Genuine spare parts of different makes at reasonable cost are required. Technical information and communication facilities are required to secure stable flow and rapid arrival of spare parts.

### 602

**Development and Evaluation of a Self-Feeding Wire Loop Type Thresher for Rice**: **B. C.Parida**, Principal Scientist Engineering, Division Central Rice Research Institute Cuttack, Orissa India

Mechanical threshers are widely being used for threshing of paddy in eastern India, specifically Orissa. The small farmers are using pedal threshers where as farmers having electrical facility are using motorized threshers. In both the cases cleaning of grain is done separately with the help of a winnower or manually in front of a blowing wind. Of late axial flow threshers run by electric motor or tractor are being accepted as they carry out threshing and cleaning operations simultaneously. But the problem with axial flow thresher is that they cut the straw into pieces making it difficult to store. In eastern India paddy straw is used for roof thatching and for animal feed. Hence the rice straw has much economic importance in this part of the country. A need was felt for a thresher that can thresh, clean and keep the straw intact. A self feeding power thresher for rice was developed at Central Rice Research Institute, Cuttack, India which is powered by two small single phase electric motors that can do the job of threshing and cleaning simultaneously. The machine keeps the straw intact so that it can be used for roof thatching, cattle feed or can be heaped for storage. The capacity of self-feeding thresher is 193 kg/hour. It requires one person to operate the machine. The cost of operation of the machine is $0.36/ quintal of clean rice.

### 611

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

A Pedal pump 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.

**619**

**Design and Development of Hand Operated Lac Grader: N. Prasad**, Senior Scientist, Indian Lac Research Institute, Namkum, Ranchi-834010 (Jharkhand), India; **B. Baboo**, Director, same; **S. K. Pandey**, Scientist, same.

Lac encrustation separated from harvested lac crop is known as sticklac. It contains impurities and foreign matters, which are removed up to a large extent in primary processing of lac. The primary processing of lac involves five major unit operations *i. e.* crushing, washing, drying, winnowing and grading. Lac grading is an important unit operation, which is carried out at different stages *i. e*. before crushing, after crushing and after and after winnowing. In small lac factories grading is mostly done by women using sieves. A woman labourer using bamboo tray (*soop*) and sieve, winnows and grades up to 150 kg lac in a day. In large lac processing units, grading before and after crushing is done with the help of power operated sieves. However, winnowing and grading after drying is done by women labourers. The manual lac grading is a slow and tedious process. In order to improve lac grading capacity and to reduce the drudgery of women labourers, a Hand Operated Lac Grader was designed and developed. The developed grader consists of a feed hopper, a fluted roller type positive feeding mechanism, a cranking mechanism, set of serves, drive mechanism and machine frame. Only one person was required to operate the grader. The developed grader was tested useing *Kusmi* sticklac using 10 and 30 mesh sieve-set. The capacity of the grader was found to be 50 kg/hr. The efficiencies of the 10 and 30 mesh sieves were found to be 94.8 and 86.4 per cent respectively. The grader was found useful for lac grading before and after crushing and after winnowing in primary processing of lac.

**620**

**Performance Evaluation of Self Propelled High Clearance Sprayer: T. Senthilkumar**, Asst. Prof., KVK, Vamban Pudukkottai - 622 303, India; **R. Manian**, Professor, Dept. of Farm Machinery, AEC & RI, TNAU, Coimbatore -641 003; **K.Kathirvel**, Professor, same.

