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EDITORIAL

Increasing Agricultural Productivity

An interesting article in this issue of AMA is a report of a research scholar, H. Raheman, from the Asian Institute of Technology (AIT), Bangkok, describing his research effort at using a floating air cushion vehicle (ACV) model for wetland rice production. The aim view is to expand riceland area, hence production, on flooded fields where neither tractors nor conventional or traditional implements such as bullock and plow can be harnessed efficiently. At the same time, the ACV "which requires no contact for traction, hence able to move freely on any difficult surface while supported on a self-generated cushion of air . . . offers potentional solution to a variety of transportation problems on terrain."

While the ACV model is in the experimental stage, its advent is a shining example of what AMA, through this editorial page, has since been rallying the scientists, researchers and scholars to pioneer in both basic and applied research for practical ways of increasing agricultural productivity so that we may not lose the race between food production and hunger. And as Raheman observes: "The world's urgent need is to raise agricultural production by *increasing cropping intensity which is possible by farm mechanization*" (underscoring supplied). When the ACV becomes available for commercial use, it will be a down-to-earth innovation in mechanization as an effort to help increase rice production.

Of course, the ACV has no monopoly in the search for measures that would increase rice production. But the fact remains, however, that farmland, being the most important resource in agricultural production, is not only limited by nature but is also being "eaten up" by urban development in the guise of modernization in amny areas in both developed or developing nations. Even as, for example, rice is now grown twice a year, and sometimes thrice in some Asian countries in recent years as a result of the IRRI innovation in the Philippines, much remains to be done in raising agricultural productivity.

It is heartening to note that such international and regional agencies such as the FAO, IDRC, APO, World Bank, ADC and JOCV, among others, are engaged in various projects on reducing post-harvest waste and loss of foodgrains and improving the marketing of farm products. Their efforts will go a long way in terms of raising agricultural productivity.

The threat of starvation is real in many African and various other countries, particularly in Somalia where children are now dying from hunger by the hundreds everyday. Add to this grim scenario the disintegration of the former Soviet Union that spells hunger even in the city of Moscow, the cessation of many former USSR republics, the civil war now tearing Yugoslavia apart and the war clouds that hang over Iraq, among other disturbances around the globe — all of which call for food more than firearms and ammunition.

In both the short- and long-terms, the current world situation and problems do not leave much option for mankind but to find ways of increasing food availability. Therefore, we who are deeply committed to seeing agricultural productivity increase faster than population increase, wish to rally once everyone to find means of introducing innovations or inventions that would increase food availability — using agricultural machineries or not.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
October, 1992

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol. 23, No. 4, Autumn 1992

Kinematics of Revolving-knife Disk-type Sugarcane Basecutter — I

— Fundamental Mathematical Relationships —

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Abstract

Equations of motion for the cutting edges of a revolving-knife disc-type sugarcane basecutter are derived using the method of linear homogeneous transformations. Using the differential calculus, an inequality is derived which expresses the criterion for sound kinematic design of this type of basecutter. The inequality is validated by the use of computer graphic simulations of the motion of the cutting edges, and is seen to be of general applicability. Although the derivation of the inequality does not consider the mechanics of the cutting process as such, the results should be usable as constraints in a design algorithm.

[Keywords] Sugarcane Basecutter, Kinematics, Computer Graphic Simulations.

Introduction

Although sugarcane harvesting machines are common in regions such as Australia, Central and Latin America, Japan, South Africa, and the United States of America, information regarding the rational design of the basecutter, a mechanism used on sugarcane harvesting machines to cut the cane at the base, is hard to find. In this paper a kinematic theory is proposed, that may be used in the design of one type of basecutter.

Cutters Commonly Used on Agricultural Machines

Cutters commonly used on agricultural field machinery, typically execute either a combination of reciprocating and translatory motions or a combination of rotary and translatory motions. In either case the translatory motion, which shall be referred to as advance motion, is necessary in order to transport the implement to its work.

Rotary Cutters

Rotary cutters used on agricultural field machines may be split into two major categories on the basis of their characteristic kinematics;

Category 1 — Cutters whose cutting edges move in a plane perpendicular to the axis of rotation. These may be referred to as "Disc" cutters since their motion is akin to that of a spinning translating disc. This category includes the common types of disc mowers.

Category 2 — Cutters whose cutting edges describe a cylinder about the axis of rotation. These may be thought of as "Cylinder" cutters since their motion is akin to that of a rolling cylinder with more or less slip or skid. This category includes horizontal axis mowers.

Category 2 cutters need to travel over the crop which they cut and are, therefore, not suited to tall crops such as sugarcane. Category 1 cutters may be further split into two sub-categories;

Category 1A — Cutters with a continuous cutting edge formed on the periphery of a circular disc. Cutting is effected either by the slicing action of a smooth cutting edge, or the abrading action of a serrated cutting edge.

A category 1A cutter with a serrated cutting edge was used on a sugarcane cutting machine at the Indian Institute of Sugarcane Research (Sharma et al., 1985). A variant of the category 1A cutter consists of twin contra-rotating discs with either one or both discs having smooth or serrated cutting edges (Mollah et al., 1986).

Category 1B — Cutters with a number of discrete cutting edges formed on blades coupled to the periphery of a disc or other rotating frame. The cutting edges may be of fixed orientation relative to the rotating frame or may be hinged to the frame. Cutting is effected either by a combination of impact and slicing, in the case of a smooth cutting edge, or a combination of impact and abrasion, in the case of a serrated cutting edge.

This last category, with blades rigidly fastened to the rotating frame, finds the widest application on sugarcane harvesting machines and is the subject of this paper. It shall be termed as the Revolving-knife Disc-type Sugarcane Basecutter, which seems to be adequately descriptive of its form and functioin. **Fig. 1** illustrates a basecutter of this type which was used in some laboratory experiments (Oduori et al., 1988).

Kinematic Analysis

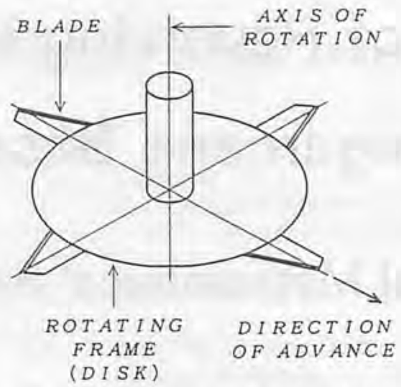

Fig. 1 Revolving-knife disk-type basecutter.

Definitions and Assumptions

Fig. 2 illustrates the configuration of cutting edges on the cutter, at an arbitrary time, t_0, which shall be the initial moment of consideration. At this moment, the origin, *O*, of the stationary Cartesian coordinates frame of reference coincides with the center of rotation of the cutter. For simplicity, straight cutting edges are illustrated. However, where the cutting edge is curved, either along its whole length or along some part of its length, it may still be represented by a straight line joining its tip (understood to mean the point on the cutting edge farthest from the centre of rotation of the cutter) and its root (understood to mean the point on the cutting edge nearest to the centre of rotation of the cutter) without nullifying the applicability of the results of this analysis.

In **Fig. 2**, R_T, R_R, and L are the sides of a triangle whose other properties are θ, ϕ_R, and ϕ_T. Kinematically, the blades and the rotating frame comprise a single rigid body. Since a just-rigid system of three points, such as the apices of a triangle, requires three constraints (Rosenberg, 1977), any three properties, not all angles, would be adequate to define a unique triangle. It is convenient, in this analysis, to use R_T, R_R, and θ to define the configuration of the cutting edges.

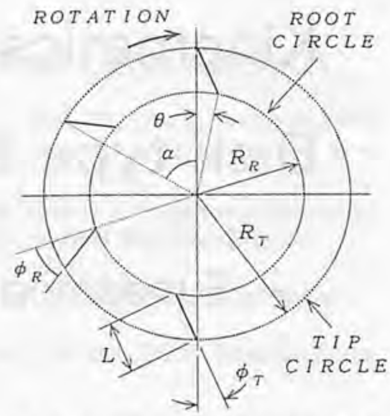

Fig. 2 Configuration of the cutting edges.

The following assumptions are made throughout this analysis;

1. The cutting edges are of fixed orientation (defined by ϕ_R in **Fig. 2**) relative to the rotating frame.
2. The blades are uniformly distributed around the periphery of the cutter. Thus, if there are n blades in total, the angle denoted α in **Fig. 2** is equal to $2\pi/n$ radians or $360/n$ degrees.
3. The cutter rotates in a horizontal plane about its centroidal axis with a constant rotational velocity ω (rad/s), taken to be positive in the clockwise sense. The rotational velocity may also be denoted N (rpm) such that $N = 30\omega/\pi$.
4. The cutter translates along a straight path within the plane of its rotation and towards the positive X-direction with a constant velocity V (m/s), termed the advance velocity. The advance velocity may also be denoted S (km/h) such that $S = 3.6V$. Furthermore, it is often convenient to express the advance velocity in terms of the rotational velocity as follows;

$$V = \omega R_0 \qquad (3.1)$$

R_0 may be thought of as the rate of advance of the cutter, in metres per radian of the cutters rotation.

Trajectories of the Cutting Edges

By the method of linear

homogeneous transformations, the displacement of a point in a rigid body whose motion is two-dimensional may be represented by a matrix equation of the following form (Crouch, 1981; Kinzel et al., 1981; Suh et al., 1967; Pettofrezzo, 1966; Denavit, et al., 1955):

$$\begin{bmatrix} X_2 \\ Y_2 \\ k \end{bmatrix} = \begin{bmatrix} D_{11} & D_{12} & D_{13} \\ D_{21} & D_{22} & D_{23} \\ D_{31} & D_{32} & D_{33} \end{bmatrix} \begin{bmatrix} X_1 \\ Y_1 \\ k \end{bmatrix} \quad (3.2)$$

where;
the column vector $\{X_1, Y_1, k\}$ represents the position of the point in question, before displacement.
the column vector $\{X_2, Y_2, k\}$ represents the position of the point in question, after displacement.
the square matrix of order three $\{D_{ij}\}$ is known as the displacement matrix.

In the column vectors in equation *(3.2)*, the third component, k, can be any real number. In **Fig. 3**, commencing with the leading blade *(BLADE 1)* and the trailing blade *(BLADE 2)* at the indicated positions at time t_0, at a subsequent arbitrary time t, the positions of the blades relative to the stationary reference frame, may be derived as follows:
① For the tip of the cutting edge of the leading blade:

$$\begin{bmatrix} X_{T1}(t) \\ Y_{T1}(t) \\ R_0 \end{bmatrix} = \begin{bmatrix} \cos\omega t & \sin\omega t & \omega t \\ -\sin\omega t & \cos\omega t & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_{T1}(t_0) \\ Y_{T1}(t_0) \\ R_0 \end{bmatrix} \quad (3.3)$$

Noting that $X_{T1}(t_0) = 0$ and $Y_{T1}(t_0) = R_T$, and using equation *(3.1)*, equation *(3.3)* may be expanded to yield the following:

$$X_{T1}(t) = Vt + R_T \sin\omega t \quad (3.3a)$$
$$Y_{T1}(t) = R_T \cos\omega t \quad (3.3b)$$

② For the root of the cutting edge of the leading blade, the displace-

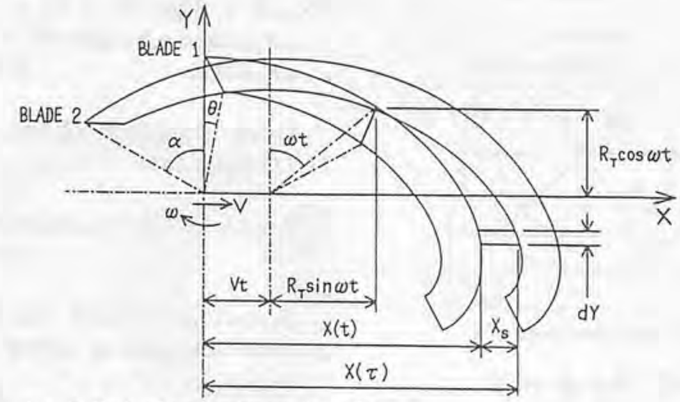

Fig. 3 Path of successive cutting edges.

ment matrix remains unchanged, since the cutter is a single rigid body. However, the initial position of the point in question must be specified correctly, as follows:

$$\begin{bmatrix} X_{R1}(t) \\ Y_{R1}(t) \\ R_0 \end{bmatrix} = \begin{bmatrix} \cos\omega t & \sin\omega t & \omega t \\ -\sin\omega t & \cos\omega t & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_{R1}(t_0) \\ Y_{R1}(t_0) \\ R_0 \end{bmatrix} \quad (3.4)$$

Noting that $X_{R1}(t_0) = R_R \sin\theta$ and $Y_{R1}(t_0) = R_R \cos\theta$, and using equation *(3.1)*, equation *(3.4)* may be expanded to yield the following:

$$X_{R1}(t) = Vt + R_R \sin(\omega t + \theta) \quad (3.4c)$$
$$Y_{R1}(t) = R_R \cos(\omega t + \theta) \quad (3.4b)$$

Similarly, for the tip and root of the trailing edge, which rotationally lags the leading edge by the angle α, the follwoing equations may be derived:

$$X_{T2}(t) = Vt + R_T \sin(\omega t - \alpha) \quad (3.5a)$$
$$Y_{T2}(t) = R_T \cos(\omega t - \alpha) \quad (3.5b)$$
$$X_{R2}(t) = Vt + R_R \sin(\omega t + \theta - \alpha) \quad (3.6c)$$
$$Y_{R2}(t) = R_R \cos(\omega t + \theta - \alpha) \quad (3.6d)$$

In the above equations the subscripts T and R refer to the tips and the roots of the blades, respectively, and the subscripts *1* and *2* refer to the leading and trailing blades, respectively. The blades describe trochoidal trajectories, partly illustrated in **Fig. 3**. Blade motion beyond the final positions indicated in **Fig. 3** comprises idle strokes (as opposed to cutting strokes) during which the blades move over the area where the crop has already been cut.

Criterion for Sound Kinematic Design of Cutter

Considering the moments in time, denoted t and τ, such that the Y-coordinate of the tip of the leading edge at time, t, is equal to the Y-coordinate of the root of the trailing edge at time, τ, one finds that:

$$Y_{T1}(t) = Y_{R2}(\tau) \quad (3.7a)$$
$$\text{or } R_T \cos\omega t = R_R \cos(\omega\tau + \theta - \alpha) \quad (3.7b)$$

Though t and τ are variable, each pair of such values satisfies equation *(3.7b)*. The corresponding X-coordinates are:

$$X_{T1}(t) = Vt + R_T \sin\omega t \quad (3.8a)$$
$$X_{R2}(\tau) = V\tau + R_R \sin(\omega\tau + \theta - \alpha) \quad (3.8b)$$

If analysis is limited to cutting strokes of the blades in one complete rotation of the cutter, the relevant values of ωt are defined by the equation below, and illustrated in **Fig. 4**:

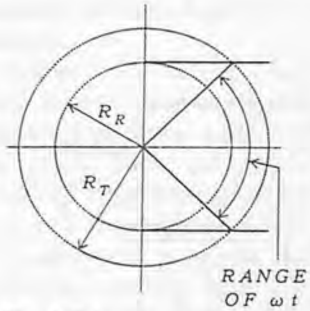

Fig. 4 Relevant range of t.

$$cos^{-1}(R_R/R_T) \leqq \omega t \leqq -cos^{-1}(R_R/R_T) \quad (3.9)$$

Here, a variable X_S is introduced such that:

$$X_S = X_{R2}(\tau) - X_{T1}(t)$$
$$\text{or } X_S = V(\tau - t) + R_R sin(\omega\tau + \theta - \alpha) - R_T sin\omega t \quad (3.10)$$

Within the relevant range of ωt, patches of area in the wake of the cutter which would not be traversed by the cutting edges would occur wherever X_S is greater than zero. The cutter should be designed to avoid such occurrence. For negative values of X_S, the paths of successive blades would overlap, a situation which can be tolerated.

In **Fig. 3**, an elemental strip of area, of length X_S and width dY, is indicated, which is not traversed by the cutting edges. If the largest possible of such elemental strips of area were to be equal to, or less than zero, all such areas would be eliminated. Since dY is infinitesimal and, therefore, essentially constant, the elemental areas such as the one indicated in **Fig. 3** may be considered to be directly proportional to X_S. Thus, the largest of these elemental areas corresponds to the following:

$$\frac{\partial X_S}{\partial t} = 0; \frac{\partial^2 X_S}{\partial t} < 0 \quad (3.11)$$

Differentiating equation *(3.10)* with respect to t yields the following equation:

$$\partial X_S/\partial t = V[\partial\tau/\partial t - 1] + \omega R_R cos(\omega t + \theta - \alpha)\partial\tau/\partial t - \omega R_T cos\omega t \quad (3.12a)$$

Using equations *(3.7b)*, and *(3.11)* leads to:

$$\frac{\partial X_S}{\partial t} = [\partial\tau/\partial t - 1][V + \omega R_T cos\omega t] = 0 \quad (3.12b)$$

Equation *(3.12b)* has two possible solutions as follows:

$$\text{①} \ \frac{\partial\tau}{\partial t} = 1 \quad (3.13)$$

By differentiating equation *(3.7b)*, one finds:

$$\partial\tau/\partial t = R_T sin\omega t/[R_R sin(\omega\tau + \theta - \alpha)] = 1 \quad (3.13a)$$

Thus, if the first solution (equation *(3.13)*) holds, then:

$$R_T sin\omega t = R_R sin(\omega\tau + \theta - \alpha) \quad (3.13b)$$

and if both *(3.7b)* and *(3.13b)* hold, one finds that:

$$R_T = R_R \quad (3.13c)$$

This result is not consistent with the design of the cutter under consideration and therefore solution ① is not relevant.

$$\text{②} \ V + \omega R_T cos\omega t = 0 \quad (3.14a)$$
$$\text{or } R_T cos\omega t = -V/\omega = -R_0 \quad (3.14b)$$

As a further check on the condition for the elemental area to be the largest, the second derivative of X_S with respect to t is obtained by differentiating equation *(3.12b)* and then applying the second condition stated in *(3.11)* to obtain:

$$\partial^2 X_S/\partial t^2 = [V + \omega R_T cos\omega t]\partial^2\tau/\partial t^2 - \omega^2[\partial\tau/\partial t - 1]R_T sin\omega t < 0 \quad (3.15a)$$

By using equation *(3.14a)* in expression *(3.15a)*, the following inequality may be obtained:

$$\omega^2[\partial\tau/\partial t - 1]R_T sin\omega t > 0 \quad (3.15b)$$

Now, within the relevant range of ωt, $R_T sin\omega t$ is positive, and, since ω^2 is positive too (ω is real), it must follow that:

$$\frac{\partial\tau}{\partial t} > 1 \quad (3.16a)$$

By a similar procedure to that used earlier to obtain equation *(3.13c)*, the inequality *(3.16a)* leads to the following result:

$$R_T > R_R \quad (3.16b)$$

This conforms to the design of the cutter under consideration and, therefore, equation *(3.14a)*, which has been used to obtain *(3.16b)* is the relevant condition for the elemental area to be the largest. An expression for the largest value of X_S can now be formulated and set to be less than or equal to zero as a condition for the sound kinematic design of the cutter. The procedure is as follows:

Using *(3.7b)* and *(3.14b)*;

$$R_T cos\omega t = R_R cos(\omega\tau + \theta - \alpha) = -R_0 \quad (3.17a)$$

Thus $cos\omega t = -R_0/R_T$

$$\text{or } \omega t = -cos^{-1}[R_0/R_T] \quad (3.17b)$$

$$\text{and } sin\omega t = [1 - (R_0/R_T)^2]^{1/2} \quad (3.17c)$$

Similarly

$$cos(\omega\tau + \theta - \alpha) = -R_0/R_R$$

Thus

$$\omega\tau = -cos^{-1}[R_0/R_R] + \alpha - \theta \quad (3.17d)$$

and

$$sin(\omega\tau + \theta - \alpha) = [1 - (R_0/R_R)^2]^{1/2}$$

(3.17e)

The value of X_S corresponding to the largest elemental area, denoted X_{smax}, is obtained using equation *(3.10)*, reproduced below, and equations *(3.17b-3.17e)*, and then set equal to or less than zero.

$$X_S = V(\tau - t) + R_R sin(\omega\tau + \theta - \alpha) - R_T sin\omega t \quad (3.10)$$

or

$$X_S = \omega R_0(\tau - t) + R_R sin(\omega\tau + \theta - \alpha) - R_T sin\omega t \quad (3.18)$$

Thus,

$$X_{smax} = -R_0[cos^{-1}(R_0/R_R) - \alpha + \theta - cos^{-1}(R_0/R_T)] + R_R[1 - (R_0/R_R)^2]^{1/2} - R_T[1 - (R_0/R_T)^2]^{1/2} \leqq 0$$

which can be manipulated to yield;

$$\alpha \leqq \theta + cos^{-1}(R_0/R_R) - cos^{-1}(R_0/R_T) + [(R_T/R_0)^2 - 1]^{1/2} - [(R_R/R_0)^2 - 1]^{1/2} \quad (3.19)$$

In expression *(3.19)*, the variables α, θ, R_R, and R_T, define the configurations of the cutting edges as illustrated in **Fig. 2**, and R_0 is the rate of advance of the cutter, in *m/rad.*, as defined in equation *(3.1)*. All angular quantities, including the values of the arccosine terms are in radians, and all linear quantities are in metres. That this inequality should be satisfied is the criterion for sound kinematic design of the cutter.

Validation

To validate expression *(3.19)*, an "experiment" was performed on computer. An interactive computer program was written in N88BASIC, which runs under MS-DOS on the NEC PC-9800 series of personal computers. The program requires the input of the number of blades on the cutter and R_T, R_R, and ϕ_R. The value of α is then readily computed $(\alpha = 2\pi/n)$ and that of θ is computed using the following equation, which is readily derived from **Fig. 2**;

$$\theta = \phi_R - sin^{-1}[R_R sin\phi_R/R_T] \quad (4.1)$$

The program then searches for the value of R_0 which, along with the given values of α, θ, R_R, and R_T, satisfies expression *(3.19)*, for the critical case when the right-hand-side is just equal to the left-hand-side. Having found that value, the program then computes and plots the successive positions of two successive cutting edges. A sample result of the experiment is given in **Fig. 5**, which shows expression *(3.19)* to be valid.

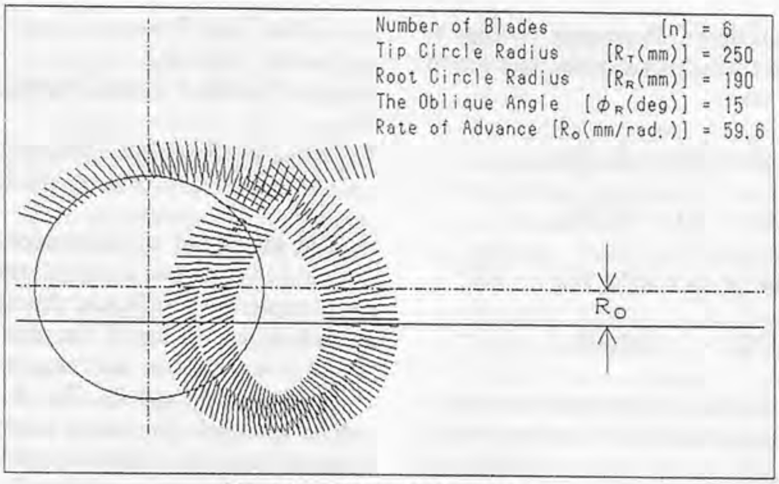

Fig. 5 Sample result of validation.

Discussion

Since the absolute value of the cosine of an angle cannot be greater than unity, and the square root of a negative number is imaginary, cases where R_0 is greater than R_R cannot be evaluated by expression *(3.19)*. Furthermore, negative values of R_0/R_R and R_0/R_T have no physical relevance since R_0, R_R, and R_T cannot be negative. Thus, it follows that $R_0 \leqq R_R \leqq R_T$.

A situation may be considered such that R_0, R_R, and R_T are all equal; then $\phi_R = \phi_T$, and $\theta = 0$. This implies an infinite number of cutting edges of zero length $(\alpha = L = 0)$, which is not consistent with the design of the cutter in question. However, an infinite number of tangentially oriented, infinitesimally short cutting edges conforms to a disc with a continuous cutting edge on its periphery. Therefore, expression *(3.19)* applies to the more general design of disc cutter beyond that with a finite number of discrete cutting edges. Furthermore, it is apparent that for the disc with a continuous cutting edge on its periphery, R_0 should not be greater than the radius of the cutter.

In practice one may design a cutter of the type under discussion with R_0 greater than R_R, by choosing the values of V, ω, and R_R accordingly. However, such a cutter would be incompatible with the criterion for sound kinematic design.

Expression *(3.19)* is in a form that is not convenient to use, but may be transformed into a set of simpler but equivalent expressions as follows. Referring to **Fig. 6**, one finds the following relations to be true:

$cos(\pi - A) = R_0/R_R;$

$cos(\pi - B) = R_0/R_T$

$tan(A) = -[(R_R/R_0)^2 - 1]^{1/2}$

$tan(B) = -[(R_T/R_0)^2 - 1]^{1/2}$

Using the above expressions, a transformed version of expression *(3.19)* can be written as follows:

$$\alpha \leqq \theta + tan(A) - A - [tan(B) - B]$$
$$A = \pi - cos^{-1}(R_0/R_R)$$
$$B = \pi - cos^{-1}(R_0/R_T) \qquad (5.1)$$

In the above set of expressions, all angles are in radians. This set of three expression contains seven variables, which means the values of any four of the variables may be chosen arbitrarily, and then the rest calculated to satisfy the set of expressions. An interesting and simplifying case occurs when θ is set equal to θ_1 = A − B, which means $L = L_1$. By using the set of expressions *(5.1)* and **Fig. 6** one then finds the following:

$$\alpha \leqq [(R_T/R_0)^2 - 1]^{1/2} - [(R_R/R_0)^2 - 1]^{1/2}$$
$$L \geqq \alpha R_0$$

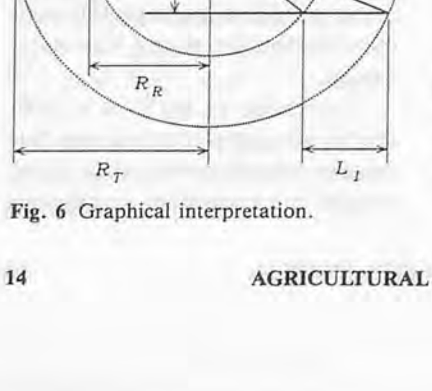

Fig. 6 Graphical interpretation.

$$\phi_T = sin^{-1}(R_0/R_T)$$
$$\phi_R = sin^{-1}(R_0/R_R)$$
$$\theta = cos^{-1}(R_0/R_T) - cos^{-1}(R_0/R_R)$$
or
$$\theta = sin^{-1}(R_0/R_R) - sin^{-1}(R_0/R_T) \qquad (5.2)$$

The above set of expressions cannot be used when $\theta = 0$, but the expressions are simple and should be convenient to use if the additional constraint on the relationship between θ, and R_0, R_R, R_T, can be tolerated. The values of any three of the eight variables in this set may still be chosen arbitrarily. If the additional constraint proves to be incompatible with the design problem, the more general set *(5.1)* may be used.

The kinematics of a disc cutter of the type considered in this paper has been dealt with by other scholars. An equation that appears elsewhere (Kanafojski et al., 1976) instead of expression *(3.19)*, is derived by assuming that the largest value of X_S, (defined in section 3.3) corresponds to the condition that $Y(t)$ (and therefore $Y(\tau)$) is zero, an assumption which is not mathematically justifiable. However, according to this assumption, equation *(3.7b)* reduces to:

$$\omega t = \omega \tau + \theta - \alpha = \pi/2 \qquad (5.3)$$

and equation *(3.10)* then reduces to:

$$V(\tau - t) + R_R - R_T = 0 \qquad (5.4)$$

Using equations *(5.3)* and *(5.4)* one finds:

$$\alpha = \theta + \frac{R_T - R_R}{R_0} \qquad (5.5)$$

The equation actually appearing in the book (Kanafojski et al., 1976), written in the notation used in this paper, is:

$$\alpha = \frac{L cos\phi_T}{R_0} \qquad (5.6)$$

If ϕ_T (and, therefore, θ) is small, equation *(5.6)* conforms, approximately, to the second of the set of expressions *(5.2)*. However, it should be noted that the set of expressions *(5.2)* should be applied as a set. To use any single expression from the set without satisfying the other expressions in the set is likely to lead to inaccurate results.

A version of expression *(3.19)* for the case of radially oriented straight cutting edges $(\theta = 0)$ was derived elsewhere using a rather less rigorous approach (Oduori et al., 1988). Expression *(3.19)* in this paper is a generalization of that earlier expression, to include cutting edges of arbitrary orientation relative to the rotating frame.

Summary of Important Mathematical Expressions

Expressions derived in section 5, and deemed to be important, are presented below in units of measure which are more often used in practice than the SI units used in section 5.

The set of expression which represent the general criterion for sound kinematic design of the revolving-knife disc cutter:

$$\alpha \leqq \theta + B - A + 57.3\,[tan(A) - tan(B)]$$
$$A = 180 - cos^{-1}(9.55V/NR_R)$$
$$B = 180 - cos^{-1}(9.55V/NR_T) \qquad (6.1)$$

The above set of expressions may be used in conjunction with the following equation:

$$\theta = \phi_R - sin^{-1}[\frac{R_R sin\phi_R}{R_T}] \qquad (6.2)$$

For the particular case where we set $\theta = A - B$ (θ is not zero), the following set of expressions may be used;

$$\alpha \leqq 57.3\,[(NR_T/9.55V)^2 - 1]^{1/2}$$

$$- 57.3\,[(NR_R/9.55V)^2 - 1]^{1/2}$$

$$L \geqq \alpha V/60N$$

$$\phi_T = sin^{-1}(9.55V/NR_T)$$

$$\phi_R = sin^{-1}(9.55V/NR_R)$$

$$\theta = cos^{-1}(9.55V/NR_T) - cos^{-1}(9.55V/NR_R)$$

or

$$\theta = \sin^{-1}(9.55V/NR_R) - sin^{-1}(9.55V/NR_T) \quad (6.3)$$

In all the above expressions, V is in metres per second, N is in revolutions per minute, the angles A, B, α, ϕ_R, ϕ_T, and θ, are in degrees, and the distances R_R, and R_T, in metres. The expressions should be used with reference to **Fig. 2** and **Fig. 6**.

Conclusions

① The equations of motion of a revolving-knife disc-type sugarcane basecutter, assumed to rotate at constant rotational velocity while simultaneously translating at constant advance velocity, were derived from first principles using the method of linear homogeneous transformations.

② Using the differential calculus, an inequality was derived which represents the criterion for sound kinematic design of the basecutter. The inequality was validated by means of computer graphic simulation of the motion of the basecutter.

③ A geometrical interpretation of the criterion for sound kinematic design of the basecutter led to two sets of mathematical expresions, of a more convenient form for practical use. The first set of three expressions contains seven variables, any four of which may take on arbitrary values. The second set of five expressions contains eight variables, any three of which may take on arbitrary values. The second set should be used wherever possible.

④ The design of the basecutter should take into account not only the kinematics of the cutter but also the mechanics of the cutting process as such. Theoretical and empirical investigations into such factors as the forces acting and the energy expended in the cutting process are necessary.

⑤ Though this paper considers the sugarcane basecutter in particular, the results obtained here should apply to the general class of disc cutters with a number of discrete cutting edges, moving in a plane perpendicular to the axis of rotation.

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Manufacturing and Testing of AIT Jab Seeder in Nepal

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Abstract

A manually-operated AIT jab seeder was manufactured in Nepal using locally available materials. Farmers, both men and women, found the seeder convenient to use and less tiresome as it avoids constant bending or squatting resulting in savings of about one-fourth in labour use. The cost of the seeder could be recovered in one cropping 1 ha of maize and soybean. The seeder should be a meaningful substitute for manual dibbling in the hills of Nepal.

Introduction

Nepal, a mountainous country in South Asia, is dependent almost entirely on agriculture for its economic development. Although the agriculture sector has been accorded top priority in the national development plans, the productivity, especially in the hills, is low. Nevertheless, there is ample scope for increasing agricultural production. This will, however, require more emphasis on technological packages specially tailored for hill conditions. Labour shortage during planting is one of the constraints in agricultural activities hence, there exists a need for selective mechanization of crop planting. The manual dibbling which is a popular planting technique, is time-consuming and physically demanding. An effective manual seeder which will improve land and labour productivity and reduce physical drudgery will be a meaningful technology for the hills.

On reviewing the pros and cons of the available manual seeders, it was found that the AIT jab seeder could be a meaningful substitute for manual dibbling in the hills of Nepal. This study was, therefore, conducted in Nepal in order to assess the prospects of adoption of the AIT jab seeder. The major objectives of the study were: (i) to fabricate the seeder in Nepal and assess the feasibility of domestic production, and (ii) to test and evaluate the field performance of the seeder under Nepalese conditions.

Description of AIT Jab Seeder

The AIT jab seeder is a manual, multi-crop seeder developed at the Asian Institute of Technology, Bangkok, Thailand [1]. The equipment is so called because of its method of operation. The farmer punches the seeder to make a hole and the seed is then simultaneously dropped into the hole when the seeder is lifted from the ground. Thus, both hole-making and seeding are done in the same stroke. The major components of the seeder include a handle or seed tube, metering roller, cut-off spring, pushing rods, outer sliding tube, seed delivery tube, observing hopper and soil opener. The metering roller has two metering slots on opposite sides. The slot size is selected based on the seed to be planted. Four different types of soil openers, viz. round type, jaw type, shovel type and rectangular type can be used depending on the soil conditions. However, the shovel type soil opener has been found suitable in all soil textures. **Fig. 1** shows the exploded view of the jab seeder.

Material and Methods

Both laboratory and field tests were conducted in order to evaluate the performance of the seeder. The laboratory tests were

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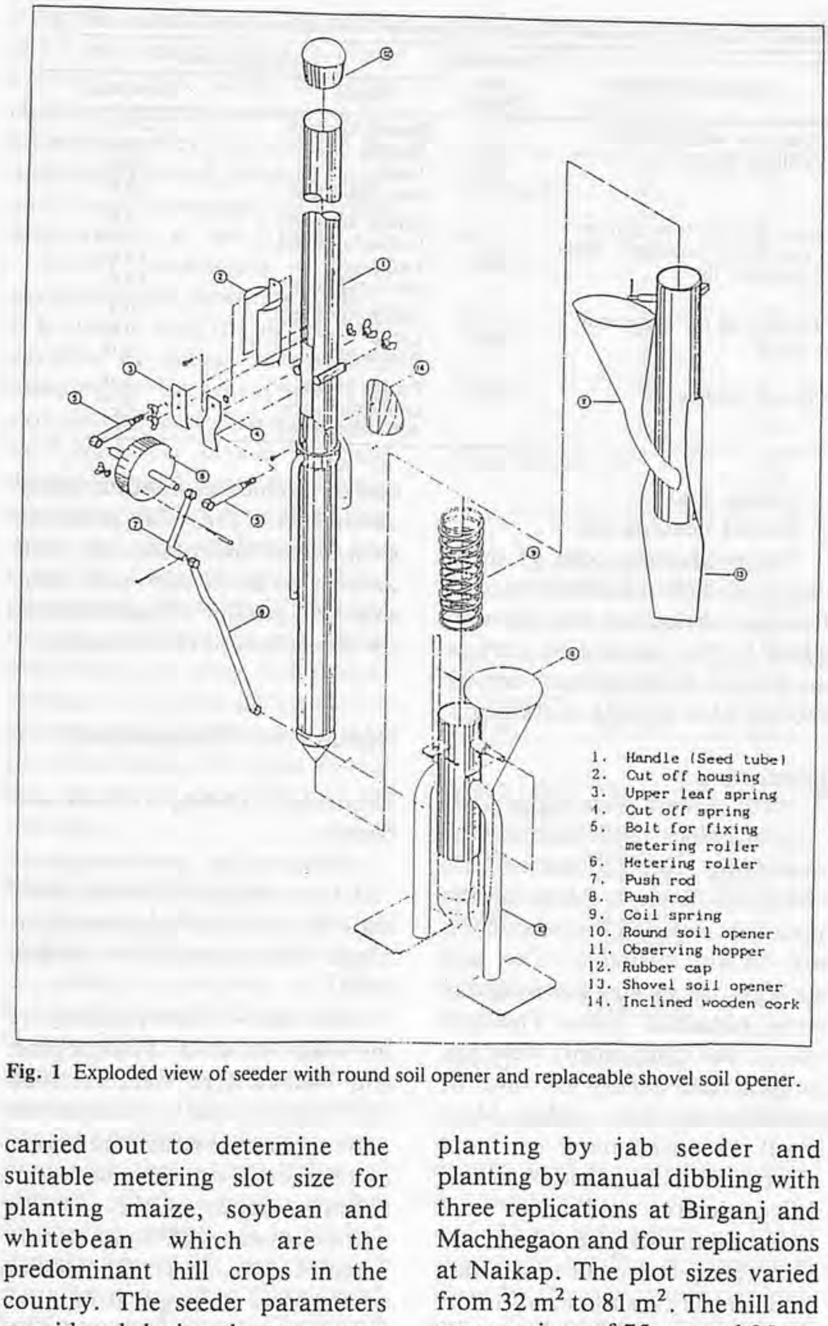

Fig. 1 Exploded view of seeder with round soil opener and replaceable shovel soil opener.

carried out to determine the suitable metering slot size for planting maize, soybean and whitebean which are the predominant hill crops in the country. The seeder parameters considered during the tests were: number of seeds delivered per stroke; uniformity of seed delivery; regularity of metering roller operation; and mechanical damage to seeds.

The field tests were conducted at three sites, namely, Birganj, Machhegaon and Naikap. The local variety of maize seeds with a germination percentage of more than 90% was used for planting. There were two treatments, viz. planting by jab seeder and planting by manual dibbling with three replications at Birganj and Machhegaon and four replications at Naikap. The plot sizes varied from 32 m^2 to 81 m^2. The hill and row spacings of 75 cm and 25 cm were maintained at Birganj. These spacings were 75 cm and 40 cm at Machhegaon and Naikap. The shovel type soil opener and depth regulator adjusted for 5 cm depth of planting were used for the field tests [2]. The metering roller had a semi-circular slot of 10 mm diameter. This slot size was found suitable from the laboratory tests. The field performance parameters considered were: labour requirement;seeding rate; seedling emergence; and ease of seeder operation.

The seeders were also distributed to farmers in different village *panchayats* in Kathmandu valley. These farmers used the seeders for planting maize and soybean in their fields. Information on seeder performance was collected from the users; and based on their feedback, the performance of the seeder was compared with that of the traditional method.

Manufacturing of Seeders

The seeders were manufactured at the Agricultural Tools Factory, Birganj, Nepal. The various activities undertaken in connection with the manufacture are presented below.

Design Modification

The design modification included changing the material used and development of seeder attachments. Keeping in view the local availability, changes were made in the materials used for fabrication of the seeders [3]. In order to improve the performance, a prototype was developed with the following attachments:

Depth regulator — A depth regulator made from steel sheet of 2 mm thickness was attached to the soil opener. This seeder has the advantage of adjusting the depth of planting in accordance with the crop and soil requirements. Uniformity in the depth of seed placement is also obtained with the depth regulator.

Fertilizer applicator — A fertilizer applicator was developed and mounted to the seeder. The attachment consisted of a metering roller and a hopper with a capacity of one litre. A metering slot 20 mm in diameter and 14 mm deep was made on the metering roller. The shafts of the fertilizer

Fig. 2 Prototype jab seeder showing the fertilizer application attachment.

metering roller and the seed metering roller were coupled by means of bush and pin arrangement. Thus, with the same action of the seeder, the seed and the fertilizer were metered and discharged simultaneously. During laboratory tests, the seeder delivered approximately 3.1 g of fertilizer per stroke. The attachment is shown in **Fig. 2**.

Production of Jigs, Fixture and Die

The jigs, fixtures and die produced are as follows;

a. Side tube welding-cum-milling fixture;
b. Seed delivery tube and up-and-down movement guide assembly jig;
c. Drilling jig for upper leaf spring; and
d. Shovel bending die.

The production costs of these devices and the machines required for the fabrication are given in **Table 1**. The fabrication devices are simple in design and can be fabricated in a small workshop.

Table 1 Machines Used and Production Costs for Fabrication of Jigs, Fixtures and Die

Fabrication device	Production cost (NRs.)	Machine used	
		Name	Time (min)
Side tube welding cum milling fixture	250	Power hacksaw	24.0
		Shaper	2.0
		Lathe	10.0
		Arc welding set	20.0
Seed delivery tube and up and down movement guide assembly jig	180	Power hacksaw	2.0
		Guillotine shear	3.0
		Lathe	15.0
		Arc welding set	10.0
Drilling jig for upper leaf spring	20	Guillotine shear	0.5
		Lathe	7.0
		Arc welding set	3.0
Shovel bending die	55	Power hacksaw	1.0
		Guillotine shear	0.5
		Arc welding set	3.0

Fabrication

Fifty seeders were fabricated. The machines used and cost of machining for fabrication are shown in **Table 2**. Most of the materials required for production are locally available. The leaf springs, coil springs and wing nut were obtained from Thailand since these components were not in local use during the time of manufacture of the seeders. Most small manufacturers or local workshops in Nepal have lathes, drills, electric welding set and other traditional machines. As such, the seeders can be manufactured locally using local tools, techniques and materials.

The cost of the seeder was NRs. 370 (US$13.5). The cost components are given in **Table 3**. The cost of production constitutes only about 76% of the selling price. As such, small manufacturers with lower overheads can earn considerable profits by undertaking the manufacture of the seeder.

Table 2 Machines Used and Cost of Machining for Fabrication of Jab Seeder

Name of machine	Time (min)	Cost (NRs.)
Milling machine	2.0	1.20
Power hacksaw	4.0	1.45
Bench drill	15.5	4.50
Lathe	17.0	8.85
Carpentry lathe	3.0	1.65
Guillotine shear	1.5	1.30
Arc welding set	30.0	23.70
Spray gun	10.0	3.00
Total cost of machining		45.65

Table 3 Cost Component of Jab Seeder

Component	Cost (NRs.)
Material	198.40
Machine	45.65
Labour	35.60
Total	279.65
Overhead @ 25% of production cost	69.90
Marketing and profit @ 5.5% of selling price	20.45
Selling price/unit	370.00

Results and Discussion

Laboratory Testing of Seed and Seeder

Germination percentage — All three varieties of maize seeds had well above 90% germination hence were selected for further tests.

Seed size — The majority of the maize seeds of Machhegaon and Naikap type were retained on 9 and 8 mm sieves, whereas the Arun type maize seeds were mostly retained on 8 mm sieve and pan. Likewise, much of the soybean and white bean seeds were held on 7 and 6 mm sieves. The maize seeds varied in length from 10.1 to 11.2 mm; in width, from 5.4 to 7.6 mm; and in thickness, from 4.3 to 5.2 m. Similarly, the white bean seeds ranged in length from

8.6 to 10.3 mm; in width, from 5.6 to 7.7 mm; and in thickness, from 4.3 to 5.2 mm. Based on these characteristics, the probable suitable metering slot sizes selected for maize seeds were 8, 10 and 12 mm, and those for soybean and white bean were 6, 8, and 10 mm.

Seeder parameters — These parameters are shown in **Table 4**. It is evident that for all the three varieties of maize, the suitable metering slot size was 10 mm. This slot size delivered an average of 2 to 3 seeds per stroke; standard deviation was 1.1 to 1.3; number of missing strokes per 100 strokes was 2 to 5 and breakage was less than 1%. Considering the above parameters, the suitable metering slot size for soybean and whitebean was 8 mm which delivered an average of 3.7 seeds per stroke for soybean and 2.8 seeds per stroke for white bean, which are almost the same as the traditional method.

Table 4 Results of Laboratory Tests of Seed Discharge with Different Sizes of Metering Slots

Seed (type)	Size of metering slot (mm)	No. of seeds/stroke	Standard deviation	No. of missing strokes/100 strokes	Breakage (%)
Maize (Machhegaon)	12	3.1	1.4	5	0.3
	10	2.2	1.1	5	0.8
	8	1.7	1.1	16	6.4
Maize (Naikap)	12	3.2	1.3	3	0.2
	10	3.0	1.3	3	0.3
	8	1.9	1.1	10	4.7
Maize (Arun)	12	3.7	1.4	2	0.1
	10	2.5	1.1	2	0.4
	8	1.9	1.3	17	4.7
Soybean	10	5.0	1.6	0	0.7
	8	3.7	1.6	0	1.5
	6	2.6	1.0	1	7.0
Whitebean	10	5.1	1.5	0	0.7
	8	2.8	1.2	0	0.9
	6	2.1	1.0	4	5.2

Table 5 Characteristics of Test Plots

Site	Texture	Moisture content (%)	Bulk density (g/cm³)	Cone penetration resistance (kPa) at depths (cm)				
				0	3.5	7.0	10.5	14.0
Birganj	Sandy loam	12.4	1.28	8	100	163	286	448
Machhegaon	Loam	22.7	1.17	110	274	453		
Naikap	Silt loam	7.7	1.08	11	175	279	455	815

Field Testing of Seeder

The field condition during planting is summarized in **Table 5**.

Labour requirement — **Table 6** gives the average labour required in man-h/ha at the varoius test sites. The figures in parentheses represent the labour requirement for the traditional method computed for the same number of hills/m^2 which is similar to that of the jab seeder. It is evident that planting by jab seeder ensured a saving of one-fifth to one-third in labour requirement. The labour requirement using seeder is significantly lower than the traditional method at 5% level of significance.

Seeding rate — The rates of seed use at various test sites are given in **Table 6**. The figures in parentheses indicate the seeding rate for the traditional method computed for the same number of hills/m^2 which is similar to that of the jab seeder. The difference in seed use rate, in general, is insignificant.

Table 6 Labour Requirement, Seed Use Rate and Seedling Emergence at various Test Sites

Site	Method of planting	Labour requirement (man-h/ha)	Rate of seed use (kg/ha)	No. of hills/m^2	No. of plants/hill
Birganj	Jab Seeder	87	37	4.9	1.6
	Traditional	127	25	4.3	1.2
		(143)	(29)	(4.9)	
Machhegaon	Jab Seeder	84	38	2.9	1.7
	Traditional	106	26	2.1	1.3
		(143)	(35)	(2.9)	
Naikap	Jab Seeder	40	35	3.1	1.2
	Traditional	59	34	2.8	1.2
		(67)	(39)	(3.1)	

Seedling emergence — **Fig. 3** shows the seedling emergence at Birganj after one month of planting. The average number of hills/m^2 and average number of plants per hill with the two methods of planting at the various test sites are given in **Table 6**. The number of hills per unit area and the number of plants per hill were higher with jab seeder due to a slightly higher seeding rate with the use of jab seeder vis-à-vis the traditional method.

Fig. 3 Seedling emergence at Birganj, Nepal.

Farmers' Feedback

The feedback about the seeder performance was collected from 17 farmers in four village panchayats in Kathmandu valley. These farmers had planted soybean as an intercrop with maize. The farmers who had planted the crops using their own local techniques were also contacted. The feedback received is summarized in **Table 7**.

Assuming 6 h of farm work per day, it is seen that the labour requirements for planting maize and soybean by jab seeder were 14 and 15 man-days/ha, respectively. Similarly, for planting by traditional method, the labour requirement/ha for maize was 21 man-days and for soybean, 23 man-days. This means a saving of 7 and 8 man-days, respectively, for planting 1 ha of maize and soybean. There was no significant difference between the seed rates of the two methods of planting. Assuming a labour wage rate of NRs. 25 per day, this saving amounts to NRs. 375. Hence, a farmer can recover the cost of the jab seeder by planting maize and soybean in just 1 ha of land.

The farmers commented that planting by jab seeder was easier compared to their traditional method. They did not have to bend or squat while planting hence, could work with the planter for a longer duration continuously. The planting speed in the beginning was slow for about 15 to 30 min but once the farmers got used to the seeder operation, they could work faster than the traditional planting speed. The farmers were of the opinion that the seeder was very useful for planting soybean. However, for planting maize, the metering slot size ought to be properly selected to suit the crop variety which they used. The farmers also suggested that the seeder should be equipped with a fertilizer application attachment since they preferred to plant seed and place fertilizer simultaneously during planting operation.

Table 7 Feedback Received from Farmers

Crop	Planting method	Labour required (man-h/ha)	Rate of seed use (kg/ha)	No. of hills/m^2	No. of plants/hill
Maize	Jab seeder	80	33	4.6	1.6
	Traditional	122	31	4.6	1.3
Soybean	Jab seeder	87	53	4.9	3.2
	Traditional	133	51	4.9	3.0

Conclusion

1. The jab seeder can be manufactured locally in Nepal using locally available tools, techniques and materials.
2. The depth regulator and the fertilizer applicator improved seeder performance.
3. The seeder saves about one-third in labour use and, consequently, improved the timeliness of operation.
4. The cost of the seeder can be recovered in one cropping planting 1 ha of land.
5. The seeder is convenient to use for both men and women and reduces drudgery by avoiding constant bending or squatting.
6. The seeder can be used as a multi-crop seeding device.
7. There is a good potential for adoption of the jab seeder in the hills of Nepal.

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ERRATA

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Effect of Plowing Depths Using Different Plow Types on Some Physical Properties of Soil

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Abstract

Field studies were conducted at the College of Agriculture and Telafar Experimental Station to study the effects of 10-15 cm and 15-20 cm depth plowing by mouldboard, disc and "chisel" plows on some physical properties of the soil. The results of plowing depths showed that the values of bulk density were significantly lower at 10-15 cm depth for both fields. Values of mean weight diameter (MWD) were significantly different at 10-15 cm depth in Field I, while opposite values were obtained in Field II. On the other hand, results of plow types show that disc and mouldboard plows gave significant difference in bulk density values at Fields I and II, respectively. Also, the results showed that chisel and mouldboard were significantly different in MWD values at both fields. Results indicate that the mean values of MWD for study areas were significantly different by using mouldboard plow.

Results of the interactions between plow types and plowing depths indicate that chisel plow at 10-15 cm depth gave significantly less bulk density. While the values of MWD at Field I with the mean values for both fields were significantly different by chisel plow at 10-15 cm depth and disc plow gave significant difference at the same depth for Field II.

On the other hand, the interaction between plowing depth for the two fields showed that significant difference in MWD and moisture content values at 10-15 cm and 15-20 cm depths for Fields I and II, respectively. The results of the interactions between plow types for each fields indicate that chisel and disc plows gave significant difference in MWD for Field I and the bulk density value was significantly different with disc plow for Field II. Finally, the interaction between plowing depths and plow types shows that chisel plow at 10-15 cm depth were significantly different in MWD and bulk density for Fields I and II, respectively.

Introduction

The effect of different plowing treatments on some soil physical properties is examined in terms of aggregate stability, bulk density and moisture content.

Aggregate Stability

Different plowing depths affect soil stability; either negatively or positively. The negative effect could be direct or indirect. On the other hand, the direct effect occurs when heavy machinery and equipment are passed over the soil due to compaction. On the other hand, the indirect effect occurs during the oxidation of organic matter which affects aggregate formation (Stalling, 1957).

The positive effect of plowing depth takes place — in land preparation during which plant residue is mixed with the soil that forms granular structure which improves soil aggregate (Fathallah, 1979).

The application of crop rotation is considered positive in effect, especially growing crops of effective root followed by other crops which form good structure (El-Gibaly and Nufaty, 1973). Unplowed soils at 2.5 cm depth and plowed soil by tine cultivator at depth of (5-8), (10-15) cm, respectively, showed higher values of aggregate stability than soils plowed by mouldboard plow at a depth of 15-25 cm (Douglas and Goss, 1982).

Aggregate stability of soils plowed by disc plow at 8-10 cm was less significant than unplowed soils (Hamblin, 1984).

Bulk Density

Bulk density is affected by plowing treatments directly and indirectly. Direct effect of plowing soil is pulverized, disturbed and its volume increased at which the bulk density is decreased. Indirect effect of plowing happens when heavy machinery and equipment pass over the soil which compacts it and its bulk density is increased.

Bhushan (1973) noticed that using both disc and rotary plows decreased the value of bulk density compared with unplowed soils. In 1973 Voorhees, Sensl and Nelson studied the effect of mouldboard and disc plows on silty clay soil. They concluded that soil compaction at 15-20 cm depth was reduced by using a mouldboard plow. The disc plow caused soil compaction directly below 20 cm depth.

Ellis (1982) studied the effect of plowing at 5-7 cm depth using a cultivator and 15-25 cm depth by using a mouldboard plow and compared with an unplowed fields on silty loam soil for seven years. He found that the bulk density for unplowed soil was different than both treatments. The difference was not significant for the first three years. However, the difference was significant for the last four years.

Moisture Content

Rainfall is not uniformly distributed in arid regions hence moisture content is an important factor in crop production during the growing season.

Hamblin and Tennant (1979) studied the effect of three tillage methods in two soil types (sandy loam and sandy clay loam) on moisture content. They noticed that the moisture content for the no-tillage method at 0-10 cm depth was significantly higher compared with the other methods in sandy loam soil. In sandy clay loam the differences were not significant. The moisture content were 0.28-0.38 cm^3/cm^3 for unplowed clay loam soil and 0.25-0.31 cm^3/cm^3 for plowed soil. This difference is due to the decrease of evaporation for unplowed soil (Gantzer and Blake, 1968).

Table 1 Maximum and Minimum Temperatures and Rainfall for the Study Areas, 1988-89

Month	Field I				Field II			
	Rainfall (mm)	max	min	mean	Rainfall (mm)	max	min	mean
November	1.1	16.9°	2.0°	9.7°	14.2	17.8°	0.6°	9.2°
December	84.3	15.8	4.6	10.2	81.4	13.3	0.5	6.9
January	9.4	11.5	0.1	5.7	5.9	10.1	0.2	5.2
February	23.5	16.7	1.6	8.8	30.6	13.9	1.9	7.9
March	126.0	21.2	8.3	14.8	108.2	20.1	9.3	14.7
April	0.0	28.2	13.0	21.7	3.7	20.2	12.3	16.3
May	8.5	35.2	17.9	26.0	0.0	34.4	19.7	27.1
Total	252.8				244.0			

Table 2 Some Soil Physical Properties in Study Areas

Study area	Depth (cm)	Particle size disturbution (%)				Bulk density g/cm^3	Particle density g/cm^3	Total porosity (%)
		Sand	Silt	Clay	Texture			
Field I	10-15	34.7	28.0	37.3	LC	1.24	2.66	53.4
	15-20	32.4	23.0	44.6	C	1.34	2.67	49.8
Field II	10-15	14.1	35.6	50.3	CL	1.23	2.65	53.6
	15-20	15.5	37.3	47.2	CL	1.29	2.66	48.5

Ellis (1982) found that the moisture content is increased significantly for 0-15 cm depth in no-tillage compared with plowed soil for 15-25 cm depth in silty loam soil. In 1984 Hamblin compared the moisture content of plowed soil using disc with the moisture content in unplowed soil. He noticed that higher moisture content at 0-50 cm depth for unplowed soil compared with the plowed soil.

Materials and Method

Field studies were conducted during 1988-89 at two locations. Field I was located at the College of Agriculture and Forestry while Field II was at Talafar Experimental Station.

Three kinds of plows were used in both locations (mouldboard, disc and chisel plows) to cultivate the soil at 10-15 cm and 15-20 cm depths. Soils for both locations were prepared for planting in the spring of 1988. The fields in both locations were divided into main plots measuring 3 m × 25 m. Split plot design was used and the first treatment represented the depth of cultivation (main plots). The second treatment was represented the kinds of plows which randomly disturbed (sub plots), (six treatments × two locations × three replicates). For this study, the maximum and minimum temperature and rainfall were recorded (**Table 1**). Moisture contents were determined for both fields immediately after cultivation and six months later (Black, 1965). Also, bulk density was determined for both locations and each treatment using the core method (Black, 1965). MWD was determined for both depths after cultivation (Black, 1965). The physical properties of the soil are shown in **Table 2**.

Results and Discussion

Aggregate Stability

The result of the present study shows significant differences in MWD for both locations (**Table 3**). Significant values for MWD were observed at depth of 10-15 cm (location I) and depth of 15-20 cm (location II) due to the variation of organic matter in both locations.

Bulk Density

Table 3 shows that the bulk density is significant at 10-15 cm depth compared with 15-20 cm for both fields. This is probably related to the decomposing plant roots at 10-15 cm depth by microorganisms.

Moisture Content

The data in **Table 3** shows that moisture contents are decreased gradually with time for each depths according to evaporation which in turn, related to the variation of climatological conditions for each locations. On the other hand, values of moisture contents after 6 months of plowing were significant at 15-20 cm depth for Field II. This is probably related to surface area which increased the moisture holding capacity (Bander, 1981).

Table 3 Effect of Plow Depth on Some Soil Physical Properties at Study Areas

Study area	Depth (cm)	MVD mm	Bulk density g/cm^3	Moitsure content (%) April 26, 1988	Oct. 29, 1988
Field I	10-15	1.45 a	1.24 a	9.7	2.3
	15-20	1.24 b	1.34 b	8.0	1.8
Field II	10-15	0.38 b	1.23 a	1.3	0.9
	15-20	0.65 a	1.24 b	1.4	1.6
Average for two fields	10-15	0.92 b	1.24 a	1.1	1.6
	15-20	0.95 a	1.32 b	1.1	1.7

Table 4 Effect of Plow Types on Some Soil Physical Properties at Study Areas

Study area	Plow Type	MVD (mm)	Bulk density g/cm^3	Moisture content (%) April 26, 1988	Oct. 29, 1988
Field I	Mouldboard	1.33 c	1.31 b	12.5	2.0
	Chisel	1.36 a	1.33 c	18.0	2.8
	Disc	1.35 b	1.24 a	10.0	2.2
Field II	Mouldboard	0.56 a	1.24 a	12.1	1.2
	Chisel	0.47 c	1.31 c	14.2	1.3
	Disc	0.52 b	1.25 b	13.7	1.4
Average	Mouldboard	0.5 a	1.28 b	12.3	1.6
	Chisel	0.91 c	1.32 c	16.1	2.1
	Disc	0.93 b	1.24 b	11.9	1.8

Table 5 Effect of Plowing Depths and Plow Types on Some Soil Physical Properties

Study field	Plowing depth	Plow type	MVD (mm)	Bulk density g/cm^3	Moisture content (%) April 26, 1988	Oct. 29, 1988
Field I	10-15	Mouldboard	1.39 b	1.240 c	9.61	2.10
		Chisel	1.60 a	1.242 bc	9.60	2.40
		Disc	1.36 c	1.239 c	10.00	2.40
	15-20	Mouldboard	1.27 e	1.383 e	9.00	1.80
		Chisel	1.11 f	1.410 e	9.60	1.90
		Disc	1.34 d	1.238 c	7.00	1.70
Field II	10-15	Bouldboard	0.37 d	1.234 d	12.10	0.80
		Chisel	0.49 b	1.208 a	13.40	1.20
		Disc	0.28 e	1.256 b	13.80	0.80
	15-20	Mouldboard	0.75 a	1.240 c	12.10	1.60
		Chisel	0.45 c	1.402 e	15.00	1.40
		Disc	0.75 a	1.240 c	13.50	1.90
Average of two fields	10-15	Mouldboard	0.88 c	1.237 cd	10.90	1.50
		Chisel	1.05 a	1.225 d	11.50	1.80
		Disc	0.82 d	1.248 c	11.50	1.60
	15-20	Mouldboard	1.01 b	1.312 b	10.60	1.70
		Chisel	0.78 e	1.306 e	12.30	1.70
		Disc	1.04 a	1.239 cd	10.30	1.80

Aggregate Stability

Data in **Table 4** indicate that there is a significant difference in MWD for chisel plow compared with other plows at Field I, while the value of MWD is low for the mouldboard plow. This could be explained by the disturbed subsurface soil to surface and vice-versa by using both mouldboard and disc plows. On the other hand, values of MWD is significant for mouldboard plow at Field II. This is probably related to the formation of big clods at this field. These results are similar to the results obtained by Bhusham (1973) and Unger (1984).

Bulk Density

Lower values of bulk density were obtained using the disc plow compared with high values obtained by using the chisel plow in Field I (**Table 4**). The data also indicates low values were obtained using mouldboard and higher values by chisel at Field II. This is because the mouldboard plow turns over the soil and lowers the value of bulk density. In comparison, the chisel plow disturbs the soil and gives higher value (Bhushan, 1973).

Moisture Content

Effect of plowing Depth and Plow Types on Soil Physical Properties. **Table 5** shows higher significant in MWD at 10-15 cm depth with chisel plow for Field I compared with Field II. Also, the mouldboard and disc plows gave lower values for bulk density at 10-15 cm and 15-20 cm depths for Fields I and II, respectively. Values of moisture contents were not significant for each depth and plow type.

Field I gave high significant value of MWD at 10-15 cm depth compared with Field I (**Table 6**), while there was no significant difference in bulk density at each depth and location. In contrast, results of moisture content tests

Table 6 Effect of Plowing Depths on Some Soil Physical Properties at Study Fields

Study field	Plowing depths (cm)	MVD (mm)	Bulk density (g/cm³)	Moisture content (%)	
				April 26, 1988	Oct. 29, 1988
Field I	10-15	1.45 a	1.24	9.70 bc	2.30 a
	15-20	1.24 b	1.34	8.50 c	1.80 b
Field II	10-15	0.38 d	1.23	13.10 a	0.90 a
	15-20	0.65 c	1.29	13.50 a	1.60 a

Table 7 Effect of Plow Types on Some Soil Physical Properties at Study Fields

Study fields	Plow type	MVD (mm)	Bulk density (g/cm²)	Moisture content (%)	
				April 26, 1988	Oct. 29, 1988
Field I	Mouldboard	1.33 b	1.312 d	12.50	2.00
	Chisel	1.36 a	1.326 d	18.00	2.80
	Disc	1.35 a	1.239 b	18.00	2.20
Field II	Mouldboard	0.56 c	1.237 b	12.10	1.20
	Chisel	0.47 e	1.305 c	14.20	1.30
	Disc	0.52 d	1.248 ab	13.70	1.40

Table 8 Effect of Plowing Depths, Plow Types and Study fields on Some Soil Physical Properties

Study fields	Plowing depths (cm)	Plow type	MVD (mm)	Bulk density (g/cm³)	Moisture content (%)	
					April 26, 1988	Oct. 29, 1988
Field II	10-15	Mouldboard	1.39 b	1.240 b	9.66	2.70
		Chisel	1.60 a	1.242 a	9.60	2.40
		Disc	1.36 c	1.239 b	10.00	2.40
	15-20	Mouldboard	1.27 e	1.382 d	9.00	1.80
		Chisel	1.11 f	1.410 e	9.60	1.90
		Disc	1.34 d	1.238 b	7.00	1.70
Field II	10-15	Mouldboard	0.37 g	1.234 b	12.10	0.80
		Chisel	0.49 h	1.208 a	13.40	1.20
		Disc	0.28 i	1.256 c	13.80	0.80
	15-20	Mouldboard	0.75 j	1.240 b	12.10	1.60
		Chisel	0.45 k	1.402 d	15.00	1.40
		Fisc	0.75 j	1.240 b	13.50	1.90

indicate that Field I gave significant values at 10-15 cm and 15-20 cm depth after 6 months of plowing and the same results were obtained after a few days of plowing in Field II.

Table 7 indicates significant differences in MWD with disc and chisel plows at Field I and with disc plow only at Field II. Also, the results of bulk density is highly significant with disc plow at Field I compared with Field II.

Chisel plow at 10-15 cm depths give significant difference in MWD and bulk density at Fields I and II, respectively, as shown in **Table 8**. However, the results of moisture contents analysis were not significant for both study fields **(Table 8)**.

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Development and Testing of A Power Tiller-operated Boom Sprayer

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Abstract

A power tiller-operated boom sprayer was developed for spraying groundnut and other crops planted in rows. Tests were carried out on the developed sprayer both in the laboratory and in the field. The spray boom has seven hollow cone nozzles, placed 50 cm apart. It has a swath width of 3.5 m for a speed of 2.25 km/h. In comparison, the cost of operating the boom sprayer showed 29% reduction in cost compared with the hand compression knapsack sprayer.

Introduction

Crop yield is reduced by 40% mainly due to attack of pests, diseases and weeds. Chemical control is the popular method adopted for controlling most insects, weeds and diseases. The chemicals are applied either by spraying or dusting. Spraying is one of the most effective and efficient techniques for applying small volumes of spray liquid to protect crops. A power tiller-operated boom sprayer has been developed to produce uniform spray pattern using minimum amounts of spray material.

In Orissa 74% of the farmers are under small and marginal categories and they farm only 38% of the cultivable land. Due to small and scattered farms the farmers mainly depend upon draft animals inspite of their high maintenance cost. The initial investment on tractor is very high which is beyond the reach of a common farmer. Hence, power tillers were introduced in the State of Orissa with Government subsidy. In order to render power tillers more versatile, a power tiller-operated boom sprayer was designed and developed for effective spraying operation in crops planted in rows.

Materials and Methods

This sprayer consists of a roller-vane pump of size 25 mm × 25 mm as shown in **Fig. 1**. The

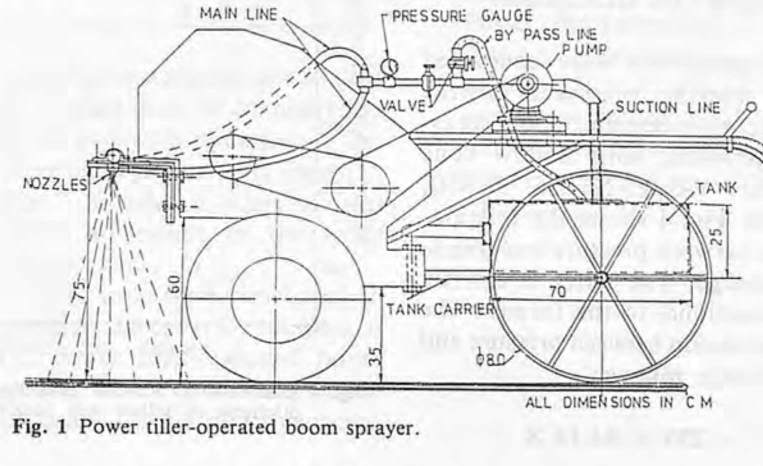

Fig. 1 Power tiller-operated boom sprayer.

pump was placed on the main frame of the power tiller which is 60 cm in front of the operator's position. It was rigidly mounted to the power tiller with the help of a frame and bolts. The pump was operated by the power tiller clutch pulley through a V-belt transmission. A 30 mm flexible hose pipe with filters carries spray liquid from the tank kept on the tank carrier to the pump inlet. On the discharge line one by-pass line with pressure regulator was also provided to reduce the discharge and pressure on the nozzle. On the main line one pressure gauge of range 0-10 kg/cm^2 was also provided before the boom. The set up is shown in **Figs. 2** and **3**.

The supply of liquid to the boom is given at two points on the boom for getting uniform discharge from all nozzles. The nozzles were mounted on a flexible hose pipe of 8 mm internal diameter. The flexible hose pipe was clamped to a rigid G.I. pipe of diameter 13 mm. The spacing between nozzles on the boom could be adjusted by means of clamps. This boom was mounted on the front of power tiller at a height of 75 mm from ground and 30 cm in front of the power tiller with the help of a suitable frame. The specifications of the machine are given in **Table 1**.

Fig. 2 Power tiller-operated boom sprayer.

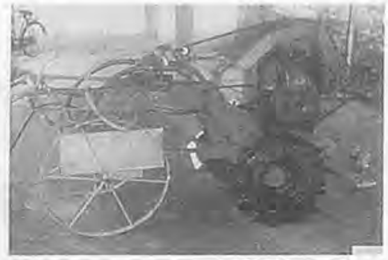

Fig. 3 Power tiller-operated boom sprayer (side view).

Table 1 Specifications of the Power Tiller-operated Boom Sprayer

Power source	National power tiller 6.5 hp
Type of pump	Roller-vane pump
Swath width of boom	3.5 m
Boom discharge	3.15 ℓ/min at 3 kg/cm^2
No. of nozzles	7
Type of nozzle	Hollow cone, Aspee
Spacing	50 cm (adjustable)
Overlap of spray	14%
Tank capacity	100 ℓ

Results and Discussion

Experiments were conducted for varying pressures on the power tiller-operated boom sprayer provided with hollow cone nozzle (Aspee-NMDS 50 450, 30N). **Fig. 4** shows the relationship between pressure and nozzle discharge. The latter is directly proportional to the former. The relationship between pressure and discharge follows:

$$Y = 270 + 64.14\,X$$

Y = discharge in cc/min

where,

X = pressure in kg/cm^2

Fig. 5 illustrates the relationship between pressure and cone angle, where cone angle is the angle subtended at the orifice by the edge of the spray pattern. This angle is formed due to tangential axial velocity component of the fluid coming out of the nozzle. Cone angle increases with an increase in pressure as shown by the following equation:

$$Y = 52.27e^{0.042X}$$

Y = cone angle in degree

where,

X = pressure in kg/cm^2

The nozzle spray distribution was observed for three pressure settings in the patternator. The distribution is shown in **Fig. 6**. At higher pressure of 3 kg/cm^2 and 4 kg/cm^2 it shows more even distribution than that of 2 kg/cm^2 pressure. The total liquid collected in all tubes of the patternator in 1 minute was less at higher pressure due to drift and evaporation of the fine particles.

The droplet size of the selected nozzle studied at various pressure and volume mean diameter (VMD), number mean diameter (NMD) and uniformity coefficient (UC) were calculated and shown in the **Table 2**.

A decrease in particle size (VMD) is attained by increasing the pressure, and uniformity coefficient at 2 kg/cm^2 and 3

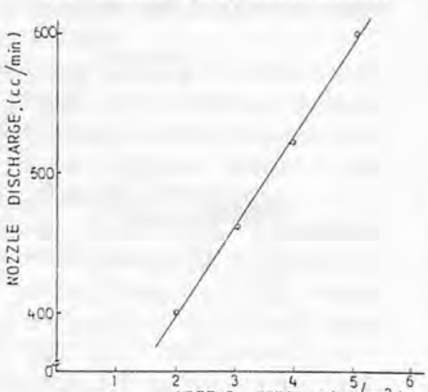

Fig. 4 Relationship between pressure and discharge of hollow cone nozzle.

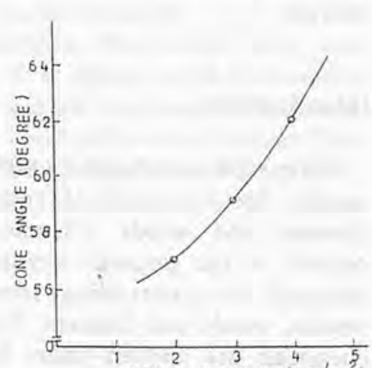

Fig. 5 Relationship between pressure and cone angle of hollow cone nozzle.

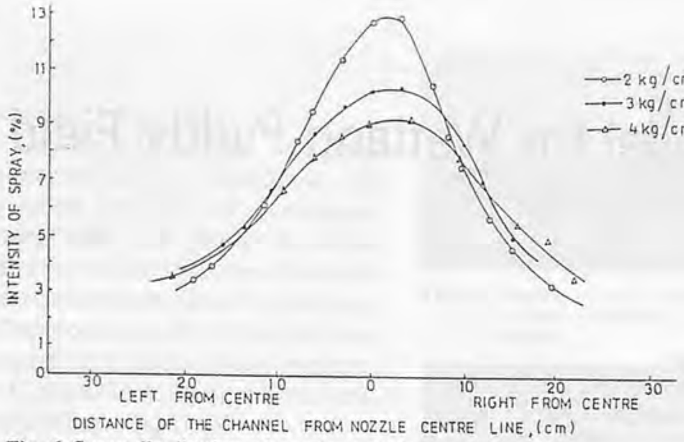

Fig. 6 Spray distribution of nozzle at different pressure.

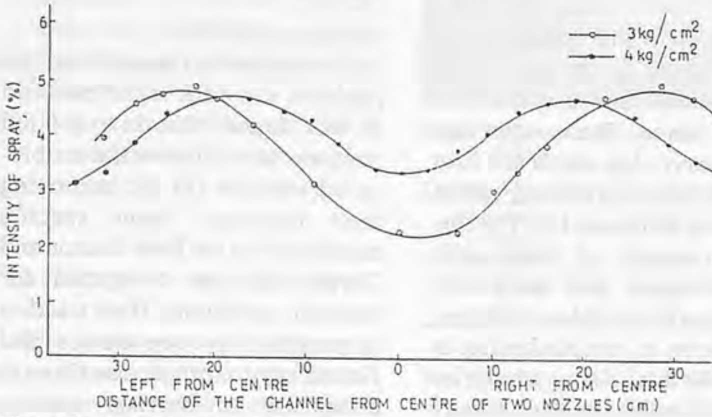

Fig. 7 Spray distribution of two nozzles.

Table 3 Individual Nozzle Discharge on Various Discharge Pressures

Discharge pressure kg/cm²	Discharge from each nozzle cc/min 1	2	3	4	5	6	7	Average discharge	C.V. among nozzles	Total discharge of boom ℓ/min
2	395	410	390	380	395	400	390	394.3	2.18	2.76
3	455	570	460	450	455	460	450	457.1	1.42	3.2
4	535	545	530	520	535	540	530	533.5	1.39	3.753

Table 4 Cost Comparison of Power Tiller-operated Boom Sprayer with 9 ℓ Hand-compression Sprayer

Item	Power tiller-operated boom sprayer with power tiller	Hand-compression sprayer
Initial cost	Rs.30,350	Rs.950
Field capacity	0.65 ha/h	0.08 ha/h
Cost of operation/h	Rs.21.44	Rs.3.45
Cost of operation/ha	Rs.33.50	Rs.43.12

kg/cm² were better than that of the 4 kg/cm² pressure.

The individual nozzle discharges on the boom were tested at various pressure levels and their performance is shown in **Table 3**. The pump speed during the test was 950 rpm. It was observed that the coefficient of variation among nozzles was within 2% for pressures at 3 kg/cm² and 4 kg/cm².

The spray distribution from the boom for two nozzles was studied by keeping them 50 cm apart and 50 cm above the patternator. The observed distribution is shown in **Fig. 7**. Nozzles at 4 kg/cm² was better in regards to the spray distribution.

Field tests were conducted to compare the cost of operation of the power tiller-operated boom sprayer with a hand compression knapsack sprayer of 9.1 capacity.

Table 2 Droplet Size Analysis for Nozzle at Different Pressure

Pressure (kg/cm²)	VMD (μM)	NMD (μM)	UC = VMD/NMD
2	240	115	2.1
3	232.5	110	2.1
4	225	95	2.3

The cost comparison is shown in **Table 4** showing a 29% savings in cost of operation per ha. In addition, the time required to spray 1 hectare by the power tiller-operated boom sprayer was only 1.53 h while the hand-compresion knapsack sprayer took 12.5 h to spray the same area of ha.

Conclusion

The effective field capacity of the sprayer was 0.65 ha/h. for a power tiller speed of 2.25 km/h. The performance of the power tiller-operated boom sprayer was satisfactory at a pressure of 3 kg/cm² and can be adopted by the farmers for spraying row crops as it saves the cost of operation per ha by 29% vis-à-vis knapsack hand-compression sprayer.

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Air Cushion Vehicle Model for Wetland Paddy Field

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Abstract

The problem of sinkage of machinery, poor trafficability and compaction of soil in wetland paddy field has stimulated new interest in air cushion vehicle (ACV). This vehicle has the ability to travel unimpeded over a variety of difficult surfaces whose load-bearing properties make it difficult for other vehicles to move.

This paper describes the selection of ACV model and its cross-section suitable for wetland paddy field. The developed prototype ACV required a total power requirement of 5.1 kW. Test showed that it caused neither any soil compaction nor any water splash while operating in the flooded soil condition. This proved the suitability of operating an ACV in wetland paddy field.

Introduction

The world's urgent need is to raise agricultural production to meet the food demands of a growing population. With the limitation of land this can be achieved only by increasing cropping intensity which is possible by farm mechanization.

But mechanization in rice cultivation is limited by its physical environment. Rice, which is the staple food of approximately one-half of the world's population is mostly grown and consumed in Asia. It grows particularly well when the soils are in a shallow, flooded state. These soils are usually heavy clay which are firm when dry but progressively soften as flooding continues (1). The low bearing capacity of these soils creates traction and machinery immobilisation problems limiting the adoption of mechanization in rice producing Asian countries (2). Considerable time and energy are lost in attempting to cultivate in these soft soils. The drudgery involved as well as the difficulty of using tillage machinery in soft, boggy fields have led farmers to either underutilize or completely abandon the cultivation of some riceland.

Therefore, a suitable traction device is necessary for mechanizing these areas, as the physical environment of the wetland area places certain demands on the design and capabilities of machinery to be used for cultivation.

So far, machines designed for dryland cultivation are used for wetland cultivation with some attachments like cage wheels, tracks, strakes, etc. (3 & 4) where both traction and flotation are provided by the same device. Though the cage wheel seems to be a suitable traction device, their accumulated use due to increase in cropping intensity causes the hard pan to deepen. This adversely affects the soil condition and the tractor will have poor tractive efficiency (5 & 6).

Considerable research on this problem was done in the past and it was found that low ground pressure can improve the mobility of vehicles (7) by improving their flotation. Some specific machines like the Boat tractor and Turtle tiller are developed for wetland operations. Here traction is provided by one device and flotation by another, exactly as in a ship. But low-bearing capacity, poor field levelling and uncontrolled water depth limit their performance. However, they are suitable for flooded fields. The major difficulty associated with these vehicles is their transportation from one place to another. They need some modifications before they can be accepted by the South-East Asian farmers.

Taking into account the above problem, it is felt worthwhile to make an investigation of a new device.

Since air cushion vehicle has low contact pressure 2-3.3 kPa (8) as compared to 85-250 kPa for most standard tractors (1) and unlike most other ground supported modes of movement, it requires no contact for traction and is able to move freely on any difficult surface while supported on a self-generated cushion of air. This capability offers potential solution to a variety of transportation problems on terrain. Hence, this vehicle may be used to overcome the above mentioned problems in wetland paddy field.

In the past, effort has been concentrated in developing air cushion vehicles for over-water operations. No work has been done so far on this type of vehicle in relation to wetland operations. Therefore, a study of this type was undertaken at the Asian Institute of Technology, Bangkok with the following objectives:

(i) Selection of type of ACV suitable for wetland paddy field soil conditions.
(ii) Selection of suitable cross-section of ACV.
(iii) Design and development of a prototype ACV based on the test results of ACV models.

Fig. 1a Models of air cushion vehicle, plenum chamber type AVC models.

Fig. 1b Models of air cushion vehicle, peripheral jet type AVC models.

Table 1 Particle Size Distribution and Atterberg's Limits

Particle size Distribution	
Clay	47%
Silt	38%
Sand	15%
Consistency Limits	
Liquid limit	46%
Plastic limit	24%
Plasticity number	22

Fig. 2 Pulling mechanism used for ACV models.

Table 2 Measured Soil Properties

Moisture content (%)	Cohesion (kPa)	Angle of internal friction (deg)	Specific weight (g/cm^3)	Average cone index (kPa)
46	7.04	5.81	1.78	33.95
67	3.46	3.02	1.45	23.15

Test Program and Methods

The two most commonly used air cushion vehicles for sea transportation are the Plenum Chamber type (PCT) and Peripheral Jet type (PJT). Models of these two types of ACV were selected for testing in wetland paddy field soil conditions. They were fabricated from mild steel sheet of dimension 300 × 300 mm (**Fig. 1**) and were tested in the soil bin (12 000 × 800 × 250 mm) at three different soil conditioons (46%, 67% moisture content (db) and in the flooded condition). Each model was supplied with air (2 kPa) at the rate of 32 m^3/h from a compressor through a flexible pipe and was pulled by a 24 V dc motor (18 rpm, i.e., 100 mm/min). Forces required to pull the model without air supply and with air supply for different soil conditions were measured with the use of a load cell mounted in the vehicle which was moved by the motor with the help of a belt and pulley (**Fig. 2**). The output signals coming from the load cell through a Wheatstone bridge were amplified by a strain amplifier. The amplified signals were plotted with the help of an X-Y plotter. All the models had the same dimensions and they were supplied with the same pressure and volume of air. Conclusions drawn from this study were not affected by these parameters. The total weight of each model (weight of the model + external weight) was 108 N. Each test was repeated three times for each model to obtain a reasonable average value of drag force for a given moisture content.

After selecting the type of ACV, its cross-section suitable for wetland paddy field soil conditions was determined by comparing the drag forces between the square and rectangular (1 : 1.6) cross-section of the same cushion area (0.09 m^2), for a given cushion pressure and volume of air.

All the experiments were conducted in a soil bin using Bangkok clay soil. The various soil properties are listed in **Table 1**. On each occasion after adding the desired quantity of water, the soil was manually kneaded and refilled into the bin. After the desired moisture content and cone index were reached, the tests were conducted. Preparation of soil to produce absolutely the same condition for each test run was not a simple task. Moreover, it is an art. However, a fixed procedure was adopted every time the soil was prepared so that the soil properties remained more or less the same. The average values of cone index and cohesion for different soil conditions are given in **Table 2**.

The prototype ACV was fabricated based on the test results obtained from the 1st phase of experiment (ACV models) with a base area of 2.4 m^2. An axial flow fan was placed exactly at the center to supply air and was powered by the diesel engine with the help of belt and pulley (**Fig. 3**). The prototype ACV was tested in the soil bin (18 000 × 2 500 × 1 000 mm) for determining the power requirement and height of lift from the soil surface (without forward movement) with the help of a torque transducer mounted on the shaft of the fan and two linear voltage displacement trans-

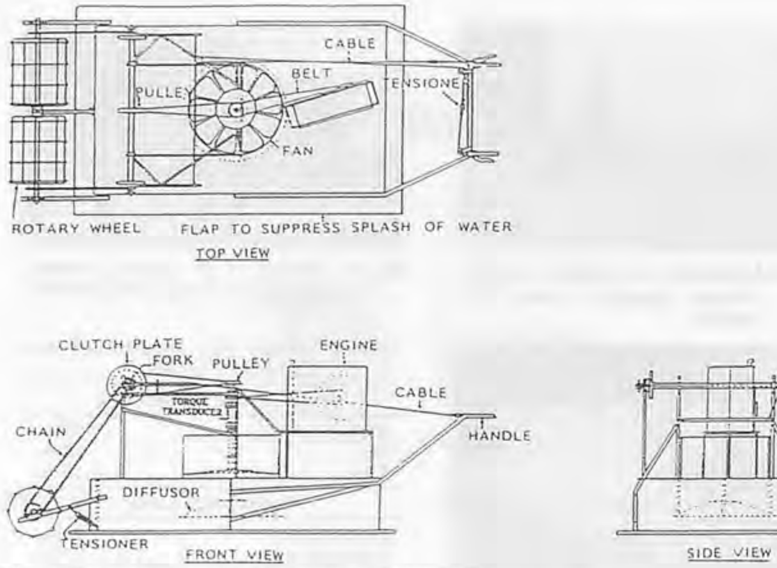

Fig. 3 Air cushion vehicle for wetland paddy field.

Fig. 4a Funnel attached to the PCT ACV to reduce depression on the soil surface.

Fig. 4b Foot prints of PCT ACV model without and with funnel.

ducers mounted at two ends of ACV, respectively. Then the prototype ACV was tested in the soil bin to determine the drag force with and without supply of air to propel the ACV in wetland paddy field soil conditions. The soil in the bin was prepared with the use of a rotavator operated by the soil bin carriage. After rotavating the soil it was levelled, covered and allowed to get the desired soil strength and soil moisture level. The ACV was pulled by the soil bin carriage and the force required to pull the ACV at a speed of 1.5 km/h was determined with the use of two load cells mounted at the front of the ACV. The signals coming from the load cell through strain amplifier were plotted by an X-Y plotter. The total drag force was then calculated by summing up the two forces measured by the two load cells.

Results and Discussion

The drag force of ACV models was measured for both cases when air was not supplied and supplied at three different soil conditions (46%, 67% moisture content (db) and in flooded condition) to determine the effect of air cushioning. While testing, it was seen that in the case of Plenum Chamber Type ACV model, the pressure of air was concentrated at the centre resulting in depressions and cracks on the soil surface. In order to overcome this problem, air has to be distributed for which a funnel-like structure with screens was attached to the Plenum Chamber type ACV model **(Fig. 4a)** for uniform distribution of air. Tests showed that it did not make any depression further on the soil surface. **Fig. 4b** shows the foot prints of PCT ACV model without and with funnel.

Fig. 5 shows a comparison of maximum drag force of ACV models for three different soil conditions. From the data obtained for the drag force, it was found that when the moisture content was 46%, the reduction in drag force when air was supplied was a round 67% for both models. When the moisture content was 67% the reduction in drag force were 68% and 54% for Plenum Chamber and Peripheral Jet type ACV models, respectively. This variation was due to the fact that for the Plenum Chamber type, bulldozing effect was greater as it sank more in the soil in comparison to the Peripheral Jet type when there was no supply of air. In the case of the flooded condition (standing water of 20 mm), the reduction in drag force was 56% for both models. There was no significant difference in reduction of drag force between the models except at 67% moisture content. At this m.c. the difference is significant at 95% confidence interval. Hence, of these two ACV models, the Plenum Chamber type was selected for further experiments because of the simplicity in construction.

Fig. 5 also indicates that as the moisture content of the soil increased the drag force of both models decreased. This was due to the decrease in adhesion with the increase in soil moisture. In the case of the flooded condition the drag force was further reduced because water acted as a lubricant between the lower surface of the models and soil.

While testing in the flooded condition the problem of water spray arose. An attempt was made to overcome this problem by putting thin plates around the periphery of the ACV model **(Fig. 6)**. Tests showed that this not only reduced the spray of water but also gave some additional lift thereby causing further reduction in drag **(Fig. 7)**. This happened because water escaping from the periphery of the model struck the thin plate with a certain force resulting in further lift.

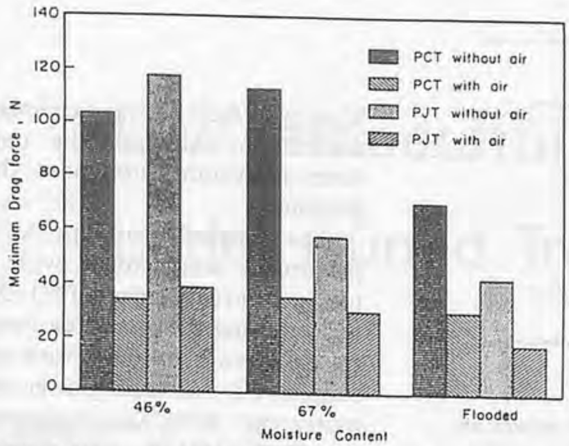

Fig. 5 Comparison of maximum drag force of ACV models.

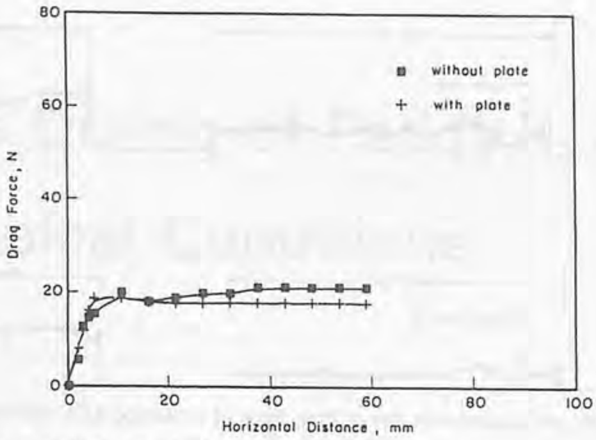

Fig. 7 Reduction in drag force with attached plate.

Fig. 6 This plates attached along the periphery of ACV model to reduce water spray.

For selecting the suitable cross-section of ACV, two models of Plenum Chamber type ACV (one with square and the other one with rectangular cross-section) were fabricated and the drag force was measured for both models of similar weight when they were supplied with same pressure and volume of air at three different soil conditions. **Fig. 8** shows the comparison of maximum drag force between the two models for different soil conditions. This figure indicates that difference in drag force is significant between the two models (at 99% significance level), i.e., the drag force of rectangular cross section is lower than that of square one. This was due to the fact that both models were not fully lifted from the soil surface. At some points there was contact between lower surface of the model and the soil surface. For the square cross-section the width of the model coming in contact with the soil was greater than the width of the rectangular one. Thus friction between soil to metal as well as soil to rubber (skirt attached to the lower surface of the model) was greater, hence drag force was greater also. From this figure it can also be seen that the difference in drag force decreased with an increase in soil moisture. This was due to the reduction in adhesion of soil resulting in reduction of friction.

Based on the test results, a prototype ACV (Plenum Chamber type) of rectangular cross-section was fabricated with a base area of 2.4 m^2. **Fig. 9** shows the power requirement, height of lift and cushion pressure of prototype ACV at different rpm of the fan. This figure indicates that both power requirement and height of lift increased with an increase in fan rpm.

The drag force of the developed prototype ACV was measured in the soil bin at 46%, 67% m.c. (db) and in the flooded condition by pulling the ACV with the soil bin carriage at a speed of 1.5 km/h without and with air supply (at a fan rpm of 2 300). **Fig. 10** shows an example test run. The drag force together with power requirement without and with air supply is given in **Table 3**. From this table it can be seen that the drag force

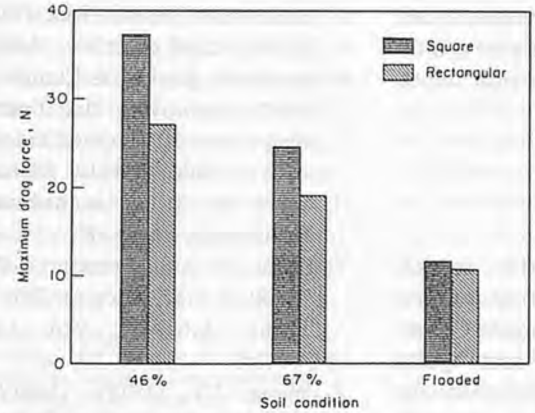

Fig. 8 Comparison of maximum drag force for selection of suitable cross-section of ACV for wetland paddy field soil conditions.

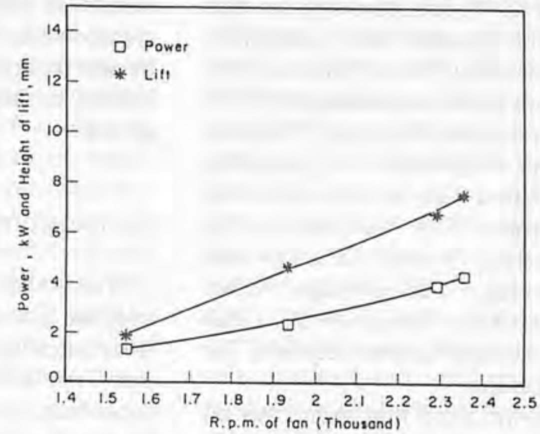

Fig. 9 Power requirement, height of lift and cushion pressure of prototype ACV at different fan rpm.

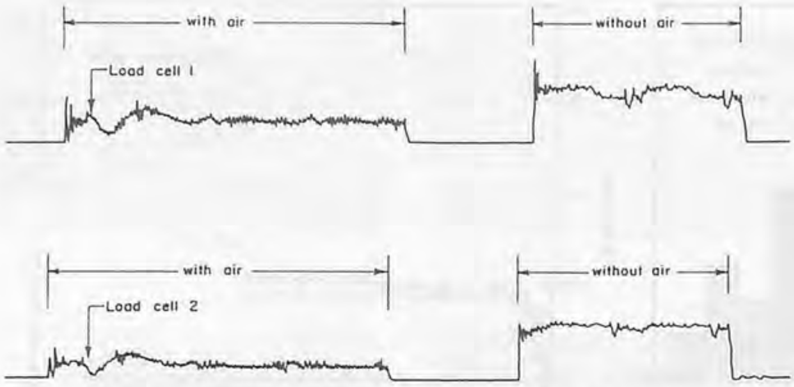

Fig. 10 Example test run of drag force of prototype ACV with and without air.

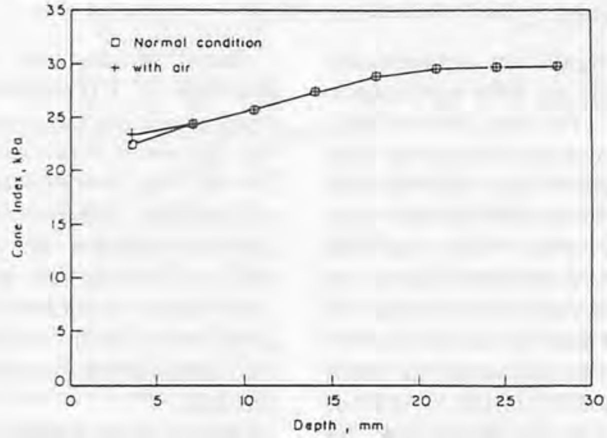

Fig. 11 Cone penetrometer reading after the operation of ACV.

Table 3 Drag Force and Power Requirement of Proty-type ACV

Soil m.c.	Drag force with rotary wheel		Reduction	Power requirement for		
	without air	with air		lifting	propelling	Total
(%)	(kN)	(kN)	(%)	(kW)	(kW)	(kW)
46	5.0	1.8	64.7	4.3	0.8	5.1
67	4.0	1.3	67.5	4.3	0.5	4.8
Flooded	2.5	0.8	60.7	4.3	0.3	4.6

with air supply was reduced by 643%, 67.5% and 60.7% than when there was no air supply for 46%, 67% moisture content and in the flooded soil condition, respectively. For all the soil conditions power requirement for lifting remained the same. Whereas power requirement for propelling decreased with an increase in soil moisture. This was due to the reduction in soil cohesion and adhesion. The average power required for lifting was 9.4 times the average power required for propelling.

It was seen that there was no water spray while the prototype ACV was operated in the flooded condition. Tests were performed using the standard cone penetrometer to determine the relative degrees of compaction. Example results of penetrometer readings are shown in **Fig. 11** where it can be seen that the compaction is only limited to the top 30 mm depth of soil.

Conclusions

The tests on ACV models indicate that though both models were suitable, the Plenum Chamber Type ACV with rectangular cross-section was preferred for wetland paddy field soil conditions because of the simplicity in construction. For the peripheral jet type ACV, it was extremely difficult to maintain the uniform jet width throughout the periphery.

The designed prototype ACV performed satisfactorily with a total power requirement of 5.1 kW and reducing the total drag force on an average by 60% with air supply. Of this total power requirement, 89% was consumed for lifting and 11% was required for propelling. Tests showed that there was absolutely no compaction and that in the case of the flooded condition, there was no water spray.

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Low-temperature Drying of Paddy under Humid Tropical Conditions

by

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Abstract

A low-temperature drying system for paddy consisting of a rectangular bin, an air sweep floor for air distribution and unloading, an electric heater and a centrifugal fan was tested during the rainy season in the Philippines during 1989 and 1990. The investigations showed that even during humid tropical weather conditions a layer of paddy up to 2 m thick can be dried from an initial moisture content as high as 27.5% w.b. in one step to a safe storage level. The bin, which is 1.8 m wide, 2.5 m long has a maximum capacity of 5 tons at a bulk depth of 2.0 m, allows the yield of 1 ha to be dried within 6 days. Low air flow and the use of a high efficient fan for forcing the air through the bulk yield the extremely low power requirement of 40 Watt per m^3 of grain. Under humid tropical conditions, slightly pre-heating the ambient air of 6 to 9 K is urgently needed at night in order to prevent spoilage of the crop. Compared to high temperature drying the specific heat consumption is considerably lower. Low-temperature drying makes this process weather independent and in combination with an efficient thresher it can reduce losses significantly. In terms of milling quality, discolouration and germination rate, paddy dried with low temperature was of premium quality according to Philippine quality standards. A significant increase of fungi, which could cause mycotoxin, was not detected.

The low-temperature drying system can be modularized for maximum flexibility. It can be easily adapted to the required capacity and reduces labour input considerably. Introduction to farmers or cooperatives would involve replacing the electric heater by a biomass furnace or a solar heater and using locally available materials in the construction of the dryer. Multi-purpose use for drying commodities other than rice increases the profitability of the system.

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Introduction

The traditional post-harvest system for paddy in humid tropical countries includes manual harvesting by sickle, pre-drying of the bundled and piled crop in the field followed by sundrying on mats or paved surfaces after threshing. While sundrying is the cheapest and, therefore, most common drying method it has certain disadvantages such as non-uniform drying, increased susceptibility to breakage, losses due to birds and rodents, contamination with foreign materials and pathogenic germs like coli and salmonella, insects and lead, soot and polycyclic aromatic carbohydrates from the exhaust fumes of cars. Furthermore, sundrying requires a high labour input for spreading out the paddy, turning the crop at frequent intervals, collecting and storage at protected places during the night (Gayanilo 1988).

The introduction of high yielding and early maturing varieties (HYV) increases yields significantly and allows an additional harvest during rainy season. However, this also requires changes in traditional post-harvest operations. To prevent shattering losses during harvesting and handling to minimize the risk of losses caused by typhoons, grain lodging and scattering losses in the field, harvest of the crop takes place even at a moisture content above 25%. After manual harvesting, it is still necessary to store the crop in piles for a few days in the field because of limited threshing capacity. To prevent spoilage due to rains and attacks by rodents, the crop has to be arranged with the panicles inside the piles. However, this also prevents efficient drying in the field and the crop has to be threshed with a relatively high moisture content. Due to the lack of high-temperature dryers, as used in industrialized countries, sundrying is still the only alternative. During rainy season, cloudy weather and periods of continuous rainfall prevents proper drying. Marketing wet paddy during the rainy season reduces the farmers' income due to significant lower prices for wet grain (Bonifacio 1989). On the other hand, storing wet paddy over longer periods leads to deterioration and grain discolouration. To reduce post-harvest losses, estimated from 5 to 37% by Mendoza 1984, and to increase the quality of the rice it is highly desirable to develop efficient drying systems which can be economically adapted either on small farms or at the cooperative level. As harvesting, threshing and drying of the first crop often overlaps with the transplanting of the second crop, such a drying system should considerably reduce labour requirement (Altendeitering 1989).

Literature Review

Low-temperature in-storage drying as a typical on-farm method is commonly used in Europe for drying wheat (Mühlbauer 1982) and in the United States of America for drying maize and soybeans (Converse 1974, Forster 1967). A low-temperature drying system consists of a round or rectangular bin, an air distribution system such as a perforated false floor, air ducts or an air sweep floor, and a small centrifugal fan. Ambient or slightly pre-heated air is forced vertically upwards through the 1 to 4 m thick bulk. Utilizing mainly the drying potential of the ambient air and extremely low air flow rates of 3 to 9 m^3/m^3 min, equivalent to an air velocity of 0.1 to 0.15 m/s leads to the low power requirement and low thermal energy consumption. Since the bin can be used for drying as well as for later storage the investment can be kept reasonably low.

Incorporating the bin into an already existing building reduces investment cost to a minimum. Compared to high-temperature drying, LT-drying offers certain advantages, such as modest investment, minimum energy consumption and labour requirement, as well as uniform drying. Yet, low-temperature drying is vulnerable to unpredictable weather conditions and thus requires careful analysis of the weather before introduction in order to reduce the risk of spoilage (Mühlbauer 1982). It also requires some judgement and operator skill.

Investigations have shown that under the moderate Korean weather conditions paddy can be dried to safe storage conditions with ambient air without supplementary heat. Between 1984 and 1990 about 100 000 low-temperature in-storage dryers were introduced on Korean farms (Kim 1989). Within the NAPHIRE/ACIAR* project low-temperature drying was firstly investigated under humid tropical conditions in the Philippines (Tumambing 1986). The tests have shown that the combination of high-temperature drying followed by low-temperature drying, as originally developed by Mühlbauer (1981) and Gustafson (1978) for maize, is an efficient system which covers the specific drying requirements of warehouses and bigger rice mills as the best. However, such a system cannot economically be used by smallholders or at small cooperatives since the required high-temperature dryer is far too expensive. Proper handling requires additional storage bins and well trained staff. Despite the promising results under moderate climatic conditions, up to now low-temperature drying has not been adopted in humid tropical countries.

Objectives

Work was undertaken at Los Baños in 1989 with the general objective of the investigations to test a low-temperature drying system for paddy under humid, tropical climatic conditions. The specific objectives included:

- Selection of a modular low-temperature drying system which can be constructed by farmers themselves or small-scale industry using cheap and locally available materials and which can easily be adapted to different capacities, either on small farm or at the cooperative level.

* NAPHIRE: National Post Harvest Institute for Research and Extension, Philippines. ACIAR: Australian Centre for International Agricultural Research.

- Investigation of the influence of weather conditions during the rainy season on drying time, energy consumption, power requirement and uniformity of drying.
- Evaluation of product quality in order to determine milling potential, germination rate, as well as microorganism growth during drying, in comparison to shade and sundrying.
- Determination of the minimum airflow and the optimum temperature rise which allows proper drying of high moisture paddy in one stage to safe storage conditions.
- Testing different fan and heating management procedures in order to minimize energy consumption.

Equipment

The investigations were conducted with a commercially available low-temperature in-storage drying system manufactured by Seemüller Company, Unterschweinbach, Germany (**Fig. 1**). The dryer was modified in order to allow system optimization by variation of bulk depth, air flow rate and temperature rise. In the next phase of the project it is planned to construct the dryer using locally available components and replacing the electric heater by a small biomass furnace or a solar heater.

The low-temperature dryer used for the investigations consists of a bin, an air distribution system, a heater and a fan. Instead of using a circular corrugated steel bin, which is commonly used for low-temperature drying in industrialized countries, a rectangular bin was selected which, on the one hand, can be produced using locally available materials and, on the other hand, as a modular system can be adapted easily to the required capacity. Furthermore, such a bin can be incorporated into existing structures, which lowers investment cost significantly. The sidewalls of the bin consist of chipboard reinforced with vertical beams and support bars. The bin measures 1.8 m wide and 2.5 m long. Loading up to a bulk depth of 2 m, the bin facilitates 5 000 kg moist grain. Rectangular bins can be either equipped with a perforated false floor or an air duct system for uniform air distribution. In order to minimize labour requirement for unloading, the dryer was equipped with an air-sweep floor which allows complete unloading by gravity supported by the airstream fluidizing the grain. For the experiments, a bucket elevator was installed which eases the loading of the bin and prevents cracking of the kernels during conveying.

Special care was taken to reduce the power requirement of the fan to a minimum, because the fan and motor are the most expensive parts of the system and electric power supply is very limited on small farms and even in many villages in tropical countries. In order to get the desired high efficiency a centrifugal fan with backward curved blades was chosen and attached to the drying bin. The fan was driven by a 1.0 kW electric motor. For testing the influence of the airflow on the drying rate, the airflow can be up to a minimum of 1 600 m^3/h by controlling motor speed. For slightly pre-heating ambient air an electric heater with 3 phases of 1.8 kW each was attached, which allows raising the temperature gradually. Furthermore, it was possible to attach the electric heater to a humidistat controller maintaining the inlet air at a fixed relative humidity.

Instrumentation

Thermocouples and capacitive humidity sensors were installed to continuously measure temperature and humidity of the ambient, drying and exhaust air. The data were recorded in 5-minute intervals by a computer-controlled data acquisition system.

The water removed during the

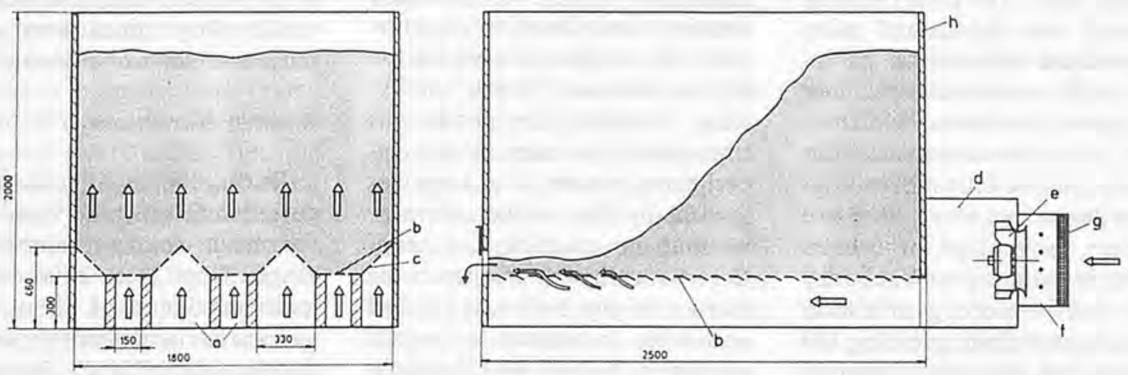

Fig. 1 Low temperature dryer (improved System Seemuller). a - air ducts, b - air sweep floor, c - perforated steel sheet, d - expansion chamber, e - centrifugal fan, f - electric heater, g - air filter, h - rectangular bin.

drying process was determined by weighing the paddy before and after drying. The changes of the moisture content of the paddy in relation to bulk depth and drying time was determined daily, twice a day, respectively, by taking samples with a double concentric tube sampling device from a maximum of 168 positions in up to 9 different layers of the bulk. The average of all samples served to determine the initial and final moisture content of the paddy. The moisture content of the paddy was ascertained by the oven method (105°C, 24 h). The drying process was controlled by taking samples in the top layer and measuring the actual moisture content with a quick test moisture meter. The total airflow as well as the air distribution over the cross section of the drying bin were measured at the top layer by an integrated airflow meter, the pressure drop in the bulk by a manometer. For measuring the energy consumption of electric heater and fan two electric-meters were used. In order to investigate the influence of the drying process on paddy quality characteristics, a control sample was spread out in a thin layer in the shadow and turned 3 to 4 times a day which ensured that no change of the quality can occur. For quality evaluation mean samples were taken after drying was finished from the bottom, middle and top layer. The paddy milling potential was determined using standardized laboratory equipment such as aspirateur, rubber roll husker, horizontal whitener, trieur and a photometer in order to determine the brown rice recovery, milled rice recovery, head rice recovery, percentage of broken kernels and whiteness (Wimberley 1983). Furthermore, germination rate was ascertained spreading 100 seeds on wet paper covered petri dishes for 5 days at a temperature of about 25°C (Anon. 1981). Discoloured and damaged kernels were determined by manual inspection. The milling quality of the rice was evaluated in accordance with the Philippine quality standards (Webb 1972). Special care was taken to determine the influence of the low-temperature drying process on the growth of different species of microorganisms, especially in the top layer. To investigate the degree of mold infection, samples were surface-disinfected with a 5% sodium hyperchloride solution. Afterwards, the seeds were placed on a 1.5% brown rice extract. After an incubation of 7 days at 25°C the percentage of kernels yielding field and storage fungi were identified and recorded with microscopic examination.

Materials and Procedure

The drying tests were conducted at the experimental station of the International Rice Research Institute, Los Baños, the Philippines, during the rainy season from September to November 1989 and 1990, respectively. The paddy used for the tests was harvested by sickle and threshed with an axial flow thresher. Moisture content of the wet paddy ranged from 21 to 27.5%. Due to heavy rainfall, sometimes the wet paddy was stored for a short time by farmers or millers which caused deterioration. Therefore, in some cases the paddy available for the drying tests was of lower quality. After threshing, the paddy was transported in bags to the experimental station. The dryer was loaded by the bucket elevator without pre-cleaning the crop. Before starting fan and heater the surface of the bulk was levelled accurately. In contrast to the tests carried out by ACIAR (Tumambing 1986) the paddy was dried in one step to safe storage conditions. Drying was finished when the moisture content in the top layer reached 15%. Afterwards the paddy was discharged using the air-sweep floor and the bucket elevator. In order to determine the optimum drying conditions the investigations were conducted with different bulk depths (1 and 2 m) and various pre-heating levels (3 - 6 - 9 K). During all tests the air velocity was kept constant at about 0.1 m/s. Furthermore, attempts were made to minimize the energy consumption by operating fan and heater in the following modes:

- Continuous fan operation
- Intermittent fan operation
- Fixed temperature rise
- Constant inlet humidity

Results and Discussion

In the following, the results of selected tests are described and the influence of pre-heating level, bulk depth, initial moisture content, air flow rate as well as fan and heater management procedure on drying capacity, uniformity, energy consumption and quality are discussed. Based on the experiences gained with low-temperature drying tests with paddy in Korea (Kim 1989), the velocity of the drying air was kept constant at about 0.1 m/s. Despite changing weather conditions during the several tests which limited comparability, the results allow conclusions about general trends to be drawn.

Weather Conditions

During the investigations conducted in October 1989 and 1990 the mean ambient temperature ranged from 25 to 27°C, with a mean maximum of about 33°C and a mean minimum temperature during night of 24°C. Due to the cloudy weather and rain periods lasting several days, humidity exceeded 90%, on average, for more than 14 hours of the day. On rainy days, only during a few hours was humidity low enough to allow sundrying. In 1990 total precipitations reached 2 263 mm which is close to the long term average. In October 1989 three typhoons followed by heavy rainfall caused a precipitation of 810 mm within one month.

Pre-heating

An analysis of the weather data shows that ambient air drying alone is insufficient during the rainy season. In order to optimize supplementary heat for pre-heating the ambient air, tests were conducted with temperature rises of 3, 6 and 9 K, respectively. The results are summarized in **Table 1**. Independent of the temperature rises, a 0.8 to 0.9 m thick layer of paddy can be dried from an initial moisture content of 27.4% to 23.4% w.b. to safe storage conditions using an air flow rate of 7.5 to 9.4 m^3/m^3 min. The tests showed that pre-heating with 3 K is not sufficient to reduce the averae moisture content to the desired level of 14% w.b. Compared to the tests with 6 and 9 K temperature rise, the drying rate was reduced by 31% and 39%, respectively. Furthermore, there was no considerable decrease of the thermal energy consumption while the electric energy consumption of the fan increased due to the extension of the drying time. Raising the ambient air temperature by 9 K results in an increased drying rate of 12% compared to the tests conducted with 6 K. Yet, the higher temperature in combination with lower humidity caused non-uniform drying due to overdrying in the bottom area, **Fig. 2**, as well as reduced head rice recovery, **Table 1**. From a thermodynamic and product quality point of view a temperature rise of 6 K seems to be the optimum. However, depending on the economic evaluation of the quality losses, higher drying air temperatures lead to higher drying capacity which can have a positive influence on the income. Derived from the investigations conducted during rainy season it seems feasible to operate the dryer during the dry season to the greatest possible extent without pre-heating the ambient air.

Table 1 Influence of Different Pre-heating Levels on Drying Capacity, Energy Consumption and Head Rice Recovery

Temperature rise	K	$\Delta\delta = 3K$	$\Delta\delta = 6K$	$\Delta\delta = 9K$
Mass of wet paddy	kg	2 092	2 230	2 480
Mass of dry paddy	kg	1 877	1 932	2 106
Removed water	kg	215	298	374
Initial moisture content	% w.b.	23.4	25.0	27.4
Final moisture content	% w.b.	14.6	13.7	14.6
Bulk depth	m	0.79	0.85	0.93
Drying time	h	97	70	70
Air flow rate	m^3/m^3 min	9.4	8.2	7.5
Air velocity	m/s	0.12	0.12	0.12
Static pressure drop	Pa	140	158	159
Power equirement fan	W	190	190	190
Fan efficiency	%	41	43	44
Mean drying rate	kg/d	520	760	853
Specific heat consumption	kJ/kg H_2O	3 240	3 007	3 469
Specific electric energy consumption	Wh/kg H_2O	9.8	6.9	6.3
Change in head rice recovery[1]	%	+0.4	+0.9	−3.6

[1] Base: shade drying = 100%: mean head rice recovery of shade drying 94.7%.

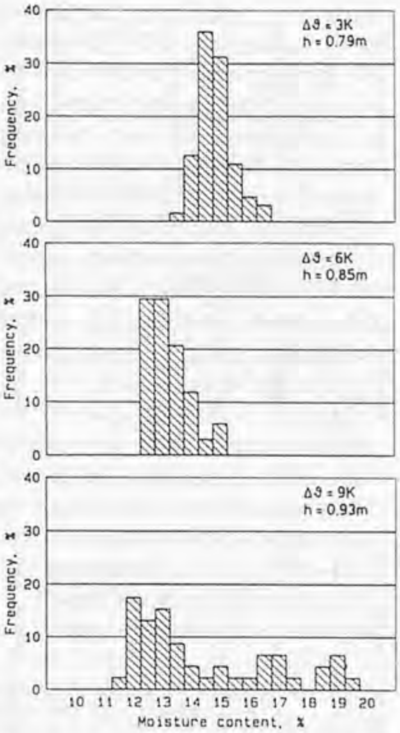

Fig. 2 Influence of different pre-heating levels on the uniformity of drying.

Bulk depth

In order to determine the maximum permissible bulk depth, tests were carried out with two different bulk depths with about 0.9 and 2.0 m thick layers. The results are summarized in **Table 2**. **Figure 3** shows the influence of the weather conditions on the drying behaviour in different layers of the bulk at a fixed pre-heating level of 6 K. **Figure 3** demonstrates a drying behaviour which is characteristic for low-temperature drying.

The slight increase in the moisture content of the upper layer indicated a highly saturated exhaust air. In contrast to experiments carried out under moderate climatic conditions, the lower layer does not show the undesired drying and rewetting cycles caused by changing ambient conditions which could result in fissuring (Kunze 1978).

Compared to high-temperature batch drying, low-temperature drying leads to more uniform drying, **Fig. 4**, which is an important condition to reduce storage losses to a minimum. **Table 2** indicates that even an almost 2 m thick layer of paddy can be dried uniform from high initial moisture content of 26.4% w.b. within 7 days. Drying a 1.0 m thick layer required about 3 days. In principle, it should be possible to dry even thicker layers (Mühlbauer, 1982),

Table 2 Influence of Bulk Depth on Drying Capacity and Energy Consumption of Low Temperature Paddy Drying Tests

Bulk depth	m	0.85	1.88
Mass of wet paddy	kg	2 230	4 998
Mass of dry paddy	kg	1 932	4 222
Removed water	kg	298	776
Initial moisture content	% w.b.	25.0	26.4
Final moisture content			
bottom	% w.b.	12.4	12.1
top	% w.b.	14.3	13.5
average	% w.b.	13.7	12.8
Air flow rate	m^3/m^3 min	8.2	3.8
Air velocity	m/s	0.12	0.12
Static pressure drop	Pa	158	399
Temperature rise	K	6	6
Power requirement fan	W	190	360
Fan efficiency	%	43	59
Drying time	h	70	157
Mean drying rate	kg/d	760	760
Specific heat consumption	kJ/kg H_2O	3 007	2 486
Specific electric energy consumption	Wh/kgH_2O	6.9	13.4

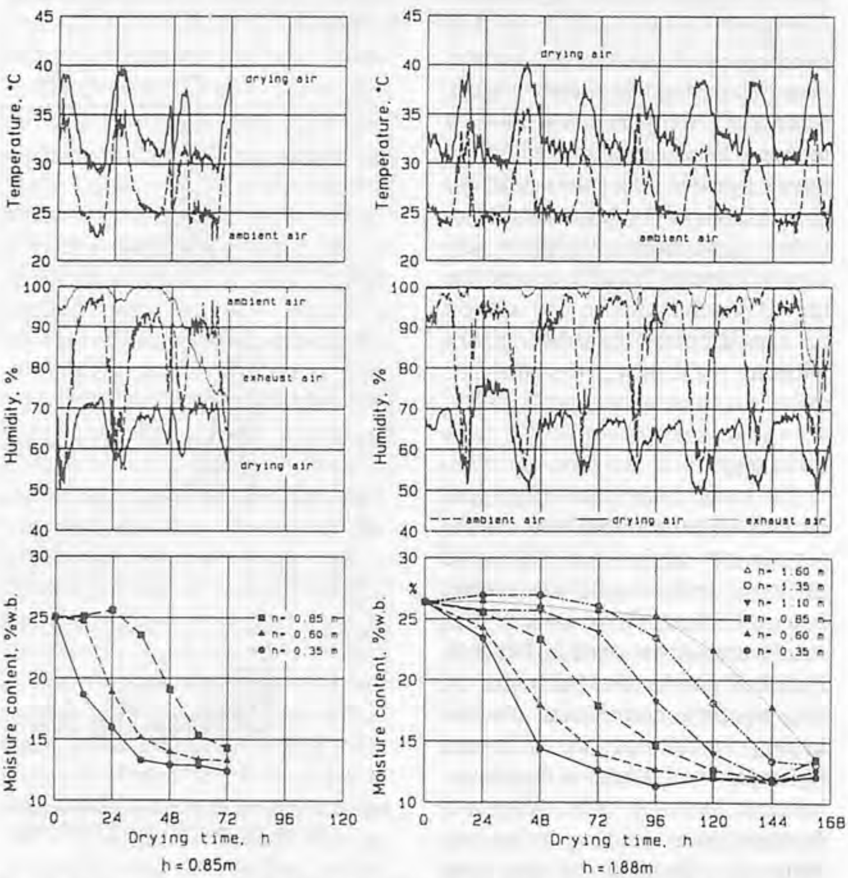

Fig. 3 Influence of the weather conditions and bulk depth on the drying behaviour of paddy during low temperature drying (Temperature rise 6 K, air velocity 0.11 m/s).

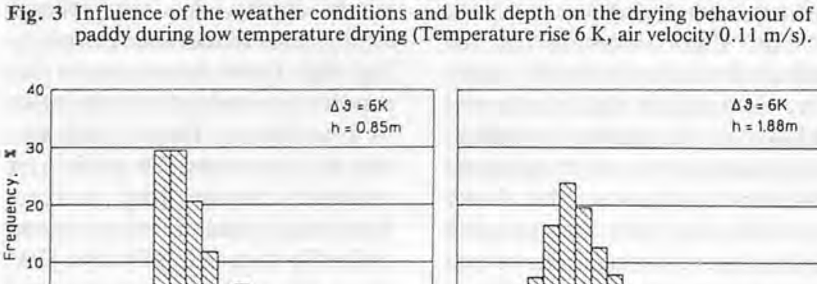

Fig. 4 Influence of bulk depth on the uniformity of drying.

(Kim, 1989), but this requires mechanical conveyors which are, in most cases, not available in tropical countries. Independent of the bulk depth the yield of one hectare can be dried within one week using a bin with an area of only 4.5 m^2.

As a result of the low air flow rates and the high efficiency of the fan, the power requirement is extremely low compared to all other mechanical dryers. Forcing the drying air with a velocity of 0.11 m/s through a bulk 0.85 m in depth, only 190 W was required. Increasing the bulk depth to about 1.90 m almost doubled the power requirement. The low power requirement of the fan and, therefore, the low energy consumption results in a reduction of the operating cost and is suitable for areas with insufficient electric power supply.

A main advantage of the low-temperature dryer is the low specific heat consumption which decreases with increasing bulk depth. Compared to conventional high-temperature batch dryers which require 6 000-8 000 kJ to remove 1 kg of water (Mühlbauer 1987), the specific energy consumption of the low-temperature dryer, considering an efficiency of a biomass furnace of 70%, is almost half.

Based on the results of the quality tests it can be pointed out that low-temperature drying has no negative effect on the quality of the rice at all. Neither yellowing nor browning or reddening, which are most common quality losses during rainy season occurred. Compared to the shade-dried control sample a significant reduction of the headrice recovery, the milling recovery, whiteness and germination rate could not be detected, **Figure 5**. Milled rice can be classified as premium grade according to the Philippine grading system. In some experiments,

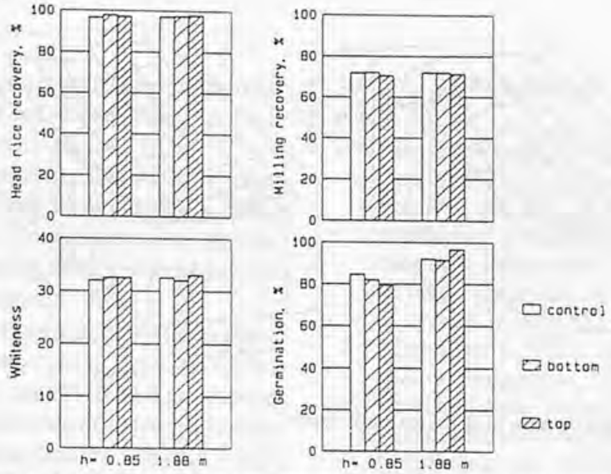

Fig. 5 Influence of low temperature drying on milling properties and germination rate of paddy.

Table 3 Percentage of Wet Kernels Invaded by Fungi and Change of Infection Rate During LT-drying of Paddy at Different Bulk Depths in Comparison to Shade-dried Control Sample

Bulk drying time	0.85 m 70 h				1.88 m 157 h			
	Initial	Final			Initial	Final		
Species	infection	Shade	Bottom	Top	infection	Shade	Bottom	Top
Trichoconiella	16	+1	−4	+2	22	−3	−4	−1
Curvularia	10	+1	−2	+1	6	+1	+5	+5
Sarocladium	14	−2	−2	+3	3	+4	+5	+8
Fusariuim m.	4	0	−4	−1	1	−1	−1	−1
Dreschlera o.	1	−1	−1	−1	0	0	−1	0
Phoma sp.	5	−4	−2	+3	4	0	−2	+3
Tilletia b.	15	+4	+1	−5	58	0	−3	+10
Nigrospora sp.	1	+1	−1	−1	1	0	0	0
Aspergillus sp.	1	+2	+1	+1	1	+2	+1	0
Penicillium sp.	5	−3	+3	−1	2	−2	−2	−1

the relatively low whiteness is caused by storage of the wet paddy for a few days before drying due to lack of transportation capacity, a common problem in the Philippines.

The moderate heat treatment which is one of the characteristics of low-temperature drying, on the one hand, minimizes fissuring and, on the other, it has no negative effect on grain germination. Therefore, this drying method is most suitable for seed production.

Special care was taken to determine the growth of field and storage fungi, especially in the upper layer. **Table 3** indicates the expected reduction of the field fungi during drying. The insignificant increase in storage fungi such as aspergillus flavus and penicillium sp. justifies the conclusion that the probability of contamination with mycotoxins is negligible.

Fan and Heater Management Procedures

Intermittent fan operation and humidistat-controlled pre-heating are the most promising methods to minimize the energy consumption of low-temperature drying systems (Mühlbauer 1982, Tumambing 1986). During intermittent fan operation, the fan and heater were operated from 6.30 am to 6.30 pm. Since the drying potential of the ambient air during daytime is almost sufficient for low-temperature drying, the drying air temperrature was raised only 3 K. The investigations have shown that intermittent fan and heater operation leads to the expected increase in the drying time compared to continuous operating procedure with a temperature rise of 6 K. Further, intermittent fan and heater management lower the specific heat consumption by 40%, **Table 4**. Beside the considerable reduction of the thermal energy consumption, intermittent drying most accurately meets the requirements of the users since the heater has to be operated only during daytime. The test conducted with paddy (moisture content 20.1% w.b.) indicated no negative impact on the milling quality. However, additional tests with paddy of higher moisture contents are necessary to verify this promising procedure.

From the thermodynamic point of view, humidistat-controlled

Table 4 Influence of Different Fan and Pre-heating Management Procedures on Drying Capacity, Energy Consumption and Head Rice Yield

Fan operation / Heater operation		Continuous / Constant	Intermittent[1] / Constant	Continuous / Humidity-controlled[2]
Mass of wet paddy	kg	2 230	2 333	2 945
Mass of dry paddy	kg	1 932	2 120	2 629
Removed water	kg	298	213	316
Initial moisture content	% w.b.	25.0	20.1	22.1
Final moisture content	% w.b.	13.7	12.6	13.6
Bulk depth	m	0.85	0.88	1.11
Drying time	h	70	66	176
Temperature rise	K	6	3	—
Ambient air				
Mean temperature	°C	27.5	29.3	25.1
Mean humidity	%	83.2	76.6	82.4
Drying air				
Mean temperature	°C	33.4	32.3	26.6
Mean humidity	%	65.2	67.0	76.1
Air flow rate	m^3/m^3 min	8.2	7.0	5.6
Air velocity	m/s	0.12	0.10	0.10
Mean drying rate	kg/d	760	848	402
Specific heat consumption	kJ/kg H_2O	3 007	1 764	1 386
Spec. electric energy consumption	Wh/kg H_2O	6.9	5.8	15.7

[1] Fan operation 6.30 am to 6.30 pm. [2] 75% drying air humidity.

pre-heating at a humidity level of 75% is the optimum drying method. Minimum thermal energy consumption and most uniform drying are its desirable characteristics. As indicated in **Table 4**, humidistat-controlled pre-heating, on the one hand, reduces the specific heat consumption to around 40% while, on the other hand, the drying time was increased from 70 to 176 hours, which is only acceptable if the crop after drying is stored over a longer period. For on-farm use the application of a humidistat-controlled heater constitutes an advanced technology and thus exceeds the practical requirements — even in industrialized countries in most cases it cannot be economically used. Yet, for large rice mills or warehouses where paddy has to be stored over longer periods a humidistat-controlled gas burner could be a promising way to considerably reduce heat consumption.

Handling

Uniform air distribution in the bulk is of great importance in a low-temperature drying system to achieve the desired uniform drying. This can be reached by careful loading and accurate levelling before starting ventilation. Traditionally threshed paddy contains a high percentage of relatively wet husks and straw particles. Pre-cleaning before drying, on the one hand, lowers the air resistance of the bulk, and, on the other, accelerates drying. However, on small farms, equipment for pre-cleaning is generally unavailable. Despite the relatively high percentage of fines the air sweep floor guarantees an almost uniform air distribution, especially at increased bulk depth, **(Fig. 6)**.

The tests have shown that the present design of air-sweep floor,

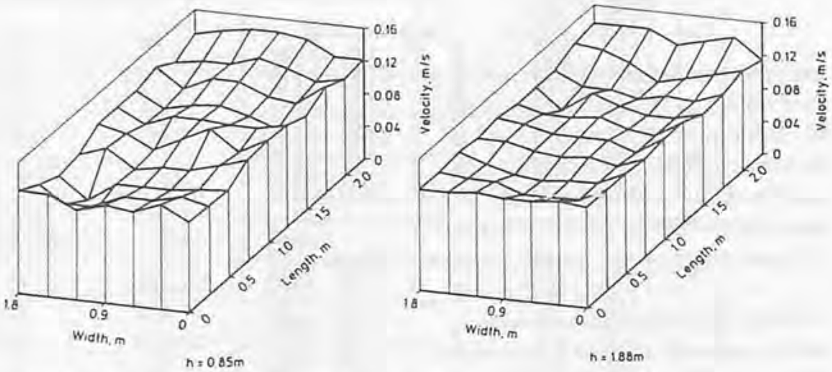

Fig. 6 Air distribution at different bulk depth.

originated from wheat LT-dryers, shows some disadvantages with paddy. The high content of fines hinders fluidization and causes dust emission during unloading. For on-farm use it is recommendable to replace the air-sweep floor by air distribution ducts (Kim 1989). However, this significantly increases labour input for unloading. In case of application to large mills or governmental warehouses where equipment for cleaning the paddy is available and electricity is not as scarce as on farms, the air-sweep floor as labour-saving equipment seems to be the more adequate solution.

Summary and Conclusions

Based on the results of low-temperature drying tests with paddy conducted in the Philippines during 1989 and 1990 wet seasons the following conclusions can be drawn:

- Low-temperature drying, originally developed for drying low moisture cereals under moderate climatic conditions, can also be successfully used for drying high moisture paddy even during tropical humid weather conditions.
- Up to a bulk depth of 2.0 m paddy with an initial moisture content of 27.5% w.b. can be uniformly dried in one step to safe storage conditions.
- To prevent spoilage, slight pre-heating of the ambient air during periods of high humidity (humidity > 75%) is a necessity.
- Air flow rates of 3.7 to 9.5 m^3/m^3 min, which are equivalent to an air velocity of 0.1 m/s in the bulk in combination with an high efficient centrifugal fan with backward curved blades lead to the desired low specific power requirement of 40 Watt/m^3 grain.
- The energy costs for operating the fan are negligible in relation to the profit due to reduced losses.
- Compared to high temperature batch or continuous drying systems low-temperature drying leads to more uniform drying which is an important condition for minimum storage losses and high quality.
- Low-temperature drying has no negative effect on milling properties such as milling recovery, head rice recovery, cracking ratio and whiteness and did not significantly differ from the shade-dried control sample. According to the Philippine quality standards the low-temperature dried paddy can be classified as a premium quality.
- The slight increase of mycotoxin-forming storage fungi in the upper layer such as aspergillus flavus and penicillium are within the tolerable limit and most likely the risk of contamination with mycotoxins during the drying process is almost zero.

- Low-temperature drying reduces the risk of discolouration to a minimum.
- High germination rate, in connection with low cracking ratio, makes low-temperature drying the most suitable method in seed production.
- Low temperature drying in combination with an efficient thresher seems to be a promising method to reduce overall losses.
- Low-temperature drying considerably reduces the labour input compared to traditional sundrying and could be a promising way to eliminate the existing bottleneck during harvesting the first crop and transplanting the second or subsequent crops.
- Low-temperature drying using rectangular drying bins is the most flexible drying system and with modules can be easily matched to the user drying capacity.
- The need for a fan to force the air through the bulk limits distribution of the principal to electrified areas or alternatively requires a small generator.

Recommendation for Further Work

For further work in the next phase of the project, it is recommended that a low temperature dryer using just locally available materials and to replace the electric heater by a small biomass furnace or a solar heater be constructed. Further improvements can be achieved by using the system for drying other commodities such as peanuts, ear corn or shelled corn and soybeans. Before dissemination a careful socio-economical study has to be conducted in order to determine the most suitable size of the drying system for different endusers.

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Effects of Drying Parameters on Quality of Artificially Dried Rough Rice

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Abstract

In the design and utilization of mechanical grain driers, it is important to understand the effect of drying parameters such as drying air temperature, length of time the grains are exposed to the drying medium, air flow rate, tempering time and tempering temperature on the quality of the dried grain.

The objectives of this study were to develop and evaluate an effective grain drier and drying technique for accelerating the drying of rough rice without any deterioration in quality of the dried grain and produce grains with high milling quality.

A test drier was built that allowed for independent control of the drying parameters and was used for the drying of newly harvested rough rice under different conditions. The effects of drying parameters on the quality of the dried grains were examined and the results presented.

Introduction

The introduction of high yielding cereals, well planned and effective irrigation systems and improved weed and pest control mechanisms led to increased cereals yield per hectare. Once grown, the grain crops must be harvested, processed, stored, transported without excessive losses and waste. According to Chandler (1979) current losses of about 30% are apparently occurring throughout large areas of the world, particularly in the tropics and subtropics. These losses occur due to respiration and consequent heat production depending on moisture content of the grain, the type of crop, its degree of maturity and ambient storage temperature.

The mechanization of harvesting has rapidly progressed in recent years. This is coupled with the introduction of high yielding cereals with short growing season that must be harvested at high field moisture content to minimize shattering losses, and multiple cropping in the main rice producing areas of the world. This has resulted in rainy season harvesting of the first crop and increased the total volume of harvested grains containing much moisture (28% to 32%, wet basis). Left in bags or heaps over a short period the grains will deteriorate through putrefaction or fermentation. They must be dried to a safe moisture control level 13% to 15%, wet basis), so that decrease in quality from moulds, enzymic action and insects will be negligible. Any loss or reduction of quality after maturity causes a double waste. First, the waste product does not fulfill its primary objective of providing food, and, second, the low quality grain provides little returns on investment for its production.

For these reasons, there is urgent need for artificial drying of grains. Widespread introduction of grain driers cannot be avoided in the near future in many countries.

Designers of agricultural grain driers have devoted little attention to the effects of drying parameters on the quality of the dried grain.

Previous studies were devoted to understanding the effect of drying air temperature, air flow rate and moisture content on development of stress checks and cracks in rough rice.

The present study examines the extent to which rice quality such as crack ratio, germination rate, free fatty acid content and palatability are affected by the drying parameters.

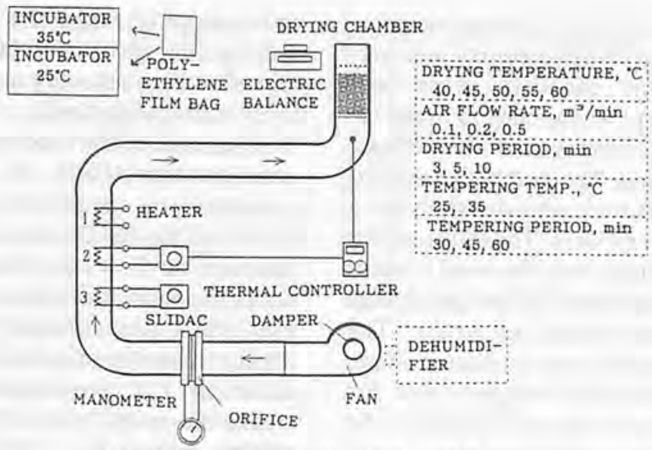

Fig. 1 Schematic diagram of the test dryer.

Materials and Methods

The study reported here concerns methods that could be adopted in increasing the effectiveness of mechanical grain driers and the effect of drying parameters on the dried product.

An experimental drier shown in **Fig. 1** was built and used for drying newly harvested rough rice of Japonica species "Natsuhikari" in the summer of August and "Nipponbare" in the autumn month of October under each of the following drying conditions:

Drying temperature: 40, 45, 50, 55, 60°C;

Grain air ratio: 0.1 to 0.5m^2/min kg;

Tempering temperature: 25, 35°C;

Tempering time: 30, 45, 60 min;

Exposure time: 3, 5, 10 min;

Weight of grain: 1kg;

Initial moisture content: 27.1% w.b. and

Final moisture content: 14.5 ~ 15% w.b.

After the grains were dried for a specified period of time, they were removed from the drier and placed in an incubator kept at constant temperature of 25°C and 35°C, respectively, to temper for a period of 45 min. This process was repeated per drying cycle until the grain moisture content reached the desired level. A sample of 10 g of the grain was used to determine the initial moisture content by an oven method, 135°C for 24 h. (JSAM standard). The dry matter thus determined from the 10 g sample and the weight lost due to the oven drying was used to determine the initial moisture content, wet basis.

The effect of the drying parameters such as drying temperature, grain air flow ratio, tempering conditions and exposure time on the quality of the grain were examined

Crack ratio, under a particular drying condition, was determined by inspecting a sample of the dried grain under fluorescent light. The number of cracked grains per given sample was used to calculate the cracked ratio for a particular batch of grain.

Free fatty acid (FFA) content of the grains, which is an important index for determining the quality of rice grain was analyzed using the colorimetric method which is the improved Duncombe method for fatty acid determination.

Conventionally, the taste of rice is judged by an overall evaluation of the results of sensory test in which the five factors of appearance, taste, viscosity, hardness and flavour are evaluated. The physical chemistry method of rice taste analysis, which has a high correlation with the overall evaluation in conventional sensory testing, examines the protein content of milled rice, the amylographic characteristics of powdered milled rice, the maximum and minimum viscosity and the iodine colour degree. In cooked rice, the hardness and stickiness, texturometer characteristics are examined. These methods are effective, but time consuming.

The palatability of the dried grain was determined by the use of near infrared spectrum analyzer. In order to analyze the taste of rice by nondestructive method, near infrared (NIR) spectrum analysis is used to measure the quantities of certain key components which make up taste, such as amylose or amylopection starches, protein, moisture and free fatty acid. These measured quantities are then computed by a mathematical formulae designed to produce results coinciding with taste appraisals obtained in sensory testing.

Effort was also made to examine the effect of drying parameters on seed germination and to verify the common belief that grains having low germination rate often have low taste value.

Ten days after the grains were dried to 15% moisture cntent, 100 matured grains were selected from each batch of the dried grains, the grains were soaked in distilled water for 48 h at room temperature and transferred to a seed germination chamber, were heat treatment was applied to break the seed dormancy and to facilitate sprouting. The number of sprouted seeds were recorded daily for a period of 7 days. The total number of sprouted seed was used to compute the germination percentage for each batch of grain. The experiment was replicated three times and the average value for each batch was considered to be the true germination rate.

Results and Discussion

Stress cracks are fine fissures in kernel endosperm. In general, the formation of stress cracks is associated with rapid drying of the rough rice. The development of stress cracks is proportional to the magnitude of the temperature and moisture gradient set up when heat is applied to moist grains.

The first indication of drying stress is a small, single crack. As stress increases multiple cracks develop. L.A. Balastreire et al (1982) observed through the use of optical microscope that stress cracks narrowed as they approach the kernel surface. Based on this, they concluded that stress cracks initiate at the center of the kernel and grows toward the periphery. This finding was later substantiated by Gunasekaran et al (1985) through microscopic studies.

In drying high-moisture rough rice with heated air, drying starts from the surface of the kernel and progresses inward. Drying too rapidly causes "case hardening" whereby the surface of the grain dries out rapidly sealing the moisture within the inner layers. The internal pressure thus developed causes cracks to develop. The same phenomenon accounts for the development of chalky grains. Cracked grain contributes to breakage of rice grains during milling and hence results in reduction of milling recovery quantitatively and qualitatively.

The result of the experiment to examine the effect of drying parameters on cracking of grain is shown in **Fig. 2**. Drying air temperature, air flow rate, tempering temperature and the length of time the grains are exposed to the drying air are the principal factors affecting the development of cracks in rough rice. Previous studies reveal the relationship between drying temperature, air flow rate and cracking of rough rice during drying operation. The present study goes further to demonstrate the importance of tempering method. The temperature of the air in the tempering tank of most commercial grain driers range between 35 and 40°C (T. Abe et al 1989). The present study shows that better results could be obtained by lowering the temperature in the tempering tank to about 25°C. This would not only reduce the ratio of cracked grains but would also result in dried grains of much better quality. Drying air temperature of 45 to 55°C, air flow rate 0.1 m^3/min kg, exposure time of 5 to 10 min and tempering temperature 25°C are considered appropriate for reducing the percentage of cracked grains during drying.

Over 70% of the world food supply is derived directly from the seeds of a small number of field crops. In most crop species, seed formation initiates the next reproductive cycle. This dual requirement, food and reproduction, place unusual demands on the biological processes of seed development, preservation and germination.

Preservation and appropriate post harvest handling of the diverse but delicate resources is imperative in order to meet future food needs.

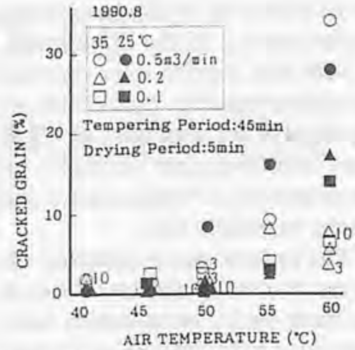

Fig. 2 Effect of drying parameters on cracking of rough rice. (Figures affixed to symbol indicates the length of time the batch of grain was exposed to the heated drying air per drying cycle, otherwise the exposure time was 5 minute.)

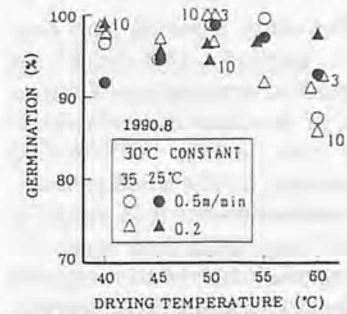

Fig. 3A Effect of drying parameters on rice seed germination.

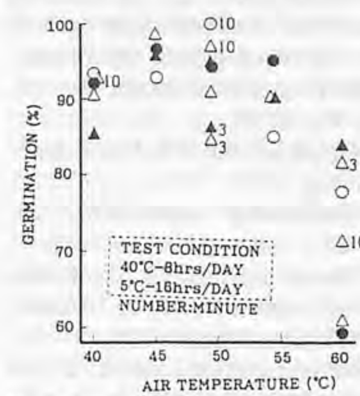

Fig. 3B Effect of air flow rate on rice seed germination.

Drying of seed grains to a moisture content level that would prevent germination during storage is a first step in seed preservation. However, this very important procedure, if not carried out properly, could limit the value of sound grain for use as seeds.

Figs. 3A and **3B** show the effect

of drying parameters on seed germination, In **Fig. 3A**, it is shown that the length of time grain is exposed to the drying air, drying air temperature and tempering temperature are important factors affecting the ability of seeds to germinate after drying.

The highest germination percentage was recorded when drying air temperature was 40°C, air flow rate of 0.2 m^3/min kg tempering temperature of 25°C and 35°C exposure time of 5 to 10 min, respectively, germination percentage was above 98%.

Similar result was also obtained at a drying air temperature of 50°C, air flow rate of 0.2 m^3/min kg and tempering temperature of 35°C and exposure time of 3 min. In order to determine the optimum air flow rate for drying grains intended for use as seed, grains, were dried at different drying air temperature, and exposure time but at constant air flow rate of 0.3 m^3/min kg. This air flow rate was selected for this experiment after, examination of the germination results from trials using different air flow rates.

Fig. 3B shows that grains intended for use as seeds could be dried, with air heated to a temperature of 45°C to 50°C, air flow rate of 0.3 m^3/min kg, tempering temperature of 25°C to 35°C and exposure time of 5 to 10 min without any loss in value.

Generally, increases in the free fatty acid in stored rice grain is a good indicator that the rice quality is deteriorating. Drying method and condition can accelerate the development of free fatty acid in dried rice grain.

Figs. 4A to **4C** show the effect of drying parameters on the development of free fatty acid in rice grain. It can be observed from **Fig. 4A** that the least quantity of free fatty acid was recorded for the batch of grains dried with air heated to 50°C, air flow rate of 0.5 m^3/min kg and tempering temperature of 25°C. The highest value was recorded for the batch of grains dried with air heated to 40°C, air flow rate of 0.2 m^3/min kg and tempering temperature of 35°C.

Marked increases in the value of free fatty acids were also recorded for the batch of grains dried using air heated to 55°C and 60°C. The high value of free fatty acid recorded for the batch of grains dried at 40°C and air flow rate of 0.2 m^3/min kg can be attributed to the length of time it took to dry the grains to a safe storage moisture content of 15%. The rate of biochemical activity taking place in high-moisture grain increases with an increase in temperature. During drying operation this continues until a moisture content level is reached at which these activities can no longer be sustained. It, therefore, follows that the longer it takes to attain the safe moisture level, the more of the by-product of biochemical activity contained in the grain becomes. The reasons for the increase in the value of free fatty acid in the batch of grains dried with heated air at 55°C and 60°C is yet to be fully understood.

In **Fig. 4A**, it will be shown that grains dried with heated air at 50°C and air flow rate of 0.5 m^3/min kg had low value of free fatty acid content. The experiment was taken further to investigate the effect of tempering temperature on free fatty acid development in rice grain.

It can be observed from **Fig. 4B** that tempering temperature of 25°C is better than 35°C within the range of drying temperatures investigated.

Fig. 4C shows the effect of air flow rate on free fatty acid development in the rice grain. It can be observed for the range of drying temperature investigated, high air flow rate of 0.5 m^3/min kg and tempering temperature of 25°C gave a better result.

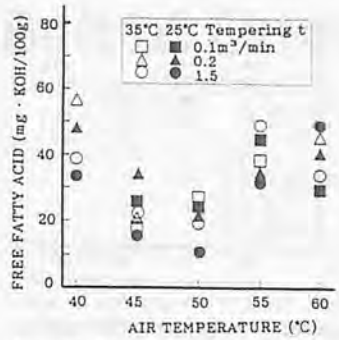

Fig. 4A Effect of drying parameters on free fatty acid development in rough rice.

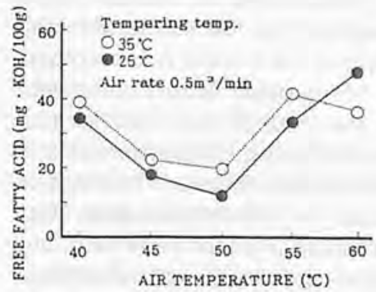

Fig. 4B Effect of tempering temperature on free fatty acid development in rough rice.

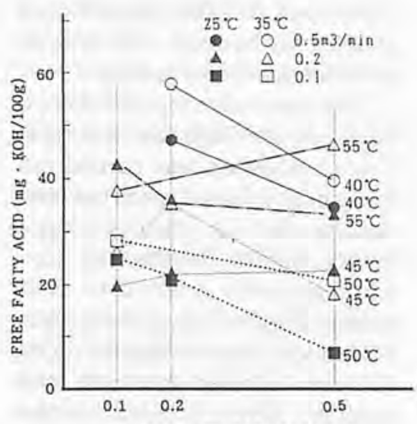

Fig. 4C Effect of air flow rate on free fatty acid development in rough rice.

Rice grain lower in amylose produces a cooked rice high in viscosity and rice high in protein produces a cooked rice that is less sticky. Rice of high moisture content 16% wet basis produces

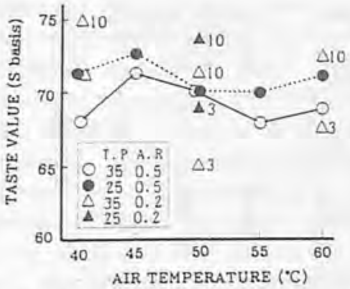

Fig. 5 Effect of drying parameters on rice taste.

cooked rice that is softer and stickier. The higher the free fatty acid content, the less favourable the taste of the cooked rice becomes.

Many other factors contribute to the taste of rice, such as rice species, cultural practice, soil type and climatic factors. The batch of grain for the present study was harvested from the same field, but dried under different conditions for the purpose of investigating the effect of drying parameters on the taste of rice. It is important to note that what may be a delicious food to different group of people may be quite unacceptable to other groups of people.

The taste value reported here is based on the Japanese standard. Taste evaluation was carried out using near infrared spectrum taste analyzer for rice grain developed by the Satake Engineering Co., Ltd., generally referred to as (S basis). **Fig. 5** shows the taste evaluation result obtained using the near infrared spectrum taste analyzer. The highest taste value were recorded for the batch of grains dried at 50°C, air flow rate of 0.2 m^3/min kg and tempering temperature of 25°C, exposure time of 10 min.

The batch of grain dried at 45°C, air flow rate of 5 m^3/min kg, exposure time of 5 min and tempering temperature of 25°C also had a high test value. The batch of grain dried with air heated to 55°C and 60°C had taste values lower than for the batch dried with air heated to 45 and 50°C, the taste evaluation result reveals that within the range of drying temperature investigated, exposure time of 10 min air flow rate of 0.5 m^3/min kg and tempering temperature of 25°C gave a better result.

Conclusion

Drying parameters affect the quality of the dried grain. Drying air temperature range of 45°C to 50°C, air flow rate of 0.3 m^3/min kg to 0.5 m^3/min kg, exposure time of 5 min to 10 min, tempering temperature of 25°C and tempering time of 50 min is considered most appropriate for obtaining good quality and tasty rice. Grains must be dried promptly and fast after harvest. Grains that took time to dry to a safe moisture content usually turn out to be of poor quality. Incorporating a cooling device in the tempering tank of continuous flow driers to keep the ambient temperature within 25°C is recommended.

New equipment and new management technology for grain drying when fully developed will give agriculture and grain farmers the ability to utilize production inputs more efficiently and better profit.

Up to the present time, the control of drying operation has a tendency to concentrate on the physical phenomena like cracking. However, chemical phenomena such as breakdown of some lipids and sugar during drying operation requires to be understood and controlled.

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Utility of Windmill in Coastal Belt of Orissa

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Abstract

Nature has huge energy in the form of blowing wind. This energy source is non-exhaustive and unlimited. Its utilization in agriculture and, for jobs for stationary nature, is possible. Moreover, the coastal belts of the country experience sufficient wind speed throughout the year. Effort has been made to analyse wind speed at the coastal belt of Orissa in order to determine the probable windmill pump discharge and economics of use.

Introduction

Energy is one of the basic inputs in man's everyday life. The major sources of energy in the day-to-day life are fossil's fuel and coal which are being depleted at a fast rate. In contrast, wind, solar and bio-mass energy are non-exhaustive in nature as they are either reproducible or unlimited. These sources must be tapped before the supply of fossil fuel and coal run out.

The State of Orissa is gifted with a long coastal belt where sufficient wind speed is available throughout the year. This energy can be harnessed in order to pump water for irrigation and other purposes. Thus huge quantity of energy consumed for pumping water can be saved by the introduction of windmill pumps. Realizing the importance of the device, studies were undertaken at the College of Agricultural Engineering and Technology, Bhubaneswar with following objectives:

1. To estimate the probable wind energy at different localities in the coastal belt of the State.
2. To estimate the possible discharge during different periods of a year in the coastal belt of the State.
3. To determine the economics of wind mill pumping system in the coastal belt of the State.

Theoretical Consideration

Wind speed being a random variable, is a reliable estimate of available wind energy. Windmill pump output can be made by stochastic analysis of wind speed data.

Wind flux may be computed on the basis of kinetic energy of wind blowing naturally. The available wind energy may be computed by:

$$P = 1/2\ mV^2$$

where,
P = Available wind energy in W
m = Mass of air coming in contact with windmill i.e. equal to ϱ av
v = Wind speed m/sec

Putting above values and mass density of air as 1.29 kg/m^3, the available wind energy may obtained as

$$P = 0.014\ a\ V^3$$

where,
V is windspeed in km/h

On the basis of wind flux the discharge of a wind pump may be computed by formulae

$$P = QHn\nu$$

where,
P = Wind flux available, in W
η = Efficiency of the system, %
ν = Weight density of water, kg/m^3
Q = discharge of windmill pump, m^3/h
H = Head of operation of pump, m

hence,

$$Q = 0.3671\ P\ \eta/H$$

Regarding economic consideration, the annual cost of a system may be computed by following relationship (Meredetl, 1973).

$$A = \left(\frac{(1 + i)^n 1}{(1 + i)^n - 1}\right)$$

where,
A = Annual cost of the system, $
C = Capital cost of the system, $
i = Rate of interest, fraction
n = Life of the system in years
M = Annual maintenance cost of the system, $

Materials and Methods

For purposes of this study, six meteorological stations of the Indian Meteorological Department situated in the coastal belt of Orissa were utilized. These stations are each located at Balsore, Paradeep, Cuttack, Bhubaneswar, Puri and Gopalpur. The wind speed of each day for the period of 10 years (1977-1986) was collected from Indian Meteorological Department office at Bhubaneswar. The daily wind flux for all these stations for the entire period was computed. Further, wind flux for each week of the period was estimated in order to determine the weekly average value. Based on these data, the probability analysis at 30, 50 and 70% risk level were obtained using the Weibull plotting position formula (Behera, et al, 1986).

In order to obtain water pumping rate and efficiency of windmill pump, an Apoly-12 PU 500 type windmill installed by the Orissa Renewal Energy Development Agency at Malipada near Khandagiri hill (Bhubaneswar) was also used. The discharge of the windmill at different wind velocities (measured at the site) was recorded during different periods of the year. Observations reveal that the discharge of the pump varied from 0.2 to 1.2 ℓ/sec at working head of 7.38 m at speed ranging from 7 to 18 km/h. Computation efficiency varied between 10 and 26%, for wind power less than 400 Watts. On the basis of the computed probable weekly average wind flux, the discharge for each week of a year at the head of 3 m was estimated, taking overall efficiency of the pump into consideration **(Fig. 2)**.

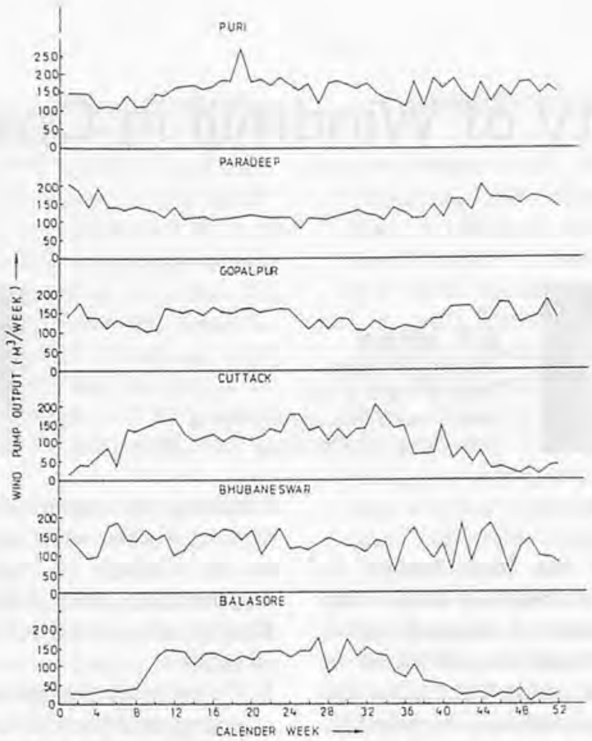

Fig. 2 Discharge of windmill pump at 50% probability at a head of 3 m.

Fig. 1 Windmill "Apoly-12 PU500 type".

The capital cost of wind mill pump, alongwith installation charges is $634 as reported by the Orissa Renewable Energy Development Agency. The Government of Orissa provided subsidy of 75% per farmer, thus the total cost of the system is only $174 per unit. Considering an interest rate of 15%, amortization period of 20 years and maintenance cost as 1%, the annual cost of the windmill pumping system is $35 (Behera D. 1986). Further, considering the cost of requisite tank for reservoir at $578 with life span of 10 years, interest rate and maintenance charge, the annual cost of reservoir was estimated at $121. Thus the total annual cost of the system was $156.

Results and Discussion

Based on daily wind speed data for all meteorological stations, computed windmill pump efficiency curve and annual cost of the system, the following results were obtained:

Wind Energy Flux

Wind flux was computed at 30, 50 and 70% risk level. But for the present discussion only 50% risk level was considered desirable. The minimum and maximum flux are shown in **Table 1**.

Table 1 Maximum and Minimum Average Weekly Wind Energy Flux at 50% Risk Level

Station	Wind energy flux at 50% risk level (W)	
	Maximum	Minimum
Balasore	423.80	20.95
Paradeep	873.32	106.30
Cuttack	892.45	9.80
Bhubaneswar	1800.77	46.00
Puri .	5647.91	123.475
Gopalpur	2670.81	143.59

Table 2 Available Wind Flux (W/h) in Different Weeks of a Year

Station	Wind flux possible in different weeks at 50% risk level (W/h)			
	Below 94	94-754	754-1333	Above 2544
Balasore	1st-9th 28th 35th-36th 38th-52nd	10th-27th 29th-34th 37th		
Paradeep		1st-14th 16th-18th 21st-31st 33rd-52nd	15th 19th-20th 32nd	
Cuttack	1st-6th 37th-52nd	7th-15th 19th-36th	16th-18th	
Bhubaneswar	41st-43rd 52nd	1st-13th 21st-23rd 24th-40th 44th-51st	14th-20th	
Puri		1st-9th 36th-52nd	10th-14th 24th-35th	15th-23rd
Gopalpur		1st-10th 26th-52nd	11th-15th 19th-25th	16th-18th

Table 3 Annual Probable Discharge (m^3) of Appoly-12, PU 500 Model at Different Locations

Location	Discharge (m^3)			
	Annual	Kharif	Rabi	Summer
Balasore	9595	4385	—	5130
Paradeep	48616	20917	8559	19140
Cuttack	23004	8541	—	14880
Bhubaneswar	60767	14035	5165	41567
Puri	169588	72616	10312	86662
Gopalpur	100296	35416	11264	53616

Table 4 Cost of Pumping by Different Power Sources

Station	Annual discharge (m^3)	Cost of pumping		Cost of pumping	
		100% efficiency ($/100m^3)	50% efficiency ($/100m^3)	by electric power ($/100m^3)	by diesel pump ($/100m^3)
Balasore	9595	1.62	3.25	7.81	15.61
Paradeep	48616	0.29	0.58	7.81	15.61
Cuttack	23421	0.65	1.30	7.81	15.61
Bhubaneswar	60767	0.26	0.51	7.81	15.61
Puri	169590	0.09	0.18	7.81	15.61
Gopalpur	100296	0.16	0.31	7.81	15.61

The windmill Appoly-12 PU 500 model cease to operate when wind speed is less than 9 km/h, hence utility of this pump will be limited to some parts of the year. **Table 2** shows the probable wind flux in different weeks of the year.

Table 2 indicates that a windmill will operate throughout the year at Puri, Gopalpur and Paradeep. It will remain operating throughout the year except the 41st to 43rd and 52nd week at Bhubaneswar, 1st to 6th, and 37th to 52nd at Cuttack and 1st to 9th, 28th, 35th, 36th and 38th and 52nd weeks at Balasore.

Wind Pump Discharge

The total annual and seasonal available water by this pumping system at different sites under consideration is summarized in **Table 3** which shows that there is sufficient water available from this pumping system in the localities Paradeep, Bhubaneswar, Puri and Gopalpur throughout the year. Also, sufficient water may be pumped out in the locality of Balasore and Cuttack in all seasons except rabi season.

Economics of Wind Pump

The economics of windmill pumping unit model Appoly-12 PU 500 was computed at 50% risk level and at a head of 3 m.

Thus, the cost of pumping by windmill pumping system is much cheaper than any other system even if only 50% of probable discharge is utilized.

Conclusion

The following conclusions may be drawn from the results of the present study:

1. Sufficient wind flux is available in the coastal belt of Orrisa.
2. Wind pump discharge and wind speed has S-curve relationship.
3. Water for irrigation is available in sufficient quantity in all seasons in the localities of Paradeep, Bhubaneswar, Puri, and Gopalpur, whereas at Balasore and Cuttack water is available only in the summer and kharif season.
4. Water pumping rate by windmill pump is very economical.

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Effect of Plant Orientation in the Windrow on Groundnut Combining Losses in Irrigated Clay Soils of the Sudan

by
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Abstract

Different ways of preparing the windrows for combining, after mechanical digging, are followed by farmers in irrigated projects. Four plant orientations were compared in this study: random orientation, plants shaken and vines placed down, plants shaken and vines placed up, and plants not shaken but vines placed down.

Two seasons (1987/88-1988/89) results show that there were no significant differences in the combining losses. It was observed that the largest contribution to the total combining losses was from the pre-combining losses.

Introduction

The Sudan is one of the largest exporters of groundnut (*Arachis Hypoqae* L.) in the world. In 1978 the country exported about 17% of the world's groundnut exports (Woodroof, 1983). The total area cultivated is about 1.1 million hectares about 15% of which is cultivated in irrigated clay soil representing about 40% of the total production. At present, groundnut production is mechanized at varying levels in Rahad (27 000 ha), Gezira (90 000 ha), New Halfa (17 000 ha), and Suki (5 000 ha) irrigated agricultural projects. In these heavy clay soils, various harvesting problems are encountered because of the nature of the soil which makes soil particles adhere to groundnut pods. Field losses are about 20% for digging and about 4% in threshing (Dawelbeit, 1986 and 1987).

The Rahad project has the highest percentage of mechanization with about 42% of the cultivated area being mechanically dug and 62% of the total area being mechanically threshed (Ibrahim et al., 1986). Different digging machines are used: digging blades, digger-shakers, digger-shaker-windrowers, and digger-shaker-inverters. In the Rahad Project, after the digging operation, farmers follow different ways in the manual preparation of the windrows for direct combining. Some shake the plants to remove the soil and place the plants either vines up or down, while others just invert them and still others leave the dug-out rows in their random orientation. After these preparations, the common practice is to leave these rows to cure before they are combined. Combining consists of picking up the plants from the windrows, pulling off the pods from the vines and collecting the pods in the basket for subsequent cleaning and drying. The windrow harvesting method reduces the quantity of labor required per hectare from 411.3 to 19.5 man-hours (Dawelbeit, 1989). However, low field capacities, low field efficiencies as well as high field losses of direct combining operations are also problems in these irrigated government projects.

The objective of this research was to investigate the effect of groundnut windrow preparation and compare the effects of different plant orientations in the windrow on combining losses. This information will help the farmers in deciding the best way of preparing their fields to combining.

Materials and Methods

The field studies were conducted at Elfau-Rahad Research Station for two consecutive seasons (1987/88 and 1988/89). The soils are vertisolic (50-60%)

clay, low organic matter (0.03%), and alkaline pH (8.78-9.4) (Fahal, 1984). The design of the experiment was randomized complete blocks with four replications. The experimental area was mechanically dug out using a Lilliston digger-shaker-windrower model 850. Treatments were made on the same day of digging. The treatments are as follows:

A. Mechanically dug out using only the digger-shaker-windrower. Plants were randomly placed in different orientations.
B. After mechanical digging, the plants were manually shaken to remove sticking soil and placed vines on bottom, pods on top.
C. After mechanical digging, the plants were manually shaken to remove sticking soil and placed vines on top, pods on bottom.
D. After mechanical digging, the plants were placed pods on top and vines on bottom with no shaking.

Threshing was done when the pods were dry using a Lilliston groundnut combine (model 1580). Plot size was 30 × 1.6 m. All recommended cultural practices were complied with, including ridge planting (80 cm wide), seed rate (90 kg/ha), sowing date (June), green ridging, and watering (10 waterings at fortnight intervals). Plots were kept weed free. Groundnut variety MH383 was used. At optimum harvesting date (about 150 days from emergence) plots were dug out at soil moisture of 15% (DB). In both seasons digging was done in November. Maximum temperatures were 36.3°C in November and 33.4°C in December. Mean temperatures in November and December were 14.8°C and 20.8°C, respectively, while relative humidity was 35% in both months. The data collected at Medani also showed zero precipitation during these two months (Ibrahim, 1983).

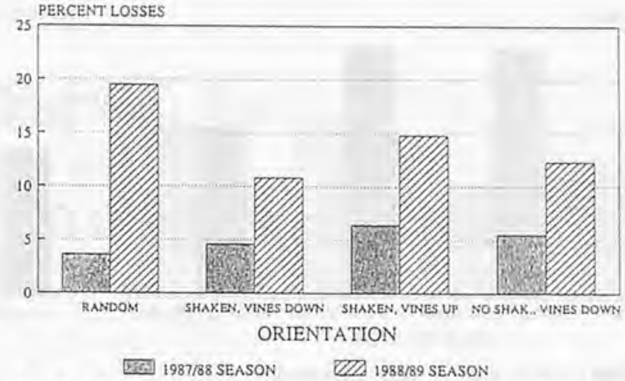

Fig. 1 Effect of orientation on groundnut pre-combine losses.

Calculations were done according to the following definitions:

a. *Total yield* — This is the sum of digging losses, pre-combine losses, header losses, tail losses, and basket yield.
b. *Digging losses* — These are pods left in the ground after digging operation.
c. *Pre-combine losses* — These are pods that are on the ground before the combine header picks up the plants.
   Percent pre-combine loss = (pre-combine loss) / (total yield) × 100
d. *Header losses* — These are pods which are left on the surface of the ground after the combine header passes.
   Percent header losses = (header losses) / (total yield) × 100
e. *Tail losses* — These are pods lost with the hay thrown at the back of the combine.
   Percent tail losses = (tail losses) / (total yield) × 100
f. *Total combining losses* — This is the sum of the pre-combine losses, header losses, and tail losses.
   Percent total threshing losses = (total threshing losses) / (total yield) × 100

Results and Discussion

Data collected in this experiment were processed and the analysis of variance (using SAS, 1985) was performed.

Pre-combine Losses

Results of the first season (1987/88) showed that the highest pre-combine losses were obtained with the vines up and with no shaking orientation (**Figure 1**). Both orientations of the vines down had less losses than the vines-up orientation. The random orientation had the least losses. Shaking seems to have no effect on losses. However, in the second season the random orientation had the highest pre-combine losses. This could be due to the change of weather conditions. Also, it was observed that shaking had no effect and that the average pre-combine losses in the first season were about half that of the second season. Pre-combine losses are mainly affected by the weather and natural conditions. Due to the high temperature and low relative humidity, the plants dried quickly regardless of the orientation. This caused the plants to become crispy and can easily shed their pods.

Header Losses

Header losses refer to groundnut pods which have been missed or dropped by the header while picking up the plants from the windrow. In this experiment header losses in the two seasons ranged between 2.5 and 5.6%. The lowest header losses were found at the random orientation

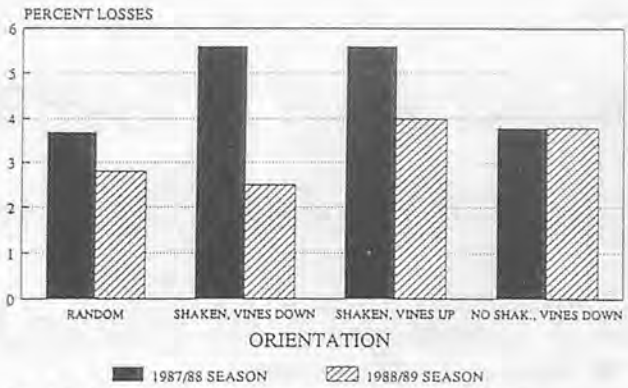

Fig. 2 Effect of orientation on groundnut header losses.

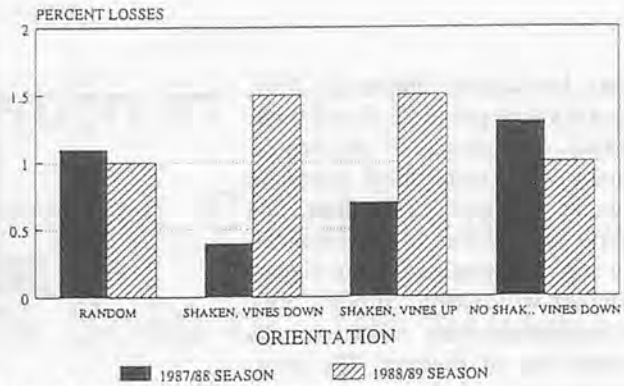

Fig. 3 Effect of orientation on groundnut tail losses.

in the first season and at the shaken, vines-down orientation in the second season (**Fig. 2**). However, the lowest average header losses for the two seasons were obtained at the random orientation. Vines-down orientation had lower header losses than vines up for the two seasons. This may be due to the fact that it is easier for the fingers of the pick-up cylinders to work against the pods rather than the vines.

Tail Losses

No significant differences in losses were observed between the treatments (**Fig. 3**). Tail losses were very low in the two seasons and ranged from 0.4 to 1.5% only.

In comparing the contribution of the different types of losses towards the percent total combining losses, it was found that the pre-combining losses were the largest contributor. This was followed by the header losses, and finally, the tail losses. **Table 1** shows the percentage total threshing losses and total yield for the two seasons. It seems that the hot and dry weather conditions at the time of combining has the most dominant effect on windrow losses. It is a common practice that windrows are left to cure and dry before combining in order to control the equality of the groundnut. Woodroof (1983) reported that mechanical groundnut inverting began in New Mexico about 1957 and has become a common practice since then. The increased interest in mold and aflatoxin stimulated the development. Some advantage of inverted windrows include easier maneuvering of the picker, fewer trips through the field, less affected by wind or rain and allowing for more maturity before harvest. Dickens and Khalsa (1967) in North Carolina, U.S.A., compared inverted and randomly oriented groundnut windrows. They found that groundnut in the inverted windrows dried more rapidly than groundnut in the random windrows. They also concluded that groundnut combined from inverted windrows received less mechanical damage and are of better quality in the following aspects: (a) fewer loose shelled kernels and less pod damage; (b) better milling quality; and (c) less risk of aflatoxin contamination. In this experiment, it was observed that the different treatments dried evenly and that could be due to the high temperatures and low humidities of this semi-arid area. This could be the reason for not having significantly different total combining losses (**Table 1**). Furthermore, visual inspection did not show any mold contamination for all the treatments. It appears from the results of this experiment that there is no advantage of one orientation over the other. Farmers can follow the most economical way in preparing the windrows for combining.

Table 1 Effect of Plant Orientation on Percent Total Threshing Losses and Yield for Two Seasons.

Treatment	Percent threshing losses (%)		Total yield (kg/ha)	
	1987/88	1988/89	1987/88	1988/89
Randomly oriented	8.4	23.3	4 026	3 685
Shaken, vines down	10.6	14.8	3 489	3 559
Shaken, vines up	12.7	20.3	2 945	3 194
Not shaken, vines down	10.6	14.8	2 841	3 264
Mean	10.6	18.3	3 325	3 264

Although there were no difference in the total yield for the two seasons, it was observed that the percentage total losses in the first season were about half that of the second season. This is attributed to the pre-combine losses.

Conclusions

1. No significant differences were observed in the effects of the different tested orientations on combining losses.
2. The largest contribution to the total combining losses is from the pre-combine losses.

(Continued on page 56)

Development of A Test Rig for Performance Evaluation of Seed Metering Devices

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Abstract

A test rig with provision to accommodate various seed metering units and moving grease-coated, flat-belt simulating ground speeds of a drill was developed. Sponge feed and universal seed wheel, seed metering units of Aitchison and Hassia drills were evaluated in this study. These units were mounted in the hoppers with angle of repose equal to that in original drills. Regularity of seed spacing of wheat, paddy, millet and rape/mustard were evaluated at speeds of 3.7, 4.5 and 5.4 km/h. A speed of 4.5 km/h was found suitable for all crops except millet with universal seed wheel metering unit. In the case of sponge feed metering unit, a speed of 3.7 km/h was found suitable for wheat and paddy. Whereas, millet and rape/mustard distribution was found better at a speed of 4.5 km/h.

Introduction

Proper placement of seeds in rows is one of the important factors in crop production which can affect crop growth and yield. Uniformity of seeds in row depends on the performance of metering device of a drill. Therefore, the proper design of a metering device is an essential element for satisfactory performance of a seed drill.

Irregularity in longitudinal placement of seeds is an index of estimation of seeding quality sown by drill. However, the determination of the longitudinal irregularity factor of seed deposition in the soil is very difficult due to unpredictable behaviour of seeds. Bernacki et al (1972) reported that researchers have made attempts to determine longitudal uniformity under laboratory conditions. They consolidate soil rows by coating with melted paraffin after sowing. Then they cooled the paraffin and separated the coagulated strips with seeds to make lontigudinal sections of the soil fragments. But this practice proved to be very inconvenient. The isotropic method using gamma rays to screen the soil does not also give clear indication of the cylindrical dispersion of seeds in the soil.

The most popular method is by determining the longitudinal irregularity of seed deposition in open furrows which can be achieved by using sufficiently moist sand. Since this method does not take into account the operation of furrow openers and due to sliding of furrow slopes, its accuracy is always questionable. But the method is useful in the assessment of the operational properties of different types of seeders.

Kaviani et al (1985) developed an apparatus for measuring seed placement in 3 dimensions to assess the accuracy of seed placement by direct drilling machines. In this method, samples are taken after drilling and transferred to a glass house for germination. After sprouting of seeds, each piece of turf was placed in the 3-dimensional measuring apparatus. Germinated seedlings indicated the position of seeds in the soil and the soil is carefully scraped away until the seed is located. A mobile pointer needle was then moved to locate the position of seeds in horizontal and vertical planes.

The regularity of seed spacing can also be observed by mounting the drill or the hopper and metering device on a suitable stand and passing a grease-coated belt under the furrow opener or seed tube in such a way that the speed of the belt is equal to the running speed of the drill. Keeping in view the simplicity of this method, a test rig was developed at the Farm Machinery Institute (FMI) to evaluate different seed metering devices.

As mentioned earlier, uniformity of seeds in rows depends upon seed metering device of a drill. Fluted roll-type seed metering units are being used in locally produced drills. These flutes have improper grooves and are made of poor quality material. This results in rapid wear out and hence affects the seed distribution pattern. The FMI has locally developed an Aitchison multi-crop seed-cum-fertilizer drill with a sponge feed metering system. Another universal seed wheel metering device mounted on Hassia drill was also tested. In this study both seed metering devices were evaluated for their seed distribution performance using the FMI-developed test rig.

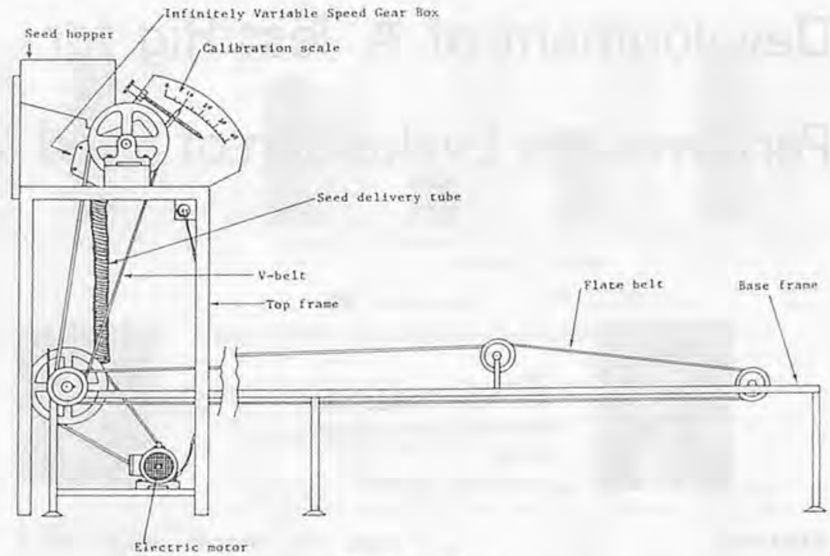

Fig. 1 Test rig.

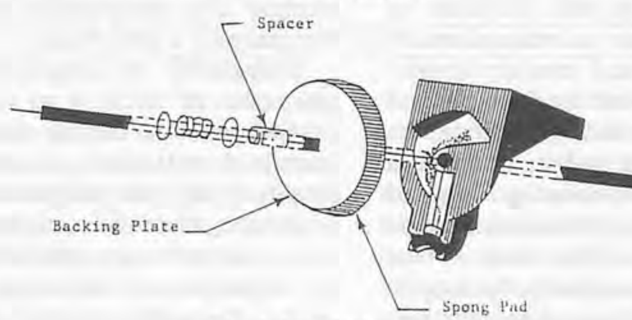

Fig. 2 Seed feed mechanism.

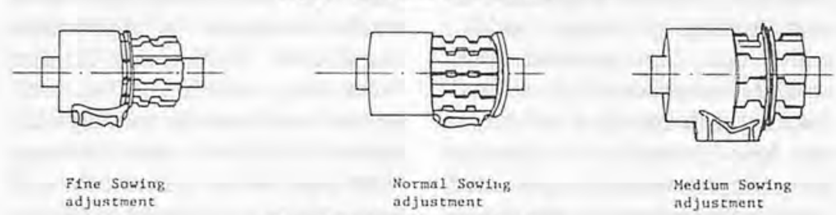

Fig. 3 Universal seed wheel.

Description of Test Rig

The rig frame is simple in construction and was fabricated using 2.5 × 5 cm MS angle iron (**Fig. 1**). It is composed of base and top frames. The base frame of 420 × 31 cm (L × W) which has six legs of 46 cm height was fabricated. An electric motor of 1 hp was mounted on one end of this frame. Drive from this electric motor is transmitted to a 8 m long continuous flat belt of 150 mm width through V-belt drive system. Flat belt is wrapped around 8.5 × 14 cm length rollers mounted at both ends of frame. A third roller is mounted in the middle of the frame to keep the flat belt at proper tension.

The top frame has mounting for infinitely variable speed gear box. The drive to gear box was taken from the electric motor mounted in base frame through a V-belt drive system. Hoppers of identical cross sections and angle of reposes of Hassia and Aitchison drills with provision for fitting of one seed metering unit of these drills were mounted on the top of frame. The seed metering unit driving shaft was coupled to the gear box output shaft. The description of other components of the test rig is given below.

Sponge-feed Metering Unit (Aitchison Drill)

A soft and resilient sponge rotates against a specially shaped groove of seed metering plate. It envelops the seed irrespective of its shape and slowly pulls it down the groove where it is released and dropped down the seed tube (**Fig. 2**). The seed agitator is used only with larger seeds to avoid bridging around the entry point of the seeds in the groove.

Universal Seed Wheel Metering Unit (Hassia Drill)

This is a fluted roll type seed metering unit with adjustment for fine, normal and medium seed sowing. Four different adjustments are provided for the seed gate, according to the type of seed (**Fig. 3**). By adjusting the stopping slides provided on the back of the hopper the seed flow to the individual metering units can be regulated. The adjustable seed gate is spring-loaded to prevent blockages by foreign bodies and for even seeding.

Infinitely Variable Speed Gear Box

In this gear box, two plastic cams with an eccentricity of 56 mm are spaced at an angle of 180 degree from each other on the input shaft. These cams move two followers in the curved groove paths with fixed vertical displacement. The followers are connected through flat bars to the ratchet bearings mounted on the output shaft. The distance travelled by the followers in the paths is varied by changing the inclination angle of the paths with the horizontal axis. This results in charges of the speed of output shaft. There is a spring-loaded lever used for changing the inclination angle and serves also as seed rate index lever.

Methodology

A sticky layer of grease was applied on the top of the flat belt to facilitate proper embedding of seed without any displacement. The flat-belt speed as indicator to drill ground speed was varied by changing the V-belt pulleys. **Table 1** shows the calculated and measured speeds of flat belt by using various flat-belt driving pullies.

The rig was used to evaluate the seeding distribution performance of both sponge feed and universal seed wheel metering units for wheat, paddy, millet and rape/mustard. The information on the agronomic requirements of these crops in terms of seed rate and row spacing was collected **(Table 2)**. The time required to deliver 100 g of seed using single row was calculated with the following formula:

Time required to deliver 100 g of seed (seconds) = (3.6 × 105)/(Seed rate × Row spacing × Speed)

where,
Seed rate = kg/ha
Row spacing = cm
Speed = km/h

Table 1 Calculated and Measured Speeds of Flat Belt

Pully diameter (cm)	Calculated speed (km/h)	Measured speed (km/h)
30.0	4.30	3.70
26.5	5.00	4.50
21.5	6.00	5.40

Table 2 Agronomic Requirements of Selected Crops

Crop	Seed rate (kg/ha)	Row spacing (cm)
Wheat	100	15
Paddy	75	30
Millet	10	75
Rape & mustard	10	30

The time required for collecting the above crop seeds at three different speeds is shown in **Table 3**.

The test rig was operated for the time shown in **Table 3** at selected travel speeds for all the four crops with both seed metering units. The data was recorded for seed rate index lever position and number of seeds embedded per meter length on flat belt.

Table 4 shows the index lever position of the gear box in collecting 100 g of seed at three different speeds.

Results and Discussion

The seed distribution data was analysed in order to determine the average number of seeds per meter length, standard deviation and coefficient of variation **(Tables 5** and **6)**.

These parameters were used to characterize seed spacing and uniformity of distribution. A low CV represents a row with more uniform seed spacing whereas a large CV indicates a row with less-uniform seed spacing. The results shown in **Table 5** using universal seed wheel metering device indicate that the coefficient of variation is low at the speed of 4.5 km/h for wheat, paddy and rape seed than attained at 3.7 and 5.4 km/h. This means that 4.5 km/h is a suitable speed to operate the drill for these three crops. Theoretically, the CV should increase with an increase in speed because of more disturbance of seed as it falls on flat belt operating at high speed. Since the flat belt was coated with grease, this disturbance was found negligible.

Table 3 Time Required to Collect 100 Grams of Seed

Unit: (Seconds)

Speed	Wheat	Paddy	Millet	Rape/ Mustard
3.7	65.2	32.6	87.0	326.0
4.5	53.3	26.6	71.0	266.6
5.4	44.5	22.5	59.0	222.0

Table 4 Gear Box Index Lever Position for Various Crops

Speed (km/h)	Wheat	Paddy	Millet	Rape/ Mustard
3.7	14.0	34	15	6
4.5	14.3	37	15	7
5.4	14.5	36	12.5	7

In the case of sponge feed metering device, the 3.7 km/h travel speed was found most suitable for wheat and paddy **(Table 6)**. For millet and rape seed the coefficient of variation was found low at the speed of 4.5 km/h.

The coefficient of variation was observed low for millet and rape seed using both the sponge and universal seed wheel metering devices at the speed of 4.5 km/h.

Conclusions

1. A speed of 4.5 km/h gave more uniform seed distribution for all crops except millet with universal seed wheel metering unit.
2. In the case of sponge feed metering unit, a speed of 3.7

Table 5 Seed Distribution with Universal Seed Wheel Metering Unit

Crop	Ground speed (km/h)	Avg. No. of seeds per meter linear length	SD	CV
Wheat	3.7	30	4.69	0.31
	4.5	36	2.56	0.14
	5.4	38	4.0	0.21
Paddy	3.7	111.0	10.67	0.19
	4.5	111.2	6.80	0.12
	5.4	116.0	9.85	0.17
Millet	3.7	97	3.88	0.08
	4.5	136	7.97	0.11
	5.4	107.4	12.2	0.23
Rape seed	3.7	71	7.71	0.22
	4.5	76	4.36	0.11
	5.4	67	6.0	0.18

Table 6 Seed Distribution with Sponge Feed Metering Unit

Crop	Ground speed (km/h)	Avg. No. of seeds per meter linear length	SD	CV
Wheat	3.7	31.0	2.94	0.19
	4.5	37.0	4.93	0.27
	5.4	34.0	5.35	0.33
Paddy	3.7	130	6.68	0.10
	4.5	153	9.91	0.13
	5.4	148	7.87	0.11
Millet	3.7	139	9.73	0.14
	4.5	123	5.20	0.08
	5.4	110	11.11	0.20
Rape seed	3.7	63	5.35	0.17
	4.5	68	3.97	0.12
	5.4	76	7.30	0.19

km/h was found suitable for wheat and paddy. A better seed distribution uniformity was found at a speed of 4.5 km/h for millet and rape/mustard.

3. Inconsistent effect of speed was observed on uniformity of seed distribution with both seed metering units.

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(Continued from page 52)

Effect of Plant Orientation in the Windrow on Groundnut Combining Losses in Irrigated Clay Soil of the Sudan

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Manpower and Energy Requirements for Different Dairy Farm Operations

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Abstract

Efforts have been made to establish manpower and energy requirements for different important activities in dairy farms. These estimates have been made under normal but continuous working conditions. However, the values recorded do not include any slack time. The maximum manpower and water required for washing of a single cow was 4.96 ± 0.219 man-min and 122.6 ± 4.9 litres. The above values for washing of floor was 6.226 ± 0.205 sec and 5.76 ± 0.041 litres for each square meter area. The average time observed for morning time machine milking of each kilogram of cow milk was 0.98 ± 0.03 min. This value for hand milking was observed as 3.23 ± 0.499 min. Energy required for chopping of fodder crops and some selected dairy farm operations were also observed.

Introduction

This paper is a case study of the livestock cattle farm of the Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh having about 800 cows and buffaloes. The cattle farm is basically engaged in the cross-breeding programme of native cattle with improved dairy type of temperate-breeds. At present various types of cross-bred animals are available Indian farmers. However, the management requirements of these cattle are not well established. Therefore, this study has been undertaken with the following objectives:

1. To establish management norms for the cross-breed animals for different dairy farm operations in terms of manpower and energy requirements.
2. To have reference information also and the present management practices.
3. To explore the possibility of improving the current management practices.
4. To calculate comparative manpower and energy requirements for selected dairy farm operations.

It was not possible to cover information about all the operations in a livestock farm. However, efforts were made to generate information about the important activities which play a major role in the livestock farm management. These activities are listed below.

1. Manpower and water requirement for lactating animals for washing and showering.
2. Manpower and water requirements for floor washing.
3. Manpower requirements for machine-milking of cows for morning and afternoon milking.
4. Manpower requirements for hand-milking of cows.
5 Manpower requirements for tying and untying of cows in the milking barn.
6. Energy requirements for chopping of different fodder crops with a power cuttter.
7. Manpower requirements for transport and unloading of fodder.
8. Manpower requirements for the feeding of silage to

animals.

9. Energy requirements for manual collection of dung using spades.
10. Energy requirements for collection of dung using bullock-operated dung cleaner.
11. Energy requirements for manual dung lifting.

The data collected for all the above operations have been recorded in normal but continuous working condition without any psychological pressure over the workers as they were not made aware of the data recording facts. Therefore, it could be presumed that the data gave a true representation of the working efficiency of the farm workers in a continuous working pattern. However, since these data have been collected in a discrete manner, slack time which is an essential part of a continuous activity, was not included most of time.

Review of Literature

Large numbers of crossbred cattle of various grades have been developed in the last few decades in India under different agro-climatic conditions. However, very little information is available on the management norms of these crossbred grades. Information available on the native and exotic cattle is being utilized for the crossbreds.

Very little information is available on the energy requirement for shed cleaning and lifting of dung from a large-sized cattle farm excepting reports of Joshi et al (1982) and Joshi et al (1987). It was observed that collection of wet dung was more time-consuming than dry dung. The average time required for the collection of dung by "belacha" (shovel) under wet and dry dung condition was 18.87 and 22.0 man-h, respectively, for 4 000 m^2 area. The use of dung cleaner without wheels reduced this time to 12.81 and 15.62 man-h, respectively. The wheel type dung cleaner further reduced the time to 4.73 and 6.62 man-h for dry and wet dung conditions for similar area. A highly improved bullock operated dung cleaner with seating arrangement for the operator and lever mechanism for the lifting and lowering of scraping blade assembly which was provided with pneumatic wheels reduced this time period to 0.9 h per 4 000 m^2 of floor area. A pair of bullocks and two labourers were required for the operation of the dung cleaner. The capacity of this dung cleaner developed by Joshi and Pandey (1988) was 73.92 m^2/min.

Nalbant and Uiger (1989) studied the comparative performance of machine milking methods. The maximum number of cows milked per man-h were 11 and 30 for hand and pipeline milking machine with 12 milking units, respectively. The mean times of work routine components in hand milking were 1.5 min for walking to and from cow and discharging milk bucket; 0.6 min for washing and drying of teats and 0.2 min for miscellaneous activities.

Claesson (1977) also determined the required average time for milking routine as 0.27 min for stimulation of let down, 0.25 min on cluster, 0.39 min for machine stripping, 0.17 min for emptying of recorder jar, 0.30 min for change of cows, 0.05 min for concentrate feeding, and 0.23 min for milking wasted time per cow in milking parlours with bucket milking machine. The milking capacity was 38.6 cows per man-h.

Materials and Methods

Data for management norms, viz, requirement of water for washing and showering of animals, washing of animal sheds and labour requirement for various livestock farm operations were collected in the years 1985 to 1987.

Water requirement for washing of concrete floor was estimated by washing of measured area of floor by pumping the water through a 50 × 37.5 mm size "ejecto" pump from a measured tank. The volume of water required per m^2 area was calculated on the basis of total water used and area washed. Various size of floor area were washed repeatedly for 5 days and mean water requirement in litres per square meter was estimated. Manpower and water requirements for washing of the lactating cows was estimated in two conditions, viz, (a) when bedding was provided and (b) when bedding was not provided to animals. The water was pumped through a 50 × 50 mm size centrifugal pump. The delivery of the pump was reduced to 25 mm and water was sprayed on cows through approximately 50 meter long rubber hose of 25 mm diameter. The volume of water discharge by the pump per min was estimated. Manpower and water required for washing of lactating cows was also estimated.

The quantity of water and manpower required for showering of lactating cows during summer was estimated by recording the time required for showering a known group of cows through a pump of 50 × 50 mm size of 72 ℓ/min discharge. The groups of lactating cows of varying numbers were given showers and the time was recorded. On the basis of these observations the average volume of water and man-minute per cows were estimated.

The manpower required for washing of the milking byre concrete cement floor was estimated while one labourer was deployed for collection of dung and subsequent washing of floor with the help of an "ejecto" pump supplying water under pressure through a 25-mm diameter rubber hose. After washing the floor was swept with broomstick.

The total time required for milking of cows was observed under three sets of experiments. The time was recorded for machine-milking of cows in the morning, machine-milking during noon and hand-milking of cows during morning period. These observations were repeated for seven days. In all the observations cows were kept ready for milking in a tail-to-tail type milking byre. The total time required for the milking of each cow included the time required for tying and untying of legs, milking and stripping of cows and weighing of milk in the central milk recording room. The GDR-made milking machine used in these experiments was individual bucket type "Impulsa" machine with a pulsation ratio of 1 : 1. Four to five sets of machines were operated at a time and all machines were provided vacuum from a single vacuum pump. