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EDITORIAL

The advanced nations currently enjoying national prosperity have had the experience of agricultural development which later became the basis of industrial development. Today third and the fourth industries have developed enough to drive the economy. Yet, we have to admit that the basis of all industries is agriculture which produces food and a good natural environment required for human survival. In the history of agricultural development, mechanization has had the greatest impact on agriculture.

After WW2 in Japan, the investment in agricultural mechanization raised, not only agricultural production, but, also, industrial production by farmers. Only one percent of that total production value of farmers was invested in agricultural machines which sustained Japanese agriculture and industries. More than thirty years ago it was said that mechanization of agriculture caused unemployment. The history of advanced nations, however, has proven that this was not true. On the contrary, mechanization generated new industries and expanded the opportunity for employment.

There are still many countries, mostly in the developing world, in need of agricultural mechanization. The gap between developed and developing nations has widened steadily both economically and technologically. The farmers in developing nations want more support from developed nations. Their income is far lower than that of the farmers in developed nations which stands in the way of mechanization. In view of these realities, developed nations should give full support to promote mechanization in developing countries that would match each local situation.

The United Nations organizations and FAO are responsible for taking the initiative in providing that support. It is said that FAO is to cut down the department which has promoted agricultural mechanization in developing countries. I am greatly concerned about the support for mechanization of agriculture in developing countries as a result of that change in FAO. I would like to ask all of AMA readers, and the other people who have concerns to convey the message against this change for the worse to FAO by letters and e-mails.

AMA will maintain unchanging activity with its readers to back up the development of agricultural mechanization and engineering in developing countries. The largest part of the world population is farmers in the developing world. Unless they are making a good living, stable world peace will be never realized.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
October , 2005

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol.36, No.2, November 2005

A Mathematical Model for Predicting Output Capacity of Selected Stationary Grain Threshers

by

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Abstract

A mathematical expression for predicting the output capacity for the threshing process in a throw-in-feed system of a selected stationary grain thresher is presented. The thresher output capacity model was developed by dimensional analysis, using the concept of Buckingham's Pi Theorem. The model was verified and validated by fitting it into an established experimental data from stationary mechanical millet thresher. The result reveals that the fitted model correlates well with the experimental data with R-square value of 0.99. Also, the difference between the means of the predicted and measured output capacities was not statistically significant at 5 % level of significance. The yield factor (K_m) obtained with the predicted model is approximately the same with the values obtained from known and measured results.

Introduction

One important criterion in evaluating the performance of grain threshers is the output capacity, which is the amount of grain threshed in an hour. The method of threshing often influences the output capacity. Traditionally, threshing of crops is carried out by beating with pestle or stick and bullock treading of harvested crops (Ndirika et al., 1996). However, the output capacity of these methods is very low, leading to delays in handling large volume of products and consequent losses (Singh and Joshi, 1979).

The development of agriculture during the past century and the increased productivity per agricultural worker are due largely to the adoption of mechanical power for farm operations. The adaptation of the internal combustion engine and electric motor for threshing operation in stationary powered grain threshers has contributed to the progress in mechanization as they increase in magnitude of the crop processed and reduce time spent to complete threshing operation when compared to human-and animal-power (McColly and Martin, 1955).

The successful design and performance evaluation of a grain thresher depends on one's knowledge of the output capacity, power requirement, threshing efficiency and grain loss (Ndirika, 1997; Enaburekhan, 1994; Gregory, 1988; Vas and Harrison, 1969). But not much information is available on the determination of the output capacity of grain threshers.

It has been reported that information pertaining to the crop-machine and operational parameters for stationary grain threshers are limited. Also, it has been reported that grain-straw ratio, bulk density, feed rate, separation efficiency and concave configurations influence the output capacity of grain threshers (Dash and Das, 1990, Enaburekhan, 1994, Ndirika, 1997). Therefore, in modeling the output capacity these parameters have to be studied and considered in order to provide a better understanding of their fundamental relationships for the different machines and crop variables. The limited work on mathematical models for stationary grain threshers has been reported by Huynh et al. (1982). The purpose of this study was to develop and verify a mathematical model for predicting the output capacity of a stationary grain thresher.

Materials and Methods

Theoretical Development

The thresher output capacity model was developed by dimensional analysis using the concept of Buckingham's Pi Theory (Smith et al., 1970). The output capacity of a thresher (C_T) can be modeled using dimensional analysis. Assume that the variables of importance are the feed rate (F_r), grain-straw ratio (Z) and the separation efficiency (S_e) which is the fraction of threshed grain that was recovered through the concave opening by the concave configuration. Then,

Variable	Symbol	Dimensions, [M],[L],[T]
Output capacity	C_T	MT^{-1}
Feedrate	F_r	MT^{-1}
Grain-straw ratio	Z	-
Separation efficiency	S_e	-

Table 1 Dimensions of the variables influencing output capacity (CT)

Dimensions	C_T	F_r	Z	S_e
M	1	1	0	0
L	0	0	0	0
T	-1	-1	0	0

Table 2 Dimensional matrix of variables

$C_T = f(F_r, Z, S_e)$ ....(1)

Using the [M],[L],[T] system of dimension, the dimensions of the variables identified in this study are presented in **Table 1** while the dimensional matrix is presented in **Table 2**. The procedure for applying the Buckingham's Pi Theorem to identify the dimensionless group to be formed is as follows:

The total number of variables = 4

Number of fundamental dimensions = 3

Number of dimensionless groups to be formed = 4 - 3= 1

The required solution would be:

$\pi = K_m$ ....(2)

Where, π = Pi term = dimensionless constant, K_m

K_m = Yield factor

Using the Buckingham's Pi theorem, p was found to be:

$$\pi = \frac{C_T}{F_r Z S_e} = K_m \quad (3)$$

Rearrange equation 3 then,

$C_T = K_m F_r Z S_e$ ....(4)

Huynh et al. (1982) predicted separation efficiency as: (5)

Substituting the value of S_e from equation 5 into equation 4 then, (6)

where,

Λ_1 = Threshing Parameter (mean rate of threshing).

Λ_2 = Grain migration parameter (mean rate of migration or separation for a grain through the crop stream thickness).

Λ_3 = Concave separation parameter (Number of grains passing through the concave openings in one second per input).

According to Ndirika (1997), dwell time can be estimated as follows:

t_d = Dwell time of the crop in the thresher $= \dfrac{L_c}{K_b V_b}$ ....(7)

where,

K_b = Slippage factors for beater bars

L_c = Concave length

V_b = peripheral velocity of beater

The cylinder-concave arrangement and the description of crop motion during threshing and separation processes of the spike tooth thresher used in the modeling are presented in **Figs. 1** and **2**, respectively.

$$S_e = \frac{1-[\Lambda_1\Lambda_3(\Lambda_3-\Lambda_1)e^{-\Lambda_2 t_d}+\Lambda_2\Lambda_1(\Lambda_1-\Lambda_2)e^{-\Lambda_3 t_d}+\Lambda_2\Lambda_3(\Lambda_2-\Lambda_3)e^{-\Lambda_1 t_d}]}{(\Lambda_1-\Lambda_2)(\Lambda_3-\Lambda_2)(\Lambda_3-\Lambda_1)} \quad (5)$$

$$C_T = \frac{K_m F_r Z[1-[\Lambda_1\Lambda_3(\Lambda_3-\Lambda_1)e^{-\Lambda_2 t_d}+\Lambda_2\Lambda_1(\Lambda_1-\Lambda_2)e^{-\Lambda_3 t_d}+\Lambda_2\Lambda_3(\Lambda_2-\Lambda_3)e^{-\Lambda_1 t_d}}{(\Lambda_1-\Lambda_2)(\Lambda_3-\Lambda_2)(\Lambda_3-\Lambda_1)} \quad (6)$$

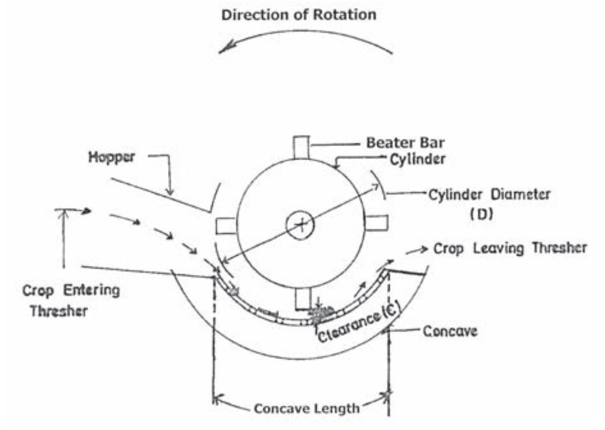

Fig. 1 Cylinder-Concave arrangement of the spike tooth thresher

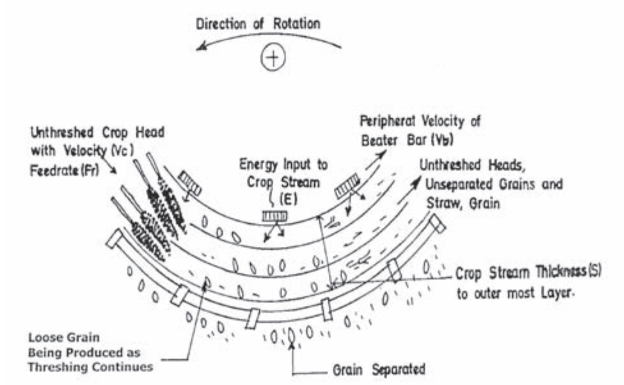

Fig. 2 Schematic description of crop motion during threshing and separation processes of the model

Determination of the Threshing, Grain Migration and Concave Separation Parameters

The Threshing Parameter, Λ_1

The threshing parameter, Λ_1 which is the threshing frequency or the mean rate of threshing was determined by dimensional analysis using the concept of Buckingham's Pi theorem and can be expressed as (Ndirika, 1997):

$$\Lambda_1 = \frac{[V_b^2 \sigma_d D]}{(1-\beta)F_r} \quad (8)$$

where,

K_T = Threshing constant

V_b = Peripheral velocity of beaters

σ_d = Crop bulk density (dry basis)

D = Cylinder diameter

β = Moisture content of wet crop (decimal)

F_r = Feederate

Grain Migration Parameter, Λ_2

The grain migration parameter (mean rate of migration or separation for a grain through the crop stream thickness (**Fig. 3**) was modeled based on the application of Newton' s second law of motion for a body under uniform acceleration starting from rest. It was assumed that the crop motion resistance (force) is constant and proportional to the force acting on the grain. The grain migration parameter was modeled and expressed as Ndirika (1997):

$$\Lambda_2 = \frac{[g^1+2V_b^2/D]^{1/2}}{K_n[\{1-\beta\}F_r/\sigma_d V_b)^{1/2}]} \text{ ....(9)}$$

where,

K_n= mean time coefficient

g^1 = acceleration due to gravitational force in the vertical direction

Concave Separation Parameter, Λ_3

The following assumptions were made in determining the rate of grain passage through concave opening:

i. That the grain slides through the crop stream with constant velocity across the concave surface;

ii That the passage of grain through a given concave opening formed by the rods and bars as shown by the concave geometry in **Fig. 4** is only possible if the projection of the grain on the concave surface is within the concave opening and;

iii That if the grain fails to pass through the concave opening it will move to the next concave opening at a constant speed.

The probability of grain passage through the concave opening was determined using the concept established by Huynh et al. (1982):

$$P = (a_1-a_2-d_1)(b_1-b_2-d_1)/(a_1b_1) \text{ ......(10)}$$

for the concave geometry as in **Fig. 4**, where,

a_1 = center line distance between rods;

b_1 = center line distance between bars;

a_2 = rod diameter

b_2 = width of the bar

S/N	Constant	Value	Equation	Source
1	K_m	0.69	6	Ndirika (1997)
2	K_b	0.40	7	Huynh et al. (1982)
3	K_T	0.00218	8	Wagami (1979)
4	K_n	2.25	9	Long et al. (1967) and Huynh et al. (1982)
5	Z	0.66	6	Ndirika (1993)

Table 3 Values of constants

S/N	Parameter	Dimension
1	Effective cylinder diameter, D	0.350m
2	Concave Length, L_c	0.360m
3	Cylinder concave clearance, C	0.006m
4	Center line distance between adjacent concave rod, a_1	0.018m
5	Concave rod diameter, a_2	0.008m
6	Center line distance between adjacent concave bars, b_1	0.025m
7	Width of the concave bars, b_2	0.0085m

Table 4 Cylinder and concave date for millet thresher

d_1 = average size of the grain which is considered spherical

P = probability of grain passage through the concave opening

The concave separation parameter, Λ_3 was modeled and can be expressed as Ndirika (1997):

$$\Lambda_3 = 2/3V_b(a_1-a_2-d_1)(b_1-b_2-d_1)/a_1b_1^2 \text{..(10)}$$

Values of Constants

The constants in the developed relations were determined by the method of least squares analysis and by calculations using information from available literature and published data. The values of constants and sources used are presented in **Table 3**.

Verification and Validation of the Model

The output capacity model was verified in order to confirm its consistency with established experimental results from a thresher. The study was conducted on an existing millet thresher and the predicted model was also compared with the experimental data. The specifications of the cylinder-concave unit and the operating conditions of the thresher used are shown in **Tables 4** and **5**, respectively.

A model would have greater confidence if a good fit and a high significance level is attained. However, the method developed by Gregory and Fedler (1986) for calculating the coefficient of determination, R^2 statistically for non-linear as well as for linear function and with one or more independent variables is adopted here. Thus,

$$R^2 = 1 - V_o/V_t \text{ ....(11)}$$

Where,

R^2 = coefficient of determination

V_o = estimated variance about the mean from the measured data

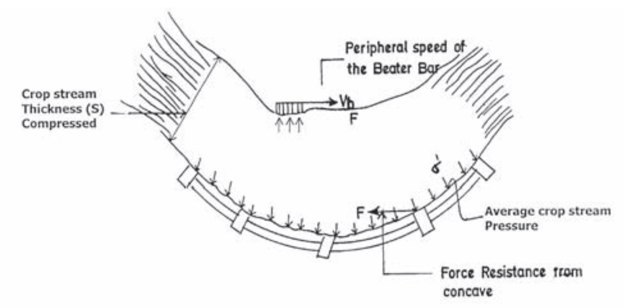

Fig.3 Force analysis of the crop stream in the threshing zone

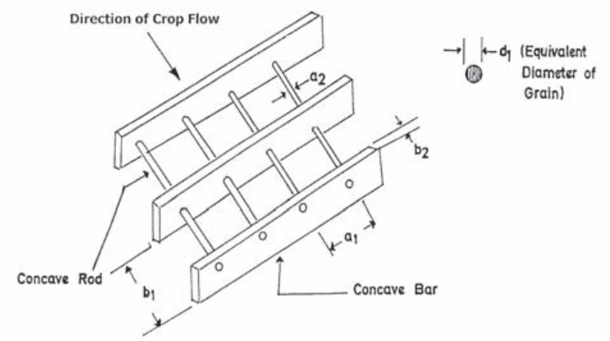

Fig.4 Concave configuration

S/N	Parameter	Value / Level					
		1	2	3	4	5	6
1	Feed rate, F_r (kg^2)/s	0.02	0.03	0.04	0.05	0.06	0.07
2	Cylinder speed with road, V_b (m/s)	3.40	3.72	3.85	4.14	4.65	5.0
3	Cylinder speed in rpm	400	500	600	700	800	900
4	Moisture content, ß (decimal)	0.09	0.10	0.11	0.12	0.13	0.14
2	Bulk density σ_d (kg/m^3)	102	98.6	90.2	82.83	75.8	62.12
3	Average grain Diameter, d_l (m)	0.003m					
7	Crop variety	Ex-Borno					
4	Acceleration due to gravity of crop, g^l	10m/s					
9	Power of prime mover used (kw)	3.7kw (5hp)					

Table 5 Crop and operating conditions for millet thresher

Cases	F_r (kg/h)	Z (decimal)	S_e (decimal)	X (Fr Z S_e)	C_T (kg/h)	
					Predicted (computed)	Measured
1	29.87	0.66	0.956	19.02	13.12	13.31
2	31.62	0.66	0.966	20.16	13.91	14.11
3	49.66	0.66	0.968	31.73	21.89	22.21
4	57.45	0.66	0.983	37.27	25.72	26.09
5	60.67	0.66	0.984	39.40	27.19	27.58
				Mean:	20.37	20.66

Table 6 Experimental date: Measured and computed values of C_T

V_t = estimated variance about the mean of the data from the predicted model

Since the R^2 value from equation 11 must have a level of significance before the model is considered verified, the statistical significance test was done to ascertain how adequately the sample data test used for developing the model represents the whole population. The significant level for a given R^2 can be obtained by computing 't' using the following equation (Snedecor and Cochran, 1980);

$$t = R(D_f)^{1/2} / (1-R^2)^{1/2} \text{.....................(12)}$$

where,

t = Students 't' value

R = Square root of coefficient of determination

D_f = Degrees of freedom (Number of data points minus Number of constant defined in the model)

The line of good fit is presented graphically (**Fig. 5**) and also used to compare the predicted output capacity model and the measured results. In order to further ascertain the validity of the model, equation 4 was linearlized by the method of least square, and by using the data in **Table 6**, the value of the constant, K_m in the equation was estimated and compared to known values of K_m. This was done using the results from **Table 6** by plotting the values of output capacities, C_T from both the measured and predicted (computed) results against the product of feedrate (F_r), Grain-straw ratio (Z) and separation efficiency (S_e) as shown in **Fig. 6**. The same set of data was used to compute the R-square value (R^2).

Instrumentation and Measurements

The data generated from the stationary millet thresher used in the verification of the output capacity model were measured or evaluated by the following methods:

Capacity measurement: The output capacity was measured by weighing the grains collected from the grain outlet at hourly intervals in the threshing operation.

Weight measurement: A mettler balance with 0.01 g calibration was used for weighing.

Time measurement: Time was measured using a stop watch.

Moisture content determination: Moisture content of crop was determined by oven dry method at a temperature of 130 ºC for 18 hours (ASAE, 1972).

Bulk density determination: The bulk density was found by weight-volume method under natural filling condition.

Speed measurement: A revolution counter (tachometer) was used for speed measurement.

Length measurement: A meter rule and vernier caliper was used in length measures.

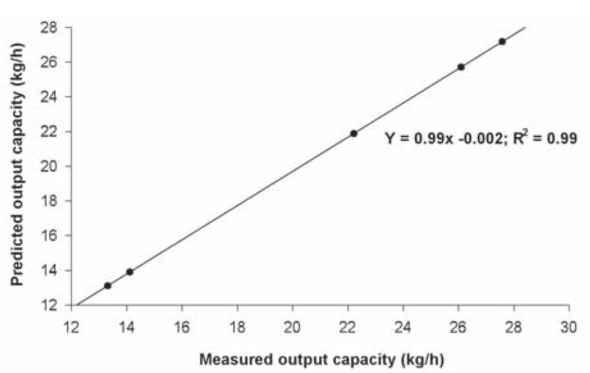

Fig.5 Mesured vs predicted capacity for a millet thresher

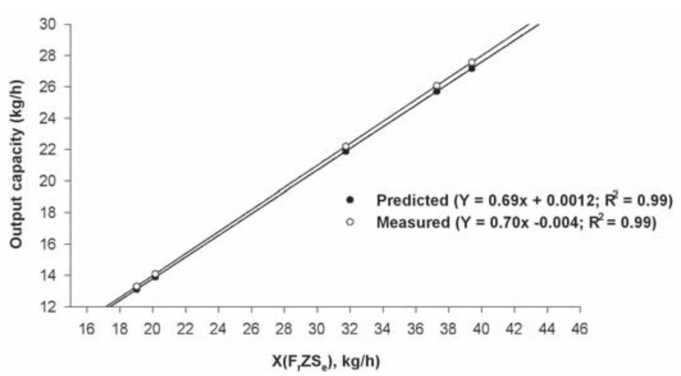

Fig.6 Output capacity vs product of feedrate, grain-straw ratio and separation efficiency

Table 7 Calculated R2 and 't' values of the compared output capacity model with measured date from millet thresher at P ≤ 0.05 level of significance

Model	Validation Parameters			
	R^2 Value	Calculated 't' Value	Table 't' Value	Significance
Output Capacity (CT)	0.99	0.070	2.306	n.s.

n.s.= Not significance

Results and Discussions

Model Validation

The output capacity model (Equation 6) was validated with the measured data from the existing millet thresher. From **Fig. 5**, it was observed that the model has a high correlation with the measured data obtained from the thresher with R^2 value of 0.99 (**Table 7**). When the means of the predicted and measured output capacities were compared statistically, it was shown that there was no significant difference between the means at 5 % level of significance, since the calculated 't' value (0.070) is less than the table 't' value (2.306) as shown in **Table 7**. From **Fig. 6**, the regression equation obtained from the least square analysis for the predicted and measured results were:

$C_T = 0.0012 + 0.69X$ and $C_T = -0.004 + 0.70X$, respectively. Comparing the slopes (K_m) of the two regression equations, it was observed that the values of K_m in both cases (0.69 and 0.70, respectively,) were approximately the same. This also agrees with the value, 0.70 obtained from Ajibola (1980). The results show that the model has a high correlation with the measured data from a millet thresher.

Conclusions

Based on the results of this study, the following conclusions can be drawn: The output capacity of stationary grain thresher can be described using a mathematical model which includes parameters such as feed rate, grain–straw ratio, mean rate of threshing, mean rate of migration or separation of grain through the crop stream thickness, number of grains passing through the concave openings in one second per impact and dwell time of crop in the thresher.

This also takes into account variables such as velocity of beaters, crop bulk density, cylinder diameter, crop moisture content, concave configurations and dimensions.

The difference between the means of the predicted and measured output capacities is not statistically significant at 5 % level of significance.

The yield factor (K_m) obtained with the predicted model is approximately the same with the values obtained from known and measured results.

The predicated output capacity model fits well with experimental results from existing millet thresher.

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Study on the Development of Agricultural Machines for Small-Scale Farmers, Part 2 (Applied Technology to the Improvement of an Animal-Drawn Plow for Morocco and Africa)

by

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Abstract

The purpose of this research is to improve the working performance of the animal-drawn plow for small-scale farmers in Africa, as based on conditions in Morocco. Animal-traction farming is not widespread in Africa, except in a few regions. Furthermore, tractor cultivation is still difficult for small-scale farmers due to economic constraints and the need for shared use of machines, which involves solving operational, technical and maintenance problems.

The plowing depth with seed-covering cultivation is about 10 cm on the dry land of Morocco. Traction forces are, therefore, low during actual operation. As a result, stable operation of animal-drawn plows and subsequent reduction of the workload on the draft animals are being sought for farming operations.

The minimizing of the standard deviation (SD) of measured data (amplitude of ranges) of the draft force was selected as the performance evaluation parameter for stable and efficient handling and for steady operation.

Throughout these experiments contributing most to the uniformity of plow performance the longest plow sole (51 cm) turned out to be the element when draft force, required horsepower, stepping reduction rate, and operational stability were considered.

Introduction

Infection of animals due to tsetse flies is one of the primary reasons that animal traction has not been popular in the agriculture of Africa, especially in the Sub-Saharan regions (FAO, 1990), as reported by Munzinger (1982). The use of horses, mules, asses (donkeys), or cows for animal traction is statistically very low, and the practical use of animals for draft power is lower than in other countries. No infection from tsetse flies is presently reported in Morocco. However, every country of Sub-Saharan Africa is endeavoring to eradicate infectious diseases, such as that from tsetse flies, through widely developed cooperation with Kenya, Tanzania, Ghana, the Ivory Coast, Nigeria, and other countries.

Animal traction is presently widely used in Morocco, regardless of farm size. An investigation (Tsujimoto, 2002) of 35 agricultural cooperative associations indicated that one dominant feature of small-scale farmers was the possession of an animal plow, harrow, or transport equipment item. S hared machines for animal power were considered to be important elements of farm machinery inventory. Horses and mules were the main types of draft animals used for farming. The small-scale farmer, in particular, used the ass as a draft animal. Use of these domestic animals for farming is commonly noted among farmers holding 10 ha or less. Many farmers with holdings of a 50 ha scale also own cattle and other animals for use on their farms. Use of the traditional wooden plow for animal traction is dominant. The iron plow is made principally by two manufacturers; however, a local factory for small-scale farm machines and implements produces a similar plow, which can be made to order. The same firm can also perform maintenance on the units produced.

The Moroccan government provides a subsidy when the farmer buys these implements. For the animal-drawn plow the amount of subsidy has been designated as 50%. The government tries to encourage improvement of animal plows for small-scale farmers, but thus far, no research has been performed to improve plow stability or ease of handling. Therefore, research on modification of the plow was carried out under typical conditions in Morocco. Technology from North Africa, from a country such as Morocco, or from Europe, should be adopted for application to animal-drawn plows in other African countries such as the Sub-Saharan nations where upland crops, including wheat, are cultivated and traditional animal power is used, rather than adapting techniques based on different farming conditions, for example, those from the rice farming areas in the Asian region.

Traditional plowing is used for wheat cultivation, and is called crop seed coverings. Plowing is done immediately after broadcast seeding. Therefore, it is not necessary to plow very deeply. The plowing depth is generally about 8 to 10 cm. Thus, local manufacturers in Morocco produce animal-drawn plows with a 31 cm plow sole. This results in poor handling efficiency and inconsistent operational stability and causes difficulties. There is also a problem with the durability of the animal plow.

The features of an animal-drawn plow in Morocco are described below.

1. It is used extensively in hilly terrain and mountainous regions.

2. The greatest advantage of using an animal-drawn plow in Morocco should be its ease of handling since plowing and covering of seed with soil are carried out simultaneously after hand sowing, with extremely shallow plowing of 8 to 10cm.

3. The fields are sandy, stony, and dry.

4. The harnesses and yokes of the draft animals are generally simple, thus, draft uniformity and easy handling of the plow are necessary.

5. The horse, mule, or the donkey generally works at a high speed, but they do not have sufficient energy, which causes the walking speed to decrease within 20 minutes of starting work (Bansal, 1992). This factor can apply additional stress to the animals. Therefore, the farmer could work more easily if draft force uniformity and handling were improved, so that more continuous and stable work could be accomplished.

An experiment comparing the conditions of different lengths of the original plow sole for animal traction was conducted during this research. Depth and draft-force uniformity, as well as efficiency of handling were evaluated, and a simple-to-use plow was developed for small-scale farmers in North Africa.

Experimental Method

The experimental devices and field conditions are depicted in **Figs. 1** and **2**. A single horse was used for traction to help achieve stability and continuity of operation. A male horse that weighs about 2000 N (204 kg mass is the standard for

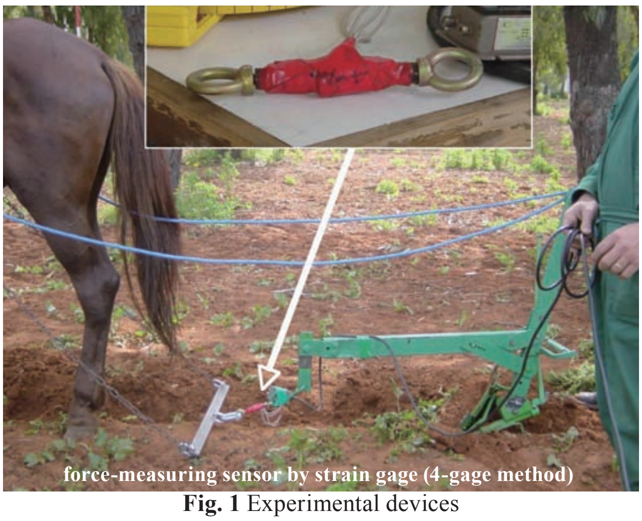

Fig. 1 Experimental devices

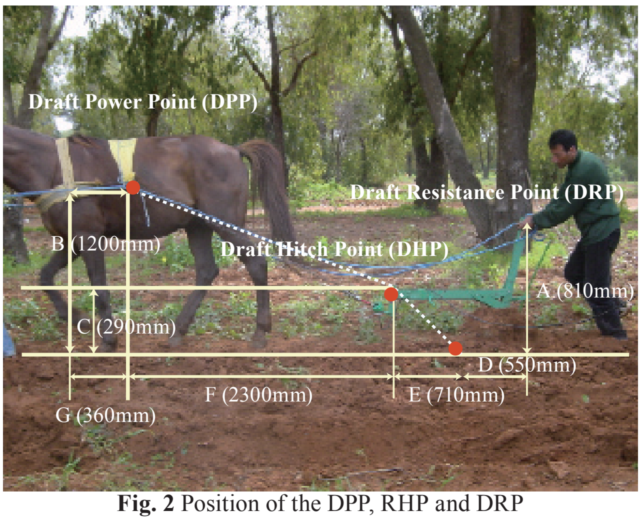

Fig. 2 Position of the DPP, RHP and DRP

Morocco. The horse's health was excellent on the day of the experiment. Although the experiment extended from morning to afternoon, the horse did not exhibit fatigue and was plowing constantly. The improved animal plow used for the experiment was designed as a modified version of the reversible type commonly used in Japan (an improved Japanese plow), and a trial was conducted in a factory for small-scale farm machines and implements in Morocco. Another example is the reversible type, of plow which is manufactured in northeast Spain and is called a Catalan plow (Spanish plow), which was made and assembled for trial purposes at this factory.

Experimental Apparatus

Figure 3 illustrates the improvement made in the experimental plow relative to the plow currently used in Morocco. This improved plow was modified from a Japanese plow; its primary feature is the reversible mechanism. Animal plowing is generally carried out after broadcast sowing; thus, soil turning and seed covering are done at the same time. The plow should be carefully handled by the operator while observing the condition of the overturned soil and degree of seed coverings in the field. Plow soles with lengths of 31 cm, 41 cm, and 51 cm were designed for trial purposes and tested experimentally, as illustrated in **Fig. 3**.

Figure 4 depicts the long-sole plow and a round iron bar which serves as the share point for the plow manufactured in Spain. The plow sole is 51 cm long. This plow is also of the reversible type. The reversal operation turns the main body of the plow 90 degrees in the other direction, where it is fixed against the plow handle stop (**Fig. 5**). This Spanish plow is all iron, including the beam, and weighs 177 N (18 kg. mass) The improved Japanese plow weighs 198 N (20.2 kg. mass) The total weight of the plow should not exceed 196 N (20 kg mass).

The characteristics measured were forward speed, hardness of soil, plowing depth, soil moisture content, draft force, and the time required for plowing. The measuring instruments were set up on a truck.

Field Conditions

The field experiment was conducted over two days at the Institute of Agronomy and Veterinary Medicine Hassan (IAV) in Rabat. The weather on those two days was slightly cloudy, with a temperature of 20 ºC, and 50 % to 62 % relative humidity. The soil was a mixture of sand and red loam. It is known as hamri, or harch, in Morocco. Two types of mixed soil, clay with sand and a loam with sand are native to Morocco. The names of several soils in Morocco are provided in **Table 1**. The geographical distribution of soil types indicates that there is a clay type in the north and a sandy, stony soil in the south. The soil moisture content at the time of the experiment was 35.21 % on the average. Rainfall in 2003 was heavier than in previous years, and soil conditions were good.

Relations between depth (cm) and soil hardness are illustrated in **Fig. 6**. Soil resistance measurement instruments (soil cone penetrometer and soil shear strengh apparatus) (SR-2 type and DIK-5501) were used to detect field-test conditions. It was apparent that the soil in Morocco was generally very hard (plow-pan layer) and deeper than 10 cm. It gradually becomes harder at depths beyond 10 cm. The difficulty

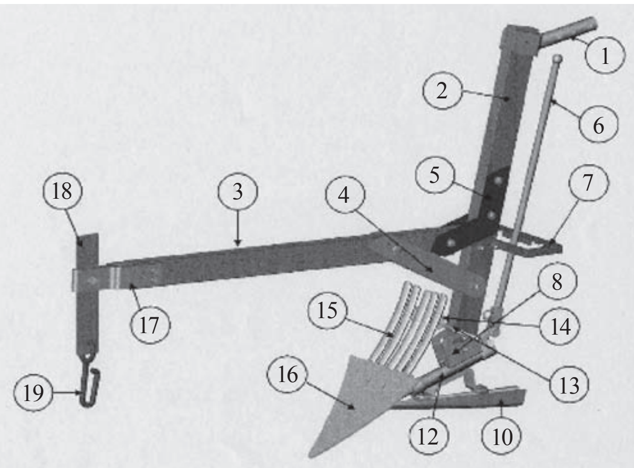

Fig. 3 Improved Japanese plow
1. Handle, 2. Beam A, 3. Beam B, 4. Stay A, 5. Stay B, 6. Reversible handle, 7. Reversible bracket, 8. Beam support, 9. Plow support, 10. Plow sole piece, 11. Plow support shaft, 12. Reversible handle shaft, 13. Differncial bracket, 14. Mould-finger bracket, 15. Mould-board finger assy., 16. Share, 17. Clevis support, 18. Clevis, 19. Hook

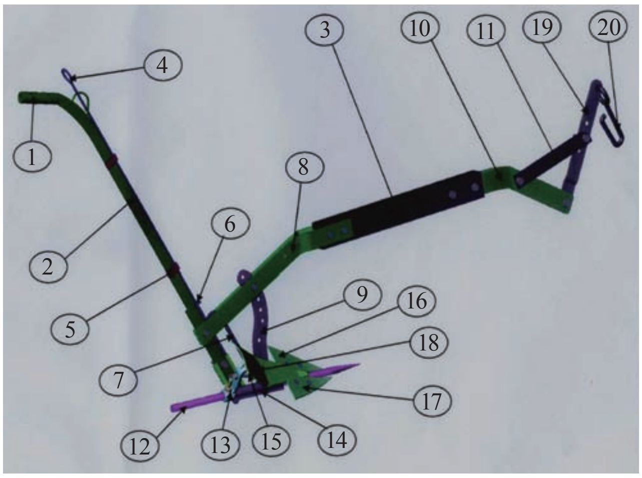

Fig. 4 Spanish plow (Catalan plow)
1. Handle, 2. Beam A, 3. Beam B, 4. Reversible handle, 5. Reversible handle support, 6. Reversible handle holder, 7. Reversible handle stopper, 8. Stay A, 9. Stay B, 10. Beam stay A, 11. Beam stay B, 12. Plow sole piece, 13. Plow sole holder, 14. Plow sole support, 15. Mould-finger bracket, 16. Left share, 17. Right share, 18. Center share, 19. Clevis, 20. Hook

Fig. 5 Reversible action of the Spanish plow

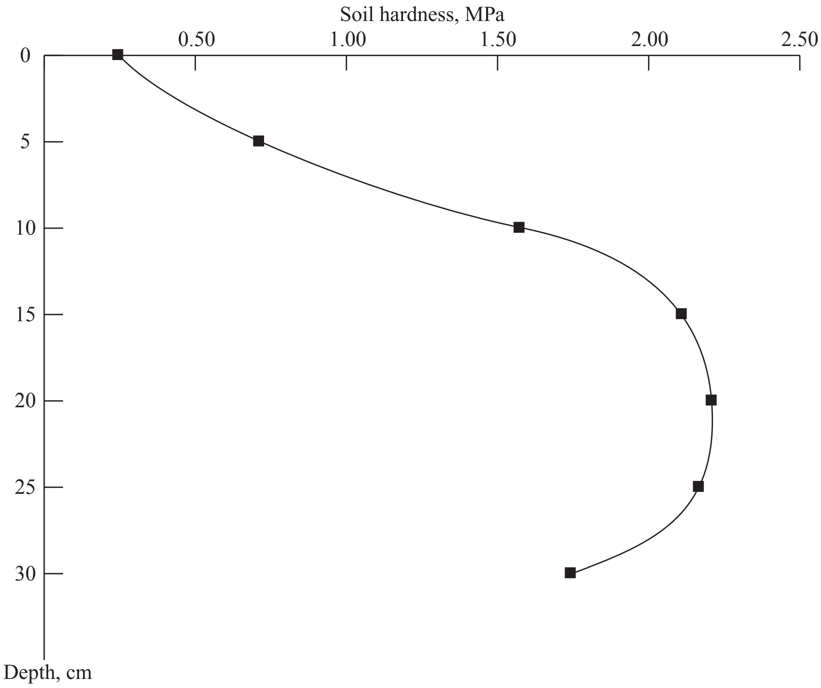

Fig. 6 Relation between depth (cm) and soil hardness (MPa) as measured by a soil cone penetrometer

of plowing with single-horse traction in Morocco's hard soil was evident. The plowing depth was 8 to 10 cm in accordance with traditional tillage methods, and therefore, a single horse was used as the traction power source for this experiment.

Data Analysis

Draft Force

Animal traction using mules, horses, asses, and camels is a common agricultural practice in Morocco, with the heaviest animal being the mule at 2452 to 3433 N (250 to 350 kg mass, followed by the horse at 1766 to 2943 N (180 to 300 kg mass). The average draft force for continuous traction is 795 N (81 kgf for a single horse); this is 30 % of the total weight of the horse (Bansal, 1992).

The weight of the horse can be estimated by the following equation: (Brian, 1987 and Sergio, 1992).

$$P=82.47(G^2L)-20.43 \quad (1)$$

(r=0.93)

where,
P=Total weight in kgf (1 kgf=9.81 N)
G=Girth of the chest of the horse (m)
L=Distance from the horse's scapula to the root of the tail (m)

The horse used for the experiment had a 1.56 m chest girth and it was 1.12 m from the horse's scapula to the root of the tail. Equation 1 indicates that the horse used in the experiment weighed 204.35 kgf.

Required Horsepower

The draft force was measured by strain gauges set on both sides of an iron bar at a width of 4 mm. The installation arrangement of the strain gages is shown **Fig. 1**. These measuring sensors were tied to the clevis and hooks placed between the plow and the single-tree (see **Figs. 1** and **2**) and were connected to the bridge box, strain meter, and pen recorder. Strain gauge readings were calculated according to a calibration relationship of (F=0.496 μ) and the range measured was maximum at 500 kgf. In the above calibration relationship F is the force in kgf and μ is the stain in units of 1/106.

The actual data measured in this experiment are provided in **Fig. 7**. Forces were measured six times with each type of plow sole tested, The traction horsepower was calculated based on the following equation:

$$N=\frac{FV}{75(Nms^{-1})/\text{horsepower}} \quad (2)$$

where,

Name of soil	Contents of soil
Argileux	Clay soil
Tris	Clay soil (Black color)
Hamri	High % of sandy and loam (Black color)
Harch	Sandy soil and mixed with low % of loam
Biada	Sandy soil (White color)
Sableux	Sandy soil
Pierreux	Stony soil

Table 1 Soil characteristics in Morocco

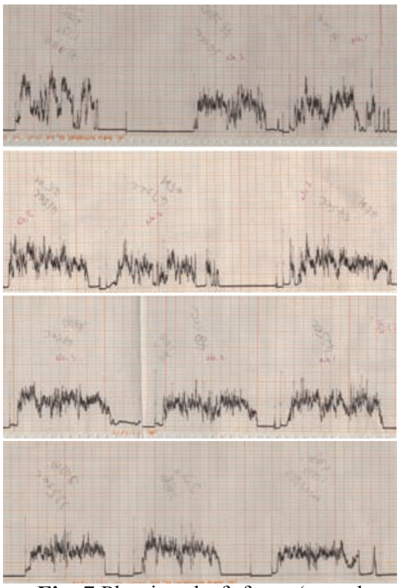

Fig. 7 Plowing draft force (actual measurement curves)

N=Required horsepower (PS)
F=Draft force in kgf (1 kgf=9.81 N)
V=Forward plowing speed (m/s)

Stepping Reduction Rate

The purpose of lengthening the plow sole was to improve the depth stability of the plow and to give it a flexible structure, so that it could function well in different soil conditions.

The handling stability of an animal-drawn plow can be indicated by charges in the forward speed of a single horse which can be obtained by using a typical no-load walking speed of t, in which: t_1=1.23 m/sec (Bansal, 1992). The following equation was used to calculate the stepping speed reduction rate,

$$N=\frac{t_1-t}{t_1}x100 \text{ ....(3)}$$

where,
t=actual working speed (m/sc)

Experimental Results

The draft resistance point (DRP), draft power point (DPP), and draft hitch point (DHP) were used primarily as the performance evaluation parameters in this experiment (**Fig. 2**). They were determined by changing the length of the plow sole using three lengths, i.e. a short plow sole, a medium plow sole, and a long plow sole, to improve the tractive load of the plow on the draft animal (horse) and to maximize the ease of handling of the Japanese plow. The structure of the Spanish plow could be adjusted with regard to the length of the plow sole. The longest possible adjustment of the plow sole was to a length of 51 cm.

A stepping reduction rate of 13.01 % was obtained with the improved Japanese plow having a long plow sole. The stepping reduction rate for the plow with the short plow sole was 22.76 %, and that for the plow with the medium plow sole length was 26.82 % (**Fig. 8**). The stepping reduction rate for the Spanish plow with the longest sole was 16.10 %. The operator's evaluation in the experiment indicated that the stability of the plow with the long plow sole was judged to be better than those of the plows with the short or medium length soles. Therefore, the plow with the long plow sole was the steadiest and the one which provided the most efficient handling. The Spanish plow which had a long sole and the improved Japanese plow with a sole of 51 cm length yielded the lowest stepping reduction rate, S, (see **Eq. 3**), and thus, the steadiest operation.

The draft force of the Japanese plow with the 31 cm plow sole length was 804.28 N, that of the plow with the 41 cm plow sole length was 725.73 N, and that of the plow with the 51cm plow sole length was 730.97 N (**Fig. 9**). The draft forces with the medium and long sole lengths were almost the same.

Equation 2 indicates that the calculated horsepower requirement of the improved Japanese plow was 1.038 PS with the 31 cm plow sole, 0.887 PS with the 41 cm plow sole, and 1.063 PS with the 51 cm plow sole (**Fig. 10**).

A draft force of 701.65 N and required horsepower of 0.982PS were obtained with the Spanish plow having a long sole (51 cm) in this experiment.

According to this experimental data, the draft force of the Spanish plow was slightly less than that of the improved type Japanese plow, but from the point view of actual reversible operation and operational stability, the Spanish plow is very complicated and more difficult to operate than the Japanese type of plow shown in **Fig. 5**.

This study also suggests the comparison of the standard deviation (SD) of the actual plowing draft force measurement over the range of the experimental data, as a method to address the handling and operation evaluations of the operator. More than 300 points of data from three experiments yielded actual draft force curves for each test condition. These, were read manually

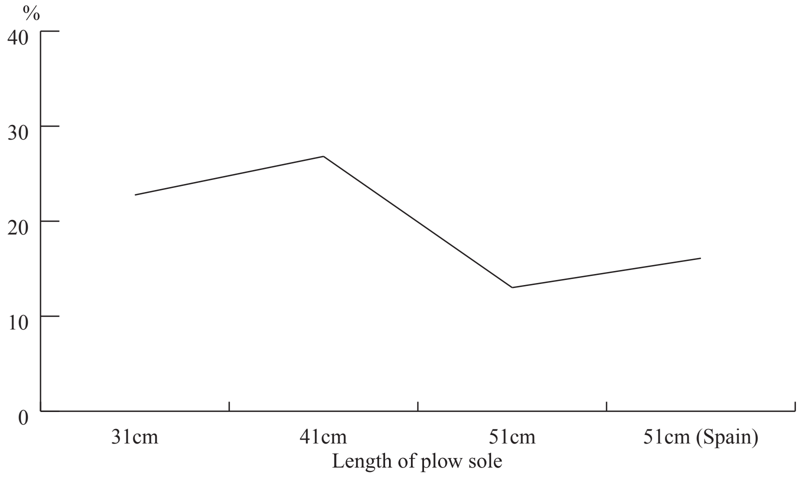

Fig. 8 Stepping reduction rate (%)

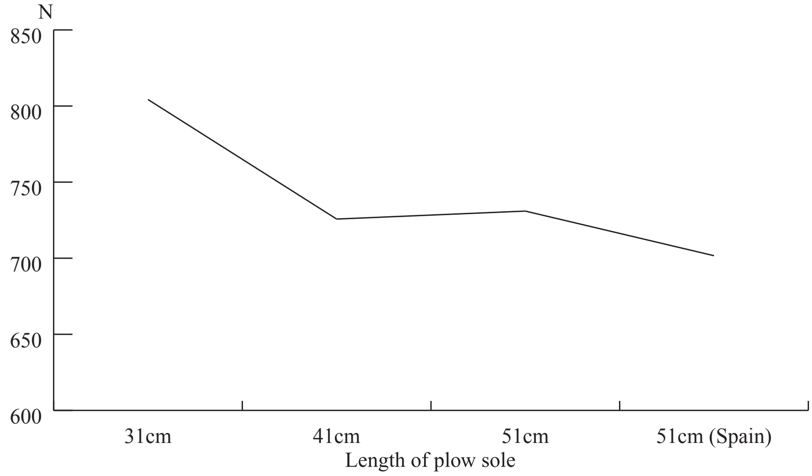

Fig. 9 Average plow draft force with different plow sole length

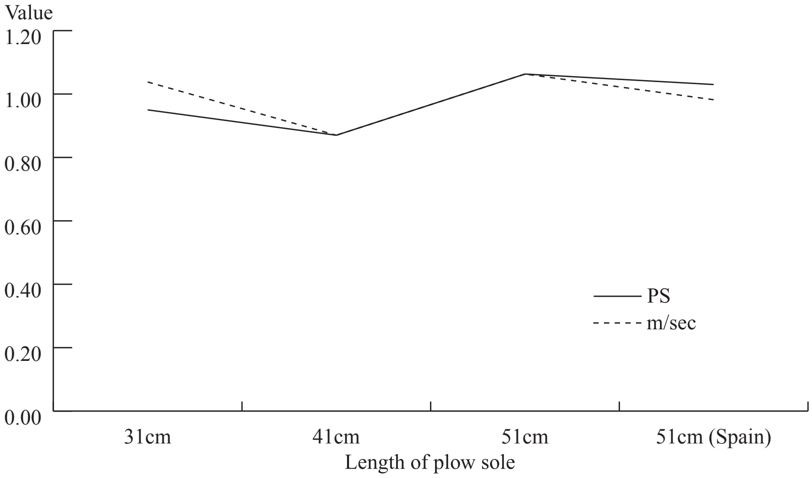

Fig. 10 Required horse power (PS) and speed during plowing

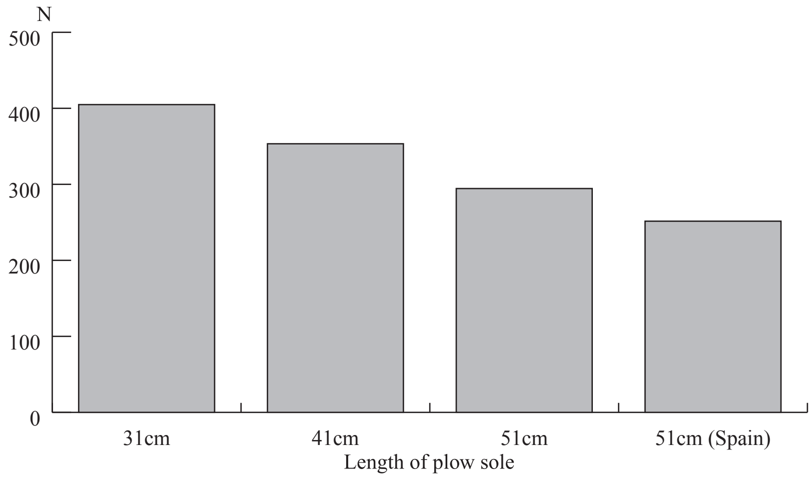

Fig. 11 Cumparison of the standard deviation (SD) values for plow draft-force date for plows with various sole lengths

and their standard deviations calculated. The actual standard deviation of the draft force for the improved Japanese plow with the long sole was the lowest obtained in this experiment to determine plowing resistance characteristics, as is indicated in **Fig. 11**.

Conclusions

It was evident throughout this experiment that the operational advantage of the improved Japanese plow was the ease of handling. It was more stable and more efficient than the traditional plow in Morocco. The results of this research demonstrate that the increase in the length of the plow sole of the improved Japanese plow should be about 20 cm over that of the traditional 31 cm plow sole to achieve increased stability and ease of handling.

Improving the depth and tractive force uniformity as well as the improving the handling of the animal-drawn plow used in Morocco and Sub-Saharan Africa can reduce the plowing labor for small-scale farmers.

The principal conclusions of this experiment are presented below.

1. The small-scale farmer in Morocco uses animal traction plows on hill slopes, in hilly districts and in ravines. The uniformity of depth and draft is, therefore, a significant consideration. A long plow sole is very effective from this standpoint.
2. The minimum draft forces were obtained in this experiment with the plow with the long plow sole however, the improved Japanese plow must be designed to have a long sole to achieve better handling characteristics and uniformity or depth and draft. The plow with the long sole had somewhat high mean values of required horsepower during its smooth operation in continuous plowing.
3. Both the Japanese improved plow and the Spanish plow were stable with regard to draft force (N), horsepower (PS), and stepping reduction rate (%) with short, medium, and long plow sole lengths.
4. Maintaining a constant plowing speed is an important factor in animal traction plowing. Therefore, the uniformity of depth and draft should be judged by the actual speed of operation as well as by the required

tractive horsepower. The stepping reduction rates of the improved Japanese plow and the Spanish plow were low. This indicates that the steadiest operation was achieved with the long-sole plows.

5. The long plow sole also proved to make the plow steadier in terms of running and operational evaluations. The results of this experiment indicate that the most important design parameter is for animal-drawn plows to have a long sole.

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Development of an Industrial Yam Peeler

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Abstract

All forms of yam tuber processing demand that the tubers be peeled. The lack of a successful commercial peeling machine has been a major factor inhibiting the growth of the yam processing industry.

In recognition of this problem, a mechanical yam peeler was built. Emphasis was placed on the peeling of *D. rotundata* (white yam). The machine consists of a (1) conveyor system which accepts the unpeeled tuber, delivers it to where it will be peeled, and withdraws it after it is peeled; (2) the peeling chamber where the peeling is done; (3) transmission; and (4) an electrical prime mover. The machine was designed for continuous peeling. Many parts are spring-loaded to accommodate various sizes and shapes of yam tubers.

The machine performance was characterized by peeling efficiency, peeling losses, and throughput rate. It peels at the rate of 16 mm of tuber length per second irrespective of the tuber size and shape. Peeling efficiency ranged from 62.7 to 80 % while material recovery ranged from 82.7 to 88.8 %. The machine performance was not affected by tuber mass, tuber diameter, and moisture content.

Introduction

General

Yams are the most important food crop in West Africa except for cereals (Onwueme, 1978). So important is the yam that in many regions it is given an almost mystical significance (Apeji, 1993). Of the many species consumed, white yam (*D. rotundata*) is the most important (Ajibola and Onayemi, 1988). According to Okonkwo (1985), *D. rotundata* is the most widely grown and eaten yam species in Nigeria, and indeed, West Africa, and it is the most important in the world.

Presently, yam has little or no place in the international market. This does not mean that it lacks the nutritional values necessary to accord it international recognition. The fact is that the crop has not received the processing necessary to keep it on the shelf internationally. In fact, FAO (1990) reported that yams have not been processed to any significant extent commercially. If a crop is processed into various forms, its probability of being consumed by more people becomes higher. The yam tuber is prepared in several ways for eating. The tuber may be peeled and boiled, and the cooked yam eaten with palm oil or any prepared sauce. Yam can also be peeled, sliced and fried in oil or made into a pottage. By far, the most popular way in which yam is traditionally eaten is as pounded yam. The peeled yam tubers are cut into pieces and boiled. When cooked, and while hot, the boiled yam is pounded in a wooden mortar and with a wooden pestle. The yam is pounded until it forms a white or slightly yellowish doughy mass; this is eaten with various sauces. Peeled yam tubers are cut into pieces, parboiled, and then sun-dried. The dried pieces are milled into a flour which is used to make a black dough called 'amala' (in Yoruba) or 'achicha' (in Ibo).

The activities involved in the processing of yam include washing, peeling, slicing, cooking, frying, drying, and milling. Of all the processes mentioned above, peeling, which is needed for any form of yam processing, has so far proved very difficult to mechanize and this is mainly due to the varying shapes and sizes of the crop. Because of the difficulties involved in developing a commercial yam peeler, some research workers have looked into the possibility of incorporating the yam peel in processed yam without adversely affecting the quality of the product. For instance, Akoroda (1987) carried out such research work and found out that the use of unpeeled tubers for yam flour production would increase the dietary fibre content of the flour. Adamson (1985) found that dietary fibre is partially resistant to digestion by secretions of human gastrointestinal tract including carbohydrate compounds such as cellulose, hemicellulose, mucilages, pectin, gums, and non-carbohydrate compounds such as lignin. The presence of peel in yam flour reduces its aesthetic quality and when eaten along with tuber flesh it is difficult to and is not ac-

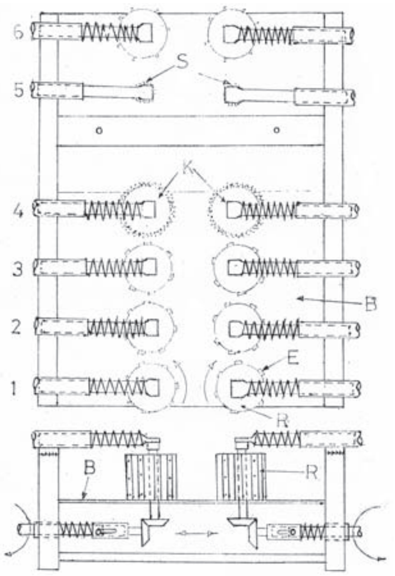

Fig. 1 Diagramatic view of the conveyor system

ceptable to consumers.

The need to isolate peels from yam products, therefore, becomes obvious. The work presented here was centred on the development of a mechanical system that would handle yam peeling for various shapes and sizes of yam tubers and with special attention to *D. rotundata*.

Review of Literature

The literature of the yam peeling machine, and recent work on yam tuber peeling systems, are very scarce. Available literature is limited to work which has not gone beyond the four walls of the engineering research workshops. No published articles that described functional yam peeling machines were found in literature.

The shapes and sizes of yam tubers are the bottlenecks in developing a yam peeling machine. Shape and size are inseparable in a physical object and both are necessary if the object is to be satisfactorily described (Mohsenin, 1986). Sitkei (1986) stated that the functioning of many types of agricultural machines is influenced decisively by the shapes and sizes of the objects participating. The shape and size of yam tuber vary from species to species (Course, 1967).

Generally, peeling involves the removal of a thin layer, called the peel, from a stock. This stock may be fruit, tuber, wood (debarking), or even metal (turning on the lathe). The work done so far on the development of material peeling systems reveal three general methods of peeling. They are the use of abrasive action, chemicals (like caustic solution, brine and oil), and heat.

The abrasion method has been used to peel potatoes, ginger, and has been tried on yam tubers. Abrasion peelers for potatoes are theoretically designed to contact uniformly the surface of the potato being peeled with abrasive discs or rolls, in such a way as to remove the peel with as little peeling loss as possible. None of the peelers has proven to be entirely satisfactory for all potatoes (Talburt and Smith, 1975). Agrawal et al. (1983) developed an abrasive brush type ginger peeling machine. The operation of the machine was later optimized by Agrawal et al. (1987). The peeler consisted essentially of two continuous brush belts being driven in opposite directions with a downward relative velocity by a variable-speed electric motor. The movement of the two brush belts in opposite directions provided the abrasive action on the ginger passing in between, while the downward relative velocity provided flow of ginger. In the manually operated ginger peeler developed by Charan et al. (1993), brushes made of coconut fibres were used as abrasive materials. A moving abrasive material was mounted on two endless canvas belts. A stationary abrasive surface was also developed with the same brushes, arranging them side by side on a wooden plank of 780 x 240 x 15 mm. A uniform gap of 15 mm was maintained between the moving and stationary surfaces so as to accommodate ginger pawn between them.

Several methods have been used for peeling onions. The common methods used in modern onion processing industry are lye treatment, flame peeling and mechanical peeling (Srivastava et al. 1997). The authors stated that lime and flame peeling methods are harsh and not suitable for many onion products and, therefore, recommended the mechanical peeling method (abrasion peeling). For their machine, they made use of four scoring blades as the peeling tool.

Attempts have been made to develop a functional cassava tuber peeler, using the abrasive action. Odigbo (1976) developed a continuous cassava peeler consisting of a cylindrical knife assembly and a rough cylinder mounted parallel to each other 20 mm apart. He reported peeling efficiency of over 95 % but only for sized lots of cassava tuber slices. Ezekwe (1979), Odigbo (1983), and Nwokedi (1984) designed and constructed batch cassava peelers that were similar in principle. The peelers rotate a mixture of cassava tubers and abrasive materials in a drum to effect peeling. It has been reported (Ohwovoriole et al., 1988) that the peelers work best for sized tubers and have no control on the depth of peel re-

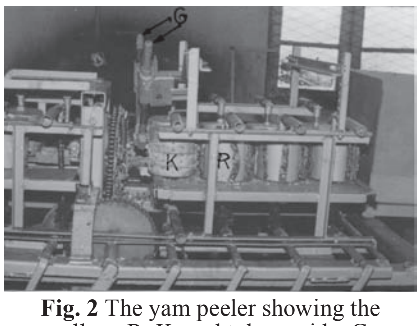

Fig. 2 The yam peeler showing the rollers, R, K, and tuber guide, G

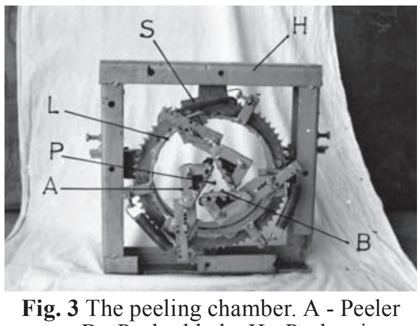

Fig. 3 The peeling chamber. A - Peeler arm, B - Peeler blade, H - Peeler ring housing, S - Spring, L - Peeler ling

moved with resultant high losses of cassava flesh.

The previous work done on the development of yam peeler have failed to achieve a break-through. The work done, using abrasive action, by Ofi (1982) and many others, including students in various tertiary institutions (as research projects), are examples of such work.

Peeling by the use of chemicals and heat obviously denatures the peeled material. This is due to the action of heat and the reaction of the chemicals with the constituents of the peeled materials. The methods are, therefore, not recommended for yam peeling.

Methodology

Machine Development

The yam peeling machine consists mainly of the following named parts:

(i) Yam tuber container: This holds the tubers ready to be peeled.

(ii) A conveyor system: The conveyor system is shown diagrammatically in **Fig. 1**. It consists of four pairs of cylindrical rollers, R, marked 1-4, for feeding the machine with unpeeled tubers; and another two pairs of rollers, marked 5-6, for withdrawing already peeled tubers. The rollers on the right hand side rotate in a clockwise direction while those on the left hand side rotate in the opposite direction such that any tuber placed between the rows and in contact with the roller surfaces is conveyed linearly forward on a bed, B. The rollers are lined with rubber material, E, to minimize slippage between them and yam tubers. The view of the machine showing the rollers, R, is shown in **Fig. 2**. (The rollers are operated by a lever-crank mechanism, and bevel gear arrangement). The rollers, K, (**Fig. 1**) next to the peeling chamber are spiked to ensure there is no slip between tubers and roller surface, and also ensure stability of tubers during the peeling action. All the rollers are spring-loaded, as can be seen from **Fig. 1**, to cater for different sizes and shapes of tubers. In the pair of rollers numbered 5, there are chain drives through the sprockets, S. From there, chains drive two smaller spiked rollers positioned right inside where peeling is done, to initiate the withdrawal of a peeled tuber.

(iii) Tuber guides: There are two tuber guides, marked G, (**Fig. 2**). This part of the machine, which is also spring-loaded, ensures that any incoming tuber is directed to the peeler blades.

(iv) Peeling chamber: This is the unit where peeling takes place and is shown in **Fig. 3**. It is positioned between pairs of rollers 4 and 5 of **Fig. 1**. It consists of (1) three peeler arms, A, which are spring-loaded such as at S to provide the pressure needed for peeling and to allow the peeler aperture, P, to be increased to the sizes and shapes of tubers; (2) peeler blades, B, fixed to the peeler arms and which scrape the tuber body to a pre-set depth; (3) a peeler ring, L, on which the peeler arms are mounted and are driven through a chain drive;

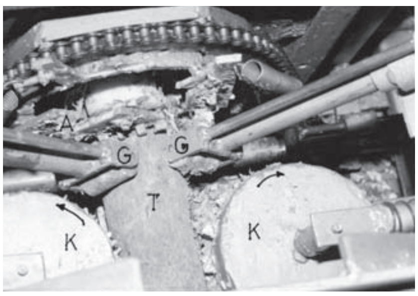

Fig. 4 Tuber, T, being fed to the peeling chamber. K - Spiked roller, G - Tuber guide, A-Peeler arm

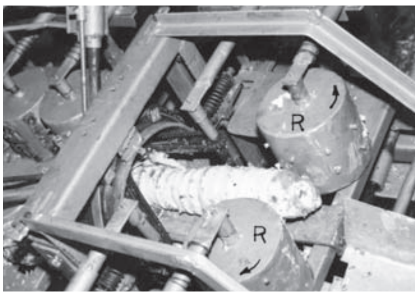

Fig. 5 Peeling oparation about to be completed. R - Lager withdrawal roller


Fig. 6 The peeled tubers

and (4) the peeler ring housing, H. The peeler arms have toothed structures that act as openers which initiate the opening of the aperture when in contact with a tuber.

Operation

The roller conveyor draws the yam tuber placed between the first pair of conveyor rollers into the peeling chamber. The peeler ring rotates through a chain drive. Any tuber being moved into the peeling chamber by the conveyor is directed by the tuber guides, G, to the aperture, P, (**Fig. 3**) formed by the peeler arms. Here the tuber makes contact with the openers. This contact causes the aperture to widen to the size and shape of the yam tuber to be peeled. The tuber immediately gets to the peeler blades which traverse round the tuber to perform the peeling. The peeler blades can be adjusted to cut various depths, according to the thickness of peel. The working of the yam peeler is demonstrated in **Figs. 4** and **5**. In **Fig. 4**, the tuber, T, is shown being fed to the peeling chamber by the pair of spiked conveyor rollers, K, through the guidance of the tuber guide, G, while the peeler arm, A, traverses round the tuber. **Fig. 5** shows a stage when the peeling operation was about to be completed and the conveyor rollers on the other side of the peeling chamber kept withdrawing the tuber as peeling progressed.

Performance Evaluation Tests

Twenty yam tubers of the *D. rotundata* bought randomly from three different locations in a local market were made available for both

Table 1 Machine performance and comparative tests date

No.	Machine Peeling: Tuber length (mm)	Mass (kg)	Ave. dia. (mm)	*P. time (s)	**T. time (s)	Peeling eff. (%)	Manual Peeling: Tuber length (mm)	Mass (kg)	Ave. dia. (mm)	*P. time (s)	Peeling eff. (%)
1	388	2.05	75.6	25	49	75.0	294	2.35	97.1	236	100.0
2	300	2.20	98.1	19	40	80.0	343	2.53	91.4	257	100.0
3	370	2.20	86.6	25	51	78.3	305	2.25	96.0	234	100.0
4	335	1.98	80.4	22	55	75.0	342	1.80	76.6	202	100.0
5	332	2.48	101.9	21	50	72.4	337	1.55	77.8	170	100.0
6	325	1.45	72.3	20	64	73.0	375	1.75	80.2	201	100.0
7	280	1.28	71.9	17	44	78.5	406	1.63	64.8	197	100.0
8	310	1.85	81.5	19	72	67.8	345	2.23	86.4	232	100.0
9	415	1.69	66.3	28	99	60.0	150	1.30	77.1	156	100.0
10	310	1.25	72.4	20	81	62.7	403	1.70	83.7	190	100.0

*P. time - Peeling time, **T.time - Trimming time

machine and manual peeling. The tubers were numbered 1 to 20 in decreasing order of average diameters, and then divided into two groups, using a table of random numbers. One group was used for machine peeling and the other for manual peeling. Prior to the machine peeling operation the surface areas of the tubers were determined, using transparent square papers.

The machine was started and ten tubers fed in simultaneously. The time for peeling each tuber was recorded, using a stopwatch. At the end of the peeling exercise, the areas of patches of peels not removed were measured. Peeling efficiency, P_e, (%), was calculated as follows:

$$P_e = \frac{A_u - A_p}{A_u} \text{ x } 100$$

where,

A_u = surface area of unpeeled tuber, cm^2

A_p = total surface area of unpeeled patches, cm^2.

The peeled tubers are shown in **Fig. 6**.

Comparative Test

A kitchen female staff (a cook) of an institution was invited to peel the ten tubers set aside for manual peeling. This individual was chosen because it is believed that such a person must have gained some mastery of the art of yam peeling, thereby bringing the error and delay due to human factor to minimum.

The ten tubers were peeled manually and the peeling time recorded.

Result and Discussions

The results of the tests are as shown below in **Tables 1** and **2**.

(i) Efficiency of peeling: **Table 3** below shows the descriptions of the tuber shapes and their corresponding peeling efficiencies.

From **Table 3**, it could be seen that higher peeling efficiencies were obtained with the tubers that are less curved. This is because, for fairly straight shapes, the peeler blades were introduced more normal to the tuber surfaces. This caused the full widths of the blades to be engaged during the peeling operation. The full widths of the blades can, on the other hand, be made to always engage the surfaces of crooked tubers, by increasing the depth of peeling. This advantage of getting the whole surfaces peeled will, however, be outweighed by high peeling losses. This calls for either of the following: (a) Selection of tubers to be peeled.

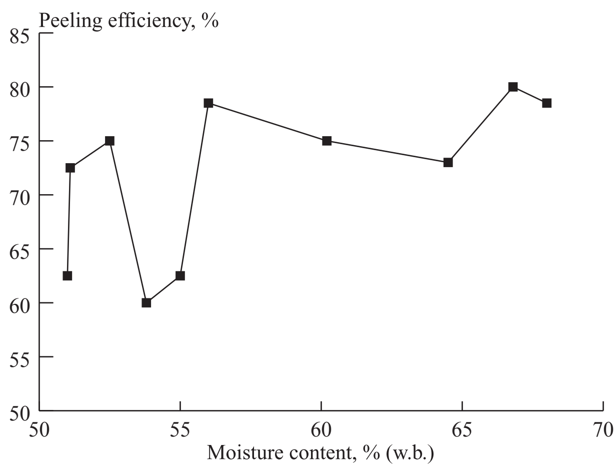

Fig. 7 Peeling efficiency vs tuber moisture content

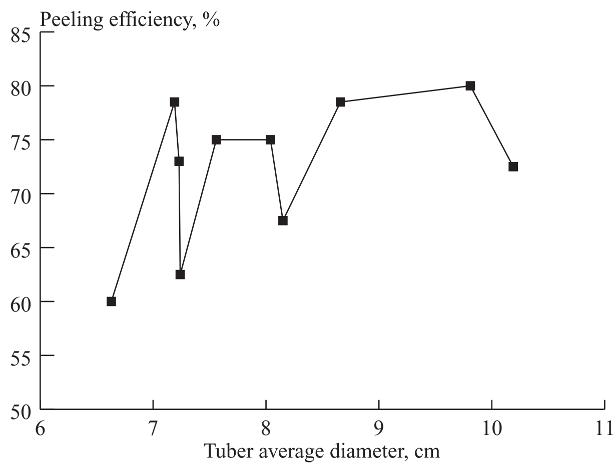

Fig. 8 Peeling efficiency vs tuber average diameter

Table 2 Machine and manual peeling loss date

No.	Machine peeling					Manual peeling			
	Tuber mass before peeling (kg)	Mass after peeling (kg)	Peeling loss (%)	Moisture content (%)	Ave. dia. (mm)	Tuber mass before peeling (kg)	Mass after peeling (kg)	Peeling loss (%)	Ave. dia. (mm)
1	2.05	1.82	11.22	60.2	75.6	2.35	1.92	18.30	97.1
2	2.20	1.85	15.91	66.8	98.1	2.53	1.99	21.34	91.4
3	2.20	1.90	13.64	68.0	86.6	2.25	1.91	15.11	96.0
4	1.98	1.70	14.14	52.5	80.4	1.80	1.25	30.56	76.6
5	2.48	2.07	16.53	51.1	101.9	1.55	1.13	27.10	77.8
6	1.45	1.25	13.79	64.5	72.3	1.78	1.35	24.16	80.2
7	1.28	1.10	14.06	56.6	71.9	1.63	1.23	24.54	64.8
8	1.85	1.53	17.30	55.0	81.5	2.23	1.90	14.80	86.4
9	1.69	1.47	13.02	53.8	66.3	1.30	1.02	21.54	77.1
10	1.25	1.10	12.00	51.0	72.4	1.70	1.38	18.82	83.7

(b) Increased time of trimming after peeling.

(ii) Effect of tuber moisture content: Tests carried out during this work (result not included here) indicate that tubers of lower moisture contents offer higher resistance to cutting tools. The ratios of peeling efficiency values to the corresponding moisture content values were subjected to the mean square successive difference test, and a coefficient of -0.147 was obtained. This is less than 0.469, the critical value. This indicates randomness between the peeling efficiency and moisture content, and this is further shown by the graph of **Fig. 7**.

(iii) Effect of tuber diameter: The ratios of the peeling efficiency values to the corresponding tuber average diameters were examined using the mean square successive difference test. A coefficient of -0.224 was obtained. This, again, is less than the critical value of 0.469. Tuber diameters, therefore, do not influence the peeling efficiencies. The graph of **Fig. 8** supports this claim.

(iv) Effect of tuber mass: It was thought that the heavier the tuber the more difficult it would be for the machine to handle. The same type of test, as mentioned above, was also used for the ratios of the peeling efficiency values to tuber mass values. A coefficient of 0.132, which is also less than the critical value of 0.469, was obtained - an indication of randomness. The graph of **Fig. 9** brings out this point. It is then concluded that tuber mass has no effect on peeling efficiency.

(v) Rate of peeling: The rate of peeling is defined as the length of tuber peeled per unit time, the mass and diameter of tuber notwithstanding. The date for tuber lengths versus peeling times are presented in **Table 1**, and the plot is shown in **Fig. 10**. From the graph, the machine peels at an average rate of 16 mm/s.

(vi) Material recovery: Material recovery, MR.(%), is calculated from the relation:

$$MR. = (M_f/M_i) \times 100$$

where,

M_i = mass of tuber before peeling
M_f = mass of tuber after peeling
Peeling loss (%) = $[(M_i - M_f)/M_i] \times 100$

From **Table 2**, a maximum peeling loss of 17.30 % and a minimum value of 11.22 % were obtained. These correspond to a minimum material recovery of 82.70 % and a maximum value of 88.80 %. It should be noted that the peeling loss (the lost tuber flesh) values given above are more than the actual values because they include the mass of peels which

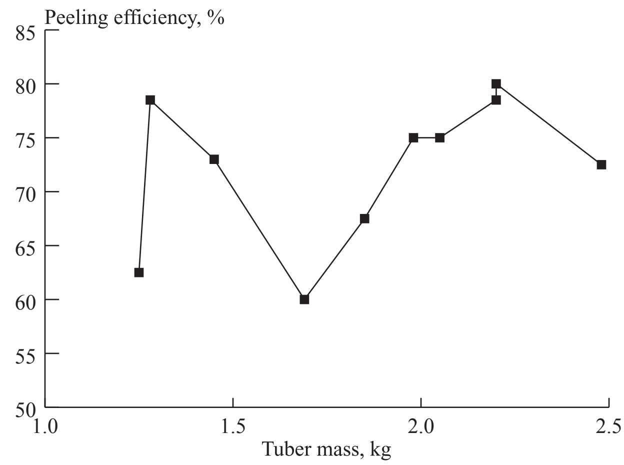

Fig. 9 Peeling efficiency vs tuber mass

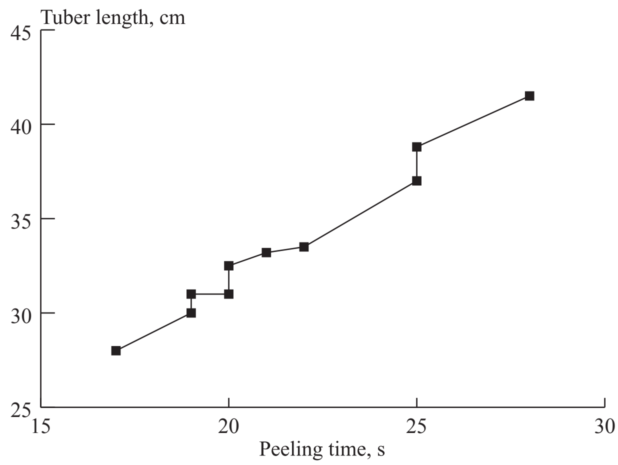

Fig. 10 Plot of tuber length vs peeling time

Table 3 The description of tuber shapes and their corresponding efficiencies

Tuber No.	Description of shape	Peeling efficiency (%)
1	Fairly straight	75
2	Very straight and fairly round	80
3	Straight	80
4	Straight	78.3
5	Straight with non-uniform cross-section	72.4
6	Straight with stepped body	73.0
7	Straight	78.5
8	Fairly curved, with depressions	67.8
9	Markedly curved	60.0
10	Straight, elliptical cross-section and with depressions	62.7

is not a loss. It was not feasible to separate the peels from the lost flesh but the method has been used in evaluating peelers for gingers and potatoes. The graphs of **Figs. 11** and **12** indicate, respectively, no relationship between peeling loss and tuber moisture content or between peeling loss and tuber diameter.

(vii) Comparative advantage: The results of tests for this purpose are shown on **Tables 1** and **2**. It took the machine a total of 216 seconds to peel ten yam tubers while manual peeling lasted for 2,075 seconds for the same number of tubers. The machine-peeled tubers were trimmed in 605 seconds.

A maximum peeling loss value of 30.56 % was obtained for manual peeling, as against a maximum value of 17.30 % for machine peeling. The marked difference is due to the fact that the thickness of cut is fixed for machine peeling and varies with hand peeling, coupled with the fact that not all peels were removed with machine peeling. The values for machine peeling are in the range of abrasion peeling for potatoes (12 to 20 %) as reported by Talburt and Smith (1975).

Peeling efficiency was always 100 % for hand peeling. From the data of **Table 1**, manual peeling required 2.53 times the time required for machine peeling. Secondly, the fact that the machine can work continuously over a longer period of time than the human hand gives it an edge over the manual method.

Conclusion and Recommendations

Conclusion

A mechanical yam peeling machine, which peels by abrasive action, has been developed and tested. The machine makes use of blades arranged to traverse round tubers to perform the peeling action. The blades can be adjusted to vary the depth of peeling.

The major parts of the machine are (i) a tuber container, (ii) a conveyor system to convey tubers to where they will be peeled, and withdraw them after peeling, (iii) tuber guides, which ensure that any incoming tuber is directed right to the peeler blades, (iv) peeling chamber, where peeling takes place.

Peeling efficiencies ranged from 60 to 80 %. Higher peeling efficiencies were obtained for the tubers that are fairly straight than those that tend to be curved. Material recovery was from 82.7 to 88.8 % when the mass of peel was treated as lost material also.

The functioning of the machine is independent of tuber mass, moisture content, and diameter. It peels yam tubers at an average rate of 16 mm/s, irrespective of tuber size and moisture content. However, as in the case of potato mechanical peelers, some trimming may be required especially when the product is to be boiled or fried for food. In the case of yam flour production, trimming might not be necessary.

Recommendations

The following recommendations are made for future work:

1. Efforts should be made to reduce the amount of metal used in the construction so as to reduce pro-

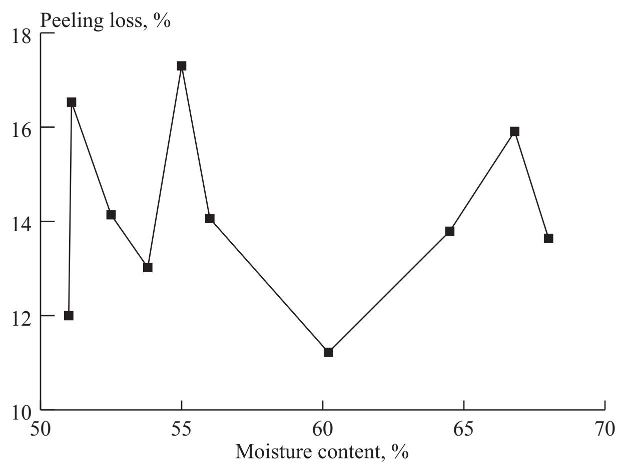

Fig. 11 Peeling loss vs tuber moisture content

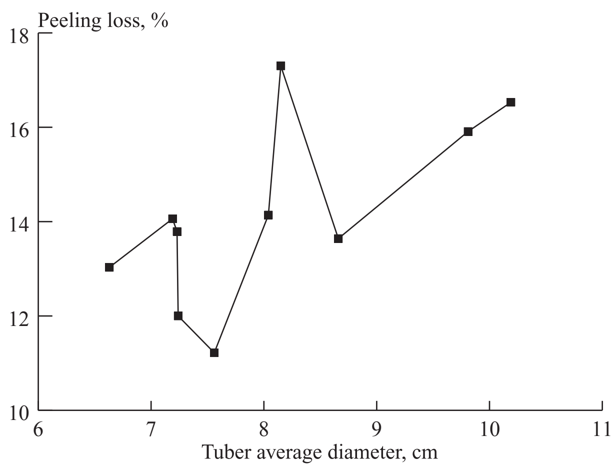

Fig. 12 Peeling loss vs tuber average diameter

duction costs.
2. Only one pair of well-designed feeder rollers could be tried for the machine since the major work of feeding tubers to the peeling chamber is done by the pair of spiked feeder roller, while others do the work of conveying the tubers from points of entry. The tuber point of entry could then be at the spiked pair of rollers, and this will assist in reducing the volume of metal used.
3. There should be a system for setting the peeling depth, instead of adjusting and measuring the length of protrusion of the peeler blades with a rule each time a certain peeling depth is desired.
4. In the current work, mild steel materials were used in the fabrication of some parts that would come in contact with yam tubers, simply because a prototype was being considered. Stainless steel should be used for those parts.
5. The drive for the peeler ring should be designed in such a way that the speed of the peeler ring is reduced. This should enable the peeling action to be more of scraping off the peels than of tearing them off which increases peeling losses and leaves the peeled surface rough.

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Design and Development of a Low-cost Potato Grader

by

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Abstract

Potatoes are sold in the market without grading in Bangladesh. If potatoes were sold after grading, this would be beneficial to both producers and consumers. Since mechanical graders are not available, potatoes are graded, when necessary, by hand. This is a time consuming, costly, and inefficient method. In view of this, a power-operated potato grader was designed and fabricated using M.S. angle, M.S. shaft, G.I. wire, and rubber tubes. The grader consists of a frame, feeding mechanism, sieve, collection mechanism, and power transmission. The first prototype was developed and tested in the laboratory in 1998 to observe its performance. Based on the performance test the grader was modified, especially the feeding mechanism. The maximum power consumption was found to be 1,637 watts. The average capacity of the grader was 2,030 kg/hr. The cost of grading was only Tk 0.03 per kg. No injury occurred to graded potatoes. Field performance at a private cold storage in Rajshahi District was highly satisfactory. The capacity of the grader at the cold storage was 1,500 kg/hr. The use of this grader will reduce the time and the cost of grading.

Introduction

The total potato production of Bangladesh in 2000 to 2001 was about 3.5 million tonnes. Of this production 0.25 million tonnes were used for seed and 300 tonnes were exported. There is a good market for both seed and ware potatoes in neighboring countries. It is expected that production will increase incoming years.

The purpose of grading potatoes is to aid in standardization and to facilitate marketing. Sorting and packaging potatoes to a set of recognized official standards enable producers and buyers to fix a reasonable price for both. Grading is a direct benefit to all parties concerned in the buying and selling transaction. It is essential to the business of processors, wholesalers and retailers. Consumers get a benefit whenever the packages carry the official grade marking (Schoenemann, 1977). Grading can be done based on physical dimension of potatoes as well as their weight. The former method of grading is preferred over the latter.

Potatoes are sold in the Bangladesh market without grading. Large, medium and small potatoes are sold together. Large potatoes are used for processing, especially for making chips, and for baking. Medium and small size potatoes are preferred for culinary use seed potatoes should be between 28 and 55 mm and are graded into two sizes of 28 to 40 mm and 40 to 55 mm. Since mechanical graders are not available, potatoes must be graded by hand through eye estimation which is very laborious, time consuming, costly and inefficient. Also, it is not possible to grade potatoes accurately by eye estimation. In developed countries, potatoes are sold in the

Fig. 1 Photographic view of the potato grader

market after properly grading by mechanical means.

A one horsepower, electric motor operated potato-cum-onion grader was developed by the Punjab Agricultural University, Ludhiana, India. It consisted of a frame, an elevator, feed conveyor, a sizing conveyor, an intermediate receiving conveyor, a sizing conveyor with rubber spools, two identical driving rollers with helical grooves of gradually increasing pitch, a collecting platform with partitions and gates, feeders, transport wheels, and a power transmission system. The separation of the smaller size potatoes occurred first and the larger ones were separated toward the end of the sizing bed. The accuracy of the sizing depended on the uniformity of the shape. Sizing accuracy was better for round shaped varieties than oblong or irregular shaped varieties. The cost of the machine was US $ 334 (Srivastava et al., 1995).

A combined apple and potato grader was developed by the Govind Ballabh Pant University of Agriculture and Technology, Pant Nagar, India. It consisted of six V belts with 20 wooden pulleys mounted over four shafts. The upper portion of the belts between the upper pulleys acted as the grading section and the entire grading length was divided into three parts to give three different grades. To increase the separation efficiency of the grader, differential speeds were provided to adjacent belts. The equipment was powered by a two horsepower electric motor and graded about 1,500 kg of potatoes per hour. The cost of the equipment was about US $ 334 (Srivastava et al., 1995).

Doraiswamy (2000) developed a groundnut grader which graded groundnuts into three different sizes. Two oscillating sieves with slot sizes of 10.75 x 50.00 mm and 9.50 x 50.00 mm respectively, were oscillated by an eccentric mechanism. The sieves could be changed for grading different varieties of groundnut pods or kernels. The output capacity was 600 kg per hour and was powered by a one horsepower 3-phase electric motor. The cost of the unit was US $ 200.

Grading of potatoes is not mandatory in Bangladesh. However, if potatoes could be graded before being sold, it would be beneficial for both producers and consumers. Also, for good yield, it would permit a more correct size for planting. Since mechanical graders are not available, seed potatoes are graded by hand through eye estimation when necessary. This is a very laborious, costly and inefficient method. If a low-cost grader could be developed and extended to cold storage owners and whole sale businessmen, then graded potatoes could be in the market. In view of this, the present work was undertaken to (1) develop a power-operated potato grader for grading potatoes into four sizes, namely, smaller than 28 mm, between 28 to 40 mm, between 40 to 55 mm, and greater than 55 mm size and (2) to study its economic feasibility.

Materials and Methods

The grader was made of locally available materials to keep the cost low. It was fabricated at the workshop of the Farm Machinery Division of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Efforts were made to keep the mechanism and operation of the machine as simple as possible. The materials used for the fabrication of different parts of the machine were M.S. angle bar, M.S. flat bar, M.S. rod, M.S. sheet, M.S. shaft, rubber tube, wood, ball-bearing, V-belt, V-pulley, and miscellaneous small items. The main parts were: (1) frame, (2) feeding tray, (3) sieve, (4) seed collecting mechanism, and (5) power transmission.

Frame: The frame It was made of 4 x 4 cm M.S. angle bar and was 200 cm long 100 cm wide and 130 cm high, respectively. All the joints were made by welding to make the machine strong, rigid, and to reduce the vibration at the time of operation.

Feeding tray: A feeding tray having dimensions of 75 x 60 x 15 cm was made of M.S. sheet. This was fitted on top of the grader at an angle of 30 degrees.

Sieves: There were three sieves at an angle of 15 degrees with the horizontal. All sieves were inclined in the same direction, the sieves were made of 5 mm diameter G.I. wire

Sl. No.	Description	Replication with date					Average
		Rep. 1 5.10.99	Rep. 2 6.10.99	Rep. 3 8.5.00	Rep. 4 8.5.00	Rep. 5 19.3.01	
1	Total wt. of potato, kg	35.5	33.4	134.0	134.0	530.0	
2	>55 mm size, kg	0.75	0.4	13.6	15.0	5.0	
3	40 to 55 mm size, kg	17.50	17.0	78.3	77.5	133.0	
4	28 to 40 mm size, kg	14.75	14.0	37.0	36.5	311.0	
5	<28 mm size, kg	2.50	2.0	5.2	5.0	81.0	
6	Wt. of injured potato,kg	0.0	0.0	0.0	0.0	0.0	
7	Time required, min.	1.08	1	4.28	4	13.93	
8	Grading capacity, kg/hr	1,972	2,004	1,880	2,010	2,283	2,030

Table 1 Laboratory test result of the potato grader at BARI, Gazipur

Fig. 2 Potato grader in operation

covered with rubber tubes. They were fitted with 2.5 x 2.5 cm M.S. angle bar frames. The length and width of the angle bar frame were 125 and 65 cm, respectively. Frames of the sieves were hung inside the main frame by a wooden crank. Sieves were moved in a to-and-fro motion by a mechanical power transmission system.

Seed collection mechanism: Provisions were made to fit gunny bags at the each end of the upper two sieves to collect the graded potatoes. At the end and below the bottom sieve, trays were placed on the ground to collect 28 to 40 mm and the smallest size potatoes, respectively.

Power transmission: A 3-hp, 3-phase 1,500 rpm electric motor was fitted at the front of the frame. Two 25 cm diameter V-pulleys and two 8 cm diameter V-pulleys were arranged on the frame through ball bearings having bearing cases, M.S. shaft, and V-belt. The motor speed of 1,500 rpm was reduced to 167 rpm and two cams were fitted at the two ends of the shaft to shake sieves at 167 strokes per minute.

Laboratory test

Figure 1 shows a photographic view of the grader. At no-load condition, the motor rpm was 1,500 and at load condition it was 1,350 rpm. The stroke length of the sieves was 5 cm. A clamp meter was used to measure the motor current which was used to calculate the power consumption. A six hour endurance test was conducted to observe any failure in machine parts. Three persons were required to run the grader successfully. One person supplied potatoes to the hopper and two persons collected potatoes in trays and bags and cleared potatoes trapped inside the sieves. **Figure 2** shows the grader in operation. During the laboratory test, bulk quantities of potatoes of different sizes were placed on the feeding tray. Potatoes fell continuously at the elevated side of the upper sieve. Potatoes were moved forward by shaking action to the end of the top sieve and those larger than 55 mm were collected in a gunny bag. Potatoes smaller than 55 mm were dropped from the top sieve to the second sieve. Potatoes larger than 40 mm and 28 mm were collected from the end of the second and the third sieves, respectively, and those smaller than 28 mm were collected from below the third sieve. The performance test was conducted in 1999, 2000 and 2001.

The cost of grading was calculated with the assumption that the cost of the grader, including the electric motor, was Tk 20,000.00 (US $ 346.00, 1 US $ = Tk 57.86, in 2002), the life of the system was eight years, and was operated at least 750 hours annually.

Field Test

One unit of the grader was fabricated at the workshop of the Farm Machinery Division, BARI to evaluate the long-term field performance, and was sold to a private cold storage at Boalia, Rajshahi. In the 2001 potato harvesting season, 22.5 tonnes of seed potatoes were graded by the machine in two days (15 hours). During the machine operation, careful observations were made to find any defect. Some potatoes were trapped in the sieves, which were removed by hand. At the end of the operation, one cast iron V-pulley was partially broken and the main shaft of the power transmission, made of 2.5 cm diameter M.S. shaft, was broken due to fatigue. These parts were replaced with a high quality V-pulley and M.S. shaft.

Results and Discussion

No parts of the grading system failed during the six hours laboratory endurance test. The laboratory performance test results of the three years operation are shown in **Table 1**. During the no-load and load condition, the power consumption was 1,490 and 1,639 watts, respectively. The average capacity of the potato grader from four observations was 2,030 kg/hr. Since potatoes from the feeding tray fall directly on the upper sieve, no bruises or cut occurred. Some potatoes were trapped on the sieves which were removed quickly by hand. In order to eliminate the trapping of potatoes on the sieve, modification is required in the shaking mechanism. Additionally, instead of only horizontal to and fro motion, a combination of horizontal and vertical movement needs to be made. Rubber tubes were cut longitudinally and glued to the G.I. wire of the sieves. Many tubes came out after continuous use. However,

Sl. No.	Description	Quantity
1	Total weight of potatoes, kg	22,500
2	Injured potatoes, kg	0
3	Total time required, hour	15
4	Grading capacity, kg/hr	1,500

Table 2 Firld test result of the potato grader at Boalia, Rajshahi

Sl. No.	Cost factor / items	Unit	Amout
1	Cost of grader	Tk/unit	20,000.00
2	Life of grader	Year	8
3	Annual use	Hour	750
4	Annual fixed cost (a) Depreciation (b) Interest (15%) (c) Repair and maintenance Total Total	 Tk/yr Tk/yr Tk/yr Tk/yr Tk/hr	 2,250.00 1,650.00 2,000.00 5,900.00 7.87
5	Operating cost (for engine) (a) Fuel (b) Lubricant (c) Labour (four labours, Tk 70/day) Total	 Tk/hr Tk/hr Tk/hr Tk/hr	 15.00 1.00 35.00 51.00
6	Total cost	Tk/hr	58.87
7	Cost of grading (assuming 2,030 kg/hr capacity)	Tk/kg	0.03

Table 3 Cost factors and items of the potato grader

these could be easily replaced by the workers. The result of the long-term field performance test at Rajshahi are shown in **Table 2**. From **Table 1** and **Table 2**, it can be seen that the grading capacity in the field was significantly lower than that of the laboratory. This happened because operators in the field were new to the machine. It is expected that the grading capacity will increase with operator experience.

Large-scale manufacturers make costly machines that may not be appropriate for Bangladesh. The cost of one such machine of European design made locally having a capacity of two tons per hour was Tk 240,000.00 (US $ 4,148.00). The present potato grader has been designed and fabricated in such a way as to keep its cost low. When the cost and capacity of the exotic machine with the present machine is compared, the local machine definitely has many advantages. **Table 3** shows the cost factors and items of the potato grader. From the table, it can be seen that the cost of grading with the present grader is only Tk 0.03 per kg, which is very negligible compared to the other costs of potato production. If we assume the yield to be 20 ton/ha, the cost of grading per ha is only Tk 600.00.

At present, the cost of grading potatoes manually is about Tk 0.11 per kg. Therefore, the use of the grader would reduce the cost of grading by 73 %.

Conclusions

The present work was undertaken to develop a power-operated potato grader to grade potatoes into four different sizes and to study its economic feasibility. Accordingly, a grader was designed, developed and tested. After the preliminary tests, some modifications were made in the design for final fabrication. Both the laboratory and field tests were satisfactory. The capacity of the grader in the laboratory was 2,030 kg/hr and that in the field was 1,500 kg/hr. The lower grading capacity at the field level will improve after the operators gather experience in operating the machine. The cost of grading by the grader was 73 % lower than manual grading. The grader has a very good prospect of extension to cold storage owners and retailers. However, the problem of trapping potatoes on the sieves needs to be solved in order to have a trouble-free operation.

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Extensive Review of Crop Drying and Driers Developed in India

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Abstract

An extensive review of drying and driers developed in India during the last 4 to 5 decades was made. Researchers in the period have explored the possibilities of use of alternate energy sources such as solar, wind and biomass for drying/ventilation. During this period a number of dryer/drying techniques have been designed/evolved, developed, perfected, and commercialized. Almost all agricultural materials have been tackled, drying characteristics studied, and operational parameters optimized under laboratory conditions. A number of drying units have been field evaluated. Recently work on osmotic dehydration of fruits and vegetables, has been investigated.

Introduction

Both natural and forced convection type driers have been developed. Natural circulation type driers are generally suitable for drying of fruits and vegetables as these driers can not function against high static pressure. In the beginning (i.e. in the 1950's) furnace oil fired LSU driers were in use in the Country particularly in paddy processing units. As the price of petroleum products increased, the use of such driers became prohibitive. It was in late 70's that there was a shift from conventional to non-conventional fuel based driers. During that period a breakthrough was made in the development of efficient rice husk-fired furnaces for steam and hot air generation at IIT, Kharagpur, FCI Rice Mill, Thanjavur, M/S Indus Services Pvt. Ltd, Kolkata (WB), Annamalai University, Annamalainagar, GBPUA&T, Pantnagar, and PAU, Ludhiana. Both step grate as well as cyclone type (**Figs. 1**, **2a**, and **2b**) rice husk fired furnaces were developed for drying purposes. These furnaces not only found application in paddy processing units but also in many other food industries in the Country. Almost all the FCI's, SWC's Rice Mills and many other Agro Industries replaced their oil fired furnaces with that of rice husk fired furnaces [20]. In addition, researchers in the last 4 to 5 decades also explored the possibilities of use of alternative energy sources such as solar and biomass for drying purposes. During this period a number of dryers have been designed, developed, perfected, and commercialized. Almost all agricultural materials have been tackled and drying characteristics studied under laboratory as well as field conditions.

Some efforts in the past have been made to document information on the subject [1, 7, 13, 15, 17 and 19], but all in piece meal. Thus, it deemed necessary to review and update the information on drying and driers developed in the Country. This paper presents an extensive review on drying techniques and driers developed in the Country in a systematic manner.

Work Done on Drying and Driers

A. Electrically Operated Driers

(i) A laboratory model of a fruit

osmotic dehydrator with 5 kg holding capacity was designed and developed at the Coimbatore Centre of Post-harvest Technology Scheme (PHTS) which included the osmotic reactor, a fruit holding pan, a mixing chamber, an impeller, and a pumping system [14]. The unit was evaluated for its performance with bananas and grapes. Sugar syrup (60 degrees Brix) was circulated at flow rates of 4, 8 and 12 l/min. The temperature of the osmotic syrup was maintained at 50 ºC throughout 5 h of osmotic dehydration. A maximum water loss of 42.5 % in bananas and 24.6 % in grapes was observed after 5 h of osmosis at a flow rate of 12 l/min and, under static conditions, the water loss was 38.5 and 22.7 %, respectively. Solid gain under static conditions was 9.1 and 0.9 % for bananas and grapes, respectively. Moisture content of osmosed banana at 12 l/min flow rate was 0.68 kg dry matter per kg water and reduced to an equilibrium moisture content of 0.12 kg dry matter per kg water after 8 h of air drying. The osmosed grapes had a moisture content of 3.1 kg dry matter per kg water which reduced to 0.13 kg dry matter per kg water after 12 h of air drying.

(ii) A recirculatory hot air dryer for chillies was designed and developed at Kharagpur Centre of the PHTS. The green chilies cut into two halves along the length gave best retention of colour and less drying time. Studies showed that green chillies took 4 h to dry at 70 º C temperature and 90.6 % recirculation with a tray loading of 4 kg/m^2 and air velocity 2 m/s. It showed a shrinkage ratio of 8.8 and a dehydration ratio of 7.9. The energy required to remove 1 kg water was 2.6 kWh. The colour values measured with a Hunter laboratory colourimeter, in terms of L, a and b Hunter values were 44.4, -1.2 and 18.6, respectively [14].

(iii) For production of sweetened slices from banana, osmosis, as well as the concentration of sugar syrup, was carried out in a batch type rising film evaporator at Kharagpur Centre of the PHTS [14]. It consists of a calender, foam separator, and shell and tube type condenser which can evaporate water at the rate of 18 kg/h. A PID steam flow controller was used for regulating the steam temperature. Air-drying of osmosed fruit slices was done in a tray dryer, until the desired water activities and moisture content were achieved. Since the osmosis and air-drying were involved, the process was not continuous and, therefore, the product had some draw backs associated with those inherent in manual handling. One kg of bananas was peeled (peel 0.42 kg) and sliced, maintaining 6 mm thickness. The banana slices (0.57 kg) were dipped in 0.05 % solution of sodium meta bisulphate for 5 min maintaining the solution to slice ratio of 1.25:1. Slices were subjected to osmosis in sugar syrup (50 degrees Brix) maintaining slice to sugar ratio 1:5 for 4 h at 50 ºC product temperature and 95 ºC steam temperature and 700 mm Hg vacuum pressure. The osmosed banana slices were then blanched for 6 min in open steam and dried in a recirculatory tray dryer. Blanched osmosed banana slices weighing 0.43 kg when dried at 60 ºC with an air velocity of 2 m/s a recirculation of 47.7 %, and a tray load of 4.17 kg, produced 0.25 kg of dried sweetened banana slices. The sweetened banana slices had water activity of 0.72 at 21.6 ºC. The colour value in terms of yellowness index was 69.5 whereas the Hunter L, a and b values were 20.4, 3.3 and 6.6, respectively.

(iv) Garlic cloves were dried with hot air and combined microwave-hot air drying methods [22]. The combined microwave-hot air drying experiments were carried out with 100 g sample sizes at 40, 50, 60 and 70 ºC temperature and at air velocities of 1 and 2 m/s using

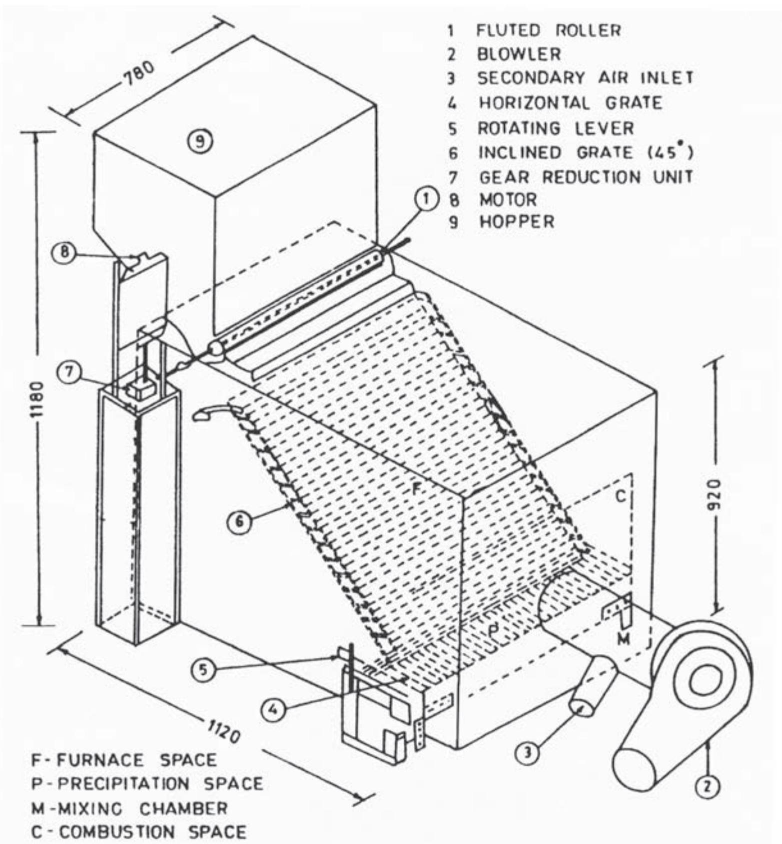


Fig. 1 Box type inclined grate paddy husk fired furnace developed at IIT, Kharagpur

a continuous microwave power of 40 W. For comparison of hot air drying, the same sample sizes were used with drying air temperatures of 60 and 70 ºC and air velocities of 2 m/s. The total drying time, colour, flavour and strength of dried garlic cloves were used to evaluate the performance of the combined microwave-hot air drying and the conventional hot air drying process. Combined microwave-hot air drying resulted in a reduction of drying time of 80 to 90 % as compared to conventional hot air drying and a superior quality final product.

(v) A model drying unit (tray system) was designed at Bhopal centre of the PHTS. The body of the drying unit was made from perforated 16 gauge aluminum sheet and trays (700 x 250 x 50 mm) with a 10 mm hole size. The overall dimensions of the drying chamber were 0.8 x 0.35 x 1.2 m, which could accommodate five trays and dry 5 kg mushroom in 2 h. The drying chamber was insulated with 25 mm thick glass wool. Hot air (70 ºC), circulated at 155 m^3/h, reduced moisture content from approximately 90 to 5 % wb in 2 h. Preliminary studies revealed that the colour of dried mushroom was greatly affected if excess water was not properly drained prior to drying. Thus, a centrifugal dewatering unit was also developed [9 and 10].

(vi) Different methods of mushroom drying, viz., sun drying, thin layer drying, solar cabinet drying, and fluidized bed drying, were evaluated at Coimbatore centre of the PHTS. Fluidized bed drying of mushroom at 50 ºC with an air flow rate of 35 m^3/min dried the mushroom to a final moisture content of about 9 % db in 2 h [14]. The loss of nutrients and browning was less in fluidized bed drying compared to other methods of drying. A mushroom grower in the vicinity installed a dryer with a batch capacity of 6 kg and powered by a 2 hp motor with 4 kW heater and blower. Mushrooms, both oyster and milky type, were dried and mixed with spicy ingredients to made a ready mix for gravy and soups.

(vii) Drying behaviour of button mushroom slices (3 to 4 mm thick) pre-treated with a 0.1 % solution of Potasium Meta Bi-sulphite (KMS) during osmotic drying was studied at Pantnagar centre of the PHTS with three levels of temperature (25, 40 and 50 ºC) and three different weights of mushroom to salt solution ratio (1:4, 1:6 and 1:8). Osmotic drying of button mushroom slices was carried out in 10 % salt solution. Approximately 50 % moisture was removed in about 16.5 h of osmotic drying. Validity of various mathematical models was tested for experimental data in order to characterise the drying behaviour of mushroom slices during osmotic drying. Drying characteristics of osmosed button mushroom (40 ºC and 1:6 mushroom to salt solution ratio) were studied at four levels of drying temperature (55, 65, 75 and 85 ºC) and at 1.7 m/s air velocity. The samples were dried until they attained almost a constant weight which required approximately 8 h. Also the validity of various mathematical models was tested for the experimental data in order to characterise the drying behaviour of osmosed mushroom slices during air drying [14].

B. Sun Drying

(i) Work was done at Bhopal, Pantnagar and Akola centres of the PHTS on the selection of surfaces for faster and higher quality sun drying. Tarpaulin, hessian, canvas cloth, black and white polyethylene, and concrete surfaces were evaluated as compared to mud floor at Bhopal [4]. Tarpaulin (olive green), black polyethylene, and concrete surface were found to reduce drying time by 10 to 20 %. At Pantnagar, slow drying was reported on horizontal elevated 0.5, 1.0 m mesh wire surface as compared to blackish concrete surface. At Akola, a sand bed gave faster drying but created a sand separation problem. Tarpaulin and GI sheet were found significantly better than mud floor.

(ii) Sun drying characteristics of whole groundnut plant practiced by Gujarat farmers was studied [16]. The groundnut crop is gener-

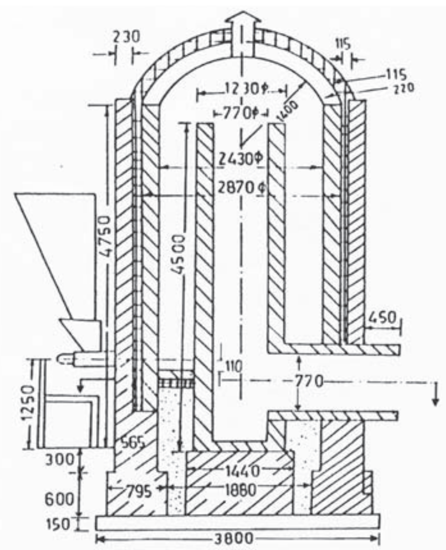


Fig. 2a Vertical cyclone type husk fired furnace, FCI, Thanjavur

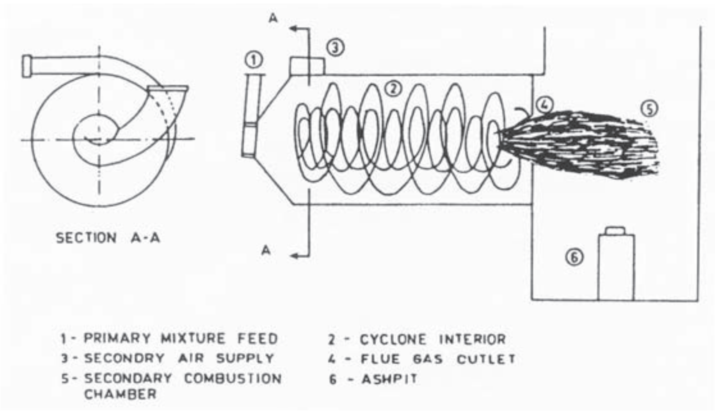


Fig. 2b Horizontal cyclone type furnace, IIT, Kharagpur

ally heaped in the field for open sun drying after harvest. To study the moisture loss, samples from three different locations in the heap (top, middle and bottom) were taken and analysed. After 96 h of exposure the initial moisture content of 61.5 % wb was reduced to 17.1, 15.1 and 13.4 % wb for the top middle and bottom layers. During the period of study, the average RH was 72 % and the maximum and minimum temperatures were 40 and 29.8 ºC, respectively.

C. Solar Driers

(a) Natural Convection Type

(i) A single glass shielded 2 x 1 m size solar cabinet dryer was designed and evaluated for chilli drying and compared with sun drying on selective surfaces with mud floor as the control [25]. In November with 3 kg/m^2 of material the cabinet dryer reduced drying time from one-half to one-third that of sun drying on tarpaulin. Even with 12 kg/m^2 of material the cabinet dryer performed well. A techno-economic study revealed that cabinet dryers are desirable for drying with 6 kg/m^2 of material or more [4]. However, the performance was affected when a strong northern wind prevailed.

(ii) A solar-cum-wind aspirator was conceived to have a solar cabinet dryer with performance independent of wind direction [26, 27 and 28]. To prevent condensation in the 2 m^2 dryer in the initial stage of drying, an air flow requirement of 1 m^3/min was estimated. To design the proper size aspirator, the performance characteristics of 0.2, 0.4 and 0.6 m diameter solar-cum-wind aspirators were studied [3 and 26]. Based on the results obtained, an aspirator of 0.25 m diameter and 1.2 m height was designed to create 1 m^3/min air flow at an average wind velocity of 4 km/h (**Fig. 3**). Intensive testing showed that the dryer was suitable for drying perishable and semi-perishable products including plantation crops.

(iii) The hot air comes in contact with the product only once in the cabinet dryer, but the air still has capacity to remove more moisture if it could be passed through additional layers of the product. Based on this idea, a multi-rack dryer was developed [29]. The product to be dried was stacked at several levels one above the other. The main frame was made of MS angle iron. The aperture area was approximately 6 m^2 and was inclined at 45 degrees with the horizontal facing south (latitude 31 degrees N). The back and sides were closed with 25 mm thick wooden panels, which also served as insulation. Fourteen horizontal trays were arranged in the two columns of seven rows. Each tray had a height of 40 mm and measured 900 x 350 mm. The trays were inserted and removed from the respective sides through small slits. After the trays were put in position, the slits were closed. The air entered through the perforations in the base of the dryer, then rose to escape from the top slit. About 300 holes of 15 mm diameter each were provided for the entrance of the air through the bottom board. These holes were uniformly distributed over the entire board so that the entrance of air was uniform. The top slit was 62.5 mm wide and ran along the entire width of the dryer which was 2 m. Two glass covers were provided in six panels of framed construction. The air flow rate was controllable by varying the opening at the top slit. The dryer was tested with vegetables such as cauliflower, onions, spinach, potato, and chips. It took about 2 to 2.5 days to dry each of these vegetables (2 kg each). With this unit, it was possible to remove 2.9 kg moisture per day/m^2 of glazed area. This was higher than the moisture removal rate of the cabinet dryer which was 1.5 kg/day/m^2.

A mini multi-rack dryer, similar to the larger multi-rack dryer but having only five racks was developed [29] for household applications. The comparative drying performance of the mini multi-rack dryer was studied with fenugreek leaves. The net aperture area for solar radiation input for the mini multi-rack dryer and cabinet dryer was 0.65 m^2 and 0.5 m^2, respectively. Fenugreek leaves (1.5 kg) were loaded in the mini multi-rack dryer (0.3 kg/tray) compared to 0.8 kg in the cabinet dryer in three trays. One kg/m^2/day moisture was removed with the mini multi-rack dryer compared to 0.68 kg/m^2/day in the case of the solar cabinet dryer (i.e. 60 % better performance).

(iv) A multi-tray type natural convection solar cabinet dryer was developed at Udaipur centre of the PHTS [19 and 23]. The dryer was fabricated from wood, plywood,

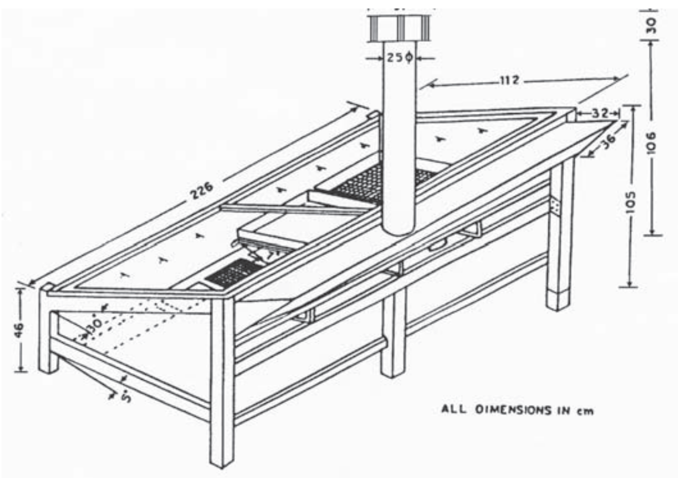


Fig. 3 Solar cabinet dryer with solar-cum-wind aspirator, CIAE, Bhopal

wire mesh, MS sheet, angle iron, and glass. (**Fig. 4**). The cabinet was inclined at an angle of 25 to degrees the horizontal which was approximately equal to latitude of Udaipur. A 25 mm side slit was provided at bottom of cabinet for fresh air entry. The front surface was covered with a 4 mm thick transparent glass sheet. At the top, two draught pipes each of 200 mm diameter and 1000 mm length were provided to carry away warm moist air by natural convection. Twelve perforated trays 1000 x 455 mm each were provided to hold material to be dried. The inside of the side and rear panels was covered with a mylar reflecting material. The trays were painted black for maximum absorption of solar radiation. The overall dimensions of the dryer were 2000 x 2220 x 2840 mm. Food products such as ginger, turmeric, chillies, onion, garlic, and leafy vegetables, could be successfully dried in a batch of 60 to 75 kg. Only two to three man/days were needed to perform the operation. In general 6 to 8 days/batch were required for complete drying of the product depending upon initial moisture of the product under clear sunny days.

(v) A 25 kg batch capacity natural convection solar dryer was also developed at the Udaipur centre for peanut drying. The dryer had 16 small trays, 1500 x 400 mm each, arranged in two columns. The unit consisted of a flat plate solar collector and drying chamber having provision for direct as well as indirect heating. Air inlet openings were provided in the bottom of the air heater (1 x 0.5 m). The air heater was insulated with sawdust from the bottom and, at the top, a chimney was provided to augment air flow rate. The drying trays made of wooden planks and wire mesh had a total area of 3.2 m^2 for holding 25 kg of peanuts. There was a gap of 100 mm between each tray. Peanuts with an initial moisture content of 21 % could be dried to about 8 to 10 % moisture content in 8 h [19].

Fig. 4 Multi-tray natural convection solar cabinet dryer, CTAE, Udaipur

(vi) A comparative study was undertaken to evaluate the quality of selected leafy vegetables (fenugreek, coriander, bathua and spinach) dried in a solar dryer and in the open sun [18]. The initial moisture content of the fresh vegetables varied from 86 to 94 % wb, and were dried to a range 7.7 to 15.0 % wb. Drying time varied from three to four h in the solar dryer which was 60 to 65 º C and 8 to 12 h under open the sun, indicating 50 to 75 % reduction in the drying time as compared to sun drying. Additionally, in the solar dried vegetables, the retention of ascorbic acid was higher colour was better, and the flavour and overall appearance was better.

(vii) A solar cabinet dryer based on the "Lawand" design, having a base area of 1.4 m^2 and a volume of 0.3 m^3, was developed and tested [12]. In this dryer the drying time for chillies was about 50 % less compared to open courtyard drying. However, damage to the wooden planks by weather, termites, and higher air temperature inside the dryer during dehydration were major problems [12]. An improved dryer (base area 1.7 m^2 and volume 1.4 m^3 was made of MS sheet. An aluminum chimney (0.15 m diameter and 0.76 m long) with a regulating valve was provided to facilitate air circulation. This permitted temperature to be limited in the range of 60 to 65 ºC while dehydrating all types of fruits and vegetables like chillies, date palm, and ber.

(viii) In order to capture maximum energy throughout the year and simultaneously reduce the size of the dryer, a solar dryer with provision to adjust the stand and stack material on an inclined plane was designed, developed, and tested [31 and 32]. The inclined dryer (capacity 10 kg) consisted of a rectangular box (1260 x 960 x 230 mm) made of angle iron and aluminum sheet. A 50 mm layer of pearl millet husk straw insulation was provided at the base. Six pieces of aluminum pipe 25 mm diameter and 80 mm long) were fixed in the front wall of the dryer to introduce fresh air. The air exited through two tapered slits on both sides of the dryer. Wire mesh was provided in the slits to protect the material from flies. Two sheets of plane glass 0.92 by 0.60 m were fitted at the top of the frame. The drying material was loaded in trays (920 x 610 x 50 mm), which were placed on the angle iron frame inside the dryer through a door on the rear side. Five partitions were provided in each tray to facilitate stacking of material on an inclined plane (**Fig. 5**). Several dryers could be connected in series depending upon the requirement. It was possible to vary inclination of the composite unit by a single operation from 49 to 4 degrees with respect to the horizontal to maintain optimum tilt in accordance with latitude and season of operation. The moisture content of fresh chillies was reduced from 82 to 7 % wb in 5.5 days at 10 kg/m^2 material spread at 29.3 ºC ambient temperature. The dryer temperature was 66.6 ºC.

(ix) A large size solar dryer with a batch capacity of 100 kg of vegetables, which could be commercially used for drying of fruits and vegetables was constructed by connecting ten units of the inclined direct type solar dryer in series. Each dryer was connected to its adjacent dryer with MS iron, and nuts and bolts.

By connecting the driers only one person is required to keep the entire array of dryers at optimum tilt in accordance with latitude and season of operation. Vegetables; viz. spinach, okra, tomato, mint, ginger, red and green chillies, carrot, coriander leaves, fenugreek, peas, cabbage, onion, sweet potato, bitter gouard, sugar beet, and bathua; and fruits; viz. ber, sapodilla, and grape were successfully dried in this dryer.

Leafy vegetables could be dehydrated up to a safe moisture content within 1.5 to 2.0 days at loading rates of 3.0 to 4.5 kg/m^2 whereas the other vegetables could be dried within 3 to 4 days at a loading rates of 10 kg/m^2. Extensive drying trials were also carried out to dehydrate 240 kg of spinach at a loading rate of 4 kg/m^2 in 6 trials each of 2 days duration. Thus, about 80 to 100 kg of vegetables could be dried in this commercial solar dryer within 4 days [30]. For maintaining original colour of the dried product an indirect type solar dryer was constructed by shading trays in the existing dryer with a blackened aluminum sheet inserted just above the slits and beneath the transparent glass cover. Comparison of the performance of direct and indirect driers showed that with the direct type solar dryer, the moisture content of green chillies, with a load density of 10 kg/m^2, was reduced from 80 to 7 % wb within 7 days while it took 10.5 days with the indirect type dryer under inclement weather during a severe winter. However, the colour of chillies was better maintained in the indirect type dryer compared to direct type dryer.

(x) A step type natural convection solar dryer for drying of papain, fruits, and algae was developed at Coimbatore centre similar to that developed at Ludhiana and Udaipur centres of the PHTS [14]. The dryer had ten trays. It took 1 to 2 h to dry latex in the dryer (50 to 60 ºC) compared to 8 to 12 h in sun drying in aluminum trays (conventional method). The solar dried product received 13.8 % higher prices compared to sun dried product. The step type solar dryer was also used for papaya leather drying. The conventional sun drying took 60.8 h compared to 39.3 h in case of solar drying for the same level of moisture reduction (i.e. a saving of 35 % in drying time). The dryer was tested intensively from March to October. It took 3 to 11 h to dry algae from about 85 to 90 % to 3 to 5 % moisture content in the step type solar dryer. A temperature as high as 60 to 70 ºC could be maintained by adjusting air inlet and outlet openings.

(xi) Chandra et al. [15] reported drying of groundnut crop in an experimental plastic covered green house structure. It was different from earlier efforts because it had no conventional energy requirement. The green house was designed to provide sufficient natural convection for crop drying. Such a solar crop drying facility held considerable promise in Indian conditions where it had to compete with traditional drying methods involving any energy expenditures. The green house type crop dryer can also be used for growing vegetables when drying operation is not needed.

(b) Forced Circulation Type Dryers

(i) A solar energy based 1 t capacity grain dryer was designed and developed [8]. The dryer was capable of drying 1 t maize grain from moisture content of 20 to 25 % to 10 to 12 % in 8 h of sunshine. A flat plate collector system was designed and fabricated for heating the drying air from 20 to 45 ºC at solar intensities ranging from 600 to 650 W/m^2. The collector system used a 4.5 x 1.5 m double glass cover and a single base plate. The complete solar collector unit was supported on an angle iron frame that holds the flat plate collector at an angle of 25 degrees with the horizontal. Two 70.9 m^3/min blowers were used to force the heated air in each of two 500 kg drying bins. The blowers were connected with a 100 mm diameter GI pipe with a globe valve to regulate air flow rate. The drying bins were 850 mm diameter and 1250 mm higher. Each bin had a false floor with 3 mm holes above a 150 mm plenum.

(ii) Three different capacity solar driers were developed for paddy drying using a flate plate solar air heater (0.25 t, 1 t and 10 t per day) [23]. The external dimensions of the solar air heater for the 0.25 t solar dryer were 4.6 x 1.6 m with a net area of 6.8 m^2 for solar energy collection. The air channel was made of GI sheet and painted with black board paint at the top. It was insulated at the top and sides. The drying cham-

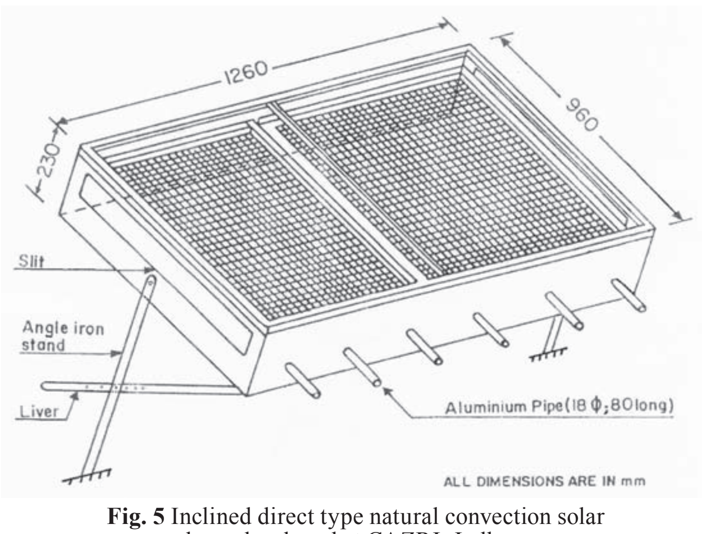


Fig. 5 Inclined direct type natural convection solar dryer developed at CAZRI, Jodhpur

ber was rectangular in shape (1.8 x 0.9 x 0.7 m) and was made of 24 gauge GI sheet. The layer of grain was supported by the wire mesh. Hot air from the solar air heater was passed through the paddy lot. The wet paddy was dried at a constant air flow rate of 4.3 kg/h/kg of dried paddy during the month of October and November. The performance of the solar crop dryer was assessed by comparing it with paddy dried in an electrically operated dryer and drying of unthreshed paddy suspended on ropes in the open sun. It took 6 to 7 h to dry paddy to safe moisture content in solar as well as electrically operated dryer compared to 4 to 5 days in open field drying.

A flat plate solar air heater like the 0.25 t solar dryer, was used for the 1 t dryer having a net solar energy collection area of 28 m^2. It was modular in construction and consisted of four modules in parallel. The outer size of each module was 4.6 x 1.9 m. The air heater consisted of two parallel plates of MS sheet of 24 gauge forming a channel for air flow and was insulated from the sides and base by glass wool and covered by a glass sheet at the top. There were heaters at the lower and top ends of this channel. The suction of air was from the lower end whereas hot air delivery was form the top end of the heater. The distance between the two plates of the air channel was 38 mm. Thickness of insulation on the base was 50 mm and on the side was 38 mm. The top side of the air channel was painted black which acted as an absorber. The space between the absorber and the 3 mm thick glass sheet was 45 mm. The inclination of the air heaters was kept at 45 degrees since most of the products were dried during the winter season.

A 3 hp air blower sucked hot air from the air heater and forced it through the paddy lot in the drying chamber (cylindrical bin of 2140 mm diameter and 1150 mm height). The hot air duct (228 x 278 mm) connecting the air blower with the air heater was made of 24 gauge MS sheet. An intensive testing of the solar air heater was done between 10:30 and 2.00 PM. The average efficiency of the air heater was found to be 46.2 %.

Designing of the 10 t/day capacity paddy solar dryer under Ludhiana conditions (October and November) involved selection of a suitable solar air heater and drying chamber. Computer models were developed for the solar air heater and drying chamber. The results indicated that as air flow rates increased the average temperature at the air outlet decreased. The drying time decreased with increase in collector area. A constraint was that the required temperature could be obtained only for 7 h in a day in the area. Therefore, a collector area 300 m^2 with air flow rate of 100.8 $kg/m^2/h$ was found adequate.

(iii) A solar batch dryer developed at Coimbatore Centre of the PHTS had three bays with an 8 x 1.8 m double glass shielded flat plate solar collector, a centrifugal blower with 83 m^3/min capacity at 50 mm of water, and a rectangular (2770 x 1770 x 300 mm) aeration bin for holding 1 t paddy as major components [5 and 7]. The solar energy absorber, made of 24 gauge GI sheet, was mounted 50 mm above the back of the collector which was insulated with 50 mm of glass wool. The 3 mm thick glass shield was mounted with a 20 mm air gap. Staggered air baffles were provided in the air duct to create turbulence for better heat distributor. It was designed for 0.9 degrees latitude (11 degrees for Coimbatore) orientation facing south. It took 7.5 h to dry 1 t of paddy from 24 to 14.5 % wb moisture content under ambient condition of 24 ºC and 60 % RH with plenum air temperature of 40 ºC.

A 0.5 t capacity solar dryer was also developed for paddy drying [23]. The dryer consisted of an 8 m^2 absorber with ducting, a 3 hp blower, and drying bin. The absorber with ducting was made into four modules each having an area of 2 m^2. The duct and collector were insulated with glass wool. The collector was made of 20 gauge GI corrugated sheet and covered with two transparent glass sheets 3 mm thick. Baffles were provided on the absorber plate in a staggered fashion. The absorber was placed at 10 degrees to the horizontal facing south. The delivery side of the blower (83 m^3/min) was connected to the plenum chamber of a circular holding grain bin.

The performance of the dryer was evaluated for paddy drying and compared with that of drying on threshing floor and roadside drying. The drying rate was found to be maximum when the dryer was tested with 300 kg paddy instead of 500 kg. Thus, the drying bed thickness corresponding to 300 kg paddy was reported optimum for this particular drying system.

(iv) A power tiller trailer mounted solar dryer using an unshielded flat plate solar collector was designed, fabricated and tested at CRRI, Cuttack [5 and 7]. Absorbers of 36 gauge corrugated aluminum sheet, 26 gauge BP sheet coated with black paint, and 26 gauge corrugated GI sheet were evaluated. No distinctive difference in the air temperature rise was obtained consequently, on strength and cost considerations the later was preferred. The solar collector resulted in 9 to 10 ºC temperature rise at an airflow rate of 16.7 m^3/min.

(v) The Jabalpur centre of the PHTS developed a low cost dryer which gave 9 ºC temperature rise at an air flow of about 38 m^3/min in bright sunny weather at an ambient air temperature of 22.5 ºC. The dryer consisted of a 1 t circular aeration bin, a 0.5 hp blower, and an unshielded absorber solar collector placed on the south facing wall enclosing the motor [2 and 7]. This dryer was adopted for groundnut drying (from 40 to 10% wb, moisture content) at the CIAE, Bhopal

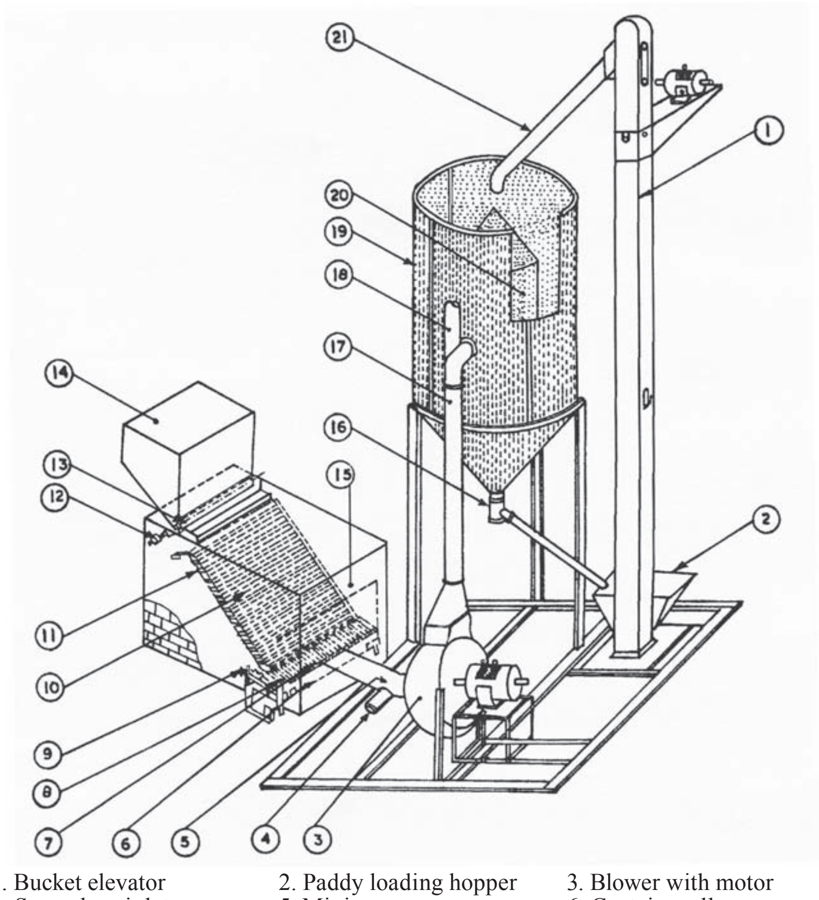
[24] with suitable modifications to make use of the standard size of available sheet metal, to make it light for portability, and to reduce cost. It had a batch capacity of 1.4 m^3. In December, it gave an air temperature rise of 6 ºC (4 to 6 ºC range). In cloudy weather it ranged from 2 to 4 ºC with average of 3.5 ºC. Results suggested additional supplemental heating for groundnut drying.

(vi) The Coimbtore centre of the PHTS developed a roof built-in-solar dryer [23]. The existing roof of a grain storage room made of 20 gauge corrugated GI sheet was covered with 6 mm thick transparent glass with a 50 mm clearance between the roof surface and the glass sheet. The roof facing south at a 40 degree angle from the ground and placed east was painted black. Total absorber area of the collector was 18 m^2 (12 x 1.5 m). The air duct (200 x 200 mm) received hot air from the collector and carried it to the drying chamber. A 2 hp blower with 60 m^3/min air discharge was incorporated with the drying system. It took 9 h to dry 0.5 t paddy from 23.8 to 12.0 % wb, moisture content with a grain bed thickness of 300 to 400 mm under normal sunny days when the solar radiation intensity was 460 to 850 W/m^2 and the ambient temperature was 29 to 32 ºC. The hot air temperature could be maintained in the range of 32 to 44 ºC.

(vii) Drying of fenugreek and coriander leaves was performed [21] in a forced circulation solar hot air dryer. The solar dryer was provided with a 9 kW electric backup heater. Thirty-six units of solar collector each with a 2 m^2 area, were arranged in series in three rows with total collector area of 72 m^2. The hot air was forced into the drying chamber loaded with 24 trays 600 x 600 mm. A 5 hp electric blower with air discharge rate 2500 m^3/h was used. The fresh vegetables were loaded in the trays with material spread 3.3 to 3.7 kg/m^2. The results revealed that 40 to 50 ºC temperature is appropriate for good quality finished products. The solar dried fenugreek and coriander leaves retained their flavour and exhibited only minor change in colour and appearance.

(viii) A roof built-in-solar collector (12 x 6 m) was designed and fabricated at the CIAE Bhopal [23]. The south facing roof of the existing shed was used for harnessing solar energy. A 1 t capacity grain dryer was developed and installed under the roof built-in-solar collector (i.e. shed). The grain was held between the two concentric perforated cylinders through which air diffused. Preliminary testing of the system indicted that 38.1 m^3/min hot air at 50 ºC can be generated. On an average 25 to 30 ºC above ambient temperature was obtained.

(ix) A cart-mounted engine waste heat-cum-solar batch dryer was developed at Jabalpur centre of the PHTS. It was a low cost dryer with mobility. It consisted of 1.77 x 1.09 x 1.00 m aeration bin with a 225 mm deep plenum [6]. Usually only about one-third of the heat energy is available for shaft work whereas the remaining two-thirds go as waste through exhaust and surface heat losses. In this dryer this waste heat was salvaged to heat the air. To further supplement the dryer a 2 m^2 unshielded flat plate solar collector with 100 mm air space was provided. In November, in partial overcast weather, using a 1.9 hp (petrol) engine, a 8.8 ºC temperature rise was



1. Bucket elevator	2. Paddy loading hopper	3. Blower with motor
4. Secondary inlet	5. Mixing space	6. Curtain wall
7. Precipitation space	8. Horizontal grate 9. Rotating leaver	
10. Furnace space	11. Inclined grate (at 45º)	12. Fluted roller
13. Pulley	14. Hopper	15. Combustion space
16. Discharge pipe	17. Hot air duct	18. Flue gas exit by pass
19. Outer cylinder	20. Inner cylinder	21. Delivery pipe

Fig. 6 Pictorial view of recirculating batch dryer coupled with rice husk fired furnace for paddy drying developed at IIT, Kharagpur

obtained, (5.8 ºC from solar energy and 3.0 ºC from engine waste heat). It dried 0.7 t of paddy from 20 to 13 % wb moisture content in 8 h.

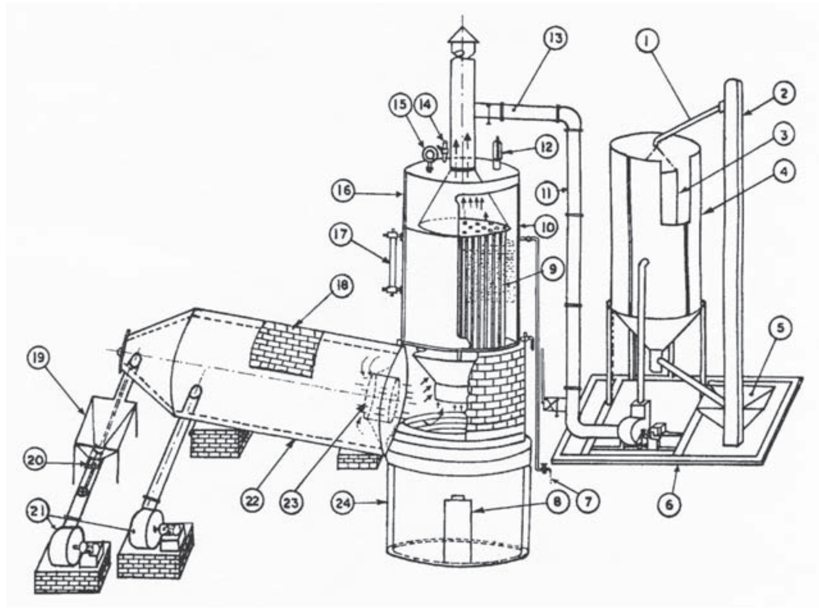
(x) A biogas aided solar roof dryer was designed and tested [33]. The dryer consisted of solar flat plate collector at the roof, ducting, a blower, a rectangular drying bin, and a biogas burner for air heating so that the dryer could also be used under inclement weather conditions. The size of the dryer was 2770 x 1170 x 840 mm with a perforated false floor that had 16 holes per cm^2 and were 1.5 mm diameter. The roof dryer was made of 20 gauge corrugated GI sheet. The collector sheet was painted black and covered with 6 mm thick single transparent glass. The size of the flat plate collector was 12 x 1.5 m (18 m^2). The angle of inclination of the roof was 40 degrees facing south. Testing of dryer was done with 1 t of paddy for moisture reduction from 23 to 12 % wb. The drying time was 16 h open sun drying, 9 h in the solar roof dryer, and 8 h in the biogas aided solar drying system.

D. Agricultural Waste Fired Dryers

(i) An agricultural waste-fired dryer was developed at Akola centre of the PHTS. It consisted of a simple furnace made of bricks in clay mortar having a horizontal grate and chimney, an indirect type heat exchanger, a 3 hp electric blower, and an aeration bin. Agricultural waste such as cotton stalks, sorghum stubble, and pigeon pea stalks were used as fuel at the rate of 30 to 37 kg/h to get hot air 65 to 80 ºC. The flue gases escaped through the chimney [5 and 7]. The dryer was tested for drying cobs as well as grains of sorghum. A batch of 1.5 q of sorghum grains required 2.5 to 3.0 h to dry from 15.0 to 9.8 % wb, moisture content. With only small modifications the same dryer was also used for drying of chillies and other high moisture farm produces. The temperature of the hot air was adjusted as required for controlling the fuel feed rate (18 kg/h in this case).

(ii) A recirculating type dryer coupled with IRRI type husk-fired furnace was developed at Pantnagar centre of the PHTS. The furnace consisted of a rectangular fire-brick chamber having combustion and settling section, installed on an iron frame. A vibrating feeder dropped the husk continuously in the combustion chamber through the grate and hopper. The hot air blew through an opening at one end of the settling chamber. Ash that mixed with the hot air settled in the trap section [5 and 7]. With increased husk feed rate from 1 to 9 kg/h, the air temperature increased from 30.2 to 77.6 ºC at ambient conditions of 23 ºC and 71 % RH. At 8 q/h paddy feed rate, 28.3 m^3/min of air, air temperature of 50 º C and initial moisture content of 24.7 % wb, the heat utilization efficiency was 83 %. The unit had been successfully applied to a rice mill.

(iii) A 1.25 t capacity recirculatory paddy dryer was developed at Kharagpur centre of the PHTS. The dryer was equipped with an inclined grate adjustable to 40, 45 and 50 degrees angle of inclination (**Fig. 6**). A centrifugal blower with a capacity of 8.5 m^3/min was attached. The accumulated ash was periodically disposed off with the help of a horizontal revolving grate. A curtain wall at the end of the horizontal grate prevented fly ash or unbrunt rice husk from going into the outlet with hot gases. The husk was fed into the furnace with the help of a flutted roller placed at the bottom of the hopper. The air necessary for combustion was sucked through the opening for feeding the husk and partially through the grate openings. Additional air was introduced through the secondary inlet to the blower in order to reduce the flue gas temperature. As there was no carbon monoxide in the flue gas, this furnace could be used for dry-



1. Delivery pipe
2. Elevator
3. Inner cylinder
4. Outer cylinder
5. Paddy loading hopper
6. Drying unit
7. Cold water
8. Ash pit
9. Water
10. Fire tubes
11. Hot air duct
12. Safety valve
13. Hot gases
14. Steam outlet
15. Pressure gauge
16. Steam space
17. Water level indicator
18. Refractory brick lining
19. Hopper with stand
20. Fluted roller
21. Blower with motor
22. Cyclone furnace
23. Reentrant throat
24. Steam generator

Fig. 7 Schematic drawing of cyclone type paddy husk fired furnace coupled with steam generator and grain dryer developed at IIT, Kharagpur ing of paddy without any undesirable affects. The furnace efficiency at a husk feed rate of 11.7 to 16.9 kg/h was 44.5 %. Later, a horizontal cyclone type, highly efficient rice husk fired furnace (**Fig. 2b**) was designed, developed, and incorporated with steam generator (**Fig. 7**). The flue gas from the steam generator was utilized for paddy drying using 1.25 m^3/min air flow rate with 5 to 30 kg/h husk feed rate. The furnace efficiency at 20 kg/h husk feed rate was 80 % [20].

(iv) An agricultural waste-fired trolley dryer was developed at Ludhiana centre of the PHTS. A standard tractor trolley of size, 3 x 2 x 0.6 m was modified for drying paddy grains in 0.40 to 0.45 m deep beds. The conventional Jullunder type pit furnace used for "jaggery" making, 1.8 m diameter and 1.8 m deep with the grate fixed at 0.45 m from top provided with a chimney, was used. A 1.5 x 1.5 x 0.25 m MS heat exchanger with 14 fins was connected to mixing chamber with a 1 m long asbestos cloth tubing. A 5 hp centrifugal blower sucked air from the mixing chamber and delivered it into a canvas plenum [7]. It took 5 h to dry a batch of 1.4 t paddy from 20 to 15% wb moisture content with 55 ºC hot air at 29.7 m3/min at an ambient tempreture of 15.5 ºC and 70 % RH.

E. Others

Refer to **Table 1**.

Conclusions

The extensive review of drying and driers revealed that both conventional and non-conventional energy based driers have been developed over many years. Oil furnace based LSU type driers were in use in the Country in the early 50's. A break through was made in the development of efficient rice husk fired furnaces for steam and hot air generation at IIT Kharagpur, FCI Rice Mills, Thanjavur, M/S Indus Services Pvt. Ltd., Kolkata (WB), Annamalai University, Annamalainagar, GBPUA&T, Pantnagar and PAU Ludhiana. Both step grate as well as cyclone type rice husk furnaces were developed for drying purposes. These furnaces not only found application in paddy processing units but also in many other food industries in the Country. Almost all the FCIs, SWCs, Rice Mills and many other Agro Industries replaced their oil-fired furnaces with that of rice husk fired furnaces. Researchers in the last 4 to 5 decades explored the possibilities of the use of alternate energy sources such as solar and biomas for hot air generation. During this period a number of driers have been designed, developed, perfected, and commercialized. Almost all agricultural materials have been tackled and drying characteristics studied under laboratory as well as field conditions. Most recently work on osmotic dehydration of fruits and vegetables have been investigated.

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Type of dryer	Developed at	Suitability	Capacity
Tray- type copra dryer	CPCRI, Kasaragod	Copra	1000 coconuts/batch
Solar dryer	CPCRI, Kasaragod	Coconut, black pepper, arecanut and cardamom	80-100 coconuts/batch (4 days), 50 kg arecanut/batch (30 days), 18 kg black pepper/batch (4 days)
Agricultural waste-fired dryer	CPCRI, Kasaragod	Coconut, arecanut, black pepper, cocos beans	400 coconut/batch, 150 kg arecanuts/batch, 40 kg fermented cocoa beans/batch
Cocoa- bean dryer	CPCRI, Kasaragod	Cocoa beans	40 kg/batch (62 h)
Low-cost poly-solar dryer	CPCRI, Kasaragod	Coconut, black pepper, fish, papads	60 coconut/batch
Cup and cone dryer	Annamalai University, Annamalainagar (TN)	Raw and parboiled paddy	1 t/batch

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■■

Insect Inhibitive Properties of Some Consumable Local Plant Materials on Grains in Storage

by
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Abstract

This work assesses the effectiveness of four locally consumable plant fractions in the control of insect infestation on food grains in storage. The consumable local plant fractions were bush mango (Irvingia gabonensis) wood, defruited oil palm bunches, ginger tuber and onion bulbs all made into ash and powder, and applied respectively to dehusked rice kernels, shelled maize kernels, and cowpea seeds kept on shelves in the laboratory for six months. Results show that all plant fractions applied proved significantly effective in the inhibition of the activities of the insect pests of the food grains (p = 0.05, LSD) in relation to the controls. However, wood ash and ginger powder treatments were especially recommended because of their high residual toxicity on the insect pests, their low cost, and their availability.

Introduction

Throughout history, grains have remained man's most common and important source of protein and in fact, food. Whether it is cereals or leguminous, post harvest grains beyond the farm gate require proper handling including storage and within storage protection against insect pests. Insect pest infestation either before or during storage and efforts toward its control has, equally, remained man's singular problem in food security. Untreated grains on storage shelves have resulted in heavy losses. The loss figure was 92.3 % for 12 months storage in the work of Giles (1963); Adu (1981) and Hall (1970) reported about 54 % and 62 % respectively for 6 months shelving. In fact, FAO (1990) summarizes it all by saying that losses of food to non-human agents may cumulate to millions of tonnes, especially for developing economies. In what follows, the quest for reducing losses to insects during storage of grains has resulted in heavy application of chemicals. These chemicals are mostly organic based in the form of fumigants and dusts that are reported to have carcinogenic side effects and, in fact, are relatively expensive (Adu, 1981). Unhappily, methods to limit the effects of these chemicals to the offending insects have continued to evade research results. Chemical treatment of stored food grains has therefore, continued to result in toxic consequences to the consuming humans, livestock, and, perhaps, the environment. Research efforts have, therefore, shifted in search of alternatives that would be less expensive, devoid of toxic side effects, and yet be at the immediate reach of the local farmer.

The possibility of obtaining insecticidal effects from some local plant materials has long been investigated. IITA (1976) used vegetable oil on cowpea seeds and stored for about two months. Several others have reported obtaining good insect inhibitive properties from plant parts - black pepper (Su, 1977), citrus peels (Taylor, 1975), garlic (Borukh et al., 1975), red chilli pepper (Zibokere, 1994) and some photo chemicals (Jacobson, 1984). Apart from the reports on garlic and chilli pepper, most plant parts used were not really consumable. It is the objective of this work to investigate the insect inhibitive properties of oil palm bunch ash (OPBA), wood ash (WA), onion bulb powder (OBP), and ginger tuber powder (GTP) on food grains in storage.

Materials and Method

Oil palm bunch ash was obtained by open air burning of defruited palm bunches in a drum. Wood ash was obtained by freely burning the wood of bush mango (*Irvingia gabonensis*)* at the fireplace of a local kitchen, and sieved through No. 60 mesh. Onion bulbs and ginger tubers were peeled, oven dried and separately hammer-milled through an 8 mm round hole screen. The ground products were sieved through No. 60 mesh (BS). The resulting powder of the two plant parts were collected and stored in airtight containers in the laboratory.

Uninfested cereal (maize and rice) and leguminous (cowpea) grains were procured from the local market place. These were dried to approximately the same moisture content (12.62 % wb). Sixty 10 kg samples were prepared for each of the food grains into 60 sterilized plastic containers. Forty-eight of these samples were thoroughly mixed with 20 g of each of the ash and powder in the order of four replicates of each food grain with each of the plant fraction as treatments. The remaining were untreated and kept as control sets. All were then inoculated with 10 live adult weevils of its kind. The inoculated sets were then weighed and kept on rodent-proof, open shelves under ambient conditions in the Agricultural Engineering laboratory of Rivers State University of Science and Technology, Port Harcourt for 24 weeks (six months). Note that the sample containers were of the same size and were covered with fine mesh fabric for free ventilation. Half of the sample sets (i.e. 30 sets) were carefully analysed at the end of the 3rd month in storage. The second half of the sample sets were analysed at the end of the 6th month. Weight loss index, (W_i) was calculated following Zibokere (1994):

$$W_i = \frac{w_i - w_f}{w_i} \times 100\ \% \quad \text{.....................(1)}$$

where,
$w_i - w_f$ represents loss in weight (subscripts representing initial and final weights, kg).

An infestation index was also calculated following Ezeike (1984):

$$IF = \frac{W - w}{W} \times 100\ \% \quad \text{.....................(2)}$$

where,
W = total weight of seeds used, g
w = total weight of seeds uninfested, g

Data were also collected on insect mortality and grain damage respectively.

At the end of the experiment viability tests were conducted on both petri-dish and soil-in-moisture cans and indices were calculated.

All the calculated indices, in addition to other physical observations on the treatments were statistically compared to those of control (p = 0.05, LSD).

** The wood of Irvingia gabonensis is locally consumed medicinally and as chewing stick, while oil palm bunch is used as additive in preparing certain consumable delicacies.*

Treat-ment	Weight loss index, %		Grain damage, %		Infestation index, %		Insect mortality, %		% seed viability
	3rd mouth	6th mouth	3rd mouth	6th mouth	3rd mouth	6th mouth	3rd mouth	6th mouth	6th mouth
GTP	0.09	0.91	3.85	5.01	1.13	1.07	86.58	94.99	84.3
OPBA	1.06	5.93	5.74	11.61	2.17	4.66	83.61	77.94	79.6
WA	0.11	0.49	3.17	4.47	1.74	0.56	84.34	98.41	84.8
OBP	0.05	3.46	2.28	7.39	0.68	2.94	86.47	82.52	83.3
Control	16.71	39.56	53.61	94.82	44.93	84.72	0.39	0.00	81.8

Table 1 Effect of consumable plant materials on storage insect pests of rice (dehusked)

Treat-ment	Weight loss index, %		Grain damage, %		Infestation index, %		Insect mortality, %		% seed viability
	3rd mouth	6th mouth	3rd mouth	6th mouth	3rd mouth	6th mouth	3rd mouth	6th mouth	6th mouth
GTP	0.96	1.73	2.69	4.86	1.44	1.08	85.08	97.96	77.9
OPBA	0.85	8.78	3.85	15.94	1.88	6.23	82.25	71.74	77.7
WA	0.99	1.27	2.47	3.69	1.18	0.29	85.18	98.22	78.6
OBP	0.94	4.89	3.23	9.77	1.86	3.47	85.60	74.93	76.5
Control	17.84	34.61	51.16	88.84	47.78	78.74	0.39	0.00	78.1

Table 2 Effect of consumable plant materials on storage insect pests of maize (shelled)

Treat-ment	Weight loss index, %		Grain damage, %		Infestation index, %		Insect mortality, %		% seed viability
	3rd mouth	6th mouth	3rd mouth	6th mouth	3rd mouth	6th mouth	3rd mouth	6th mouth	6th mouth
GTP	0.28	0.55	2.84	4.05	1.67	0.69	84.68	97.78	88.4
OPBA	0.94	9.06	2.95	18.23	1.92	7.98	81.52	80.33	81.4
WA	0.13	0.39	2.44	3.14	1.34	0.18	84.73	99.15	88.6
OBP	1.11	3.92	3.08	10.47	2.37	4.46	84.31	81.84	88.3
Control	19.88	38.72	54.51	92.06	38.65	63.73	0.27	0.00	85.4

Table 3 Effect of consumable plant materials on storage insect pests of cowpea (shelled)

Results and Discussion

Results obtained from the experiments are given in **Tables 1**, **2** and **3** on rice maize and cowpea respectively. The tables show that the wood ash is highly effective in the control of the storage insect pests of these food grains, followed by ginger powder treatment. It appears that the wood ash and ginger powder have greater residual toxicity on the insects since, unlike the other two treatments, mortality figures are about 24 % higher on prolonged storage (six months). The onion bulb powder however was shown to be very effective on the short term (three months). It appears that the active ingredient is the volatile substance, which depletes on the long run and becomes less effective than the wood ash and ginger powder. A similar effect by a volatile substance was reported on garlic (Borukh et al., 1975), and on red chilli pepper

(Zibokere, 1994). The insect inhibitive effect of OPBA was rather inferior to that of the other three. The scores on all the indices used were less significant.

Though the strongest insect inhibitive action was shown by the wood ash and ginger powder treatments, the other two consumable plant extracts used were also convincingly effective. Their scores were also significant relative to the scores of the control samples (p = 0.05, LSD).

Tolerance of the food grains to the treatments was assessed by quality assay method (AOSA, 1990). There were no real changes on the average quality parameters. This was unlike garlic and red chilli pepper that were reported to impart undesirable odour and coloration respectively on the food grains to which they were applied (Borukh et al., 1975 and Zibokere, 1994). Also there was no significant difference in seed viability between treated and untreated seeds. Mitchel and Kader (1985) had reported that most grains do not tolerate chemical treatment in storage, showing excessive loss of viability. The insect controlling plant fraction did not affect the germinability of the grains to which they were applied.

This work has, therefore, generally shown that the consumable local plant materials used here could be reliable alternatives to the usual chemicals in food grain storage practice.

Acknowledgment

The researcher expresses thanks to the Department of Agricultural Engineering of the Rivers State University of Science and Technology, Port Harcourt, for allowing the use of their laboratory for the experiments; to Miss Virginia Agedah, Mr. Otavie Sambo, and Miss Gloria Wariso for their numerous contributions offered during the process of the experiments of this work.

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Evaluation and Performance of Raw Mango Grader

by

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Abstract

A mango grader suitable for processing mangoes for export that worked on the principle of rolling the mango around the axis of minimum mass inertia was evaluated. Mangoes were made to roll down a slope in an expanding opening. Three grades were separated based on the opening size and a fourth grade consisted of mangoes that over flowed the largest opening. The opening for grade I, grade II and grade III were 50 to 57, 57 to 64, and 64 to 70 mm respectively. The grader was tested for different raw mango varieties namely; Totapuri, Alphonso, Chinnarasam and Neelum at slopes 8 degrees, 12 degrees and 16 degrees. The rates for which the grader were tested were 720 kg/h, 1800 kg/h and 2400 kg/h. The best results were with the Neelum and the lowest with Chinnarasam. Further, the best results were shown by the widest opening (64 to 70 mm). Twelve degrees was the best slope. The percentage of fruits correctly graded decreased as the feeding rate decreased.

Introduction

India is considered as the second largest fruit producing country in the World. Among the fruits, Mango (Mangifera indica Linn.) a native of India is one of the most relished fruit of the tropics, it occupies a prominent place among all the fruits and is considered as the “King of fruits” in India

India is the leading mango growing country and produces about 65 % of the worlds total mango production. It is considered as the most important fruit and covers 35 % of area and 28 % of total production of fruits in the country. At present, in India mango occupies an area of 1.4 million hectares out of total fruit crop area of 3.94 million hectares. Out of total fruit production of 49.5 million tonnes, the estimated annual production of mango is 10.2 million tonnes. Although India has 65 % of world’s mango production, India’s “King of fruits” has never had a grip on international markets. It’s export is hardly 0.02 % of total production and only 3 % of the total export of mango (Srivastava, 1998).

For export as well as processing of mangoes, the fruits have to be graded for size and quality. Efficient operation of mango peeling machines requires prior size grading. Further, the export and processing of mangoes is seasonal and when grading is done manually, it is a labour and time consuming job.

Therefore, the objective of the present study was to evaluate the performance of a raw mango grader for its efficiency in grading.

Materials and Methods

The grader consisted of a 2 x 0.5 m frame made of mild steel angles of 25 x 5 x 0.5 mm. Six 16 x 3 mm mild steel T-sections were used to make a converging opening of 50 mm at the feed end and 70 mm at the discharge end. Bolts and Nuts were used to fit the T-section in grooves at both ends of the frame. Thus the size of the opening between the two T-sections were adjustable by moving the T-section in the groove. The frame was mounted on two stands made of mild steel angle in such a way that it makes an 8 degrees angle to the horizontal. The highest end was chosen for fitting feeding chute made of mild steel with proper frame support. The frame was fitted with a side wooden cover 15 cm high along its length and was divided into three parts and marked as Grade I, Grade II and Grade III. For collection of graded mangoes, collection chutes made out of plywood boards were provided below all three grades. The chutes were given sufficient slope so that the graded mangoes could be easily collected.

The mango grader worked on the principle of rolling the mango around the axis of minimum mass inertia. The slope of the grader allowed the mangoes to roll from the feed end of the grader to the expanding opening of the frame. The grades were separated based on the opening size and the fourth grade consisted of over flow mangoes too large to pass through the expanded opening. The detailed diagram is given in **Figs. 1** and **2**.

A single person manually operated the grader, the time taken for complete sorting of the sample was noted and the capacity of the machine per hour was calculated.

The raw mango grader was tested for the following varieties; Totapuri, Alphonso, Neelum and Chinnarasam. The three variables, which decided the factors in evaluating the grader, were: (1) feeding rate (700 kg/h, 1800 kg/h, and 2400 kg/h); (2) slope of the grader (8, 12, and 16 degrees); (3) size of the opening (O_1 - from 50 to 57 mm, O_2 - from 57 to 64 mm, and O_3 - from 64 to 70 mm).

The fruits were moved through grader and the percent of fruit that moved through each opening which was correctly graded was determined. The data were analysed statistically by a three factorial randomized complete block design (RCBD) with three replications. The best combination of slope, feed rate and opening was determined by the best percent of fruits correctly graded.

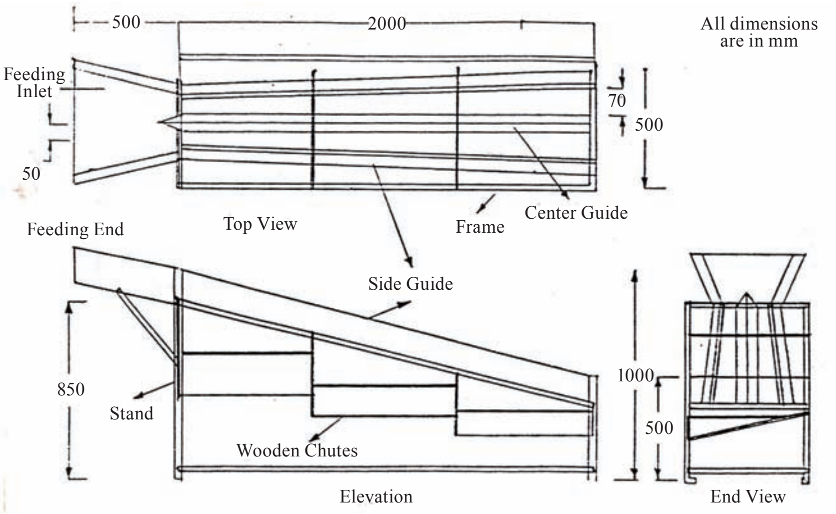

Fig. 1 Raw mango grader

Results and Discussion

Tables 1, **2**, and **3** show the percent of the correctly graded mango fruit for each variety that passed through opening for each of the three feeding rates, respectively.

For each of the three feed rates, the four varieties were significantly different from each other and the highest percent that was correctly graded was for the Neelum variety and the lowest was for the Chinnarasam variety. This may have been because of the small size of the Neelum variety compared to the others. This allowed the fruits to enter at a faster rate through any of the three openings. Further, opening O_3 was superior to the other two openings. The reason could have been that the larger opening (O_3) permitted a larger number of fruit to be graded as compared to O_1 and O_2.

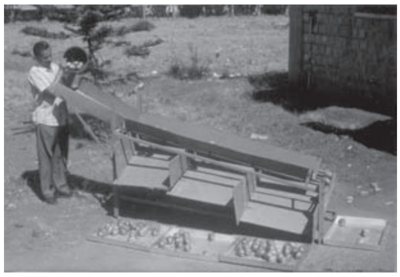

Fig. 2 Raw mango grader

Varieties	8º Slope				12º Slope				16º Slope				Mean			
	O_1 (50-57 mm)	O_2 (57-64 mm)	O_3 (64-70 mm)	Mean	O_1 (50-57 mm)	O_2 (57-64 mm)	O_3 (64-70 mm)	Mean	O_1 (50-57 mm)	O_2 (57-64 mm)	O_3 (64-70 mm)	Mean	O_1 (50-57 mm)	O_2 (57-64 mm)	O_3 (64-70 mm)	Mean
Totapuri	76	75	92	81	78	83	82	81	62	79	89	76.6	72	79	87.66	79.55
Alphonso	70	85	90	81.6	83	81	86	83.3	63	80	89	77.3	72	82	88.33	80.77
Neelum	70	90	90	83.3	86	86	83	85	73	82	84	79.6	76.33	86	85.66	82.66
China -rasam	70	83	83	78.6	77	75	90	80.6	65	78	82	76.1	70.66	78.66	86.83	78.48
Mean	71.5	83.25	88.75	81.16	81.0	81.25	81.25	82.5	65.75	79.75	86.86	77.4	72.75	81.41	86.99	80.37

Table 1 The percent of correctly graded mango fruit from each variety that passed through each opening for each slope for a feed rate of 720 kg/h

Twelve-degree slope was found to be significantly superior to 8 degrees and 16 degrees. It is possible that, for the lower 8-degree slope which was almost flat, the fruit was not rolling with sufficient velocity. Whereas, with the higher 16-degree slope, the fruits were reaching a higher velocity that caused them to over flow and be collected as the fourth grade (>70 mm). Thus, both these cases resulted in a lower grading percent. The intermediate 12-degree slope seemed to correct these deficiencies.

The percent of fruits correctly graded was decreased with an increase in feed rate. When the feed rate was 720 kg/h the mean percent of fruits correctly graded was 80.37. When the feed rate was increased to 1800 kg/h the mean percent of fruits correctly graded was decreased to 74.87. When the feed rate was further increased to 2400 kg/h, the mean percent of fruits correctly graded was decreased to 69.06. The reason for such decreased efficiency may have been that increased feed rate resulted in increased blocking of the grader opening or faster rolling of fruits which resulted in smaller fruits getting dropped into a larger category.

Similar results were obtained by Goodman and Hamann (1971) in sizing sweet potato where an increase in feed rate resulted in decreasing efficiency of fresh market grade from 95.6 % to 89.9 % and that of canning grade from 100 % to 96.6 %.

Shyam et al., (1979) working on potato sorting, found that with a decrease in feed rate from 50 q/h to 25 q/h resulted in better efficiency of grader. De Vries et al., (1997) working on soybean separation found that an increase in angle of separator conveyer from 18 degrees to 25 degrees resulted in a drop in efficiency from 100 to 93 %.

The optimum capacity of the grader for grading raw mangoes was found to be between 900 kg/h and 1400 kg/h.

The present study revealed that the very time and labour consuming task of grading mangoes can be greatly improved with the raw mangoes grader. Further, the grader was found to be most effective for the Neelum variety at 12-degree slope and with opening O_3 (64 to 70 mm).

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Varieties	8º Slope				12º Slope				16º Slope				Mean			Mean
	O_1 (50-57 mm)	O_2 (57-64 mm)	O_3 (64-70 mm)	Mean	O_1 (50-57 mm)	O_2 (57-64 mm)	O_3 (64-70 mm)	Mean	O_1 (50-57 mm)	O_2 (57-64 mm)	O_3 (64-70 mm)	Mean	O_1 (50-57 mm)	O_2 (57-64 mm)	O_3 (64-70 mm)	
Totapuri	70	66	85	73.66	76	77	76	76.33	57	75	82	71.33	67.66	72.66	81	73.77
Alphonso	65	81	86	77.33	78	76	81	78.33	58	76	83	72.33	67	77.6	83.3	76
Neelum	66	84	85	78.33	81	82	78	80.33	66	75	79	73.33	71	80.3	80.6	77.33
China -rasam	64	76	75	71.66	70	71	87	76.22	61	72	75	69.33	65	73	79.22	72.4
Mean	66.25	76.7	82.75	75.24	76.25	76.5	80.6	77.8	60.5	74.5	79.7	71.5	67.6	75.9	81.0	74.87

Table 2 The percent of correctly graded mango fruit from each variety that passed through each opening for each slope for a feed rate of 1800 kg/h

Varieties	8º Slope				12º Slope				16º Slope				Mean			Mean
	O_1 (50-57 mm)	O_2 (57-64 mm)	O_3 (64-70 mm)	Mean	O_1 (50-57 mm)	O_2 (57-64 mm)	O_3 (64-70 mm)	Mean	O_1 (50-57 mm)	O_2 (57-64 mm)	O_3 (64-70 mm)	Mean	O_1 (50-57 mm)	O_2 (57-64 mm)	O_3 (64-70 mm)	
Totapuri	65	64	80	69.66	70	71	72	71	51	70	74	65	62	68.33	75.33	68.55
Alphonso	60	76	82	72.66	70	70	75	71.88	52	70	78	66.88	60.8	72.2	78.3	70.48
Neelum	61	78	71	70.0	75	76	73	74.66	60	70	74	68	65.3	74.6	72.6	70.88
China -rasam	59	70	69	66.0	65	64	79	69.33	54	67	70	63	59.3	67.0	72.6	66.33
Mean	61.25	72	75.50	69.58	70.16	70.25	74.75	71.72	54.25	69.41	74.0	65.88	61.88	70.55	74.75	69.06

Table 3 The percent of correctly graded mango fruit from each variety that passed through each opening for each slope for a feed rate of 2400 kg/h

Engineering the Crop Establishment System for Paddy Wet Seeding

by

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Abstract

The scarcity of labor supply and high labor cost are making rice farmers shift from transplanting to the direct seeding method, which is a cost-saving and profit-enhancing technology. Farmers' direct seeding practices include the use of seeds at high seeding rate and rice stubbles were not decomposed owing to short duration of land preparation. During herbicide or fertilizer application, farmers cannot easily identify weeds and even step on some rice plants. Land leveling is also often taken for granted as most farmers wrongly believe that it is just an added cost in farming, not knowing that poor leveling will adversely affect crop and water management. For continuous field operations, a good crop establishment system requires equipment for preparing the land well including side plowing, leveling, and seeding. With this system, field operations would be much faster and easier, and use of farm machines would be more effective.

The side-plow, field leveler and seeding technologies were developed as attachments to the hand tractor. The hand tractor-drawn double disc plow was re-engineered to convert easily from levee side plowing to normal plowing and vice-versa. An L-shaped drag-type leveling device drawn by a hand tractor was developed to provide efficient leveling. For faster seeding and effective field maintenance, a 12-row hand tractor-drawn seeder was developed. The seeding rate could be adjusted from 40 to 120 kg/ha.

To ensure stable seedling establishment and good crop management using these implements, the field must be well prepared at least 21 days before seeding. To attain uniform seed distribution, seeds must be soaked and incubated for 24 h. Pre-emergence herbicides must be applied one to three days after seeding (DAS) to be effective. The field must be drained up to nine DAS to have good seedling emergence. Irrigation water should be applied at 10 DAS and maintained at 5 cm water level to facilitate fertilizer application, weed control and tiller development. With this system, labor saved in side plowing, leveling, and seeding were 60.79 %, 86.75 % and 64.13 %, respectively. The labor saved with that of farmers' practice for direct seeded and transplanted were 8.9 % and 46.35 %, respectively.

Rationale

Many farmers are shifting from transplanting to direct seeding due to the increasing cost of farm labor. Direct seeding can reduce water and labor costs for crop establishment such as seedling nursery management, cost of pulling, transporting, and transplanting. However, the shift to direct seeding is not without constraints. Pest problems (from birds, rats, snails, and weeds), especially during crop establishment and high seeding rates are prevalent in wet direct- seeded rice culture.

Direct seeding requires thorough land preparation to help manage weeds. Good leveling enhances emergence of seedlings. Few seedlings would emerge in flooded portions of a field. Some farmers use wooden planks to level their fields but most of them do not; instead they use an inefficient comb-harrow for leveling. At present, land preparation is being done through the use of hand tractors. However, side plowing and leveling are done with the use of a carabao-drawn implement or hand tractor with two operators. With this system, use of farm machines becomes ineffective. Thus, equipment for levee side plowing, leveling, and seeding that could be attached to the hand tractor is needed. The protocols of operation must be established for better seedling establishment and emergence, and crop management.

Objectives

This study aimed to improve current practices in land preparation and crop establishment in wet direct seeding, and more specifically to further reduce labor costs, improve seedling emergence, and increase the efficiency of hand tractor attachments.

Methodology

Current practices of farmers in direct seeding were first documented and improvement work was directed toward the inefficient practices. The side plow, field leveler, and mechanical seeder that could be attached to the hand tractor were developed for continuous and effective use of farm machines. The technology developed was integrated in the farmers' practices. Evaluation of seedling establishment, emergence, and crop management were conducted to identify a protocol for wet seeding using the developed technologies.

Results and Discussion

Farmers' Practices in Direct Seeding

Table 1 shows that there is no pattern of change in the percentage of farmers practicing direct seeding from 1998 wet season to 2000 wet season although more farmers do direct seeding during the dry season because of better water control than in the wet season. **Table 2** shows the mean input-use by ecosystem. In the irrigated lowland ecosystem, average seeding rate ranges from 146 to 174 kg/ha or an equivalent of four cavans at 40 kg/cav, which is 50 % higher than the recommended seeding rate. The average NPK fertilizer applied is slightly higher in the dry season than in the wet season, but is still lower than the recommended fertilizer rate, most probably due to high prices. Pesticides and herbicides applications are on the average of 1.73 and 0.83 l/ha, respectively. Labor use shows a decreasing trend both in irrigated and rainfed ecosystems respectively from 74.2 to 43.8 md/ha and from 62 to 41 md/ha owing to the use of farm machines. Across seasons, labor cost has the biggest share in the total production costs.

Land preparation was done in a relatively short period in areas with insufficient water through the use of hand tractors employing the disc-plow for plowing and the comb-harrow for harrowing. The hand tractor could not plow the sides along the levees. Floating tillers could but these are not common to farmers in Luzon. Most farmers used a carabao drawn plow; usually a moldboard plow for plowing the edges of the field. Land leveling was done through the use of a wooden plank drawn either by a carabao or hand tractor. Other farmers use the comb-harrow in leveling but some do not use a leveler at all.

Development of Technologies for Wet Seeding Operation

The hand tractor is the most common machine used by farmers in land preparation. Other equipment can be attached to it to further increase its versatility and make farm operations faster and easier. Thus,

Table 1 Percent distribution of farmers who practiced direct seeding by ecosystem, 1998 WS to 2000 WS

	Irrigated	Rainfed
Wet Season		
1998	30.0	42.5
1999	38.3	32.9
2000	29.1	28.8
Dry Season		
1999	49.5	40.0
2000	42.0	33.8

Table 2 Average input-use in direct seeded rice, 1998 WS to 2000 WS

Item	1998 WS	1999 DS	1999 WS	2000 DS	2000 WS
Irrigated Areas					
Seeds (kg/ha)	146	174	173	172	161
NPK Fert. (kg/ha)	75-11-9	82-15-11	82-15-10	91-22-18	67-15-6
Herbicide (l/ha)	1.06	1.01	1.07	0.71	1.05
Pestcide (l/ha)	1.36	1.74	1.70	1.44	2.44
Labor (md/ha)	74.2	66.1	62.8	43.7	43.8
Rainfed Areas					
Seeds (kg/ha)	130	126	142	144	155
NPK Fert. (kg/ha)	61-12-9	29-9-1	61-14-12	52-12-8	69-18-10
Herbicide (l/ha)	0.70	0.45	0.84	0.76	0.79
Pestcide (l/ha)	1.19	1.22	1.12	0.74	1.25
Labor (md/ha)	62.1	55.7	62.3	38.0	41.0

Souce: Small farm survey: Farm record keeping, PhilRice

Fig. 1 Carabao-drawn side plowing

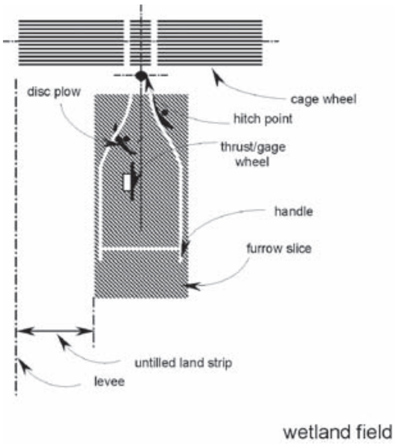

Fig. 2 Schematic diagram showing the untilled land strip along the side of the levee

land preparation, including side plowing and leveling, for crop establishment could be done continuously and efficiently.

Side Plow Equipment

The common method of plowing the sides of levees left untilled by a hand tractor (two-wheel tractor or power tiller) uses a moldboard plow drawn by a carabao (**Fig. 1**) for a fee of $8.65/ha. The use of an animal in side plowing is necessitated by the difference in width between the hand tractor tread and the double-disc working width. Since the tractor path does not precisely follow the levee, the width of the untilled portion may reach 60 to 70 cm (**Fig. 2**). Certain machinery manufacturers have been developing optional side plows (**Fig. 3**) since the 1980's but farmers still prefer the carabao-drawn moldboard plow. In-depth analysis showed that critical double-disc plow optimum design parameters such as tilt and disc angles of the plow and gage/thrust wheel were neglected in the commercial side plow design, making the hand tractor hard to maneuver and to maintain a straight line of travel. Thus, there is a need to engineer a new disc plow with its configuration suited for side plowing.

A prototype disc plow was designed and developed to effectively work with both normal and levee side plowing (**Fig. 4**). The side-mounted disc plow, 43 cm away from the hitch point, was oriented at 20 degrees tilt and 20 degrees disc angles, while the gage/thrust wheel, 109 cm away from the hitch point, was oriented at 20 degrees tilt and 10 degrees disc angles. For normal plowing (**Fig. 5**), the double disc-plows were 30 cm apart and correctly oriented at 20 degrees tilt and 40 degrees disc angles. With this configuration, the moments of side plowing resistance and thrust force were balanced, thus the problem of maneuverability was solved. Production rate for side plowing was 0.063 ha/h (**Fig. 6**) while for normal plowing was 0.14 ha/h. Field evaluation and adaptation trials are being done.

Leveling Technology

Improving soil conditions for better plant growth is a requisite of sustainable high yield. Leveling saves water and energy, brings about better and more uniform plant populations, makes cropping and all farming operations more efficient, improves surface drainage, saves labor and fertilizer, and increase its use efficiency. The benefits lead to lower production cost. Land leveling is needed more in direct seeding than in transplanting to achieve

Fig. 3 Commercial side plowing equipment

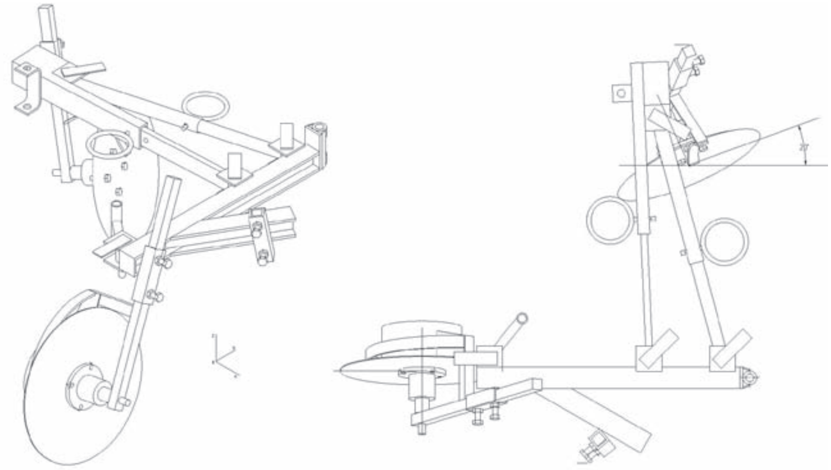

Fig. 4 Disc plow configured for levee side plowing

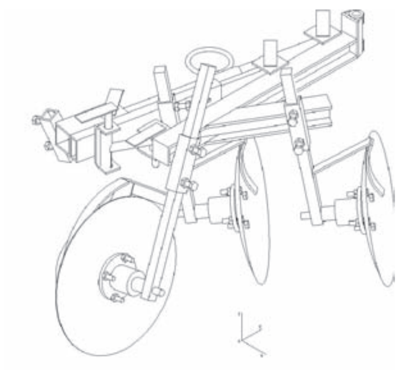

Fig. 5 Disc plow configured for normal plowing

good seedling establishment and management of water, nutrients, and pests. However, after plowing and harrowing, leveling is often neglected, resulting in crop management problems. Therefore, there is a need to address the problem of unleveled field plots for an efficient and cost-effective farming operation.

The PhilRice leveler (**Fig. 7**) was redesigned in the following manner: width was reduced from 3.0 to 2.5 m; plank support was made spring-activated with three adjusting points; and adjustor was positioned nearer the hitch point. Tests showed that in spite of the spring-activated leveling plate (**Fig. 8**), soil surface level still followed the hardpan contour. Much soil accumulated between the paddy wheels and the leveling plate. Changes such as reducing the spring deflection or index, tilting the leveling plate, and others were incorporated to solve these problems but the leveling plate still followed the hardpan contour due to the fixed position of the skid.

New designs were therefore, considered to eliminate the effect of hardpan contour in leveling the soil surface. To do this, movement of the leveling plate should be made independent. Based on the Japanese 4WT-drawn leveler, a prototype of an L-shaped drag-type leveling equipment (**Fig. 9**), 2 m wide with 50 cm long protruded wings inclined up to 45 degrees, was fabricated and improved. Forces acting on the leveling plate are described in **Fig. 10**. The weight of the leveling assembly is balanced by the vertical component of the pulling force of the hand tractor and the reacting pressure force of the soil and water mixture. It was reduced from 31 to 19 kg and prevented the leveling plate from sinking. During field operation, the leveling plate remained afloat while moving excess soil to lower portions of the field plot. When undulating portions were encountered, the operator stepped on the leveling plate directly.

Tests showed that after one pass of the leveling plate on the soil surface profile having eight varying degrees of undulation (**Fig. 11**), about 80 % of the field was uniformly leveled while the 20 % had four varying degrees of undulation (**Fig. 12**). The remaining undulations were mostly near the levees.

Mechanical Paddy Seeder

A mechanical sowing device drawn by a commercial hand tractor was developed to mechanize direct seeding operations in medium and large farms. The hand, tractor-drawn seeder attachment (**Fig. 13**) allowed seeding in furrows created by spring-loaded furrowing devices. The drum metering controls the rates of seeding through a two stage-chain-and-sprocket from

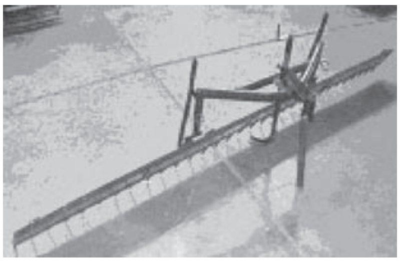

Fig. 7 Prototype of the PhilRice leveler

the hand tractor transmission. The seeder is equipped with six cylindrical hoppers, a spring-loaded furrow assembly, and a roller-type depth gauge. It can seed 2.5 m width in one pass with 12 rows at 20 cm spacing and spaced 20 cm, except the center row spaced at 30 cm. The seeding capacity is 3 to 5 ha/day. On the other hand, field efficiency largely decreases as the area of the field increases owing to increasing unproductive time such as reloading of seeds in the hopper.

Adaptation of the Technology in Farmers' Field

Adaptation in farmers' field was conducted in Aliaga, Nueva Ecija; Valencia, Bukidnon and Pigcauayan, North Cotabato. This was to evaluate the adaptability of the technology in different types of soil. These sites were selected because 100 % of the farmers were direct seeding during dry season and 50 % in wet season. The farmer-cooperators used seeding rates of 40 kg/ha and 80 kg/ha during dry and wet season, respectively. Farmer feedback was gathered through the use of questionnaire and personal interview.

Based on the utilization, the disc side-plow and leveler attachments were suitable to any field condition. The hand tractor-drawn paddy seeder could work well in shallow hardpan except for minor adjustment and fine-tuning in the seeder. The cooperator in Bukidnon suggested that the hopper assembly and furrow opener assembly should be made adjustable. Optimum performance

Fig. 6 Levee side plowing

Fig. 8 The spring-activated PhilRice leveler

Fig. 9 The prototype L-shaped drag-type leveler

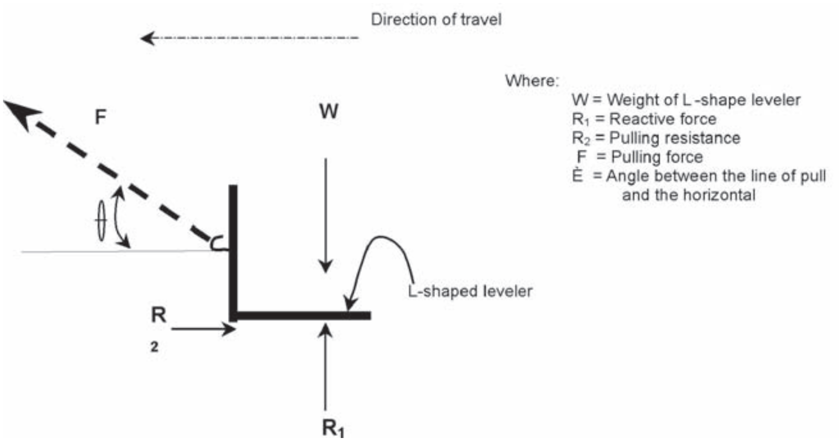

Fig. 10 Force diagram of the hand tractor-drawn leveler

of the seeder could be achieved at 20 cm depth of hardpan. Using the developed technologies, the cost of production was reduced by 37.3 % and the seedling emergence was increased by 18 % compared to the conventional method.

Establishing the System for Wet Seeding Operation

Land preparation for wet seeding normally starts at least 21 days before seeding, requiring one plowing, two harrowing, and one leveling. Land leveling is necessary in direct seeding for good seedling establishment and management of water and golden apple snails (GAS). Leveling should be done one day before seeding and the field must be drained immediately after leveling. The field should be saturated during seeding and then drained for 9 days. Small canals along the sides of the paddy must be established. The recommended seeding rate is 40 kg/ha, allowable up to 80 kg/ha during WS to anticipate seedling damage due to rainfall and GAS. Pre-emergence herbicide could be applied 1 to 3 days after seeding, beyond which it will no longer be effective. Manual pulling or mechanical weeders may be used to remove weeds that survive application of pre-emergence herbicide.

Water should be applied 10 days after seeding (DAS) to facilitate fertilizer application and weed control, and maintained at 3 to 5 cm during the growth duration of the crop. Fertilizers should be applied starting 10 DAS and divided into three to four applications depending on the maturity of the crop. Integrating all possible pest control strategies, including plant resistance and cultural, biological, and chemical practices to maintain pest populations at economically non-damaging levels, should be considered for pest management. The field is monitored regularly for pests, natural enemies and other factors of pest build-up. Farm equipment developed could be integrated in the system for faster farming operations, improved land preparation and crop establishment, and efficient use of farm machines. With this system, crop management would be easier and seedling growth would be enhanced as shown in **Fig. 14**.

Labor Productivity of the Developed Technologies

The total labor use, as shown in **Table 3**, in Nueva Ecija for transplanting was 55.10 md/ha, for direct seeded using farmers' practice was 32.44 md/ha and for direct seeded using the developed technologies was 29.56 md/ha. Use of the developed technologies for side plowing, leveling, and seeding relatively decreased labor use in direct seeding. Labor saved from the conventional method of side plowing leveling and seeding was 60.79 %, 86.75 % and 64.13 % respectively; labor saved from transplanted and farmers' practices in direct seeded rice was 46.35 % and 8.9 % respectively. Moreover, the developed technologies increased the versatility of the hand tractor.

Conclusion and Recommendation

Side plowing, leveling, and seeding for the developed technologies were much faster and easier than the current practice of the farmers and required less labor. Seeds saved from the broadcasting method

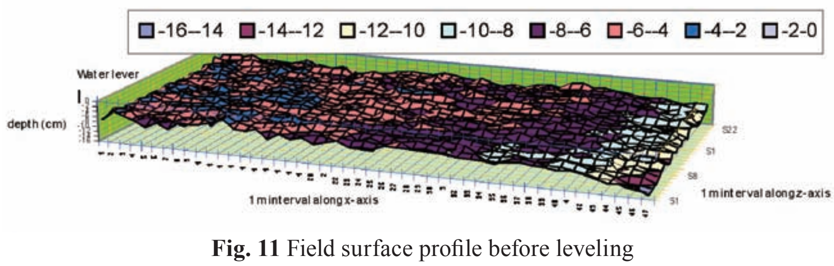

Fig. 11 Field surface profile before leveling

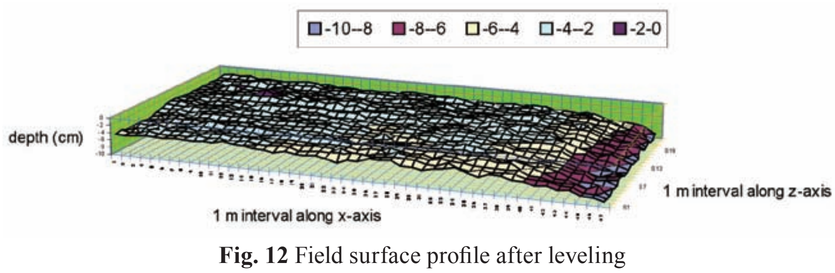

Fig. 12 Field surface profile after leveling

ranged from 50 to 70 %. Crop management is easier because the seeds are in rows. Also, the cost of production was reduced by 37.3 %, and the versatility of the hand tractor was increased. This technology is ready for field utilization, verification and demonstration in direct seeded areas. To achieve optimum seedling establishment and crop management, it is recommended that the field should be well prepared and thoroughly leveled.

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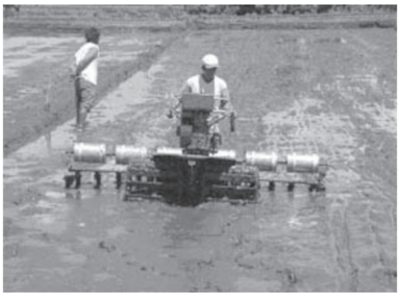

Fig. 13 The improved hand tractor-drawn paddy seeder

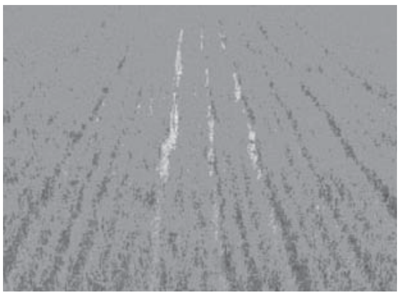

Fig. 14 Mechanized direct seeding

Operation	Direct Seeded: Farmers' practice, md/ha	Direct Seeded: Using the developed technologies, md/ha	Transplanted, md/ha
Seedbed preparation	-	-	0.78
Plowing	1.24	1.24	1.33
Side plowing	0.51	0.20	0.47
1st harrowing	1.03	1.03	1.01
2nd harrowing	0.99	0.99	0.85
Leveling	1.6	0.22	0.97
Repair and cleaning of dikes	1.9	1.9	2.17
Seed soaking and incubation	0.76	0.51	0.67
Sowing of seeds	-	-	0.47
Fertilizer application (seedbed)	-	-	0.25
Pulling/bundling of seedlings	-	-	3.67
Hauling/distribution of seedlings	-	-	3.75
Transplanting	-	-	15.9
Broadcasting	0.92	0.33	-
Replanting	0.49	0.27	0.42
Fertilizer application	0.69	0.69	0.65
Herbicide application	0.61	0.61	0.43
Insecticide application	0.65	0.65	0.53
Weeding/cleaning of canals	0.43	0.43	0.43
Irrigation	0.83	0.83	1.19
Draining	0.25	0.25	0.35
Field visit	1.3	1.3	0.23
Purchasing inputs	0.43	0.30	0.23
Harvesting	12.5	12.5	12.73
Threshing	1.96	1.96	1.83
Hauling of threshed palay	1.12	1.12	0.66
Drying	2.23	2.23	2.16
TOTAL	32.44	29.56	55.10

Table 3 Comparison of labor use in direct seeded and transplanted rice in Nueva Ecija, 2001 DS

Performance of Cage Wheel with Opposing Circumferential Lugs and Normal Cage Wheel in Wet Clay Soil

by

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Abstract

In Southeast Asia, rice is usually grown under flooded or wet field conditions. In these wet clay soils, traction and floatation of vehicles used for cultivation is a major problem. Cage wheels have proven to be one of the best traction aids during wet land cultivation. Recent study revealed that opposing circumferential lugs on a cage wheel may perform well in these soils. The main objective of this study was to investigate the performance of cage wheels with opposing circumferential lugs. The specific objectives included the study of the effect of two types of lug arrangement (straight and staggered), the study of the effect of free sinkage along with a compares on of the performance of cage wheel, with opposing circumferential lugs, with normal cage wheel with straight lugs. The study revealed that the cage wheel with opposing circumferential lugs performed well compared to the cage wheel with normal lugs. It could provide higher floatation and traction, and reduced wheel sinkage.

Introduction

Tillage is considered as the largest power consuming operation in agricultural practices. Agricultural engineers have been concerned with better performance of tillage implements for many years. As a result, there are various kinds of improved tillage tools now available in the market. However, many of them are designed on the basis of practical field experience to suit local conditions without adequate rigorous theoretical considerations. When the standard dry farming machines for the cultivation of wet paddy fields are used, they face traction and floatation problems because of high moisture content of paddy fields (Johnson, 1965).

Triratanasirichai et al. (1990) reviewed a number of findings concerning wheel performance in paddy conditions (e.g. Soemengat, 1962; Deng et al., 1984) and summarized that pneumatic, rubber-tired wheels perform poorly in paddy conditions. The power loss of these wheels can be up to 66 % of the total loss. Cage wheels perform better than rubber tires in these conditions. They are inexpensive and easy to fabricate, and can be made much wider than a conventional tire. Cage wheels have proved to be one of the best traction aids for wet land cultivation.

A study of the effect of design parameters of the cage wheel in a soil bin showed that the wheel with 680 mm diameter, 16 lugs and 220 cm lug width gave the optimum dynamic performance. Tanaka and Nakashima (1986) stated that the thrust efficiency of the lug becomes maximum at 30 % slip in the case of a wheel with 12 lugs. Additionally, they studied the effect of lug angle on the soil reaction in clay loam in a soil bin and found that the average lift by a lug increases when the lug angle becomes large while the average thrust decreases. The thrust becomes maximum when the wheel slip is 28.8 % (Tanaka and Nakashima, 1988).

Jayasundera (1980) tested a pair of cage wheels with a diameter of 93 cm and a width of 38 cm in a flooded, puddled field fitted to a 12.5 kW four-wheel (two-wheel drive) tractor. He found that the 30º lug spacing

Specification	Dimension
Outer Rim diameter	700 mm
Rim width	280 mm
Annular ring thickness	20 mm
Outer diameter of wheel (Rim diameter + Width of lug)	840 mm
Lug length (at 15º circumferential angle)	155 mm
Lug spacing	24º, 30º
Lug angle	30º

Table 1 Specifications of cage wheels

with 12 lugs gave the highest power transmission. The performance of movable lug wheels, as well as a fixed lug wheel with two types of lug moving patterns, in a soil bin test apparatus was evaluated by Hermawan et al. (1998). The results proved that sinkage, slip and driving torque of the movable lug wheels and the fixed lug wheel fluctuated periodically with the rotation angle of the wheel. The periodic fluctuations corresponded to angular lug spacing.

Wang et al. (1995) reviewed a number of recent findings concerning on the behavior of lugged wheel-soil interaction and reactions acting on lugs (e.g. Tanaka, 1984; Nakashima and Tanaka, 1986; Wu et al., 1986; Zhang and Shao, 1984; Deng and Youg, 1984; Salokhe et al., 1989; Salokhe et al., 1990a; Salokhe et al.,1990b) and summarized that in the past, most experimental studies were carried out in a laboratory under predetermined constant slip and sinkage condition and thus their applicability for the design of lugged wheel would be limited.

The availability of information regarding the studies on arrangement or configuration of lugs on the cage wheels is still inadequate. There are two configurations, which have potential to significantly reduce the resulting side forces; viz. a straight chevron arrangement and a staggered chevron arrangement like a rubber tire. The small lug opening results in fewer variations and the opposing lugs may result in reducing the side forces significantly (Watyotha et al., 2000).

The objectives of this study were to investigate the performance of free sinking cage wheels and compare it with the performance of cage wheels with normal lugs.

Experimental Apparatus and Methods

a. Experimental Apparatus

The experiments were carried out in an underground concrete soil bin with an area of about 18 x 2 m^2 on which a hydrostatic driven remote controlled carriage was mounted. Soil bin was filled with clay soil with 51 % average soil moisture content (dry basis) and 140 kN average soil cone index. A special set up to test free sinking cage wheels, consisted of a fixed and a movable frame developed for supporting the

Slip (%)	Forward speed of the test wheel (m/s)	Forward speed of the carriage (m/s)
15	0.87	0.74
25	0.87	0.65
35	0.87	0.57
50	0.87	0.44

Table 2 Desired slip and corresponding speed of carriage and the test wheel

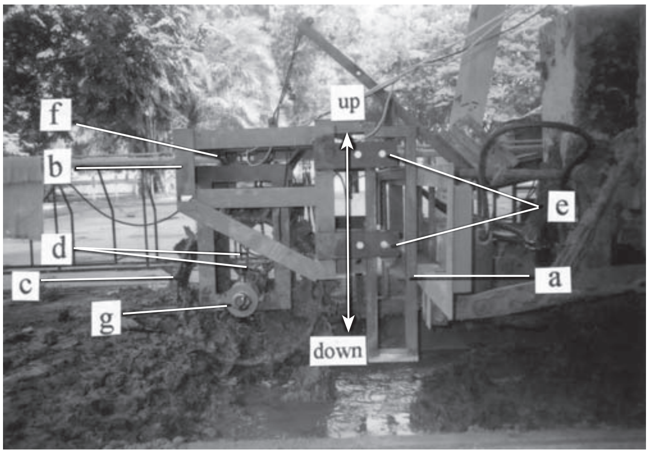

Fig. 1 Cage wheel test facility with free sinkage system (a: fixed frame; b: movable flame; c: test wheel; d: sprocket and chain; e: roller bearing; f: octagonal ring transducer; g: slip ring)

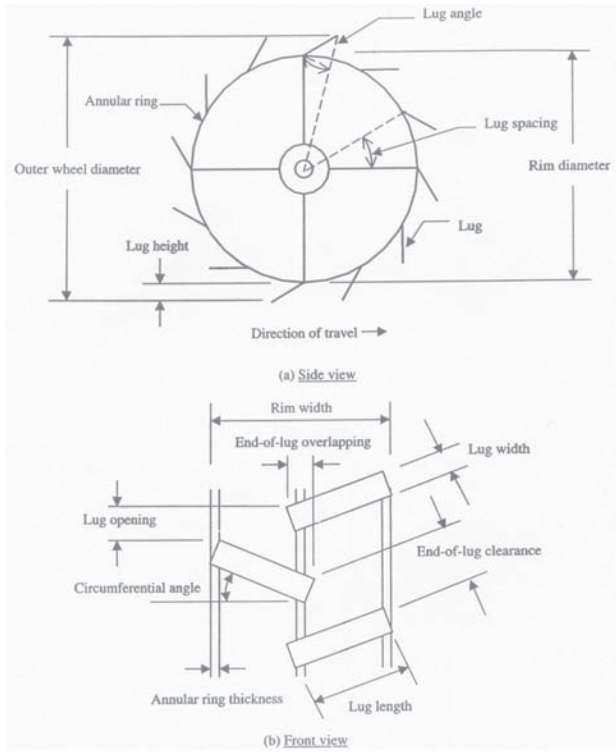

Fig. 2 Sketch of cage wheel parameter, (a) side view; (b) front view (Watyotha and Salokhe, 2001)

test wheel. It was mounted on the soil bin carriage (**Fig. 1**). Its total weight was set about half (±140 kg) of commonly used power tiller in Asia, as only one wheel was used for testing. The characteristic of two orthogonal force components (pull and lift forces) produced by the cage wheels were obtained by using octagonal ring transducer, while torque measurement was done by a load cell mounted on the wheel shaft. The sinkage was measured by installing the displacement transducer. Data obtained were amplified and recorded via a digital dynamic strain amplifier on a computer. All transducers were calibrated before use. The test wheel was rotated by the hydraulic motor through sprocket and chain. A hydraulic pump powered by the PTO drive of the carriage was used to drive the hydraulic motor.

The performance of the cage wheel with opposing circumferential lugs was compared with normal cage wheel performance. Normal cage wheel was the wheel that was commonly used for soil cultivating with straight lugs (right angle) on wheel rim. **Table 1** presents the specification of cage wheels. **Fig. 2** presents the sketch of lugs and cage wheel parameters. It is evident that the lug opening, end of lug clearance and lug overlapping values changed as the lug spacing and circumferential angle changed (Watyotha and Salokhe, 2001).

b. Experimental Method

For each experiment, the soil was prepared using a rotavator. Water was sprayed uniformly between the rotavating passes to achieve the desired soil moisture content. Then a scraper blade was used to level the soil until the desired level and cone index value was achieved. In this experiment, the test wheel could freely penetrate into the soil thus the lug sinkage fluctuated depending on the vertical (normal) and drawbar load.

In this study, all tests were conducted at 20 rpm rotational speed of the wheel or the forward speed of 0.87 m/s (±3 km/h) of the wheel at no slip. The wheel slip was changed from 15 % to 25 %, 35 %, and 50 %. The forward speed of the carriage at the desired slip was calculated. The values of forward speed of the carriage to get the desired slip of the wheel are given in **Table 2**.

The following relationships were used to calculate the axle power, drawbar power, and tractive efficiency.

Axle Power (Pa, kW)=[2πw x (Q)]/60000...(1)

Drawbar power (Dp, kW)=[P x V]/1000...(2)

Tractive Efficiency (n)=[Dp/Pa] x 100%...(3)

where, V is the actual forward speed (with load) (m/s), w is the rotation of wheel tested (rpm), Q is the axle torque (Nm), and P is the drawbar pull generated (N). Each experiment was repeated three

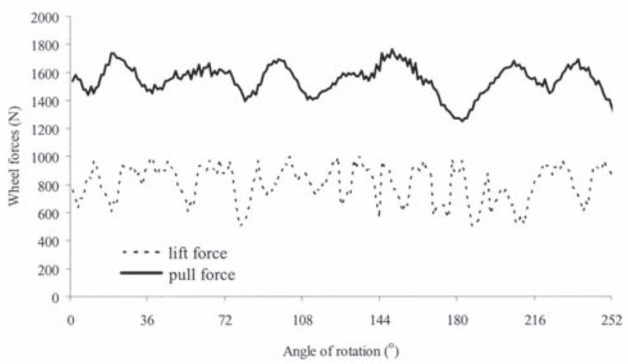

Fig. 3 Forces on the nomal cage wheel at 30º lug angle, 30º lug spacing at 25 % slip

Fig. 4 Forces on the cage wheel with opposing lugs at 15º circumferential angle, 30º lug angle, 24º lug spacing at 25 % slip

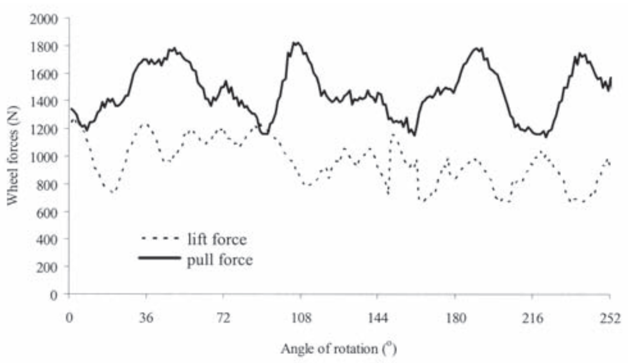

Fig. 5 Forces on the cage wheel with opposing lugs at 15º circumferential angle, 30º lug angle, 30º lug spacing at 25 % slip

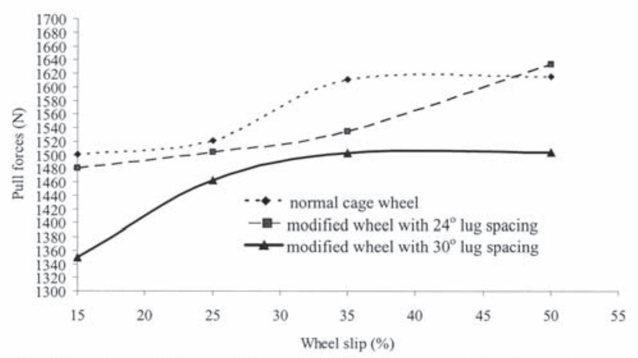

Fig. 6 Variation of pull forces at different slips for normal cage wheel and cage wheel with opposing circumferential lugs 24º and 30º lug spacing

times. To compare among the mean of data recorded and calculated, the analysis variance and the Least Significant Difference (LSD) were used.

Results and Discussion

Characteristic of Measured Wheel Forces

Figs. 3 to **5** show the characteristics of measured pull and lift forces of the cage wheels; of normal cage wheel and modified wheel with opposing circumferential lugs. The figure shows the real time and simultaneous cyclic variations of pull and lift forces fluctuating periodically with the rotation angle. The corresponding period was approximately equal to the interval of angular lug spacing. The pull force was higher than the lift force at all wheel slips and lug spacing. From the figures, it can be seen that the peak values of both pull and lift forces were achieved at certain wheel rotation. For the normal cage wheel, the peak values were attained at every 30º angle of wheel rotation which corresponded to the spacing of lugs on the wheel. On the other hand, for cage wheel with opposing circumferential lugs, as the number of lugs on the wheel were twice than on the normal cage wheel for the same lug spacing, the peak values of forces were reached at every half degree of lug spacing. At 24º and 30 º lug spacings, the peak values were achieved at about every 12º and 15º rotation angles respectively.

The characteristics of fluctuations of the wheel forces in this study agreed with the characteristics of pull and lift forces obtained by Watyotha and Salokhe (2001). It also agreed with the calculated pull and lift forces of freely sinking cage wheel studied by Wang et al. (1995), although the value of forces resulted were much higher. This might be caused by free sinking system, so the test wheel can fluctuate dynamically depending on the soil condition.

The results of mean pull force at various wheel slips and lug spacing are shown in **Fig. 6**. It can be seen from **Fig. 6** that the pull forces increased slightly with the increase of slip. The mean pull forces of the normal cage wheel and cage wheel with opposing circumferential lugs (modified wheel) indicated that at all slips, the normal cage wheel gave the highest values of pull forces followed by the modified wheel with 24º lug spacing and 30º lug spacing, respectively. The LSD analysis showed that there was a significant difference between the mean pull force obtained by the normal cage wheel and modified wheel with 30º lug spacing at 15 % of slip. However, the mean pull forces by the modified

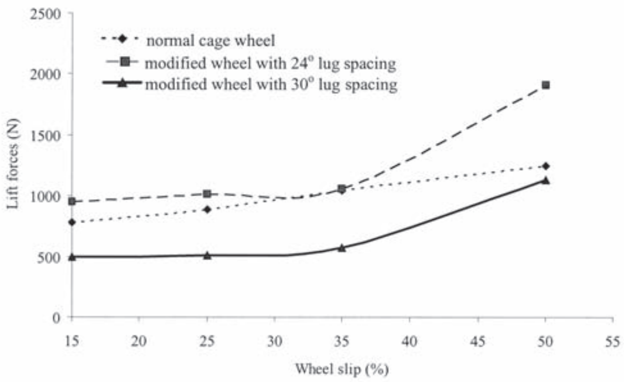

Fig. 7 Variation of lift forces at different slips for normal cage wheel and cage wheel with opposing circumferential lugs 24º and 30º lug spacing

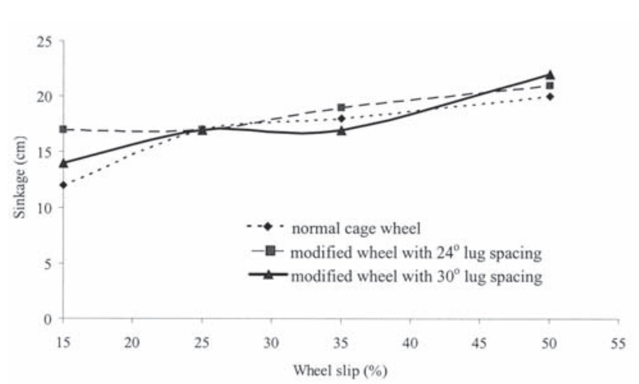

Fig. 9 Sinkage variation (cm) at different slips for normal and modified wheel

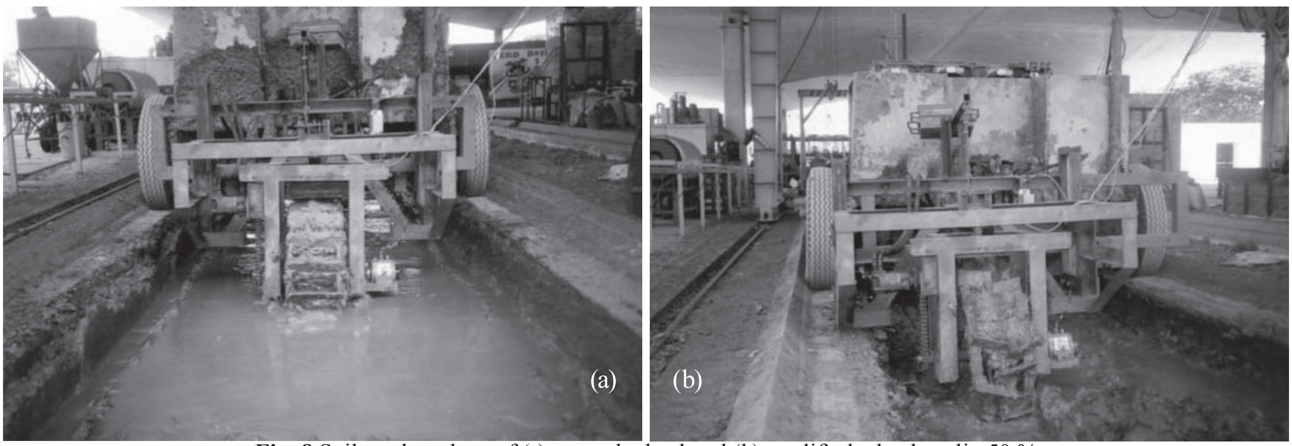

Fig. 8 Soil track on lugs of (a) normal wheel and (b) modified wheel at slip 50 %

wheel with 24º and 30º lug spacings were not significantly different from that with normal wheel at 25 %, 35 % and 50 % slips, but their values were still less than the normal cage wheel. From the same figure, the effect of lug spacing on the pull force can be observed and agreed with the study by Watyotha and Salokhe (2001) that the pull forces decreased significantly as the lug spacing increased. More horizontal soil compression and shearing caused by increasing the slip lead to increase the pull force.

Fig. 7 presents the mean lift forces as a function of wheel slip. It was observed that the lift forces increased with the increasing of the slips. The values of mean lift forces of the cage wheel with opposing circumferential lugs with 24º lug spacing showed that the lift forces were slightly higher compared to normal cage wheel. The values of mean lift forces of the cage wheel with opposing circumferential lugs with 30º lug spacing showed that the lift forces were lower compared to normal cage wheel. Thus, the cage wheel with opposing circumferential lugs with 24º lug spacing was more capable to float on soil than normal cage wheel. The effect of slip on forces agreed with study by Salokhe et al. (1994) that as the slip increased, the pull and lift forces on the succeeding and preceding lugs increased at all lug spacings.

Soil Sticking on Lugs

The effect of lug spacing and wheel slip on soil sticking on cage wheel lugs was studied. General observations showed that the soil sticking on lugs was experienced at every combination of lug spacing and wheel slip due the soil-metal adhesion. However, for the modified cage wheel, soil trapping between the lugs did not emerge and subsequent passing had no effect on progressive soil build up on the lugs. The amount of soil after the second, third and following passes was equal to that at the first pass. This was because the soil after the first pass was squeezed out to the sides on lugs before soil from subsequent passes was added. On the contrary, for the normal cage wheel, the soil stuck on lugs tended to increase after the second and third pass because the soil was not able to squeeze to the sides of the lugs.

In this study, the soil stuck on lugs was difficult to measure, because in the wet condition the soil was easy to spill from the lugs before it was weighed. The soil stuck on lugs of the normal wheel and modified wheel was visually observed (**Fig. 8**). It was observed that increasing of wheel slip would increase the pull forces, lift forces, wheel sinkage, and soil sticking on the lugs as well.

Comparison between soil sticking on lugs of normal wheel (picture **a**) and modified wheel with 30º lug spacing (picture **b**) showed that at 15 % and 25 % wheel slip, the amount of soil stuck on the lug was not significantly different. However, as the slip increased to 35 % and 50 %, the soil started to block on the normal wheel lugs or at the middle of wheel rim. For the modified wheel, soil stuck only on lugs because of the role of soil-metal adhesion. And, soil could not block at the middle of wheel rim due to the squeezing of soil along the slope of the lugs to the side position.

Effect of Slip on Sinkage

The influence of the slip on the sinkage can be seen in **Fig. 9**. The sinkage of normal cage wheel and modified wheel at 15 %, 35 % and 50 % slips was significantly different for 24º lug spacing and but it was not significantly different for 30 º lug spacing. On the other hand, increasing lug spacing from 24º to 30 º decreased the mean lift forces significantly. At 25 % slip, the sinkage did not differ significantly among all cage wheel types tested.

Fig. 10 shows the pull per unit wheel sinkage for different wheels at various slips. For cage wheel with normal lugs, the pull per unit sinkage was much higher at 15 % slip compared to other wheels. However, after 24 % slip the values were almost similar to other wheels. It means that at low slip, the normal cage wheel was more effective than other wheels tested. In terms of lift per unit wheel sinkage, the cage wheel with opposing circumferential lugs at 24º lug spacing gave lowest forces while the cage wheel with opposing circumferential lugs

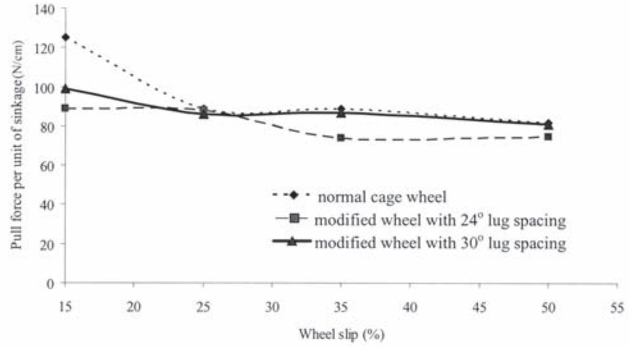

Fig. 10 Pull force per unit of sinkage (N/cm) at different slips for normal and modified wheel

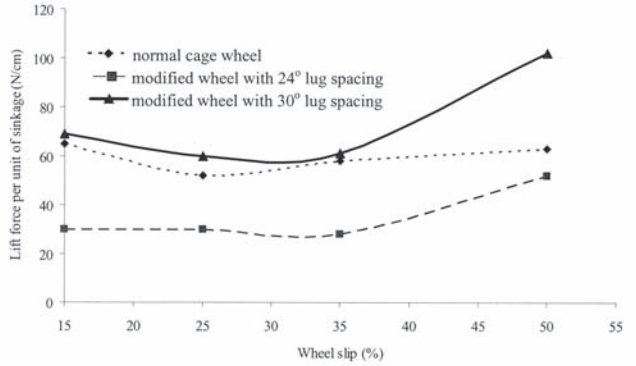

Fig. 11 Lift force per unit of sinkage (N/cm) at different slips for normal and modified wheel

at 30º lug spacing gave the highest lift forces (**Fig. 11**).

Tractive Performance Analysis

The curve of drawbar power versus wheel slip for different cage wheels is shown in **Fig. 12**. The drawbar power at 15 % slip did not differ significantly for normal cage wheel and cage wheel with opposing circumferential lugs with 24º lug spacing, but they were significantly different for normal cage wheel and cage wheel with opposing circumferential lugs with 30º lug spacing. By considering that the slip must occur to provide the pull (Gee-Clough, 1991), so the drawbar power depends on wheel slip and the calculated mean power could very well be fitted to a polynomial function of the form:

$P_o = As - Bs^2$...(1)

where, P_o is the power delivered in kW; s is wheel slip in %; A and B are constants.

The values of coefficients A and B, and the regression analysis showed a high correlation (**Table 3**). The increase of wheel slip led to a decrease of drawbar power. At 15 % slip the drawbar power reached maximum value and then decreased with further increase of wheel slip.

Fig. 13 shows the tractive efficiency curves for different cage wheels. As the slip increased, the tractive efficiency decreased due to the decreasing of traveling speed much more than the increasing of pull force. At 15 % slip, there was significant difference in tractive efficiency for normal cage wheel and cage wheel with opposing circumferential lugs with 30º lug spacing. At 25 % and 35 % slips, there was significant difference in tractive efficiency of normal cage wheel and cage wheel with opposing circumferential lugs with 30º lug spacing, as well as between cage wheel with opposing circumferential lugs with 24º and 30º lug spacings. And, at 50 % slip, there was no significant difference in tractive efficiency of different wheels.

Conclusions

For cage wheels, with either normal lugs or with opposing circumferential lugs, the wheel forces fluctuated periodically with rotation angle. The corresponding period was approximately equal to the interval of angular lug spacing. The effect of wheel forces on the pull and lift forces was similar where, as the slip increased, the pull and lift forces significantly increased. Comparison of normal cage wheel with modified wheel with 24º and 30º lug spacings showed that modified wheel with 30 º lug spacing gave lower values of wheel forces at all slips.

Comparison of the performance of cage wheel with opposing circumferential lugs with normal lugs showed that there was no significant difference between the drawbar power for all experiments. However, the tractive efficiency was found to be significantly different. The cage wheel with opposing circumferential lugs at 30º lug spacing gave the highest value at all slips.

The study revealed that the cage wheel with opposing circumferential lugs with 30º lug spacing performed well compared to the cage wheel with normal lugs. It could provide higher floatation and traction, and reduced wheel sinkage, so the power tiller could be easily used for working in wet paddy fields. The newly developed facility for free floating of the cage wheel gave results close to real life situation in the actual field.

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Table 3 Results of regression analysis of drawbar power versus wheel slip for different cage wheels

Type of cage wheel	Constant A	Constant B	R^2*	SEE**
Normal cage wheel	0.0689	0.00114	0.86	0.24
Cage wheel with opposing circumferential lug with 24º lug spacing	0.0662	0.00111	0.83	0.25
Cage wheel with opposing circumferential lug with 30º lug spacing	0.0661	0.00109	0.88	0.18

*R^2: coefficient of determination, **SEE: Standard Error Estimation

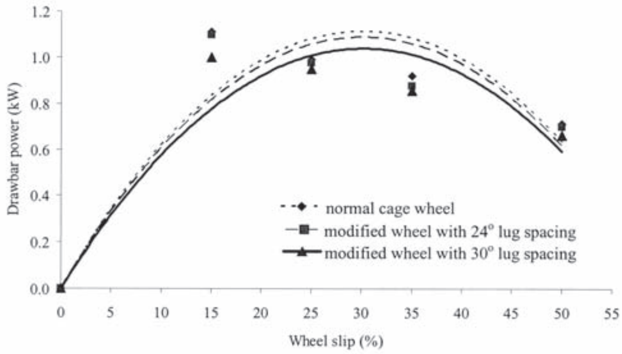

Fig. 12 Drawbar power of normal cage wheel and cage wheel with opposing circumferential lugs (modified wheel) at various slips

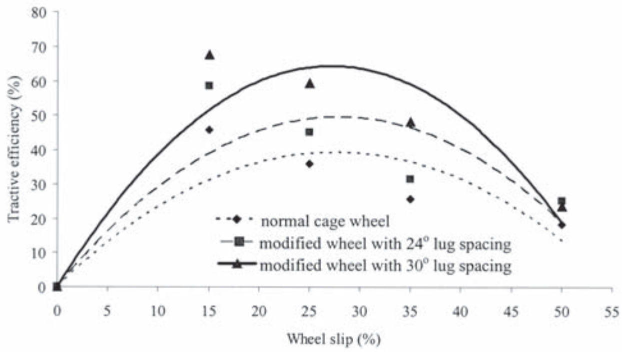

Fig. 13 Tractive efficiency of normal cage wheel and cage wheel with opposing circumferential lugs (modified wheel) at various slips

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Fabrication and Testing of Tomato Seed Extractor

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Abstract

A tomato seed extractor having a capacity of 180 kg of fruits per hour has been fabricated and evaluated at the Department of Agricultural Processing, Tamil Nadu Agricultural University, Coimbatore, India. The unit consisted of a fruit squeezing chamber, and a seed separation unit. In the fruit squeezing chamber, the tomato fruits were pressed and squeezed by a rotating screw auger and discharged to the seed separation chamber. The studs present in the rotating shaft in the seed separation chamber opened the squeezed fruit and nozzles at the top sprayed water and washed the seed from the fruit flesh. Wash water carried the seed through the perforated cover and collected them in a removable perforated tank placed inside the main tank. The fruit flesh, after separation of seed, was collected at the end of the seed separation chamber. The fruit flesh collected could then be further processed to any desired value added product. The unit had a seed extraction efficiency of 98.8 %. As compared to manual method of seed extraction, the unit recorded 96.6 % saving in time and 89.6 % saving in cost. The cost of the unit is only about $ 190.

Introduction

Tomato (*Lycopersiocon esculenthum Mill*), the second largest vegetable crop after potato in the world, is grown over an area of 2.85 million ha and has a recorded production of 88.2 million tonnes. It is a non-seasonal crop and grown largely in all parts of India. In India, it is grown over an area of 0.31 million ha and has a recorded annual production of 46 million tonnes (Opandey, 1995). Though India is the second largest producer of vegetables (86 million tonnes per annum) next to China, its per capita consumption is very low 135 g as compared to 400 g recommended for a balanced diet. Lack of available of quality seed is one of the important reasons for low vegetable production in this country. At present, the seed of tomato are extracted from tomato fruits by cutting and crushing the fruits and then allowing the fruits to ferment along with the water for 12 to 24 hours. After partial fermentation, the pulp is washed repeatedly and seed are collected. This method of seed production is highly labour intensive, unhygenic, tedious, time consuming, and produces a large effluent during the washing process. To overcome these problems and to collect the flesh portions of tomato for production of tomato pulp and paste, a tomato seed extractor has been developed.

Review of Literature

Howthom and Pollard (1954) described different methods of seed extraction using manual labourers. In one of the methods, the tomato fruits were fermented in water at 20 to 35 ºC for 3 days. Then, seed were washed repeatedly and used after drying.

Nicholos (1971) reported on a horizontal drum type brinjal seed extraction unit with rotating beaters inside. Dried brinjal fruits were used. The efficiency of the unit was 75 % and its capacity was 10 kg/h.

Ritchie (1971) reported that, in the fermentation method, the seed and pulp were squeezed from the fruit and left for fermentation in a warm room for 5 to 6 days. Due to the long fermentation, the mucilage around the seed was broken and clean seed were obtained after repeated washing. The seed were cleaned by either using a 10 % sodium carbonate solution in equal volume of seed and pulp, or 567 ml of concentrated hydro-chloric acid (HCl) for each 10 kg of fruits that was stirred well for 30 minutes.

Patel and Patel (1974) used HCl acid for extracting seed from 76 tomato varieties. The pulped flesh of 1 kg of each variety was treated with 20 ml of concentrated HCl for 30 minutes and then washed 3 to 4 times with fresh water for separation. Forty four varieties showed 100 % germination.

Brar and Hurisingh (1984) carried out seed extraction tests with four cultivars. The seed were extracted by 3 methods (fermentation, hydrochloric acid, and hydrochloric acid after juice extraction). Optimum HCl acid rate was 10, 20 and 30 ml. Hydrochloric acid had an adverse effect on germination.

Gurmit Singh et al. (1985) conducted studies of the effect on germination caused by the extraction of tomato seed. The fruits were crushed and the pulp was fermented for 24 to 120 hours. Seed germination decreased with the increased duration of fermentation. The best fermentation time was between 24 and 48 hours.

Raymond (1985) used both a wet and dry method of brinjal seed extraction. In the wet method, the fruits were crushed first and then passed through a screen to separate out the gelatinous seed from the bulk of the remaining material. Extra water was added during and after crushing in order to improve separation of seed. In the dry method, over-ripened fruit were dried until they shriveled. The drying was accompanied by fading of skin colour to a coppery brown colour. The dried fruits were beaten manually and the seed were hand extracted.

Gowda et al. (1991) conducted studies on extraction of tomato seed using fermentation, acid, alkali, and mechanical extraction techniques. Use of HCl at 5 % or sulfuric acid at 4 % for a soaking time of 45 min gave better seed germination.

Kachru and Sheriff (1992) evaluated the performance of an axial flow vegetable seed extractor. Five wet vegetables and fruits (tomato, brinjal, watermelon, muskmelon and pumpkin) were tested. The seed loss and mechanical damage ranged between 0.82 and 15.02 % and 0.97 and 5.79 %, respectively were recorded. The seed germination for tomato was 93 %.

Verma et al. (1992) designed an axial flow vegetable seed-extracting machine. In this machine the fruits were sliced, pulped, and seed were extracted. The pulp was discharged along with wash water.

Gabani and Siripurapu (1993) fabricated a chilli seed extractor. In this unit, the dried chilli fruits were crushed and a screen separated the seed from the crushed material. The mixture of seed and skin was separated in a cleaner and seed were collected separately.

More and Kanawade (1994) fabricated a power operated pomagranate seed extractor. A rotating shaft with knives, along with a concave, separated the seed from the rind. Purity of the seed was 96 %.

Wehner and Humphires (1995) developed a single fruit seed extractor for cucumber. An extractor cone present in the machine excavated the seed in the central cavity of the fruit, then washed and collected the seed through a strainer. In this method 100 % seed germination was recorded.

Kingsly (1998) fabricated a brinjal seed extractor. It consisted of a fruit-crushing chamber and seed separation unit. In the crushing chamber the brinjal fruit were crushed into pulp by crushing rods. The pulp was fed into the seed separation unit and continuously agitated by a shaft rotating at 35 rpm. Due to the difference in specific weight, the pulp floated and the seed sank in the water, passed through a sieve kept at the bottom, and were collected through a seed outlet. The seed efficiency of the unit was 98.8 %.

Materials and Methods

The newly fabricated tomato seed-extracting machine (**Fig. 1**) consisted of two main components namely,

1. Fruit squeezing chamber and
2. Seed separation unit.

In the fruit-squeezing chamber, the fruits were pressed and squeezed. The squeezed fruits were then transferred to the seed separation unit where the seed were separated from the squeezed fruits.

Fruit squeezing Chamber

It consisted of the following parts. (i) Feed hopper (ii) Rotor shaft (iii) Screw auger (iv) Outer cover (v) Power transmission system (vi) Motor and (vii) Frame.

Feed Hopper: A trapezoidal shaped tray type feed hopper, fixed at 23º to horizontal moved the tomato fruits into the fruit squeezing unit by gravity. The length of the feed hopper was 65 cm. The width at the front was 40 cm and at the rear was 15 cm. The rear of the tray was welded to a chute which was placed to deliver the fruit into the fruit squeezing chamber.

Rotor shaft: The screw auger was used for squeezing and sweeping the tomato fruit. Studs mounted on this shaft were used for more efficient separation of seed from squeezed fruits. One end of the rotor shaft was coupled to the power transmission system supported by 25 mm ball bearings. One 600 mm length rotor shaft passed through both the fruit squeezing chamber and the seed separation unit. The diameter of the rotor shaft in the fruit-squeezing chamber was 40 mm, and reduced to 25 mm in the seed separation unit. The screw auger and the studs were welded on suitable mild steel sleeves and bolted to the rotor shaft through hallen screws for easy dismantling or change of length of components of screw auger portion.

Screw Auger: The screw auger was made out of 3 mm thick mild steel round sheet by cutting and stretching it suitably and spreading through the entire length of the squeezing chamber. The diameter and pitch of the screw auger were 90 and 45 mm, respectively. As the average size of tomato fruits were 50 mm, a pitch of 45 mm could easily squeeze the fruits, in the fruit squeezing chamber.

Outer cover: A cylindrical outer cover having 95 mm inner diameter made out of 5 mm thick mild steel pipe was provided over the entire length of the screw auger to form the squeezing chamber. Like in the screw auger, provisions were given to vary the length of the outer cover depending upon the auger length. The outer cover was mounted rigidly on two other trapezoidal secondary frames attached over the main frame. The height of the trapezoidal frame was 30 cm. The inclined tray type feed hopper was welded on the top of the outer cover at the feeding end through a suitable chute. A clearance of 2 mm was provided between the outer cover and the outer edge of the screw auger for free rotation of the auger. A bearing was provided at the feed end of the outer cover, through which the rotor shaft was inserted and connected to the counter shaft fixed into a worm gear for power transmission.

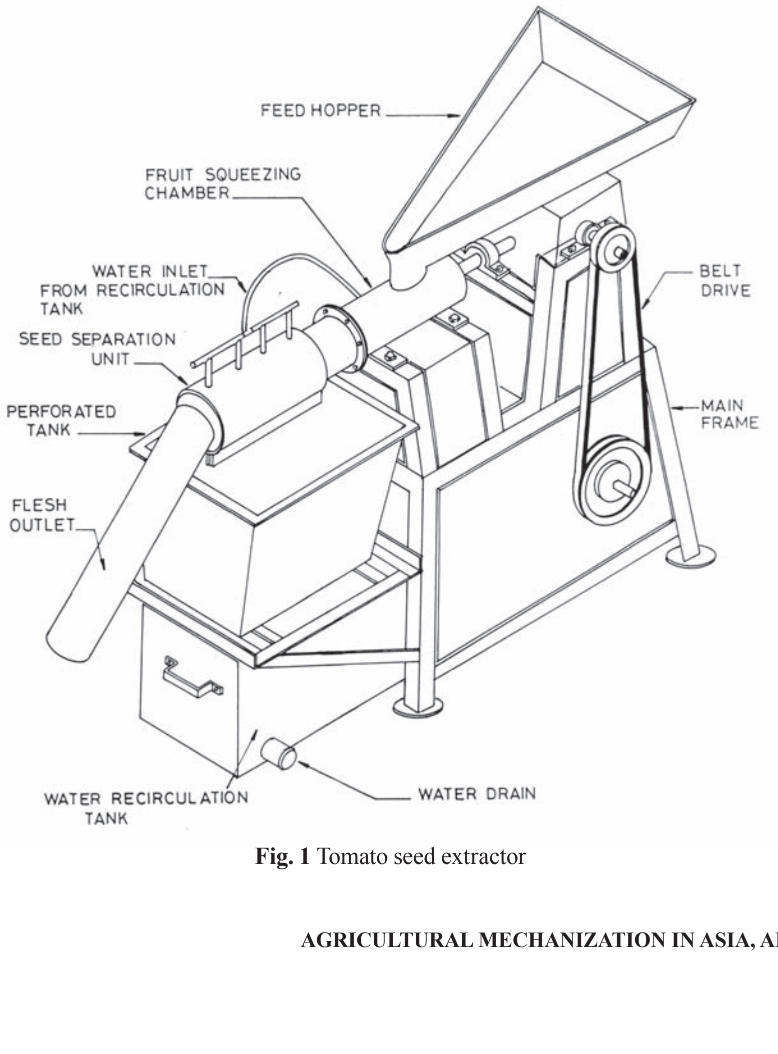

Fig. 1 Tomato seed extractor

Power Transmission system: The power transmission system consisted of a sub-frame, pulleys, V-belts, and worm gear and pinion. Two sub-frames of trapezoidal shape were provided over the main frame at the feed end just below the feed tray. The dimension of the trapezoidal sub frame was 185 mm at the top, 290 mm at the bottom, and 300 mm in height. To vary rotor shaft speed, different size single 'B' groove pulleys were used on the motor shaft and counter shaft. The pulley at the motor shaft was changed to get the desirable speeds of 50, 100, 150 and 200 rpm at the rotor shaft. A worm gear and pinion reduced the 1440 rpm motor speed to the 50 to 200 rpm required for the experiment. A worm gear and pinion was selected since it is simple, makes the unit more compact, and transmits, the power smoothly.

Motor and frame: The frame was trapezoidal and made of mild steel angle iron section of 40 x 40 x 6 mm size. Since the tomato fruit is very soft and fleshy and the unit operates at low speed, a more commonly available one-hp, single-phase 1440 rpm electric motor was selected and used in this unit.

Seed Separation Unit

The seed along with the juice coming out from the seed separation unit (**Fig. 1**) were collected first through a replaceable trapezoidal trough having a bottom made out of 2 mm perforated sheet. The seed were retained in the trough and the water drained into a large rectangular tank at the bottom of the main frame. A small water pump mounted on the lower tank, recirculated the water for washing. When the wash water becomes thick, it may be drained and used as feed for animals. Fresh water must then be added for continued washing.

The seed collected in the trough have a gelatinous coating. The seed were cleaned by treating with a 2.5 % hydrochloric acid solution for 30 min and washed. The clean seed were tested for the germination by approved international methods.

Determination of Seed Loss

Seed loss was determined by recovering the seed from the seed from the squeezed fruit collected at the squeezed fruit outlet. The entire squeezed fruit material collected from the squeezed fruit outlet during each test was dipped into water and the seed separated by gentle agitation. The percent seed loss was determined from the following equation.

$$\text{Percent seed loss} = \frac{S_2}{S_1 + S_2} \times 100$$

Where,

S_1 = weight of seed collected from seed outlet, g

S_2 = weight of seed collected from squeezed fruits at squeezed fruit outlet, g

The percent seed loss was calculated for different rotor shaft speeds and water flow rates.

Determination of Seed Extraction Efficiency

The percent seed extraction efficiency was determined from the following equation.

Seed extracting efficiency (percent)

$$= \frac{S_1}{S_1 + S_2} \times 100$$

Where,

S_1 = Weight of seed collected from seed outlet, g

S_2 = Weight of seed collected from squeezed fruits at squeezed fruit outlet, g.

Calculation of Cost and Time

The material cost and cost of fabrication were used with the standard procedures of Palanisamy, 1997 to determine the cost of operation. The cost of extraction of 1 kg of tomato seed with the machine was compared with the manual method of seed extraction. The cost and time saved were reported.

Results and Discussion

The tomato seed extractor was tested with PKM-1 tomato, a primery variety in Tamil Nadu, India. Each experiment was replicated three times and the average values were reported. Three kg of tomato fruits were used during each test. The performance of the machine was tested by varying the following parameters.

Parameter	Value
Feed water flow rate	5, 7.5, 10 l/min
Rotor shaft speed	50, 100, 150 and 200rpm
Auger length	240 and 340 mm

The following data were collected during testing.

(i) Weight of seed obtained through seed outlet

(ii) Weight of seed collected from the discharged flesh

From the data collected, the following calculations were made

(i) Seed extraction efficiency

(ii) Percent seed loss

In addition, germination studies were conducted and germination percentage were determined.

The following **Tables 1**, **2** and **3** give the performance of the tomato seed extractor for different seed extraction feed water flow rates.

Seed extraction efficiency was slightly higher with a screw auger length of 340 mm at all water flow rates. The highest seed extraction efficiency was for 5 l/min water flow rate at both auger lengths and occurred with 100 and 150 rpm shaft speeds. At 10 l/min the seed extraction efficiency reduced from the lowest shaft speed (50 rpm) to the highest speed (200 rpm). The highest seed extraction efficiency (98.8 %) was at 7.5 l/min water flow rate, 340 mm auger length and 150 rpm shaft speed. This combination also gave the highest germination rate of 98 %. Generally, the lowest germination rate was at the highest water flow rate.

Cost of Operation

The cost of operation of the prototype was estimated and compared to that of manual method of seed extraction. From the calculations made, it is seen that the capacity of the newly developed tomato seed extractor is 180 kg of fruit per hour or 1.8 kg of tomato seed per hour. The cost of operation of tomato seed extractor was determined and found to be $0.25 per kg of seed. The time required for the tomato seed extractor to extract one kg of seed was 33.33 min whereas, in the manual method, it required 1000 min. By using this machine, it is possible to save 89.6

Length of Screw Auger (mm)	Rotor shaft speed (rpm)	Seed extraction efficiency (%)	Seed loss (%)	Seed germination (%)
240	50	92.6	7.4	92
	100	94.5	5.5	95
	150	94.7	5.3	95
	200	90.0	10.0	94
340	50	95.1	4.9	95
	100	96.2	2.8	96
	150	97.6	2.4	97
	200	94.4	5.6	96

Table 1 Perfomance of tomato seed extractor with 5 l/min seed extraction feed water flow rate

% in cost and 96.6 % in time.

Acknowledgement

The authors express their sincere thanks to Thiruvalargal Sheela Manogaran, T.S. Thomas, Sukumaran, Pethurajan and other artisans who directly or indirectly helped in fabricating the prototype and successful testing of the unit.

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Length of Screw Auger (mm)	Rotor shaft speed (rpm)	Seed extraction efficiency (%)	Seed loss (%)	Seed germination (%)
240	50	94.6	5.4	95
	100	96.9	3.1	95
	150	97.2	2.8	96
	200	94.5	5.5	94
340	50	97.3	2.7	95
	100	97.5	2.5	97
	150	98.8	1.2	98
	200	95.1	4.9	96

Table 2 Perfomance of tomato seed extractor with 7.5 l/min seed extraction feed water flow rate

Length of Screw Auger (mm)	Rotor shaft speed (rpm)	Seed extraction efficiency (%)	Seed loss (%)	Seed germination (%)
240	50	97.5	2.5	94
	100	96.5	3.5	95
	150	94.5	5.5	95
	200	93.5	6.5	92
340	50	97.8	2.2	94
	100	97.1	2.9	95
	150	97.1	2.9	97
	200	95.5	4.5	94

Table 3 Perfomance of tomato seed extractor with 10 l/min seed extraction feed water flow rate

Computer-Aided Analysis of Forces Acting on a Trailed Plough

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Abstract

The traditional method of analyzing forces acting on a trailed plough was evaluated, and the sources of the errors were studied in theory. The system of equations of forces acting on trailed plough was established, and the solution was found by the use of computer-aided analysis. In light of the equations, the influence of different values of parameters on the forces was forecast. These results provided theoretical basis for designing and optimizing the structure of a trailed plough.

Introduction

Tillage is the manipulation of soil by mechanical forces (Gill, 1968) which can eradicate competitive weeds and improve the physical condition of the soil for plant growth (Smith, 1976), and is imperative to prepare the soil for planting or sowing. The common tool for soil tillage in agriculture is the trailed plough (TP). In order to look for the ways to reduce resistance to the working parts of the plough and the power consumption in tillage, to design and make use of trailed plough rationally, and to raise the efficiency of the unit, analysis of forces acting on the trailed plough is needed. The traditional method of analyzing forces acting on a trailed plough is a graphical method, that is, to solve the problem by changing the space force system to 3 plane force systems. Because only 3 unknown forces could be sought out, at most, in a plane force system, hypotheses must be made to simplify the problem before using graphical method (Shang, 1988; Beijing Agricultural Engineering University, 1986; Zhengjiang Institute of Farm Machinery, 1981; Du, 1977). Therefore, the results of graphical method are not usually accurate, and cannot meet the requirements of practical application.

The objectives of this study were to establish the balance equations of forces applied to the trailed plough, to find solutions of the equations by analytic method, and to forecast the influence of different values of the parameters on forces and torques acting on the trailed plough.

Methods

Forces Applied to Trailed Plough

Forces applied to a trailed plough form a typical space force system which is composed of three sections: forces acting on the plough bottom; forces acting on the land wheel, furrow wheel and tail wheel; and traction force of the tractor (**Fig. 1**).

Forces acting on the plough bottom: The resistances of soil against the plough bottom could be determined by a test, and then simplified as a force (R_t) acting on the share point and a couple (M_t). The normal reacting forces (N_{ti}) of the furrow wall against the landsides could be composed of a total normal reacting force of the soil against the landside (NT_t).

Forces acting on the land wheel, furrow wheel, and tail wheel: The reacting forces of the ground or furrow bottom against the land wheel (Q_{t1}), furrow wheel (Q_{t2}) and tail wheel (Q_{t3}) are different, and composed of the normal reacting forces and the rolling friction.

Traction force of the tractor: The traction force (P_t) is acting on the hitch point by the tractor that could be resolved into three forces P_{tX}, P_{tY} and P_{tZ}.

$P_{tZ} = P_{tX} \cdot Tg\alpha_t$ ....(1)

Here, α_t is the trail angle.

Existing Errors in the Graphical Method

The graphical method is of low accuracy and takes much time to draw the graph (Shang, 1988; Beijing Agricultural Engineering University, 1986; Zhengjiang Institute of Farm Machinery, 1981). There are 6 unknown forces acting on the trailed plough which are: P_{tX}, P_{tY}, Q_{t1}, Q_{t2}, Q_{t3}, and N_{Tt}. This is a typical space static's problem the solution of which could be found accurately by the use of analytic method. However, when we use graphical method to find the solution, the space force system must first be projected to three planes: xoy, yoz, and zox. After projecting, the numbers of unknown forces in the three plane force systems are, respectively, 6, 6, and 5. However, only 3 unknown forces could be sought out, at most, in a plane force system. We have to assume the values of some unknown forces in advance, which would result in that the values of the unknown forces found from different plane force system would be different. So, in order to find a reasonable solution we must draw the graphs for many times. In this way, the graphical method is not only time-consuming but also of low accuracy.

However, the most serious problems of the graphical method lie in the aspects below. This is to suppose that the normal reacting forces of the furrow wall against the different landsides were equal, their magnitudes were known, and their resultant acts on the landside of the center plough bottom or the imagined center plough bottom. By means of analyzing the wear condition of the landsides used in practice for a certain period of time, it was found that the wear condition of the front landside was different from that of the back landside. This means that, the normal pressures and frictions acting on the landsides of the front plough bottom and the back plough bottom are varied. In fact, the couple resulting from the resistance of the soil against the plough bottom causes the trailed plough and tractor unit to rotate clockwise. Under the same angular displacement, the compressed deformation of furrow wall caused by the landside of the back plough bottom is larger than that caused by the landside of the front plough bottom, and the normal pressure and friction of the furrow wall against the landside of the back plough bottom is bigger than that of the furrow wall against the landside of the front plough bottom. Therefore, it is unreasonable to suppose that the normal reacting forces of furrow wall against the different landsides in a trailed plough are equal. Besides, the magnitude of Ni was changed with the variation of working situation of the trailed plough unit, which could not be determined beforehand.

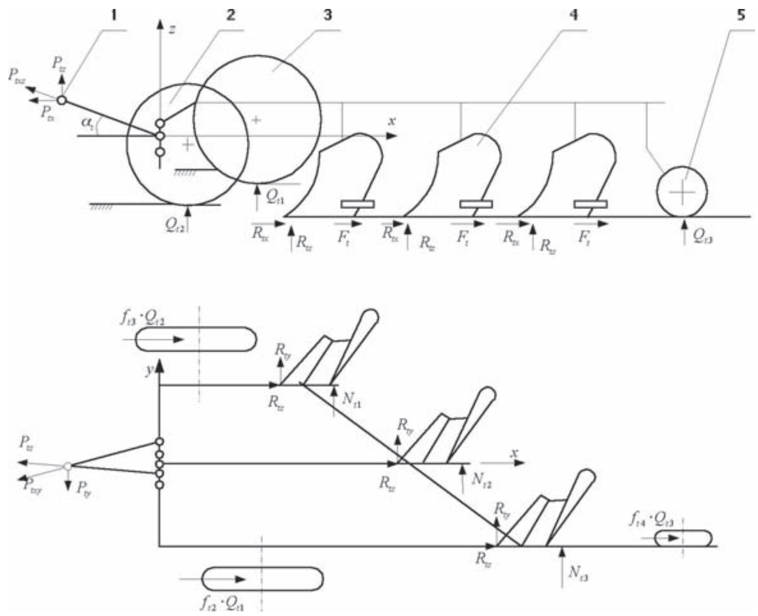
Fig. 1 Forces applied to the trailed plough

Equations of Forces Acting on the Trailed Plough

In light of the analysis above, the normal reacting forces of the furrow wall against each landside (N_{ti}) are different. If taking every N_{ti} as an unknown, the number of unknowns in this space static's problem will be more than 6, and this problem can not be solved. Therefore, we should try to reduce the unknown first. According to the theory of soil mechanics, the normal reacting force of the furrow wall against the landside is directly proportional to the area of the landside and the square root of the compressed deformation of the furrow wall. Hence, the normal reacting force of the furrow wall against a single landside could be calculated by the following formula:

$$N_{ti} = k[\theta_t(x_{tni} - x_{t0})]^{1/2} \bullet S_i \quad \text{.................(2)}$$

where,

N_{ti} = normal reacting force of furrow wall against the ith landside (N)

k = compression constant of soil

θ_t = rotating angle of the landsides in horizontal plane (°)

x_{t0} = x coordinate of the rotating center of the plough (m)

x_{tni} = x coordinates of the center of the ith landside (m)

S_{ti} = area of the *i*th landside (m^2)

The rotating angle (θ_t) of each landside around the hitch point remains the same. In order to avoid measuring k, one should suppose $K_{tN} = k\theta_t^{1/2}$ that. In this way, the K_{tN} of each landside are equal and the resultant (NT_t) for all the N_{ti} could be calculated by the following formula:

$$NT_t = K_{tN} \sum_{i_t=1}^{n_t} (x_{tni} - x_{t0})^{1/2} \bullet S_{ti} \quad \text{........(3)}$$

where, n is the number of the plough bottom, and K_N is the only one unknown.

Additionally, the resistance of the soil against the plough bottom was determined by test which could resolve into three forces: R_X, R_Y, R_Z acting on the share point and three couples: M_{RX}, M_{RY}, M_{RZ}. The unknowns then in the space static's problem of the trailed plough are: P_{tX}, P_{tY}, Q_{t1}, Q_{t2}, Q_{t3}, NT_t. The coordinates of the unit were set up as **Fig. 1**, and the balance equations of forces applied to trailed plough were established as follows: **Equations 4a** to **4f**.

where,

(x_{t0}, y_{t0}, z_{t0}) = coordinates of the hitch point in TP (m)

(x_{t1}, y_{t1}, z_{t1}) = coordinates of the share point of front plough bottom in TP (m)

(x_{t2}, y_{t2}, z_{t2}) = coordinates of the mass center of TP (m)

(x_{t3}, y_{t3}, z_{t3}) = coordinates of the center of the land wheel in TP (m)

(x_{t4}, y_{t4}, z_{t4}) = coordinates of the center of the furrow wheel (m)

(x_{t5}, y_{t5}, z_{t5}) = coordinates of the mass center of the tail wheel (m)

(x_{tk}, y_{tk}, z_{tk}) = algebraic sum of coordinates of the share point of all ploughs in TP (m)

$(x_{tni}, y_{tni}, z_{tni})$ = coordinates of the center of the ith landside in TP (m)

G_t = weight of TP (N)

f_{t1} = friction coefficient between the landsides and furrow wall in TP

f_{t2} = rolling friction coefficient between the land wheel and ground in TP

f_{t3} = rolling friction coefficient between furrow wheel and furrow bottom in TP

f_{t4} = rolling friction coefficient between the tail wheel and furrow bottom in TP

Q_{t1} = normal reacting force of ground against the land wheel in TP (N)

Q_{t2} = normal reacting force of furrow bottom against the furrow wheel (N)

Q_{t3} = normal reacting force of furrow bottom against the tail wheel (N)

F_t = friction force between the landsides and furrow wall (N)

P_t = traction force of the tractor in TP (N)

α_t = traction angle in TP (°)

R_t = resistance of soil against the plough bottom in TP (N)

M_t = couple caused by R_t (N•m)

(P_{tX}, P_{tY}, P_{tZ}) = three components of the P_t (N)

(R_{tX}, R_{tY}, R_{tZ}) = three components of R_t (N)

$(M_{tRX}, M_{tRY}, M_{tRZ})$ = three components of M_t (N•m)

Solution Finding and Simulation Calculation

The equations above could be written in the following matrix form for the trailed plough:

$A_t \bullet B_t = C_t$ ....(5)

where, **Equations 5a** to **5c**.

Results and Discussion

Through designing the calculating program, we can find the solution of the equation 5 with the aid of a computer. Besides, on the basis of this program we can also forecast the varying conditions of forces acting on the main parts of the trailed plough when one structure parameter of the trailed plough was changed. According to the

$$\sum X_t = P_{tX} + Q_{t1}f_{t2} + Q_{t2}f_{t3} + Q_{t3}f_{t4} + K_{tN} \bullet f_{t1} \sum_{i_t=1}^{n_t} (x_{tni} - x_{t0})^{1/2} \bullet S_{ti} + n_1 \bullet R_{tx} = 0 \quad \text{...(4a)}$$

$$\sum Y_t = P_{tY} + K_{tN} \sum_{i_t=1}^{n_t} (x_{tni} - x_{t0})^{1/2} \bullet S_{ti} + n_t \bullet R_{ty} = 0 \quad \text{...(4b)}$$

$$\sum Z_t = P_{tX} \bullet \tan\alpha_t + Q_{t1} + Q_{t2} + Q_{t3} - G_t + n_t \bullet R_{tZ} = 0 \quad \text{...(4c)}$$

$$\sum M_{tX} = P_{tZ} \bullet y_{t0} - P_{tY} \bullet z_{t0} + Q_{t1} y_{t3} + Q_{t2} y_{t4} + Q_{t3} y_{t5} + R_{tz} \bullet y_{tk}$$
$$- R_{tY} \bullet Z_{tk} - K_{tN} \bullet z_{t1} \sum_{i_t=1}^{n_t} (x_{tni} - x_{t0})^{1/2} \bullet S_{ti} - G_t \bullet y_{t2} + n_t \bullet M_{tRx} = 0 \quad \text{...(4d)}$$

$$\sum M_{tY} = P_{tX} \bullet z_{t0} - P_{tZ} \bullet x_{t0} + Q_{t1}(f_{t2} z_{t3} - x_{t3}) + Q_{t2}(f_{t3} z_{t4} - x_{t4}) + Q_{t3}(f_{t4} z_{t5} - x_{t5}) + G_t \bullet x_{t2} + R_{tX} \bullet z_{tk}$$
$$+ K_{tN} \bullet f_{t1} \bullet z_{t1} \sum_{i_t=1}^{n_t} (x_{tni} - x_{t0})^{1/2} \bullet S_{ti} - R_{tZ} \bullet x_{tk} + n_1 \bullet M_{tRY} = 0 \quad \text{...(4e)}$$

$$\sum M_{tZ} = P_{tY} \bullet x_{t0} - P_{tX} \bullet y_{t0} - Q_{t1} \bullet f_{t2} \bullet y_{t3} - Q_{t2} \bullet f_{t3} \bullet y_{t4} - Q_{t3} \bullet f_{t4} \bullet y_{t5} + R_{tY} \bullet x_{tX} \bullet y_{tk}$$
$$+ n_t \bullet M_{tRZ} + K_{tN} \sum_{i_t=1}^{n_t} (x_{tni} - x_{t0})^{1/2} \bullet S_{ti} \bullet (x_{tni} - f_{t1} \bullet y_{tni}) = 0 \quad \text{...(4f)}$$

Equation 4a, 4b, 4c, 4d, 4e, 4f

$$A_t = \begin{bmatrix} 1 & 0 & f_{t2} & f_{t3} & f_{t4} & f_{t1} \sum_{i_t=1}^{n_t} (x_{tni} - x_{t0})^{1/2} \bullet S_{ti} \\ 0 & 1 & 0 & 0 & 0 & \sum_{i_t=1}^{n_t} (x_{tni} - x_{t0})^{1/2} \bullet S_{ti} \\ \tan\alpha_t & 0 & 1 & 1 & 1 & 0 \\ y_{t0} \tan\alpha_t & -z_{t0} & y_{t3} & y_{t4} & y_{t5} & z_{t1} \sum_{i_t=1}^{n_t} (x_{tni} - x_{t0})^{1/2} \bullet S_{ti} \\ y_{t0} - x_{t0} \tan\alpha_t & 0 & f_{t2} z_{t3} - x_{t3} & f_{t3} z_{t4} - x_{t4} & f_{t4} z_{t5} - x_{t5} & f_{t1} z_{t1} \sum_{i_t=1}^{n_t} (x_{tni} - x_{t0})^{1/2} \bullet S_{ti} \\ -y_{t0} & x_{t0} & -f_{t2} y_{t2} & -f_{t3} y_{t4} & -f_{t4} y_{t5} & \sum_{i_t=1}^{n_t} (x_{tni} - x_{t0})^{1/2} \bullet S_{ti} \bullet (x_{tni} - f_{t1} y_{tni}) \end{bmatrix} \quad \text{...(5a)}$$

$$B_t = \begin{bmatrix} P_{tX} \\ P_{tY} \\ Q_{t1} \\ Q_{t2} \\ Q_{t3} \\ K_{tN} \end{bmatrix} \quad \text{...(5b)} \qquad C_t = \begin{bmatrix} -n_t R_{tX} \\ -n_t R_{tY} \\ G_t - n_t R_{tZ} \\ R_{tY} \bullet z_{tk} - R_{tZ} \bullet y_{tk} + G_t \bullet y_{t2} - n_t M_{tRX} \\ R_{tZ} \bullet x_{tk} - R_{tX} \bullet z_{tk} + n_t M_{tRY} - G_t \bullet x_{t2} \\ R_{tX} \bullet y_{tk} - R_{tY} \bullet x_{tk} - n_t M_{tRZ} \end{bmatrix} \quad \text{...(5c)}$$

Equation 5a, 5b, 5c

actual working situation of trailed plough, the simulation calculation of 10 parameters with 5 levels of the trailed plough (**Table 1**, where the third level stands for the common working situation of trailed plough) was carried out. The relationships between forces applied to the trailed plough and the levels of parameters were expressed in **Table 2**.

In **Table 2**,

!!!: denotes that the increase is bigger than 20%.

¡¡¡: denotes that the decrease is bigger than 20%.

!!: denotes that the increase is bigger than 10% and smaller than 20%.

¡¡: denotes that the decrease is bigger than 10% and smaller than 20%.

!: denotes that the increase is bigger than 1% and smaller than 10%.

¡: denotes that the decrease is bigger than 1% and smaller than 10%.

-: denotes that the increase or decrease is smaller than 1%.

By analyzing **Table 2**, we found that:

(1) The change of the traction angle α_t has a remarkable influence in the Q_{t1}, Q_{t2} and Q_{t3}. The increase of α_t would result in the decrease of Q_{t1} and Q_{t2}, and the increase of Q_{t3}. In contrast, the decrease of α_t would result in the increase of Q_{t1} and Q_{t2}, and the decrease of Q_{t3}. Both these two situations would degrade the stability of ploughing depth of the trailed plough. Therefore, we should make Q_{t1}, Q_{t2} and Q_{t3} close to equal to obtain an even ploughing depth when we adjust the traction angle α_t. Meanwhile, attention should be paid to keeping $Q_{t1} > 0$ and $Q_{t2} > 0$.

(2) Consider reducing the traction resistance of trailed plough, we should increase y_{t0}. That is, moving the hitch point to the ploughed soil. However, it was also found that P_{tY} is increased considerably, and the normal reacting force of the furrow wall against landside (NT_t) is decreased simultaneously, which would influence the stability of the furrow width. Therefore, in order to gain higher stability of the furrow width when adjusting the position of hitch point, NT_t should be in a suitable value.

(3) For the sake of improving the stability of ploughing depth of the trailed plough, the position of mass center should be moved backward by adding weight on the tail wheel.

Conclusions

(1) With the balanced equations of forces and the computer program set up in this paper, the forces acting on the trailed plough were analyzed, and the influence of different values of the parameters on forces and torques was forecast;

(2) It was unreasonable to suppose that the normal reacting forces of the furrow wall against the different landsides in a trailed plough were equal, their magnitudes were known, and the proportion of Q_1 to Q_2 was fixed. These hypotheses would result in serious errors in analyzing forces acting on the trailed plough; and

(3) The analytic method presented in this paper was not only timesaving but also of high accuracy. The same methodology could be equally applied for the analysis of forces being applied to other implements.

Levels	α_t	n_t	x_{t0}	y_{t0}	x_{t1}	x_{t2}	y_{t2}	x_{t3}	y_{t3}	x_{t4}
1	6	3	-1.30	-0.50	0.55	1.55	-0.86	0.10	0.30	0.80
2	8	4	-1.10	-0.30	0.75	1.75	-0.66	0.30	0.50	1.00
3	11	5	-0.80	0	1.05	2.05	-0.36	0.60	0.80	1.30
4	14	6	-0.50	0.30	1.35	2.35	-0.06	0.90	1.10	1.60
5	16	7	-0.30	0.50	1.55	2.55	0.14	1.10	1.30	1.80

Fig. 1 Variable levels of parameters in simulation calculation of trailed plough

Forces	α_t	n_t	x_{t0}	y_{t0}	x_{t1}	x_{t2}	y_{t2}	x_{t3}	y_{t3}	x_{t4}
P_{tx}	-	!!!	-	¡	-	-	-	-	-	-
P_{ty}	-	!!!	!!	!!!	¡¡	-	¡¡	-	!	-
Q_{t1}	¡¡	¡	-	¡¡	-	¡	!!!	-	¡¡¡	-
Q_{t2}	¡¡¡	¡	!!	!!!	¡¡	¡¡¡	¡¡¡	!!	!!!	!!
Q_{t3}	!!	!!	¡	¡	!	!!!	!!	¡¡	¡	¡
NT_t	-	!!	¡	¡¡¡	!	-	!!	-	¡	-
P_t	-	!!!	-	¡	-	-	¡	-	-	-

Fig. 2 Effects of different parameters on forces applied to trailed plough

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The Effects of Some Operational Parameters on Potato Planter's Performance

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Abstract

The objective of this study was to determine the effects of tuber size and forward speed on full automatic potato planter's performance. The results were related by linear regression. Uniformity of seed tuber spacing was determined by a computer programme and quantified by determining the ratio of misses, doubles and coefficient of variation of spacing. The trials were conducted on 4 different tuber sizes ($35 \leq ts < 45$ mm; $45 \leq ts < 55$ mm, $55 \leq ts < 65$ mm; $65 \leq ts < 75$ mm (whole or cut) and at 3 different forward speeds of machine (3.60 km/h, 5.40 km/h and 8.64 km/h). It was found that seed tuber distribution pattern in the row was disturbed as tuber size and machine forward speed increased. Small tuber gave better in row tuber distribution pattern than big tubers. However, lower coefficient of variation of spacing and miss ratio were found with the usage of cut tubers than with whole tubers.

Introduction

Potato is an important crop for industry and human food in Turkey. Approximately 5,370,000 tons of potato were produced on 210,000 ha in 2000 (Anonymous, 2001). The working capacity of potato planters depends on the machine forward speed and whether the planting units are fully automatic or semi automatic. The planting parameters are affected by working conditions and seed tuber characteristics as well as the structure of the machine (Sieczka et al., 1986; Gruzcek et al., 1988; Misener, 1979 and 1982). A regular planting can be achieved by leaving the potatoes at the same depth, providing equal spacing between rows and giving equal spacing between tuber seeds on the same rows. Fully automatic potato planters have 160 to 200 tuber min^{-1} planting frequency, nominal forward speeds of 4 to 6 km/h, and a working capacity of 2 to 8 ha per day.

Distribution of seed and plant on a row can be classified into three groups for precision drills (ISO 7256-1) (Anonymous, 1984). A miss is called if there is a gap between the plants equal to or grater than one and half times the intended center-to-center plant distance (Z). A double is called if the space between adjacent seed pieces is less than the half of the intended center-to-center plant distance. Otherwise, distribution of seed tubers in a row is within the acceptable limit. It is required that 80 % of seed tuber distribution in a row be within the ± 25 % tolerance limits of Z statistical distribution (Kanafojski, 1972).

Non-uniformity of seed distribution with extremely high coefficients of variation affected the tuber yield. Tuber yield is decreased by reducing the number of seed pieces planted per unit area whether or not the pieces were uniformly spaced (Sieczka et al., 1986). The missed ratio is affected by the tuber type (whole or cut) and the sizes on a planter (Misener, 1982), and the tuber yield ratio (Rykbost, 1977, and James et al., 1973). The seed tuber distribution pattern on a row is affected by the tuber characteristics (size, shape, and type (whole or cut)) as well as the machine's forward speeds (Sieczka et al., 1986; Misener, 1982; Toader and Draica, 1983 and Samploy and Eremin, 1985). The performance of the cup type planter is quite sensitive to tuber size. One important criterion for good performance is a proper match between seed size and planter cup size (Misener, 1982).

The Tokat region in Turkey has used the fully automatic potato planter for tubers that range from 35 to 65 mm diameter (whole) (TS 11617) and 65 to 75 mm diameter (whole and cut).

In this study, the effects of tuber

size and machine forward speed on potato planting frequency and distribution pattern in the row were determined with the fully automatic potato planter. The linear regression equations for the seed distribution pattern were determined.

Material and Methods

Experiments were conducted on clay-loam soil conditions at the Agricultural Faculty of Gaziosmanpasa University-Tokat. An imported fully automatic potato planter with a double cup elevator planting unit was used for planting. The technical characteristics of the planter are given in **Table 1**. The mean tuber characteristics of Granola type seed tubers used in this study are given in **Table 2**.

Turkish Standards Institute (TSE) classifies the seed tubers according to their size as: middle ($35 \leq ts < 45$ mm), big ($45 \leq ts < 55$ mm), and great ($55 \leq ts < 65$ mm) as TS 11617 (Anonymous, 1995). In addition to these three groups, in this research, $65 \leq ts < 75$ mm diameter (whole or cut) tubers were also studied. Lack of enough seed potatoes in the 28 to 35 mm range, prevented this group from being included in these experiments.

Planting frequencies were measured as the number of tubers discharged per minute from the fully automatic potato planter. To facilitate seed spacing the covering disks on one row were removed (Sieczka et al., 1986) or partially lifted, the potatoes were deposited in the furrow, and only lightly covered by soil. Seed tuber spacing was measured from center to center of tubers (to the nearest 0.01 m). Data were collected over row lengths of 30.5 m (Misener, 1979 and 1982). The results of measurements of seed tuber distribution in the row were analysed by a special computer program. The potato planter was adjusted for the experiments for a 5 cm planting depth and at a transmission ratio that provided a 40 cm spacing between tuber seeds. The experiments were carried out at 70 cm row spacing and at 3.60, 5.40 and 8.64 km/h machine forward speeds. The research was conducted under field conditions and planned in randomised block design with three replications.

In this study, the effects of tuber sizes and machine forward speed on potato planting frequency and potato distribution pattern in the row with the fully automatic potato planter were determined by linear regression equations. The linear regression model was represented by

$$y = \alpha + \beta_1 X_1 + \beta_2 X_2$$

Where;
y = dependent variable
α; β_1;, β_2 = constant
X_1 = tuber diameter (mm)
X_2 = machine forward speed (km/h)

Table 1 Technical characteristics of the potato planter used in the experiment

Characteristic	Value	Characteristic	Value
Total length (mm)	2,150	Depth of planting (mm)	50...130
Total width (mm)	1,640	Band width and tickness (mm)	175 x 115
Total height (mm)	2,140	Number of cup per unit	20 x 2 = 40
Weight (kg)	670	Ridger disc diameter (mm)	570
Hopper capacity (kg)	500	Working capacity (ha/h)	0.8

Table 2 The mean tuber characteristics with respect to the tuber size

Tuber size (mm)	Mean tuber weight (g)	Mean tuber length (mm)	Mean tuber width (mm)	Mean tuber tickness (mm)	Mean number of eyes
35≤ts<45	55.23 ±1.62	54.58 ±1.27	43.35 ±0.31	37.15 ±0.58	7.17 ±0.22
45≤ts<55	97.46 ±3.87	71.34 ±2.30	49.02 ±0.70	45.34 ±0.67	9.04 ±0.41
55≤ts<65	127.86 ±5.22	77.14 ±2.46	59.92 ±0.73	48.62 ±0.98	8.08 ±0.29
65≤ts<75	223.85 ±9.47	97.06 ±3.40	74.37 ±0.68	58.15 ±1.23	8.96 ±0.29

Table 3 Average proportion of the planting frequencies (number of tube discharged per minute) of the fully automatic potato planter with different tuber sizes at different machine forward speeds

Tuber sizes	Forward Speeds (km/h)			Mean
	3.60	5.40	8.64	
35≤ts<45	203.33	246.67	336.67	268.22a
45≤ts<55	188.33	242.33	213.33	214.67b
55≤ts<65	166.67	206.67	193.33	188.89b
65≤ts<75 (whole)	98.33	93.00	73.33	88.82c
65≤ts<75 (cut)	85.00	106.00	103.00	98.33c
Mean	148.33b	182.67a	184.00a	

LSD (Tuber diameter, $p < 0.01$): 36.133, LSD (Forward speed, $p < 0.01$): 27.989

Results and Discussion

The Planting Frequency

It was found that tuber sizes and forward speed had significant effects on planting frequency of the full automatic potato planter ($P < 0.01$). The planting frequency showed a linear increase with forward speed when the ideal tuber size 35 to 45 mm diameter was used. However, it decreases with tuber sizes of $65 \leq ts < 75$ mm (whole). An increase in planting frequency occurred when $65 \leq ts < 75$ mm diameter tubers were used as cut. However, a decrease occurred when they were used as whole. The planting frequencies of the fully automatic potato planter with different tuber sizes at different forward speeds are given in **Table 3**.

The Row Seed Tuber Distribution

The row seed tuber distributions of the fully automatic potato planter with different tuber sizes at different forward speeds were given in **Table 4**. The seed tuber distribution pattern was affected by the tuber sizes, types and forward speeds.

According to these results, the acceptable limit values decreased with an increase in tuber size and with an increase in forward speed. It has been observed that small tubers gave better results than big tubers. The 65 ≤ ts < 75 mm cut tubers also gave better results than the whole tubers. In general, miss ratios increased with increasing tuber sizes and increasing forward speeds. When 65 ≤ ts < 75 mm tubers were used as cut, the miss ratio decreased in comparision with the whole tubers. The ratio of doubles decreased with the increase in tuber sizes. For each tuber size, the lowest ratio of doubles was obtained at the 8.64 km/h forward speed. The doubles ratios decreased relavitely with the usage of the cut tubers. The coefficient of variation of spacing increased with tuber size and forward speed. As a result of that, seed tuber distribution pattern on row was disturbed. Smaller tuber sizes and lower forward speeds yielded lower coefficient of variation values. Lower coefficient of variation values were obtained for cut tubers of 65 to 75 mm size than with whole tubers. Using the experimental data, the following linear regression equations were developed for planting frequency and potato distribution pattern on row;

$y_{frequency} = 470 - 5.78X_1 + 6.27X_2$
$r^2 = 0.849$
$y_{double} = 69.1 - 0.807X_1 - 1.37X_2$
$r^2 = 0.824$
$y_{acceptable} = 115 - 0.686X_1 - 3.90X_2$
$r^2 = 0.863$
$y_{miss} = -84.9 + 1.52X_1 + 5.27X_2$
$r^2 = 0.922$

According to the linear regression equations, the planting frequency was increased by the machine forward speed and decreased by the tuber sizes. The miss ratio and acceptable limit ratio were decreased by the tuber sizes. The double ratio was increased by the tuber size and machine forward speeds (**Table 5**).

Misener (1979), established that the miss ratios and the coefficient of variation increased with an increase in forward speeds. Gupta et al., (1984) and Gruzcek et al. (1988) found the miss ratios with a range of 0.00 to 29.36 % and 0.00 to 42.00 % respectively. Gruzcek et al., (1988) found the coefficient of variation values between 48.00 and 68.00 % for 50 to 60 mm tuber size. Misener (1982) expressed that coefficient of variation values ranged from 48.2 to 50.1 % with a tuber weight of 80.2 g. The percentage of missing and doubles potato tubers increase with the increase of planting speed.

In this study, the planting frequency ranged from 73.33 tuber min^{-1}

Table 4 Average proportion of the miss, doubles, and acceptable and the coefficient of variation of the seed distribution pattern of the potato planter with different tuber sizes at different machine forward speed

Tuber diameter (mm)	Seed tuber distribution pattern				
	Forward speed (km/h)	Doubles (%)	Acceptable limit (%)	Miss (%)	CV (%)
35≤ts<45	3.60	25.71	71.43	2.86	47.79
	5.40	29.41	61.77	8.82	53.93
	8.64	23.53	52.94	23.53	79.84
45≤ts<55	3.60	24.99	65.63	9.38	43.99
	5.40	33.33	56.67	10.00	59.16
	8.64	18.18	54.55	27.27	79.16
55≤ts<65	3.60	21.88	65.62	12.50	44.60
	5.40	14.29	62.85	22.86	59.31
	8.64	2.86	40.00	57.14	96.19
65≤ts<75 (whole)	3.60	4.76	52.38	42.86	75.36
	5.40	8.57	42.86	48.57	95.87
	8.64	0.00	27.03	72.97	73.48
65≤ts<75 (cut)	3.60	2.86	54.29	42.85	55.99
	5.40	4.55	40.90	54.55	60.26
	8.64	2.50	35.00	62.50	72.36

Table 5 The linear regression model analysing for the planting frequency and seed tuber distribution pattern

	Predictor	Coefficient	St. deviation	T	P
Planting frequency	Constant	470.17	48.51	9.69	0.00
	Tuber diameter	-5.7837	0.7167	-8.07	0.00
	Forward speed	6.273	4.008	1.57	0.00
S = 32.37	R - Sq = 84.9	F = 37.79	DW = 1.68		
	Predictor	Coefficient	St. deviation	T	P
Miss ratio	Constant	-84.91	10.16	-8.36	0.00
	Tuber diameter	1.5180	0.1501	10.11	0.00
	Forward speed	5.2732	0.8394	6.28	0.00
S = 6.779	R - Sq = 92.2	F = 70.87	DW = 0.93		
	Predictor	Coefficient	St. deviation	T	P
Acceptable limit	Constant	114.947	7.602	15.12	0.00
	Tuber diameter	-0.6855	0.1123	-6.10	0.00
	Forward speed	-3.8933	0.6281	-6.21	0.00
S = 5.073	R - Sq = 86.3	F = 37.89	DW = 1.37		
	Predictor	Coefficient	St. deviation	T	P
Double ratio	Constant	69.116	7.623	9.07	0.00
	Tuber diameter	-0.8068	0.1126	-7.16	0.00
	Forward speed	-1.3663	0.6298	-2.17	0.00
S = 5.087	R - Sq = 82.4	F = 28.01	DW = 1.78		

to 336.67 tuber min^{-1} for the fully automatic potato planter. However, the miss ratio ranged from 2.86 to 72.94 %, the doubles ratio ranged from 0.00 to 33.33 %, the acceptable tuber distance on rows ranged from 27.03 to 71.43 %, and the coefficient of variation ranged from 43.99 to 96.16 % on the row seed tuber distribution for the fully automatic potato planter. Lower coefficient of variation values were obtained with cut tubers for 65 ≤ ts < 75 mm than with whole tubers. According to these results, 35 ≤ ts < 45 mm tuber size and a 3.6 km/h forward speed would be recommended for the fully automatic potato planter with double cup elevator.

Conclusion

A full automatic potato planter with a double cup belted planting unit was made for uniform planting. The seed tuber distribution pattern was effected by the different tuber sizes and types (whole or cut). Seed tuber distribution pattern was spoiled when tuber sizes and machine forward speed increased, small tubers gave better results in seed tuber distribution pattern than larger tubers.

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The Use of Hot Air from Room Type Coolers for Drying Agricultural Products

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Abstract

Room type coolers are extensively used for cooling or freezing foods such as fruits, vegetables, medicinal plants, milk, yogurt, eggs, meats, poultry, fish, and ice cream in developed and developing countries. This type of equipment continuously transfers heat energy from the cooling room to outside in order to keep a low temperature inside. This means that the heat, which depends on the specifications of cold rooms and environment conditions, is given to the atmosphere. On the other hand, several agricultural products are dried with hot air to increase their storage period in these countries. However, the production of hot air is expensive. Particularly, in areas that have high humidity and low solar radiation, the cost of hot air is more expensive, and the use of waste hot air during harvesting period in these regions is very important for saving energy. Therefore, the possibility of using waste heat energy from cold rooms for drying agricultural products was investigated in this research. Four different types of room coolers (T-1, T-2, T-3 and T-4), a harvesting period from May to October, and the Black Sea Region of Turkey that has high humidity and low solar radiation were specifically selected for this study. The results of the study shows that the hot air produced by room type coolers is suitable for drying agricultural products. During the harvesting period, 2390 kWh waste heat energy can be used for drying and 3249 kg moisture can be removed from the product.

Introduction

It is imperative to have proper cooling for storing of food to ensure maximum quality. During storage time, the deterioration of food is mainly influenced by the temperature and relative humidity. The cooling reduces the growth of decay organisms and reduces water loss. For this reason, it is needed to keep the food in coolers as required by on the food specifications.

Room type coolers (cold rooms or room type freezers) are extensively used for cooling of foods such as fruits, vegetables, medicinal plants, milk, yogurt, and eggs, and for freezing of foods such as meats, poultry, fish, and ice cream in most commercial and non-commercial farm businesses in developed and developing countries. These coolers transfer heat from the cool room to the atmosphere. However, the waste heat energy given to the ambient air is usually not used. However, in many farm businesses, several agricultural products such as vegetables, fruits, and medicinal plants are dried by using hot air for long term storage. Heat energy is supplied from different heat sources such as electricity, fossil fuels and solar energy to dry these products. In most developing countries, these sources of energy are expensive for many farmers.

The possibility of using waste heat energy from four different types of room coolers for drying agricultural products was investigated in this study.

Nomenclature

A: Surface area, m^2
C_p: Constant pressure specific heat, J/(kg ºC)
d: Diameter, m
h: Heat transfer convection coefficient, W/(m^2 ºC)
k: Thermal conductivity, W/(m ºC)
L: Length, m
m: Mass of air or moisture, kg
M: Absolute moisture, kg moisture/kg air
$\dot{m}$: Mass flow, kg/s
q: Thermal power, W
Q: Net heat energy, kWh
t: Net working time, h
V: Velocity, m/s

$\dot{V}$: Volume flow, m^3/s
γ : Density, kg/m^3
ΔT: Temperature difference

Subscripts
air: Air
av: Average
b: Bottom
cond: Conduction
conv: Convection
e: Edge
max: Maximum
moist: Moisture
p: Percentage
RH90: 90 % relative humidity
RH74: 74 % relative humidity
run: Running (working)
t: Top
trans: Transfer

Materials and methods

Four types of room coolers (T-1, T-2, T-3 and T-4) used for cooling or freezing food at Ondokuz Mayıs University, Samsun, Turkey were selected for the investigation. The schematic presentation of the coolers is given in **Fig. 1** and basic components are shown in **Fig. 2** (Wylen et al., 1993; Çengel and Boles, 1994). Each room type cooler has an evaporator, compressor, condenser, expansion device and controls. The system assembly involves connecting the condensing unit to the evaporator with piping, which has a volatile substance called the refrigerant. The expansion device is installed between the condenser and the evaporator. The evaporator is made of tubing and has a heat transfer surface. The refrigerant liquid is at low pressure and temperature and is vaporized to remove heat from a refrigerated space or product. The substance to be cooled is air, which flows over the exterior of the tubes in which the volatile refrigerant is boiling. The vaporized refrigerant is drawn from the evaporator into the compressor where it is compressed to suitable high pressure. This enables the refrigerant vapour to be condensed using atmospheric air at surrounding temperature. The power required for compression is supplied by an electric motor. The high pressure and temperature from the compressor is pushed into the condenser which, like the evaporator, is made of tubing. The air flows over the exterior of the tubing, absorbing the heat from the high temperature refrigerant. The refrigerant is cooled and condensed while still at high pressure. The heat absorbed from the refrigerated body by the evaporator is moved into the atmospheric by the condenser. The liquid refrigerant from the condenser flows in the tubing to the control device in a capillary tube or valve. Here, the pressure and temperature are reduced before it enters the evaporator and the cycle is repeated. Other components for control and safety are installed in the refrigerant piping. The compressor motor electric controls and, in some cases, evaporator defrost timing are housed in a single panel, called the control panel. In installations where the condenser is air cooled, the condensing unit is placed remote from the refrigerated space but the evaporator is always in the refrigerated space. The condensers of T-3 and T-4 are usually located at the outer side of the cooling room wall (**Fig. 3a**) while the condensers of T-1 and T-2 are placed on the outer wall of the building (**Fig. 3b**). All coolers have a polyurethane wall with a thermal conductivity is 0.0210 W/(mK). T-2 and T-4 coolers are used for cooling such products as fruits, vegetables, milk, yogurt, and eggs at approximately 5 ºC, and T-1 and T-3 are used for freezing such products as meat, chicken, and fish at about -25 ºC. T-1, T-2, T-3 and T-4 have 100, 70, 150, and 80 mm thick polyurethane walls, respectively. The dimensions (length, width and height) of T-1 and T-2 are same and equal to 2.4, 1.8, and 2.0 m. T-3 is the same size as T-4 and

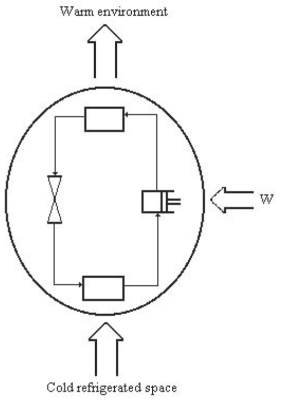

Fig. 1 Schematic presentation of the coolers

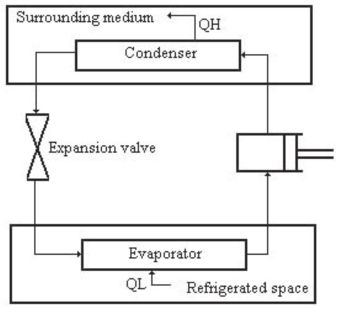

Fig. 2 Basic components of a refrigeration system and typical operating conditions

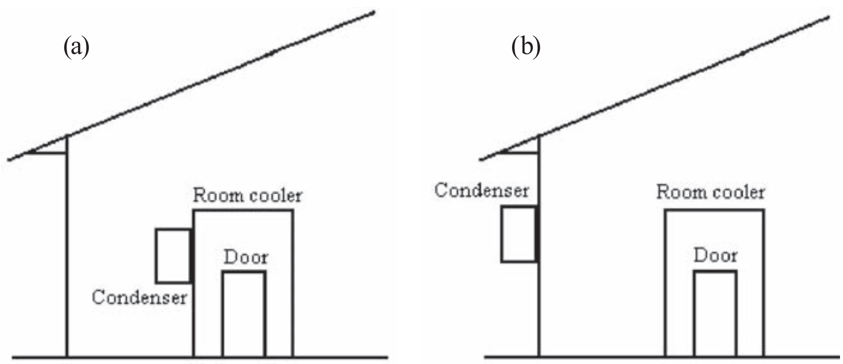

Fig. 3 The position of the condensers

the length, width and height are 3.6, 2.2, and 2.2 m.

The experiments were conducted at Ondokuz Mayıs University of Samsun. Situated in the Black Sea Region of Turkey at 4 m above sea level, the Samsun area has a rainy type climate with a high relative humidity. The yearly temperature is 14.40 ºC and the seasonal temperatures are: 21.33 ºC in summer, 16.20 ºC in autumn, 6.96 ºC in winter and 11.40 ºC in spring. The latitude and the longitude of the Samsun area are 41º 21′ N and 36º 15′ W, respectively. The six harvesting months of May, June, July, August, September and October in Samsun were chosen for the investigation. During these months, data related to the environmental conditions of Samsun were gathered from the meteorological station. In addition, the inside and outside air temperatures, surface temperatures, condenser fan capacity (air mass flow) and the air temperatures of the condensers were measured by digital instruments. In order to define the mass flow of the air from the condenser fan, a galvanised iron sheet pipe was used (**Fig. 4**). The maximum velocity of the heated air and the condenser air was measured. The average velocity, the volume flow and the mass flow of the air were calculated as shown below (Holman, 1994).

$$V_{av} = 0.85V_{max} \quad (1)$$

$$\dot{V} = V_{av}\frac{\pi d^2}{4} \quad (2)$$

$$\dot{m} = \gamma \dot{V} \quad (3)$$

While the system of the room coolers run, the heat transfers from the cooling room to the ambient. This heat energy can be computed from the following equations (Sharma et al., 1991). All symbols used in the equations are described in the Nomenclature.

$$q_{run} = \dot{m}C_p\Delta T \quad (4)$$

The heat energy that needed to be transferred by the system (qtrans) to keep low temperature inside the cooling room can also be found from the conduction or convection heat transfer equations given below (Fogiel, 1988).

$$q_{trans} = q_{cond} = q_{conv} \quad (5)$$

$$q_{cond} = \frac{k}{L}A\Delta T \quad (6)$$

$$q_{conv} = hA\Delta T \quad (7)$$

Here, the heat transfer convection coefficient, h, for edge, top and bottom surfaces of the cooling room can be calculated, respectively, as given below (Fogiel, 1988).

$$h_e = 1.4\left[\frac{\Delta T}{L}\right]^{1/4} \quad (8)$$

$$h_t = 0.61\left[\frac{\Delta T}{L^2}\right]^{1/5} \quad (9)$$

$$h_b = 1.32\left[\frac{\Delta T}{L}\right]^{1/4} \quad (10)$$

The net working (operation) time (h/day) of the room coolers can also be calculated as seen below.

$$t = \frac{q_{trans}24}{q_{run}} \quad (11)$$

The percentage of the operation time is

$$t_p = \frac{t}{24}100 \quad (12)$$

The net heat energy given to the ambient air by a condenser per day can be expressed as

$$Q = q_{run}t10^{-3} \quad (13)$$

The mass of the air heated by a condenser is

$$m = \dot{m}t3600 \quad (14)$$

When the produced hot air for agricultural drying is used, it is possible to remove moisture from the product. The mass of this moisture removal from the product can be found from the equation given be-

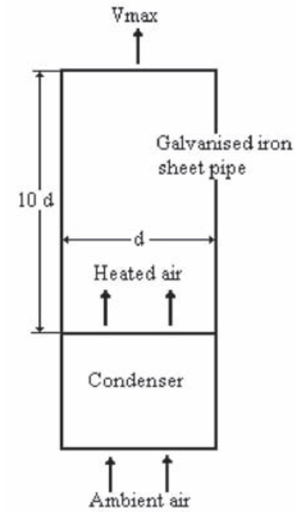

Fig. 4 Connection of the galvanized iron sheet pipe to the condenser

Cooler types	q_{run} (W)	q_{trans} (W)	t (h/day)	t_p (%)	m (kg air/day)	q (kWh/day)	m_{moist} (kg moist/day)
T-1	340	160	11.29	47	1,242	3.84	5.22
T-2	340	40	2.82	12	310	0.96	1.30
T-3	340	174	12.28	51	1,351	4.17	5.67
T-4	340	54	3.81	16	419	1.29	1.76

Table 1 Results for May for selected room type coolers

Cooler types	q_{run} (W)	q_{trans} (W)	t (h/day)	t_p (%)	m (kg air/day)	q (kWh/day)	m_{moist} (kg moist/day)
T-1	340	187	13.2	55	1,452	4.49	6.09
T-2	340	69	4.87	20	536	1.66	2.25
T-3	340	203	14.33	60	1,576	4.87	6.62
T-4	340	98	6.92	29	761	2.35	3.19

Table 2 Results for June for selected room type coolers

Cooler types	q_{run} (W)	q_{trans} (W)	t (h/day)	t_p (%)	m (kg air/day)	q (kWh/day)	m_{moist} (kg moist/day)
T-1	340	202	14.26	59	1,569	4.85	6.59
T-2	340	91	6.42	27	706	2.18	2.96
T-3	340	219	15.46	64	1,701	5.26	7.14
T-4	340	129	9.10	38	1,001	3.09	4.20

Table 3 Results for July for selected room type coolers

low (Ekechukwu, 1999; Ivanova and Andonov, 2001).

$$m_{moist} = (M_{RH90} - M_{RH74})m_{air} ....(15)$$

Where M_{RH90} is the moisture in the air leaving the product and M_{RH74} is the moisture of the air entering the product.

Here, the ambient air is heated by the condenser, then its relative humidity is decreasing. When this air is used as a drying air, it is expected that the relative humidity of the air will increase and reach 90 % because of the moisture removal from the agricultural product. The moisture mass differences give us the water removed from the product as seen from Equation 15.

Results

The use of hot air from the condensers of four room type coolers for drying agricultural products was investigated in this study. In order to do this, some data related to the meteorological conditions of Samsun and room type coolers were used. Since the harvesting period of the different agricultural fruits and vegetables extended from May to October, these six months were selected for the study. For each month, q_{run}, q_{trans}, t, tp, m, q and m_{moist} are given in **Tables 1**, **2**, **3**, **4**, **5** and **6**. The heat energy given to the ambient air by the condensers of the coolers and the possible moisture removal from the agricultural products are also shown in **Figs. 5** and **6** for May, June, July, August, September and October. As seen from these figures and tables, the most efficient type room cooler was T-2 and the least one was T-3. Thus, the most waste heat energy is given to the atmosphere by the condenser of T-3 and the least by T-2. The maximum heat was given to the ambient air during July because of the high temperature differences between cooling room and atmosphere air. In July, T-1, T-2, T-3 and T-4 gave 119, 29, 130 and 40 kWh heat energy to the ambient air, respectively. In this month, the 162, 40, 176 and 54 kg moisture (water) could be removed from the agricultural product if all the hot air were utilized from these respective coolers. In addition, it is seen from the results that during the six mouths harvesting period 2390 kWh waste heat energy could be used for drying and 3249 kg moisture could be removed from the product (**Figs. 5** and **6**).

Cooler types	q_{run} (W)	q_{trans} (W)	t (h/day)	t_p (%)	m (kg air/day)	q (kWh/day)	m_{moist} (kg moist/day)
T-1	340	204	14.4	60	1584	4.90	6.65
T-2	340	92	6.49	27	714	2.20	2.99
T-3	340	221	15.6	65	1716	5.30	7.20
T-4	340	131	9.25	39	1018	3.14	4.27

Table 4 Results for August for selected room type coolers

Cooler types	q_{run} (W)	q_{trans} (W)	t (h/day)	t_p (%)	m (kg air/day)	q (kWh/day)	m_{moist} (kg moist/day)
T-1	340	186	13.13	55	1444	4.46	6.06
T-2	340	67	4.73	20	520	1.61	2.18
T-3	340	202	14.26	59	1569	4.85	6.59
T-4	340	96	6.78	28	746	2.30	3.13

Table 5 Results for September for selected room type coolers

Cooler types	q_{run} (W)	q_{trans} (W)	t (h/day)	t_p (%)	m (kg air/day)	q (kWh/day)	m_{moist} (kg moist/day)
T-1	340	166	11.72	49	1289	3.98	5.41
T-2	340	41	2.89	12	318	0.98	1.33
T-3	340	180	12.71	53	1398	4.32	5.87
T-4	340	55	3.88	16	427	1.32	1.79

Table 6 Results for October for selected room type coolers

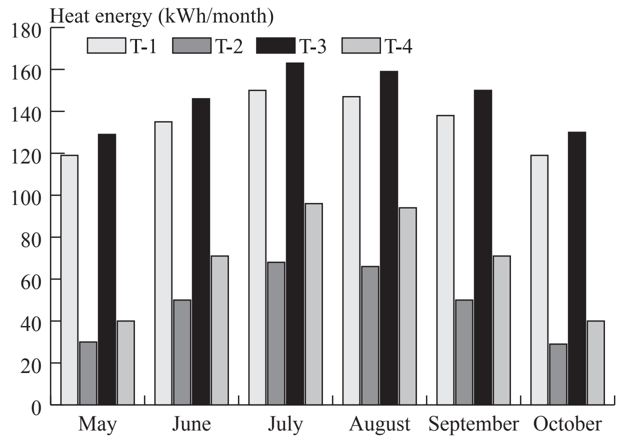

Fig. 5 The heat energy given to the ambient air by the condensers of the coolers

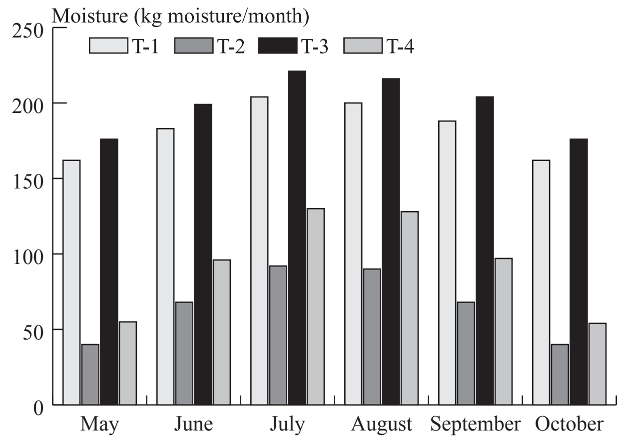

Fig. 6 The moisture that can be removed from the product by the produced hot air

Conclusions

The general conclusion is that the hot air produced by different types of room coolers can easily be used for drying agricultural products in Samsun conditions. During the six mouths harvesting period 2390 kWh heat energy can be saved for drying and 3249 kg moisture can be removed from the product by using the selected room type coolers of this experiments.

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Effect of Mechanization Level and Crop Rotation on Yield Energy Requirements

by

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Abstract

This experiment was conducted for three farming systems, four levels mechanization and under three crop rotations. The mechanization level had significant effect on yield, human energy, indirect energy, and total energy and crop rotation had significant effect on indirect energy and total energy for paddy crop. The significant effect of both mechanization level and crop rotation were marked on yield, human energy, indirect energy and total energy for groundnut and mung crop. The highest yield of 26.25 q/ha was obtained under T_3R_2 treatment for paddy crop. The T_3R_3 treatment showed the highest yield of 13.78 q/ha and 7.05 q/ha of groundnut and mung crop respectively.

Introduction

Development and application of energy resources are the key components for higher level of agricultural production. The source of energy that goes into the production of crops includes material inputs such as seed, fertilizer, manure, insecticides and mechanical energy along with human and bullock power spent on executing the production process. Energy requirements in agriculture vary mainly due to many factors such as the types of farming system, farm activities, area under cultivation, level of technology adopted, agro-climatic condition and crop rotation. The farm power acts as one of the most important factors for execution, of a multiple cropping programme.

Panesar and Bhatnagar (1987) developed energy coefficients for both animate and inanimate energy sources taking many aspects into consideration. Sing et al. (1975) studied energy input requirements of different rabi and kharif crops in various forms of mechanization. The result revealed that an increased level of mechanization will permit a reduction in cost of total production input, an increase in total energy input, and a reduction in labour input on a crop unit basis. Sing and Mittal (1991) reported that the total energy input for paddy crop varied from 19249 to 35096 mj/ha and was lowest on marginal farms and highest on medium farms. For wheat crop it was 4615 to 5979 mj/ha under rainfed conditions and 17964 to 19778 mj/ha under irrigated condition.

The energy inputs in agriculture have a composite constitution integrating the human and animal labour with mechanical power. These components of direct energy combined with indirect energy due to use of machines form the total energy input for crop production. Adequate information is not available on the pattern of energy utilization for crop production. The present research work was conducted to provide information about the effect of different levels of mechanization on yield and energy requirements for different crop under various crop rotations.

Materials and Methods

The field experiment was conducted at the Central Farm of Orissa University of Agriculture and Technology, Bhubaneswar. It is in the East and Southeastern coastal plain agro-climatic zone of the state and situated between 18º 46' and 20º 95' North latitude and between 83º 48' and 87º 3' East Longitude. The average rainfall of this zone is 1340 mm and about 74 % of the annual rainfall is received during the months from June to September. The physical characteristics of the soil of the experimental site were sandy loam, a bulk density 1.55 g/cc, a field capacity of 15 %, a permanent wilting point of 6 %, and a hydraulic conductivity 0.25 m/day.

The experimental design was

Randomized Block (Factorial) with three replications. The experiment was conducted for (1) three farming system (bullock, power tiller, and tractor); (2) four levels of mechanization (bullock with traditional implements (T_1), bullock with improved implements (T_2), 12 hp power tiller with matching implements (T_3), and 35 hp tractor with matching implements (T_4)); and (3) under three crop rotations (paddy-wheat-mung (R_1), paddy-groundnut-paddy (R_2) and paddy-groundnut-mung (R_3)). The layout plan of the experiment has been shown in **Fig. 1**. During the crop production process, observations were recorded for time taken by human, bullock, machine, and power units a per unit area and fuel and electricity consumed per unit time on per unit area for a particular farm operation. A large number of observations was taken to get the realistic average values. Average values of speed of operation and the coverage of the implements were also recorded through sufficient number of observations. For calculation of energy inputs, the observed time, fuel and electricity consumption were multiplied with energy coefficient all the above categories of energy were put under direct energy. The indirect energy input due to use of machinery in the field was computed with the help of formula putting the observed values of hours of use of the machine. The seed, manure, chemical fertilizer and pesticides, as a part of indirect energy, were kept constant in the study, as these are essentially required equally irrespective of energy treatments.

The following relationships have been adopted in order to estimate the total energy requirements with that of individual sources to perform various farm operations.

$$TE = DE + IDE$$

Where,

TE = total energy requirements for farm operations, mj/ha,

DE = direct energy requirements, mj/ha and

IDE = indirect energy requirements, mj/ha.

The direct energy input was calculated with the help of following relationship

$$DE = 1.96\ HLH + 8.07\ BPH + 56.31\ FC + 11.93\ EC$$

Where,

HLH = human labour hours used, hr/ha,

BPH = bullock pair hours used, hr/ha,

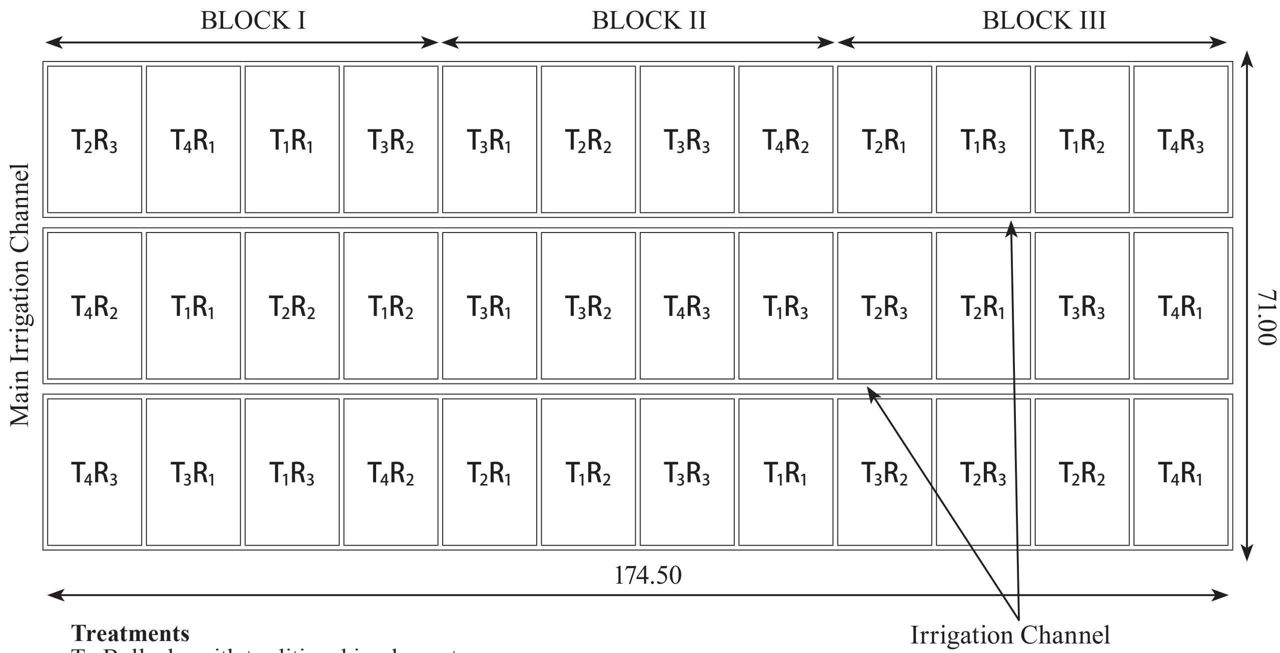
FC = fuel consumption, l/ha, and

EC = electricity consumption, kwh/ha

The constants are energy coefficients. The indirect energy input due to use of machinery in the field was computed with the help of the following relationship.

$$IDE = \frac{(C)\ (WM)\ (MOH)}{(WL)\ (AU)}$$

Where,



Treatments
T_1: Bullocks with traditional implements
T_2: Bullocks with improved implements
T_3: 12 hp power tiller with matching implements
T_4: 35 hp tractor with matching implements

Crop Rotations
R_1: Paddy - Wheat - Mung
R_2: Paddy - Groundnut - Paddy
R_3: Paddy - Groundnut - Mung

Design of Experiment: Randomized Block Design (Factorial)
Net Pot Size: 14 m x 22 m
Plot Border: 0.5 m
Irrigation Channel: 1 m

All Dimensions are in Metre

Fig.1 Layout plan of experiment

C = energy coefficient, mj/kg of machine,
WM = weight of the machine, kg,
MOH= machine operation hour, hr,
WL = wear out life of the machine, hr and
AU = annual use of the machine, hr

The total energy requirements for a particular farm operation has been expressed as

TE = HE + BE + ME + EE + IDE (machine)

Where, HE, BE, ME, EE and IDE are human, bullock, mechanical, electrical and indirect energy respectively.

Results and Discussion

Statistical analysis of observed data such as yield, human energy, indirect energy and total energy inputs under different field experiments was made. The results were tested for significance by 'F' test. The effect of various treatments and crop rotation and their interaction were analyzed. The appropriate standard error of means (SEM) and least significant difference (LSD) were calculated at 5 % level of significance and presented in **Table 1** through **3** for paddy, groundnut and mung crops.

The analysis of the result for paddy crop showed that the level of mechanization has significant effect on yield, human energy, and indirect energy whereas crop rotation has significant effect on indirect energy and total energy only. It does not have significant effect on yield and direct energy. All the treatments had significantly higher yield over T_1 due to the fact that good puddle soil could not be achieved by puddling with country plough. The yield obtained under T_3 mechanization level was significantly higher than T_4, T_2 and T_1. With respect to interaction, T_3R_3 gave the highest yield.

Treatments	Grain yield q/ha	Human energy mj/ha	Indirect energy mj/ha	Total energy mj/ha
T_1	24.83	3,234.01	116.66	7,073.65
T_2	25.38	1,972,53	244.94	5,065.94
T_3	26.14	1,600.75	242.17	6,021.26
T_4	25.61	1,582.26	377.17	6,207.10
SEM (±)	0.11	2.07	1.11	1.76
LSD (P=0.05)	0.33	6.26	3.25	5.35
Crop rotation				
R_1	25.51	2,096.11	238.47	6,086.97
R_2	25.48	2,097.66	244.50	6,091.98
R_3	25.48	2,098.38	252.74	6,097.00
SEM (±)	0.09	1.79	0.96	1.53
LSD (P=0.05)	0.28	5.43	2.82	4.63
Interaction				
T_1R_1	24.81	3,229.62	111.53	7,067.38
T_1R_2	24.81	3,235.13	116.30	7,073.65
T_1R_3	24.87	3,237.30	122.17	7,079.91
T_2R_1	25.69	1.972.47	236.80	5,059.44
T_2R_2	25.23	1.972.53	242.02	5,065.94
T_2R_3	25.24	1.972.59	256.02	5,072.44
T_3R_1	25.93	1.599.07	235.70	6,018.42
T_3R_2	26.25	1.600.75	243.06	6,021.26
T_3R_3	26.18	1,602.42	247.75	6,024.09
T_4R_1	25.58	1,583.28	369.85	6,202.64
T_4R_2	25.62	1,582.26	376.62	6,207.10
T_4R_3	25.63	1,581.24	385.04	6,211.56
SEM (±)	0.187	3.577	1.920	3.053
LSD (P=0.05)	0.566	10.850	5.631	9.262

Table 1 Grain yield, human energy, indirect energy and total energy requirement for paddy crop under different energy treatments and crop rotations

Groundnut crop was grown in two rotations. The analysis of the results showed that the level of mechanization and crop rotation had significant effect on yield, human energy, indirect energy and total energy inputs. The average yield under the T_3 treatment was the highest followed by T_4, T_2 and T_1 treatments since the average soil mean weight diameter was observed to be the best. This allowed the preparation of a good seedbed with reduced human energy. In the case of indirect energy and total energy, T_4 treatment consumed the highest followed by T_2, T_3 and T_1 and T_1T_3 and T_2 respectively. This is because the tractor system for the groundnut crop required more tillage operation for seedbed preparation than the power tiller. The interaction had a significant effect on total energy and the highest yield was obtained in the T_3R_3 energy treatment.

Unlike groundnut the mung crop was grown under two rotations (R_1 and R_3). The highest yield was obtained in the T_3 treatment followed by T_2, T_4 and T_1. Similarly yield under the R_3 rotation was significantly higher than the R_1 crop rotation. The T_1 energy treatment consumed the highest amount of human energy followed by T_2, T_3 and T_4 due to fact that most of the operations for mung crop were performed by human labour. The wheat and summer paddy were grown in one crop rotation each. The highest yields were obtained in the T_3 treatment for both the crops.

While analyzing the energy requirements operation-wise, it was seen that the irrigation energy has the major share of the in total energy requirement. It varied for different crops under most of the mechanization levels due to the fact that the crops grown in rabi and summer season required more irrigation.

The energy required for puddling of transplanted paddy is more than that for seedbed preparation in dry soil for groundnut, wheat and mung crops. The results of total energy requirements revealed that paddy crop consumed comparatively lower energy per unit of grain production that other crop.

Conclusion

The conclusion may be made from the above discussions that for paddy crop the mechanization level had significant effect on yield, human energy, indirect energy and total energy requirements and crop rotation had significant effect only on indirect energy and total energy. The significant effect of both mechanization level and crop rotation were marked on yield, human energy, indirect energy and total energy for groundnut crop. The bullock farming with improved implements, power tiller, and tractor with matching implements showed higher production over bullock farming with traditional implements for both paddy and groundnut crops. The power tiller farming was found to be superior to tractor farming with respect to yield and total energy requirements.

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Treatments	Grain yield q/ha	Human energy mj/ha	Indirect energy mj/ha	Total energy mj/ha
T_1	11.34	2,257.14	58.30	4,214.97
T_2	12.24	1,205.80	243.17	3,205.21
T_3	13.52	859.97	170.48	3,943.88
T_4	12.68	818.39	254.39	3,531.19
SEM (±)	0.03	1.55	1.35	1.79
LSD (P=0.05)	0.09	4.70	4.11	5.44
Crop rotation				
R_2	12.22	1,275.97	178.03	3,915.62
R_3	12.67	1,294.68	185.13	3,942.31
SEM (±)	0.02	1.10	0.96	1.27
LSD (P=0.05)	0.06	3.32	2.90	3.85
Interaction				
T_1R_2	11.28	2,246.80	56.46	4,205.62
T_1R_3	11.40	2,267.48	60.14	4,224.32
T_2R_2	11.98	1,193.36	238.02	3,196.70
T_2R_3	12.50	1,218.24	248.32	3,213.72
T_3R_2	13.26	852.00	168.00	3,928.52
T_3R_3	13.78	867.94	172.96	3,959.24
T_4R_2	12.36	811.72	249.67	4,331.64
T_4R_3	13.00	825.06	259.11	4,371.95
SEM (±)	0.04	2.19	1.91	2.54
LSD (P=0.05)	0.13	6.64	5.81	7.69

Table 2 Grain yield, human energy, indirect energy and total energy requirement for groundnut crop under different energy treatments and crop rotations

Treatments	Grain yield q/ha	Human energy mj/ha	Indirect energy mj/ha	Total energy mj/ha
T_1	5.82	1,626.07	98.02	5,636.54
T_2	6.33	1,355.84	149.73	5,079.30
T_3	6.99	1,195.19	150.35	5,256.26
T_4	6.16	1,160.60	211.32	5,439.74
SEM (±)	0.030	1.880	0.947	3.847
LSD (P=0.05)	0.091	5.700	2.872	11.654
Crop rotation				
R_1	2.26	1,324.28	150.26	5,336.02
R_3	6.39	1,344.76	154.44	5,369.89
SEM (±)	0.021	1.329	0.669	2.717
LSD (P=0.05)	0.065	4.320	2.031	8.241
Interaction				
T_1R_1	5.75	1,615.86	96.23	5,624.50
T_1R_3	5.89	1,637.48	99.81	5,648.58
T_2R_1	6.27	1,342.73	146.25	5,060.22
T_2R_3	6.40	1,368.95	153.21	5,098.38
T_3R_1	6.93	1,185.73	148.91	5,238.52
T_3R_3	7.05	1,204.65	151.79	5,274.00
T_4R_1	6.11	1,153.22	209.66	5,420.86
T_4R_3	6.21	1,167.98	212.96	5,458.62
SEM (±)	0.043	2.658	1.339	5.433
LSD (P=0.05)	0.129	8.068	4.061	16.481

Table 3 Grain yield, human energy, indirect energy and total energy requirement for mung crop under different energy treatments and crop rotations

Simple Quality Evaluation of Chili Pepper Based on Continuous Weight Measurement During Dehydration Process

by

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Abstract

Experiments using a continuous and nondestructive weighing system successfully identified drying-rate patterns of chili pepper during the dehydration processes. The quality factors of moisture-content uniformity, pungency, color, rehydration capacity, and water activity, were analyzed to identify the correlation between drying-rate patterns and product quality. The dehydration process with highest drying rate resulted in the best quality of product. These facts accorded with an axiom that moisture mobility inside the pod and moisture evaporation from surface of chili pepper pods during dehydration process has a relation ship to the quality of product. Therefore, weight changes of chili pepper during dehydration would be possible for quality evaluation.

Introduction

Background

Dehydration of chili pepper is necessary to make products such as oleoresin, food colorant, medicine, and spice. It is important to control the dehydration process of chili peppers because the quality attributes of color, nutritional content, and rehydration capacity depend on process conditions. Dehydration process requirements to obtain good-quality products are as follows: a suitable temperature, tempering/continuing of the dehydration process, product agitation for improvement of heat transfer, and the porous structure expansion (Govindarajan, 1985; Holdsworth, 1986; Heldman and Lund, 1992).

Generally, the three basic types of drying processes that are recognized and used for industry are sun drying, solar drying, and atmospheric drying (Jayaraman and Das Gupta, 1992). Quality improvement by introducing process technology in an industrial-scale dryer is costly because of facility, and energy use expenses. Appropriate technology with low-cost operation and energy saving is considered appropriate for the dehydration process of chili pepper for improving product quality. The sun-drying method is commonly used in developing countries because it is simple and low cost. However, this method results in inconsistent product quality, especially moisture content uniformity. Therefore, a dryer with product agitation during the process may be useful for quality improvement.

Dehydration of agricultural products is an energy-intensive operation. In the agro-food industry, the dehydration process takes about 10 % of the total energy used in the sector (Mujumdar, 1998; Iguaz, et al., 2002). High price and shortage of fossil fuels increase the emphasis on the use of solar energy as an alternative energy source. Solar energy is becoming an important alternative source of energy because it is in abundance it is inexhaustible, it has no pollution, and it has a low cost of operation.

Based on the requirements for improving quality of the product, energy use, and operation cost, a rotary-type dryer was considered the most appropriate in comparison with other factory dryer types (Luh and Jasper, 1981). In the dehydration process with a rotary-type dryer, the product was circulated and agitated to improve heat transfer and expand the bulk. Circulation and agitation increased moisture uniformity and decreased both the dehydration time and heat loss (Hui, 1992; Armstrong, 2000). However, a rotary-type dryer required significant energy to rotate the drum and agitate the product. Therefore, some consideration has been given to the use of solar-electric power for rotation, agitation and heating air inside a glasshouse system (Trim and Ko, 1982; Carnegie, 1991; Ahmad and Khan, 1997).

Quality changes during the dehydration process are closely related to the mobility of moisture in the material and the evaporation of moisture from the material surface (Hui, 1992; Okos, et al., 1992). The resultant weight loss may be correlated to quality. A continuous and nondestructive weighing system with a laboratory scale rotary-type dryer for measuring weight changes of chili pepper during dehydration was introduced by Widodo, et al., 2001. This experiment has investigated the relationship between the weight changes of chili pepper during the dehydration processes and quality of the product.

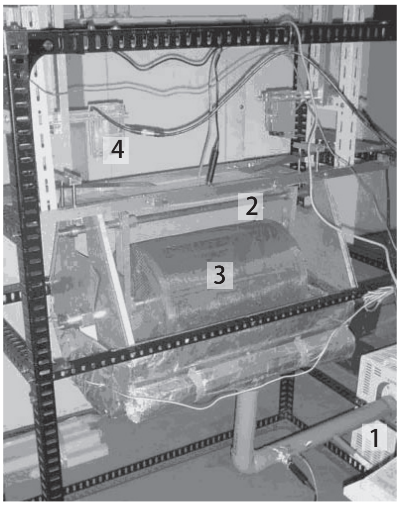

Fig.1 Experimental Apparatus:
(1) blower- heater, (2) plenum chamber,
(3) dehydration drum,
(4) measurement system

Objectives

The objectives of this study were as follows:

1. To test the continuous and nondestructive weighing system in a rotary-type dryer for dehydration of chili pepper under several process conditions.
2. To evaluate the chili pepper quality using a scoring method with several quality factors.
3. To relate the weight changes of chili pepper during dehydration to the quality.

Experimental Material and Methods

Dehydration Process

Dehydration of chili pepper (*Capsicum annuum L. cv. nikkou*) was conducted under several process conditions using a laboratory scale rotary-type dryer with a continuous nondestructive weighing system, as shown in **Fig. 1**. The average room temperature and relative humidity were 20 ºC and 25 %, respectively. Each experimental trial used 2 kg of fresh chili pepper with initial moisture content between 40 % and 70 % w.b.. The chili pepper was

Table 1 Dehydration process conditions

Experiment	Dehydration process conditions				
	M	T	B	V	R
D-1	1	1	0	2	2
D-2	2	1	0	2	2
D-3	3	1	0	2	2
D-4	4	1	0	2	2
D-5	1	3	0	2	2
D-6	1	2	1	2	2
D-7	1	2	1	1	2
D-8	1	2	1	2	1
D-9	1	2	0	2	2

Where,
M=1: dehydration drum rotation for 5 minutes and stopping for 30 min.
M=2: dehydration drum rotation for 10 minutes and stopping for 20 min.
M=3: dehydration drum rotation for 15 minutes and stopping for 15 min.
M=4: dehydration drum rotates continuously
T=1: dehydration process with drying air temperature of 60 ºC
T=2: dehydration process with drying air temperature of 70 ºC
T=3: dehydration process with drying air temperature of 80 ºC
B=0: pre-drying treatment without chili pepper blanching
B=1: pre-drying treatment with chili pepper blanching
V=1: dehydration process with airflow rates of 2 m/s
V=2: dehydration process with airflow rates of 4 m/s
R=1: rotation speed of dehydration drum of 2 rpm
R=2: rotation speed of dehydration drum of 4 rpm

blanched by soaking in potassium metabisulphite ($K_2S_2O_2$) solution at concentration of 2 mg/g with water temperature of 100 ºC for about 2 minutes before drying.

Dehydration process conditions for is experiment were the duty cycle of the dehydration drum (rotation/stop), drying-air temperature, pre-drying treatments by blanching and non-blanching, drying-air velocity, and rotation speed of the drum as shown in **Table 1**.

The parameters that were measured during the dehydration process were (a) continuous weight change of the chili pepper; (b) temperature of the inlet air, plenum chamber, outlet air, environment, and the surface of the material; (c) relative humidity of the inlet air, plenum chamber, outlet air, and environment; (d) air flow rate of the inlet air; (e) drum rotation; and (f) dried chili pepper weight.

Selection and Measurement Methods of Quality Factors

A single quality factor does not sufficiently describe the overall quality of a product. Product quality should be assessed by a combination of several characteristic quality factors. Thus, summarizing and weighing specific internal and external quality factors of the product should develop an integral quality value. While it may be easy to collect a comprehensive list of quality factors of the product, ascertaining their relative importance is difficult (Govindarajan, et al., 1998; Schreiner, et al., 2000).

Quality factors required by consumer demand, industrial demand, and international standard of chili pepper trading are moisture content uniformity in bulk, pungency, color, rehydration capacity, and water activity. These factors were selected for evaluation because their importance and because they were strongly affected by the dehydration process (Govindarajan, et al., 1988). Methods for measuring the quality factors were as follows.

(1) Moisture Content Uniformity

Moisture content uniformity was determined using the standard deviation of the moisture content of dried samples. Samples were taken from random positions inside the dehydration drum after the processes finished. Low standard deviation indicates uniformity of the product's moisture content. Moisture content of chili pepper was determined using the vacuum oven method (AOAC-1990).

(2) Pungency

A Shimadzu GC-14B gas chromatograph with 3% SE-30 on chromatosorb W® was used to analyze capsaicin content of chili pepper. The experiments adopted internal standard method using cholesterol. Standard capsaicin ($C_{18}H_{27}NO_3$) and samples of chili pepper were prepared using acetone solvent.

(3) Color

The L*a*b* (CIELAB) method was used for determining the color of fresh and dried chili pepper.

(4) Rehydration Capacity

Rehydration capacity was determined with regained moisture by soaking dried chili pepper in boiling water for a certain trial period. Rehydration capacity was calculated using the initial and final weight of the products, and rehydration time.

(5) Water Activity

Water activity of dried chili peppers was analyzed using equilibrium sorption rate method. The method used salt solutions, such as K_2CO_3 (*Potassium carbonate Anhydrate*), $Mg(NO_3)_2 \cdot 6H_2O$ (*Magnesium nitrate hexahydrate*), and $CH_3COONa \cdot 3H_2O$ (*Natrium acetate tetrahydrate*).

Quality Evaluation Method

Information on the numerical rating scale for dried chili pepper quality has not been available. Quality based on a subjective method for fresh lettuce was introduced by Kader (1973). He divided the quality into five classifications: none, slight, moderate, severe, and extreme. This classification was applied to this study. The measured values of each quality factor were classified into five ranges based on the lowest and the highest values and each range was given a score of one to five with a higher score meaning better quality.

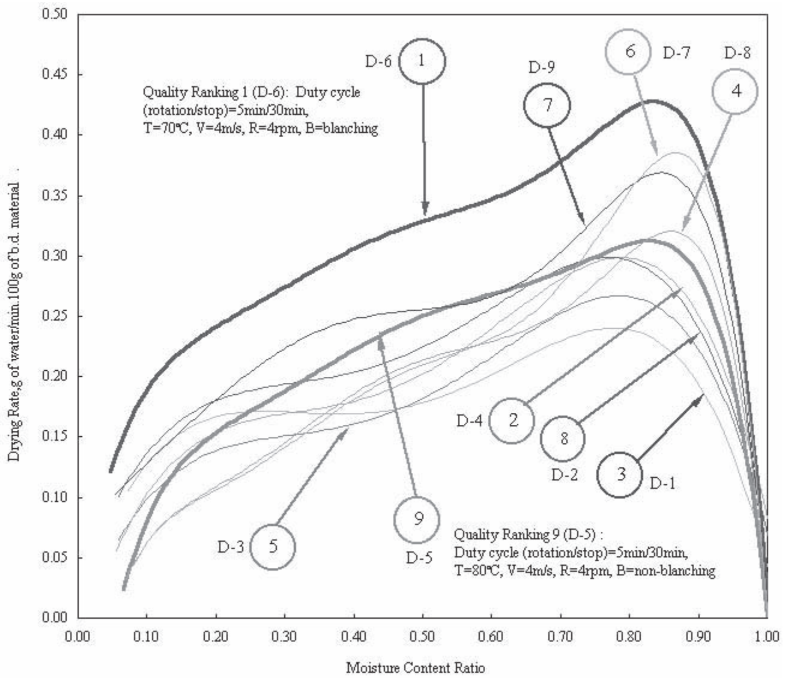

Fig. 2 Drying rates of the dehydration process of chili pepper

Result and Discussions

Effect of Dehydration Process Conditions on Drying Rate

The initial moisture-contents were not the same. Therefore, to compare each drying rate pattern, a ratio was used of the present moisture content to the initial moisture content as shown in **Fig. 2**.

Weight changes of chili pepper during the dehydration were incorporated in the drying-rate curves of **Fig. 2**. The D-4 dehydration process had the highest average drying rate of 0.29 g/(min 100g of bone-dry product) with total drying time of 13.4 hours. Conversely, the D-1, D-2, D-3, D-4, D-5, D-7, D-8, and D-9 processed had lower drying rates and longer drying times. The results varied in drying rates and drying times because the dehydration processes were conducted in different process conditions as discussed below.

(1) Duty Cycle of Dehydration Drum (Rotation/Stopping)

Drying rate decreased when the moisture content of chili pepper was low because the bond of the water molecules with the solid became stronger. However, the combination of stopping time and bulk agitation was considered adequate to overcome this phenomenon. There was evidence that the dehydration processes with longer stopping time had better drying rate. This was especially true during the second half of drying time where the drying rate tended to increase in the processes with longer stopping time as shown in **Fig. 2**. The longer stopping time was adequate for the temperature of the product to increase. The D-6 process, where the drum rotated for 5 minutes and stopped for 30 minutes, had on average chili pepper temperature of 48 ºC. In the D-3 process, where the drum rotated for 15 minutes and stopped for 15 minutes, the average chili pepper temperature was 43 ºC. The D-4 process with continuous drum rotation had a low drying rate with a drying time of 17 hours and on average chili pepper temperature of 41 ºC.

The conditions with higher temperature of the product increased sensible heat and latent heat. Sensible heat enabled the moisture inside the product to move to the surface; and the latent heat allowed the product moisture to be evaporated from the surface. These results agree with the cascade cycle concept and rotary dryer processes in which retention time is one of the important factors in the drying rate of the product (Shene, et al., 1996).

(2) Drying-Air Temperature

An individual chili pepper pod is not a rigid structure as shown in **Fig. 3**. From this property, moisture transport inside the pod is different from the common phenomena that occur in grains. Required temperature for chili pepper dehydration process has been discussed. The process with forced-air has a drying-air temperature of 60 ºC to 70 ºC, and 80 ºC for modern dryers (Govindarajan, 1985). However, to obtain the most suitable temperature for the dehydration process it should be examined with this experimental apparatus.

Effects of drying-air temperature on drying rate are shown in **Fig. 2**. At the beginning of the D-5 drying process, a temperature of 80 º C resulted in higher drying rate compared to the D-1 processes at 60 ºC and D-6 at 70 ºC. In a process with high temperature, moisture content decreased rapidly. However, in the second half-period, drying rate became slow because moisture transport inside the chili pepper pods was resisted by shrinkage and case hardening. Moreover, drying-air temperature affected rehydration capacity of dried chili pepper. The dehydration process at lower temperature permitted a porous structure that resulted in high rehydration capacity. Results indicated that the dehydration process with a temperature of 70 ºC had the best performance in drying rate and quality of product.

(3) Drying-Air Velocity

Drying air with low humidity and flowing at sufficient rates enabled the moisture to evaporate quickly from surface. Bulk agitation allowed the drying-air to pass more easily across the surfaces of the chili pepper pods. Dehydration process D-6 with drying-air velocity of 4 m/s had a better drying rate to than the D-7 process with 2 m/s as shown in **Table 4**.

(4) Pre-Drying Treatment

Blanching is the process of heating vegetables to a temperature that is high enough to destroy the enzymes present in the tissue. The blanching stops the enzyme action that could cause loss of color and flavor during drying and storage. It also shortens the drying and rehydration time by relaxing the tissue walls and softening the exocarp of chili pepper pods leading to less resistance to moisture movement, higher diffusion coefficient, and more rapid rehydration (Wagner, et al., 2001). Pre-drying treatment by blanching in the drying process D-6 showed a significant effect in drying rate compared to the dehydration process without blanching as with the D-3 process as shown in **Fig. 2**.

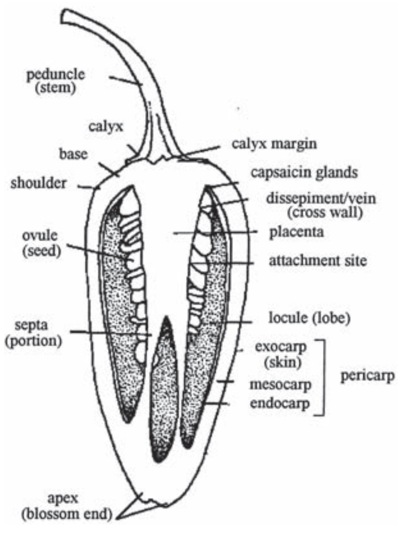

Fig. 3 Cross section of a *Capsicum* fruit (souce: Andrew, J., 1995)

Quality Evaluation

In the final analysis, after numerous date had been compiled, statistical analysis was needed to examine the correlation among groups and overall date. However, in this case, with only several experimental trials, the quality factors have been simply placed into a relative range of values from one to five with five indicating the highest quality.

Color (L*a*b*) was used for calculating the color difference (ΔE) as shown in **Table 2**. These values in **Table 2** were placed into five ranges (**Table 3**) based on the lowest to the highest value of ΔE. The lower values of ΔE indicate the highest quality product and are assigned a value of five.

Experiment	Total color difference, ΔE
D-1	1.54
D-2	1.78
D-3	1.51
D-4	1.55
D-5	3.41
D-6	1.13
D-7	1.89
D-8	2.28
D-9	1.93

Table 2 Measurement result of chili peppers color

Range of total color difference, ΔE	Score
1.13 - 1.69	5
1.70 - 2.26	4
2.27 - 2.83	3
2.84 - 3.40	2
3.41 - 3.57	1

Table 3 Evaluation of chili peppers color by scoring method

The subjective values of the other quality factors are shown in **Table 4**. To evaluate the correlation between drying-rate patterns of the chili pepper during the dehydration process and product quality, only the clear distinction among the curves that had good product quality were considered. Dehydration process D-6 had the highest drying rate and the highest quality score and was given a quality ranking of one as shown in **Fig. 2**.

Conclusion

Quality evaluation of chili pepper after the dehydration processes, at different process conditions, using a laboratory scale rotary-type dryer led to the following conclusions.

1. Experiments using a continuous and nondestructive weighing system successfully identified drying-rate patterns of chili pepper during dehydration.

2. Quality factors that included moisture-content uniformity, pungency, color, rehydration capacity, and water activity, were analyzed to determine the correlation between drying-rate patterns and product quality. Among experimental trials, the dehydration process with highest drying rate resulted in the best quality of product.

3. These facts support the axiom that moisture mobility inside the pod and the moisture evaporation from the surface of chili pepper pods during the dehydration process is related to the quality of the product. Therefore, weight changes of chili pepper during the dehydration process would identify quality.

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Table 4 Drying rates and quality factors ranking at different dehydration process conditions

Experiment	Score by drying rate*	Quality factors**						
		Moisture contents uniformity	Pungency	Color	Rehydration capacity	Water activity	Total score	Quality ranking
D-1	1	2	4	5	3	1	15	3
D-2	2	2	2	4	3	2	13	8
D-3	1	3	3	5	2	2	15	5
D-4	1	5	5	5	3	2	20	2
D-5	1	3	3	1	1	2	10	9
D-6	5	4	4	5	5	5	23*	1
D-7	1	1	3	4	3	3	14	6
D-8	1	3	4	3	3	2	15	4
D-9	2	3	1	4	3	3	14	7

*Drying rates were calculated using experimental date, i.e., initial moisture content, weight measurement during dehydration process, and drying time.

**Total score of general evaluations were 25 for the best and 5 for the worst quality. Among experiment results, dehydration process D-6 with total score of 23 and quality ranking 1 resulted in the best quality of product.

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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.

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Application of Machine Vision in Evaluating Stem of Fruits: **Ying Yibin**, Executive Dean and Professor, College of Biosystems Engineering, Zhejiang University, Hangzhou, Zhejiang 310029, P.R. China, **Hansong Jing**, Ph.D. Candidate, Dept. of Biological Resource Engineering, University of Maryland, College Park, Maryland 20742, USA, **Jin Juanqin**, Associate Professor, College of Biosystems Engineering, Zhejiang University, Hangzhou, Zhejiang 310029, P.R. China.

Huanghua pear is an important fruit in China. The condition of pear stem is an important index in the classification of Huanghua pear. Images of Huanghua pears were taken by a machine vision system. The median filtering method was used to smooth the image, and the local threshold algorithm was adopted to segment the pear from the background. As the normally used thinning and erosion-dilation algorithm in judging the presence of the stem is too slow, a new fast algorithm was put forward. Compared with other part of the pear, the stem is obviously thin and long, with the help of various sized templates, the judgement of whether the stem is present was easily done, meanwhile the stem head and the intersection point of stem bottom and pear were labeled. Furthermore, after the slopes of the tangential line of stem head and tangential line of stem bottom were calculated, the included angle of these two lines was determined. It was found that the included angle of the broken stem could be distinguished from that of the good stem. The algorithm for judging the presence and integrity of stems was effective. The accuracies for stem presence and stem integrity were 100 % and 93 %, respectively. Also, the algorithm is of robustness and can be made invariant to translation and rotation.

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Field Performance Evaluation of a Low Land Paddy Weeder: **S.K. Swain**, Training Associate (Agril. Engg.), Krishi Vigyan Kendra, Baliapal, Balasore, Orissa, India, **S.C. Pradhan,** Associate Professor, Dept. of FMP, CAET, OUAT, Bhubaneswar, Orissa, India, **N. Mohapatra**, same.

A floating type CAET low land paddy weeder (**Fig. 1**) was developed in College of Agricultural Engineering and Technology. This is a simple, low cost, push-pull type manual weeder and is easy to operate. Its performance was compared with the Japanese Rake weeder in sandy loam soil condition for paddy variety Parijat at Central Farm, OUAT. The actual field capacity of the CAET weeder was found to be 0.0145 ha/hr with field efficiency of 85.89 %, weeding index of 88.79 % and performance index of 1254.88. The cost of operation of this weeder was Rs. 276.22 per ha. Considering the parameters for evaluation such as actual field capacity, field efficiency, weeding index, plant damage, performance index and cost of operation the CAET weeder was found to be superior to the Japanese weeder and manual hand weeding method. The performance of CAET weeder with respect to actual field capacity and weeding index was superior to that of Japanese weeder when operated by different operators.

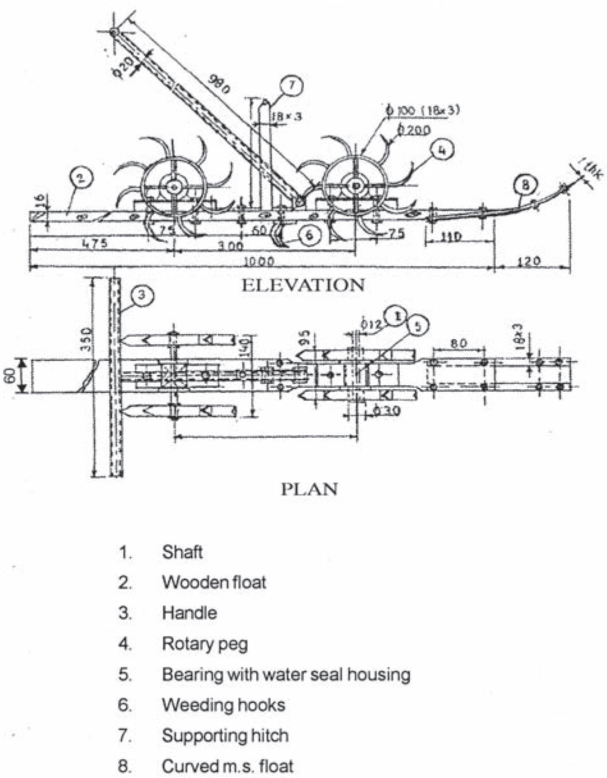

Fig. 1 CAET low land weeder

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Trough System of Withering for Black Tea Manufacture an Introductory Overview: **Samir Kumar Das**, Research Scholar, Dept. of Agricultural and Food Engineering, IIT, Kharagpur, PIN-721302, WB, India, **V.K. Tewari**, Associate Professor, same.

The trough system of withering has proved to be far more advantageous than other batch withering systems like Loft and Drum systems; also in many respects than some continuous systems like Tat and Tunnel systems, and has been popularly adopted in the black tea manufacturing countries. Open type withering trough was first developed and used, but more convenient enclosed type evolved later through development efforts. An introductory, comprehensive description of the trough withering system, based on literature review and practical observations has been given.

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Study of the Farm Accidents on Different Agriculture Farms of District Hyderabad, Sindh, Pakistan: **A.A. Channar**, Associate Professor and Chairman, Department of Farm Power and Machinery, Faculty of Agricultural Engineering, Sindh Agriculture University Tandojam, Sindth, Pakistan, **Syed Gulzar Ali Shah**, Associate Professor, Department of Energy and Environment, same, **Muhammad Siddique Memon**, M.E (Agri.), qualify, Department of Farm Power and Machinery, same, **Sheeraz Hussain Memom**, B.E (Agri.), Department of Farm Power and Machinery, same.

The study to investigate the nature and type of farm accidents on small, medium and large sized farms. 20 farm owners were interviewed about the type of accidents, which occurred on farms. The main features of farm were that tractor operators on all farms were uneducated and untrained.

Total number of accidents recorded on 20 farms were 29, out of which 06 accidents occurred on small farms, 09 accidents occurred on medium forms and 14 accidents occurred on large farms. The number of accidents caused by tractors were 05, threshers 07; farm implements and machinery 07; tube wells 02, sprayers 02; tractor and trolley 05 and hydraulic system 01. The injuries recorded due to 29 accidents were 24 temporary injuries and 5 permanent injuries.

312

Systematic Analysis and Optimization of Grain Postproduction Operation Patterns in South China: **Zheng Wen-zhong**, Assoc. Professor, Ph. Doctor, College of Biosystem Engineering and Food Science, Zhejiang University, Hangzhou 310029, Zhejiang, P.R. China, **He Yong**, Professor and Head, same.

Based on the analysis of present situation and characteristics of grain postproduction system using four indexes, i.e. cost, efficiency, grain quantity loss and grain quality indexes in Zhejiang province, P. R. China, a dynamic program model was put forward to optimize the process of grain postproduction patterns. According to the results optimization, some improved patterns were put forward, and comparison analysis between three improved patterns and three basic patterns shown that the improved patterns have higher efficiency, less losses, and higher rate of benefit to cost. The study results will help farmer and governor to make best choice and improvement of technology and equipment for grain postproduction treatment operation.

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Trends in Indian Flue Cured Virginia Tobacco (Nicotiana Tobaccum) Harvesting, Curing and Grading: **A. Manickavasagan**, Ph. D. Scholar and FCV tobacco expert, Department of Biological and Agricultural Engineering, Faculty of Engineering, University Putra Malaysia, Malaysia, **J. John Gunasekar**, Assistant Professor and FCV tobacco expert, Department of Bio Energy, Tamil Nadu Agricultural University, Coimbatore - 641 003, India, **P. Doraisamy**, Professor (Microbiology), Department of Environmental Science, same.

This paper describes the present scenario of post harvest technologies in Indian FCV tobacco. There are many unit operations involved between harvesting of leaves and processing. Each stage demands skill and experience to produce quality end product. The quality specifications in the tobacco processing factories are higher than that of some food processing industries. Here, FCV tobacco harvesting, curing and grading in Indian context are well discussed in detail. The potential area for research in the processing of FCV tobacco is also given.

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Trends in Indian Flue Cured Virginia Tobacco (Nicotiana Tobaccum) Threshing, Curing and Grading: **A. Manickavasagan**, Ph. D. Scholar and FCV tobacco expert, Department of Biological and Agricultural Engineering, Faculty of Engineering, University Putra Malaysia, Malaysia, **J. John Gunasekar**, Assistant Professor and FCV tobacco expert, Department of Bio Energy, Tamil Nadu Agricultural University, Coimbatore - 641 003, India, **P. Doraisamy**, Professor (Microbiology), Department of Environmental Science, same.

This paper gives detailed account of post graded technology such as threshing, packing and warehousing of Indian FCV tobacco. Different parameter specifications and equipments used are discussed elaborately. The quality specifications in the tobacco threshing are very stringent and are very difficult to adhere. The potential area for research and development in threshing and packing of FCV tobacco is also discussed.

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Methodology for Estimation of Over Exploitation of Ground Water Resources: **AK. Singh**, The University of the South Pacific, Private Mail Bag, Alafua Campus, Apia, Samoa, **M.W. Ullah**, same.

In the present context of the sustainable development of agriculture with special reference to crop production it is very essential to manage the ground water resources. Therefore, a periodic estimation of annual demand of water requirement for crop production will lead to prudent planning without affecting future usage. This paper attempts to put forward a simple method for the calculation of such demand which contributed the planners to take future steps in making decisions for water usage without over exploiting the ground water resources.

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Test Study on Main Parameters of Air-screen Cleaning Mechanism: **Fang Cheng**, Assistant Professor, Department of Biosystems Engineering and Food Science, Zhejiang University, Hangzhou, P.R. China, **Jun Wang**, Professor, same, **Zhaoyan Liu**, Graduate Student, same.

The effects of structure and motion parameters of air-screen cleaning mechanism on its cleaning performance are presented. Each cleaning target get worse as the crank radius became larger. The lipped sieve opening should be selected mainly according to the impurity ratio after cleaning. A mathematic model was established and the optimum combination of parameters was obtained. The validation tests show good result with regard to the predication values. The effects of materials state and feed rate on performance are analyzed also. The results provide reference basis for practical design and utilization of the air-screen cleaning mechanism.

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Hand Transmitted Vibration of Walking and Riding Type Power Tillers: **Bini Sam**, Asst. Professor (FPM), Kerala Agricultural University, Farming Systems Research Station, Sadanandapuram, Kottarakkara, Kerala 691550, India, **K. Kathirvel**, Prof. and Head, AEC & RI, TNAU, Coimbatore, India, **R.Manian**, Dean, same.

The ergonomic aspects of power tiller are of great importance as the operator of a power tiller has to endure various environment and stress. Excessive vibration and noise level are the important shortcomings in power tiller design. The hand transmitted vibration (HTV) of walking type (7.46 kW) and riding type (8.95 kW) power tillers were measured and analyzed with respect to exposure time as per the guidelines of International standards ISO 5349 (1986). The operations included rototilling in untilled and tilled field conditions at 1.5, 1.8, 2.1 and 2.4 km/h forward speeds and transporting at 3.5, 4.0, 4.5 and 5.0 km/h forward speeds on farm road and bitumen road. Acceleration levels increased with forward speed of travel under all operating conditions. The HTV during rototilling of 7.46 kW power tiller in untilled field varied from 3.43 to 5.26 m/s^2 restricting the exposure time from 1/2 to 1 h to < 1/2 h. In tilled field the values were 2.66 to 4.55 m/s^2 and 1 to 2 h to < 1/2 h respectively. For 8.95 kW power tiller, HTV varied from 3.31 to 5.09 m/s^2 with an exposure time of 1 to 2 h to < 1/2 h. Among the power tillers walking type power tiller registered 3.62 to 4.11 % higher values of vibration. The HTV and exposure time during transport with 7.46 kW power tiller on farm road varied from 2.21 to 3.61 m/s^2 and 2 to 4 h to 1/2 to 1 h. During transport with 8.95 kW power tiller on farm road HTV and exposure time varied from 2.72 to 3.66 m/s^2 and 1 to 2 h to 1/2 to 1 h with the increase in forward speed. The latent period or the duration of exposure necessary before the onset of vascular symptoms, characterized by finger blanching for 10 percentiles of an exposed population varied from 4.04 to 8.23 years during rototilling and 5.79 to 12.73 years during transport.

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NEWS

Agricultural Engineering for A Better World

World Congress, Bonn, 3rd-7th September 2006,Deadline for abstracts: 1st February 2006

(Düesseldorf/Bonn, 30.06.2005) CIGR, EurAgEng, VDI-MEG and FAO are delighted to invite you to their joint World Congress, which will be held from 3rd to 7th September 2006 in Bonn, Germany. The World Congress will combine the "XVI CIGR World Congress" with "AgEng2006" and the "64th VDI-MEG International Conference Agricultural Engineering". As part of the congress, FAO will hold a workshop on "Agricultural Engineering Contributions to Solve Future Agricultural Problems" covering two half days.

Abstracts should be submitted together with the Author Identification to the congress webpage www.2006cigr.org till 1st February 2006.

The scientific sessions, posters, Technical Section meetings, and Special Interest Group meetings of the World Congress will deal with the latest developments in agricultural engineering. The following topics will be discussed: Land & Water Use and Environment, Power and Machinery, Information Systems and Precision Farming, Livestock Technology, Processing & Post Harvest Technology and Logistics, Energy and Non-Food Production Technology, Systems Engineering and Management, Fruit & Vegetable Cultivation Systems and Global Issues.

Meetings will be held mainly in the baroque building of Bonn University and in the International Congress Centre "Bundeshaus Bonn", which includes the former parliament building of the Federal Republic of Germany.

Additional information can be found under www.2006cigr.org or contact: VDI-MEG, Graf-Recke-Strasse 84, 40239 Düsseldorf, Germany, Phone: +49 (0) 211 62 14-266, Fax: +49 (0) 211 62 14-177, E-mail: info@ 2006cigr.org

"The Father of Irrigation Engineering in Puerto Rico"

Annual Meeting of The Puerto Rico Chapter of American Society of Agricultural Engineers [ASAE] was held on September 16 of 2005 at University of Puerto Rico - Mayaguez Campus. At this meeting, Dr. Megh R Goyal, PE was recognized as:

"Father of Irrigation Engineering in Puerto Rico"

This recommendation was based his achievements during the years 1979 - 2005. Dr. Goyal received his BSc degree in 1971 from Punjab Agricultural University - India; MSc degree in 1977 and PhD in 1979 from the Ohio State University; and Master in Divinity in 2001 from PR Evangelical Seminary. He is also registered professional engineer in Puerto Rico. Dr. Goyal is a founding Chairman of this society in Puerto Rico.

He started as Agricultural Engineer in 1979 with University of Puerto Rico - Mayaguez Campus [COLEGIO] to do research, teaching and extension related to DRIP IRRIGATION. At present, he is a full professor of General, Agricultural and Biomedical Engineering at **COLEGIO**. Currently, he teaches courses in General engineering at this university. Dr Goyal has published more than 180 publications in professional journals; two bibliographies on Drip Irrigation; a text book on "Management of Drip Irrigation (Spanish)" with 21 chapters; and four books on "**Biomechanics Engineering of Human Body**". More information can be found at his webpage: http://www.ece.uprm.edu/~m_goyal/home.htm

Dr. Goyal has offered technical know-ledge to develop and manage "Climatological data for application in Puerto Rican agriculture". His work on Agroclimatology, Evapotranspiration and Drip Irrigation is a pioneer work on which irrigation systems are designed, developed and managed in Puerto Rico. The simplicity of his publications helps students as well as technicians to apply knowledge in irrigated agriculture. He is a cooperating editor of International Journal AMA (Agricultural Mechanization in Asia, Americas and Latin America).

Number of his publications in irrigation for Puerto Rico has exceeded than publications by any other engineer during the 20th century. Among agriculturists and technicians, he is nicknamed as: **Drip Irrigation Man of Pueruto Rico**. Recently, he has applied his knowledge in Agricultural and Biological Engineering to "Engineering Biomechanics of Human Body".

In the past, Dr. Goyal has received national and international recognitions such as: Best Graduate Student [1976] at Ohio State; Researcher of the Year [1981] by PR Society of Agricultural Sciences; Researcher of the Year [1989] by Gamma Sigma Honor Society; Blue Ribbon Award [1983, 1986, 1991] and Research Award [1983] and Young Engineer of the Year [1987] and Grand Prize Winner [1992] by **ASAE**; and Rashtraya Ratan Award [2002] by Friendship Forum of India. First congress on "Biofluid Dynamics of Human Body" at COLEGIO was dedicated to him.

Prepared by:
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President of Nominating Committee
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San Juan - Puerto Rico - 00915
Tel. 1-787-726-7302

From left to right: Agricultural Engineers Paul L. McConnie, Megh R Goyal, Rafael F. Davila, Francisco Monroig, Eric Harmsen, Carmelo A. Gonzalez and Hector Lopez.

The Annual Meeting and an International Conference in Collaboration with the "Agritech 2006" Exhibition

Tel Aviv, Israel, May 8-10, 2006

Invitation

The organizers are pleased to invite you to participate in the Annual Meeting of the ISAE and the International Conference on "Advance in agricultural technologies and their economic and ecological impacts", which will be held in cooperation with the "Agritech 2006" Exhibition. You are invited also to submit proposals for papers. The aim is to bring together researchers, producers and end users of agricultural equipment. Participants are asked to show their latest work and share their knowledge with their colleagues and all those involved in agricultural engineering. The participants will have a unique chance to visit the largest show of agricultural equipment in the Middle East and to visit sites of professional and general interest.

Topics

The theme of the conference encompasses emerging technologies in agricultural engineering and their economic and ecological impacts. The conference aims at highlighting technologies that were in the conceptual implementation phase.

The following topics will be considered for oral and poster presentations:

1. Advanced technologies in field and greenhouse crops and their postharvest processing
   - 1.1 Precision agriculture
   - 1.2 Energy saving in greenhouses
   - 1.3 New sensors for improvement of quality and safety of agricultural products
2. New agricultural technologies for reduction of environmental damage
   - 2.1 Recycling and purification of irrigation and sewage water
   - 2.2 Applications of GIS for agricultural and environmental tasks
   - 2.3 Environment-friendly spray application

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Dr. Samuel Gan-Mor, Chairman - ARO
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Dr. Ze'ev Schmilovitch - ARO

Papers

Speakers who wish to present papers on the above topics are invited to submit a short abstract in English (250 words) to the head of the organizing committee:

Dr. Samuel Gan-Mor
E-mail: ganmor@agri.gove.il
Fax: +972-3-9604704

Important dates

Deadline for submission of abstracts is December 15, 2005

Notification of acceptance will be sent by February 15, 2006

Deadline for full short-form papers (for inclusion in the CD ROM) - April 10, 2006

Invite International Speakers

Speakers to be confirmed

Language

English

Book Review

Sustainable Agriculture & the International Rice-Wheat System

Autour(s):

Dr. Rattan Lal - Ohio State University, Columbus, USA

Prof. Peter R. Hobbs - Cornell University, Ithaca, New York, USA

Norman Uphoff - Cornell University, Ithaca, New York, USA

David O. Hansen - Ohio State University, Columbus, USA

Detailed Description:

Addressing a topic of major importance to the maintenance of world food supplies, this reference identifies knowledge gaps, defines priorities, and formulates recommendations for the improvement of the rice-wheat farming system. The book reveals new systems of rice intensification and management and illustrates the application of no-till and conservation farming to the rice-wheat system. With contributions from 65 international experts, and case studies from India, Nepal, Pakistan, and Bangladesh, Sustainable Agriculture and residue management, weed control, water and nutrient efficiency, and integrated pest management.

UK Pound Price: 99.00

Published by:

CRC Press / Taylor & Francis Group, LLC, 6000 Broken Sound Parkway NW, Suite 3000, Boca Raton, FL33487, USA

Multi-Scale Integrated Analysis of Agroecosystems

Author(s):

Dr. Mario Giampietro - Instituto Nazionale Richerche su Alimenti e Nutirizione

Detailed Description:

Ecologist, agronomists, and others who may question the validity of current models for determining growth of agroecosystems, need a new set of analytical tools that more effectively address the complex nature of related processes. Those who challenge assumptions of optimization and static factors in agricultural modeling demand new methods beyond differential equations and traditional statistical tests.

Multi-Scale Integrated Analysis of Agroecosystems explores alternative ways to study agricultural sustainability, presenting new approaches to organizing date and applying complex systems theory to actual cases. This innovative text recognizes the changing dynamics of the multiple process and cross-relations within an environment, proposing a clearer analysis of agroecosystems than that which can be provided by rigid, reductionist methods.

Main concepts, new vocabulary and narratives, and practical examples open the book, followed by technical chapters that provide a more detailed explanation of concepts. The final section of the book presents a tool kit based on these concepts, resulting in strong support of empirical observations that challenge traditional notions regarding the sustainability of farming systems, food

systems, and agroecosystems.
UK Pound Price: 62.99
Published by:
CRC Press / Taylor & Francis Group, LLC, 6000 Broken Sound Parkway NW, Suite 3000, Boca Raton, FL33487, USA

Soils and Environmental Quality, 3rd Edition

Author(s):
Dr. Gary M. Pierzynski - Kansas State University, Manhattan, Kansas, USA
J. Thomas Sims - University of Delaware, Newark, Delaware, USA
George F. Vance - University of Wyoming, Laramie, Wyoming, USA
Detailed Description:
What continues to make Soils and Environmental Quality a perpetual bestseller is its practical relevance. Now, with the timely release of a third edition, it remains the obvious choice for instructors who strive to make their teaching applicable to contemporary issues.

The three authors, all teaching professors distinguished in soil science, have updated this student favorite to include a greater number of even more relevant topics. Responding to requests, they have also placed an increased emphasis on management issues.

As with previous editions, the third edition offers students in soil or environmental science an overview of soil science, hydrology, atmospheric chemistry, and pollutant classification.

The text moves from the theoretical to the practical with an abundance of contemporary examples, such as an exploration of allowable pesticide concentrations in drinking water and an inquiry into soil contamination from the trace elements in organic by-products. Also considered are the use of soil carbon sequestration as a remedy for global climate change, and the effects of acid precipitation on forestation.

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The text also cover environmentally-related current events, fostering discussion of the political, economic, and regulatory aspects of environmental issues, the human side of environmental problems, the use and misuse of the scientific method, and potential bias in the presentation of facts. Students in soil science, environmental science, chemistry, biology, and other disciplines will gain valuable insight from this multifaceted text.
UK Pound Price: 32.99
Published by:
CRC Press / Taylor & Francis Group, LLC, 6000 Broken Sound Parkway NW, Suite 3000, Boca Raton, FL33487, USA

Soil Sampling Preparation and Analysis, 2nd Edition

Author(s):
Dr. Kim H. Tan - Emeritus Professor, University of Georgia, USA
Detailed Description:
This second edition of the popular Soil Sampling, Preparation, and Analysis provides a hands-on guide to the method most commonly used in modern soil laboratories around the world, illustrating the methods with actual results. Divided into three sections, the book covers principles of soil sampling and sources of errors and variability of results, common producers for extraction and analysis in soil plant testing, and instrumentation. The author added three new chapters on soil and plant test methods, electron microscopy, and nuclear magnetic resonance. He has extensively revised, updated and expanded all of the other chapters to reflect recent advances and shifting interest in the field.
UK Pound Price: 74.99
Published by:
CRC Press / Taylor & Francis Group, LLC, 6000 Broken Sound Parkway NW, Suite 3000, Boca Raton, FL33487, USA

Handbook of Ecological Indicators for Assessment of Ecosystem Health

Author(s):
Dr. Sven E. Jorgensen - Royal Danish School Pharmacy, Copenhagen, Denmark
Dr. Fu-Liu Xu - Peking University, Beijing, People Republic of China
Dr. Robert Constanza - University of Vermont, Burlington, Vermont, USA
Detailed Description:
The field of ecosystem health explores the interactions between natural systems, human health, and social organization. Handbook of Ecological Indicators for Assessment of Ecosystem Health is the first comprehensive account of ecological indicators for evaluating the health of a wide variety of ecosystems. It presents a conceptual framework for selecting, evaluating and validating ecological indicators of ecosystem health and applies this framework in a series of chapters on major ecosystem types, including coastal areas, forests, wetlands, fisheries and agricultural land. This text will be useful for a wide range of professionals, including those in government agencies worldwide.
UK Pound Price: 79.99
Published by:
CRC Press / Taylor & Francis Group, LLC, 6000 Broken Sound Parkway NW, Suite 3000, Boca Raton, FL33487, USA

Regional Scale Ecological Risk Assessment: Using the Relative Risk Model

Author(s):
Dr. Wayne G. Landis - Western Washington University, Bellingham, USA
Detailed Description:
Regional Scale Ecological Risk Assessment: Using the Relative Risk Model is a collaborative summary and guidebook of the development, methods, and application of the Relative Risk Model (RRM) to meet the need for regional assessments with multiple stressors from diverse sources and numerous desired endpoints. Amenable to additional iterations as new information becomes available, this assessment model is ideal for designing a dynamic management plan that can be customized to meet specific ecological needs.

Driven to expand ecological risk assessment to reflect the structure, function, and scale of the environment, this book offers a new approach to evaluating risks at regional scales, assessing a variety of potential stressors within a dynamic landscape. The book proposes that using date on land use, hydrology, types of contaminants, the distribution of species, and the history of disturbance can result in a computation of risk gradients with in the system being managed. The calculation uses a process of setting ranks for a broad range of sources, stressors, and habitats with filters to denote exposure and effect to look at a combined risk at large geographical scales. The book provides numerous real world examples of how this process works, how it is tested, and how it is used for making management decisions.

Regional Scale Ecological Risk Assessment demonstrates the capabilities of RRM using nine case studies in the Pacific Northwest, Pennsylvania, Brazil, and Tasmania. This book provides detailed descriptions for each step of RRM-from the determination of assessment goals to documentation, evaluation, and communication with decision-makers-that can be practitioners in environmental management, remediation, and related fields worldwide.

UK Pound Price: 85.00

Published by:

CRC Press / Taylor & Francis Group, LLC, 6000 Broken Sound Parkway NW, Suite 3000, Boca Raton, FL33487, USA

Soil Organic Matter Sustainable Agriculture

Author(s):

Fred Magdoff - University of Vermont, Burlington, Vermont, USA

Dr. Ray R. Weil - University of Maryland, College Park, USA

Detailed Description:

Recognition of the importance of soil organic matter (SOM) in soil health and quality is a major part of fostering a holistic, preventive approach to agricultural management. Students in agronomy, horticulture, and soil science need a textbook that emphasizes strategies for using SOM management in the prevention of chemical, biological, and physical problems.

Soil Organic Matter in Sustainable Agriculture gathers key scientific reviews concerning issues that are critical for successful SOM management. This textbook contains evaluations of the types of organic soil constituents-organisms, fresh residues, and well-decomposed substances. It explores the beneficial effects of organic matter on soil and the various practices that enhance SOM. Chapters include an examination of the results of crop management practices on soil organisms, organic matter gains and losses, the significance of various SOM fractions, and the contributions of fungi and earthworms to soil quality and crop growth.

Emphasizing the prevention of imbalances that lead to soil and crop problems, the text also explores the development of soils suppressive to plant diseases and pests, and relates SOM management to the supply of nutrients to crops.

This book provides the essential scientific background and poses the challenging questions that students need to better understand SOM and develop improved soil and crop management systems.

UK Pound Price: 57.99

Published by:

CRC Press / Taylor & Francis Group, LLC, 6000 Broken Sound Parkway NW, Suite 3000, Boca Raton, FL33487, USA

Engineering Design Reliability Handbook

Author(s):

Efstratios Nikolaidis - University of Toledo, Toledo, Ohio, USA

Dan M. Ghiocel - Ghiocel Predictive Technologies, Pittsford, New York, USA

Suren. Singhal - NASA Marshall Space Flight Center, MSFC, Alabama, USA

Detailed Description:

Researchers in the engineering industry and academia are making important advances on reliability-based design and modeling of uncertainty when date is limited. Non deterministic approaches have enabled industries to save billions by reducing design and warranty costs and by improving quality.

Considering the lack of comprehensive and definitive presentations on the subject, Engineering Design Reliability Handbook is a valuable addition to the reliability literature. It presents the perspectives of experts from the industry, national labs, and academia on non-deterministic approaches including probabilistic, interval and fuzzy sets-based methods, generalized information theory, Dempster-Shaffer evidence theory, and robust reliability. It also presents recent advances in all important fields of reliability design including modeling of uncertainty, reliability assessment of both static and dynamic components and systems, design decision making in the face of uncertainty, and reliability validation. The editors and the authors also discuss documented success stories and quantify the benefits of these approaches.

With contributions from a team of respected international authors and the guidance of esteemed editors, this handbook is a distinctive addition to the acclaimed line of handbooks from CRC Press.

UK Pound Price: 85.00

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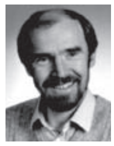
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The Editorial Staff of the AMA requests of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process:

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Priority in the selection of article for publication is given to those that –

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d. deal with practical and adoptable innovations by, small farmers with a minimum of complicated formulas, theories and schematic diagrams;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article;
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e. **The data for the graph must also be included. (e.g. EXCEL for Windows)**
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g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies in US dollars and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
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