At present to control insects and pests, insecticides and pesticides are being applied by manually operated knapsack sprayers and tractor mounted sprayers. The use of manually operated sprayer is hazardous and tiresome, in addition to non-uniform spray and low output. A self propelled high clearance sprayer was tested for spraying cotton and sugarcane crops at laboratory level for its performance. To evaluate the high clearance sprayer the parameters like discharge rate, spray distribution pattern are measured using experimental setup. The discharge rate of the single nozzle in the boom was tested for pressure range of 5 to 20 ksc at an interval of 5 ksc. The sprayer was tested at different pressure levels of 5, 10, 15 and 20 $kg/cm^2$ with the engine rpm varies from 500 to 1000 rpm in steps of 100 rpm. A patternator was used to find out the spray distribution pattern. From the study conducted the following specific conclusions were made. The discharge rate increases with increasing pressure for all the engine speed. The maximum discharge obtained for 1000 rpm at 20 ksc pressure was 44.04 l/hr. The deposition of spray fluid was maximum at centre of the patternator and decreasing from the centre to the outer ends of the pattern. The height of operation the height increased to 40 & 50 cm the non uniformity of spray distribution pattern was obtained. The maximum uniformity coefficient of 86.17 % was obtained at 30 cm operating height with the operating pressure of 10 ksc. The engine speed at 800 rpm was recorded maximum uniformity of 72.87 %. The best combination of engine speed of 800 rpm and the operating pressure at 10 ksc gives maximum uniformity of spray distribution.

**621**

**Effect of Blade and Operational Parameters on Energy Requirement to Shred Cotton Stalks in Experimental Cotton Stalk Shredder: T. Senthilkumar**, Asst. Prof., KVK, Vamban Pudukkottai - 622 303, India; **R. Manian**, Professor, Dept. of Farm Machinery, AEC & RI TNAU, Coimbatore - 641 003; **K. Kathirvel**, Professor, same.

The influence of the selected level of variables of three levels of number of blades viz. 2, 3 and 4, four levels of peripheral velocity viz. 21.52, 23.80, 26.58 and 28.60 $ms^{-1}$, three levels of blade thickness of 2, 4 and 6 mm and four levels of blade rake angle of 0, 15, 30 and 45 deg on energy consumption of cotton stalk was investigated. The results showed that increase in peripheral velocity from 21.52 to 28.60 $ms^{-1}$ increased the requirement of energy for all the levels of number of blades. Increase in blade thickness resulted in decreased energy requirement at all the levels of peripheral velocity. The peripheral velocity of 21.52 $ms^{-1}$ recorded minimum energy requirement for all the levels of variables of blade rake angle and number of blades when compared to other peripheral velocity levels. 2 blades and 0º blade rake angle recorded minimum energy requirement when compared to all other combinations of number of blades and blade rake angle. The 0º blade rake angle and 6mm blade thickness recorded minimum energy requirement. Rake angle from 0 to 45º resulted in increased energy requirement for all the levels of peripheral velocity and number of blades. The 0º blade rake angle and 21.52 $ms^{-1}$ peripheral velocity recorded minimum energy requirement when compared to other combinations.

**623**

**Effect of Speed on Wear Characteristics of Hard Surfaced Cultivator Shovels: V. K. Chahar**, Research Scholar and Senior Technical Assistant, Dept. of Farm Machinery and Power Engineering, CTAE, Udaipurand, India; **G. S. Tiwari**, Associate Professor, same.

In agricultural machines, wear is the most rapid and common form of damage. This is responsible for most of the idle time and maintenance, apart from heavy expenditure on repair and spare parts. Wear studies were conducted on cultivator shovels coated with EWAC 1002 ET surface hardening powder (Tungsten carbide base). The tests were conducted under controlled soil bin conditions in sandy loam soil at 9-12 % moisture content for 100 hours at three different speeds of 0.7, 1.0 and 1.3 m/s. Weight loss in each shovel due to wear was recorded at an interval of 20 h. Wear rate was found to increase by 29.41 % with increase in speed from 0.7 to 1.3 m/s.

**625**

**Alfalfa seed-bearer harvesting technology and machinery complex in Uzbekistan: Lee A. S.**,PhD on technics. The chief of the laboratory of mechanization of forage harvesting. Uzbek Scientifical Research Institute for Mechanization and Electrification of Agriculture. UzMEI. Uzbekistan; **Roziyev Sh. N.**, P. G. S., Tashkent Institute of Irrigation and Melioration, TIIM.

In this article the present condition of alfalfa seed manufacturing is considered. The brief review of importance of alfalfa in agriculture and it`s physical-mechanical properties, the brief information about technological process of seed manufacture by a separate way and post harvest cleaning them are also given, and various alfalfa seed-bearers harvesting technologies are considered. The question of reduction of the park of machines and their rational utilization during alfalfa seed-bearer harvesting is considered. The list of used means for seed-bearer harvesting by separate way is given.

**638**

**Design, development and evaluation of finger millet thresher-cum-pearler for hills: K. P. Singh**, Scientist, Farm Machinery and Power Vivekananda Institute of Hill Agriculture, (ICAR) Almora - 263 601 (UA), India; **A. K. Srivastva**, Principal Scientist, same; **S. Kundu**, Co-coordinator, Technical Cell, same; **H. S. Gupta**, Director, same.

Hill agriculture, dominated by rainfed upland farming. Finger millet (*Eleusine Coracana*) is widely is a major crop under rainfed upland occupying 1.36 lakh ha area in uttaranchal hills whereas the total production is 1.74 lakh tonnes. However, its threshing and pearling involves severe drudgery for women. It is evident by arduous process of traditional threshing and pearling which needs 5 hours efforts for threshing and pearling of 100 kg of finger millet grains. A finger millet thresher cum pearler with threshing capacity of 28.5 kg/h and pearling capacity of 63.1 kg/h was designed on the basis of physical properties of the grain. The thresher was developed and evaluated for its performance in terms of feed rate (FR in kg/h), pearling capacity (PC in kg/h), threshing efficiency (TE in %), pearling efficiency (PC in %), cleaning efficiency (CE in %), visible damage (VD in %), Germination percentage (%) and Total bacterial load (cfu/g). The physical properties of finger millet such as moisture content (10%), bulk density (0.71 g/cc), straw-husk-grain ratio (12: 1: 23), grain size (1.48) mm, grain strength (24.62 kg) and angle of repose (32°) were studied. The result of the test indicate that for best performance, the thresher cum pearler should be operated at a cylinder speed of 1200 rpm with cylinder concave clearance 5 mm, increased canvas width (IWC) of 2 mm, moisture content 10 % for threshing and 8 % for pearling. The threshing and pearling efficiency of thresher at this combination are 98.1 and 97.9 % respectively. The power required for operating the thresher cum pearler was 0.746 kW.

■■


G R Quick


S M Farouk


Daoulat Hussain


M A Mazed


Chetem Wangchen


Wang Wanjun


S Illangantileke


S M Ilyas


A M Michael


G Singh


T P Ojha


S R Verma


Soedjatmiko


M Behroozi-Lar


Saeid Minaei


J Sakai


B A Snorbar


C J Chung


C C Lee


M Z Bardaie




M P Pariyar


D B Ampratwum


E S Eldin


L U Opera


A D Chaudhry


A Q Mughal


R ur Rehmen


B T Devrajani


N A Abu-Khalaf


Surya Nath


R M Lantin


R P Venturina


S A Al-Suhaibani


A M S Al-Amri


S F Chang


T S Peng


S Krishnasreni


S Phong-supasamit


C Rojanasaroj


V M Salokhe


Y Pinar


I Haffar

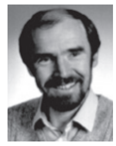

N Hay


P V Lang


A A Hazza'a


A P Kaloyanov


P Kic


H Have


J Müller


G Pellizzi




W B Hoogmoed


Jan Pawlak


O S Marchenko


J Kilgour


M Martinov

# Back Issues

(Vol.38, No.1, Winter, 2007-)

◇ ◇ ◇

**AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA**
(Vol.39, No.1, Winter, 2008)



◇ ◇ ◇

**AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA**
(Vol.39, No.2, Spring, 2008)



◇ ◇ ◇

**AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA**
(Vol.39, No.3, Summer, 2008)



■■

# INQUIRY and REQUEST to AMA

Please let us know your need. We shall promptly reply them. Inquire on any catalog listed in the advertisement in this issue. We shall try our best to serve you.

We welcome articles of interest to agricultural mechanization.

FIll in the reverse side of this card and send us by sealed letter.

**FARM MACHINERY INDUSTRIAL RESEARCH CORP.**

**7-2 Kanda nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan**

## ADVERTISED PRODUCYS INQUIRY

| Product | Advertiser | Vol., No., Page |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

## EDITORIAL REQUEST TO AMA

Your Name :

Address :

Occupation :

## SUBSCRIPTION/ORDER FORM

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA ( AMA )
Issued Quarterly

Subscription Rate (includes surface mail postage)

Annual (4 issues)........................... ¥.6,000
Single copy...................................... ¥.1,700

Back Issues (1971-75, ¥.2,000 per copy)
(1976-77, ¥.1,200 per copy)
(1978-80, ¥.1,500 per copy)

| | | |
|---|---|---|
| ★ Spring, 1971 | ☐ Vol.7 No.2, Spring, 1976 | ★ Vol.9 No.4, Autumn, 1978 |
| ★ Vol.2 Autumn, 1971 | ☐ Vol.7 No.3, Summer, 1976 | ☐ Vol.10 No.1, Winter, 1979 |
| ☐ Vol.3 No.1, 1972 | ☐ Vol.7 No.4, Autumn, 1976 | ☐ Vol.10 No.2, Spring, 1979 |
| ☐ Vol.3 No.2, Summer, 1972 | ☐ Vol.8 No.1, Winter, 1977 | ☐ Vol.10 No.3, Summer, 1979 |
| ★ Vol.4 No.1, Spring, 1973 | ☐ Vol.8 No.2, Spring, 1977 | ☐ Vol.10 No.4, Autumn, 1979 |
| ☐ Vol.4 No.2, Autumn, 1973 | ☐ Vol.8 No.3, Summer, 1977 | ★ Vol.11 No.1, Winter, 1980 |
| ★ Vol.5 No.1, Summer, 1974 | ☐ Vol.8 No.4, Autumn, 1977 | ★ Vol.11 No.2, Spring, 1980 |
| ☐ Vol.6 No.1, Spring, 1975 | ☐ Vol.9 No.1, Winter, 1978 | ☐ Vol.11 No.3, Summer, 1980 |
| ★ Vol.6 No.2, Autumn, 1975 | ☐ Vol.9 No.2, Spring, 1978 | ☐ Vol.11 No.4, Autumn, 1980 |
| ☐ Vol.7 No.1, Winter, 1976 | ★ Vol.9 No.3, Summer, 1978 | **★ : Indicates issues out of stock.** |

☐ **Abstract and Index, 1971-80(Special Issue, 1983)**

(Check issues and number of copies you wish to order)

Back Lssues from 1981, ¥.1,700 per copy (Vol. 12 No.1 and No.4 are out of stock)
**Abstract and Index, Special Issue, 1983, ¥.2,000 per copy.**

Vol.______No. _____, _____________ ,________copy / copies

(Check one)
☐ Please invoice me/us
☐ I/We enclose remittance for ¥.__________

******************************

Name: ____________________________________________

Firm: ____________________________________________

Position: ____________________________________________

Address: ____________________________________________
(block letters)

**FARM MACHINERY INDUSTRIAL RESEARCH CORP.**
7-2 Kanda nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan
Tel. (03)-3291-3671 〜 4, 5718

STAMP

FARM MACHINERY INDUSTRIAL RESEARCH CORP.
7-2 Kanda Nishikicho, Chiyoda-ku,
Tokyo 101-0054, Japan

1st FOLD HERE

2nd FOLD HERE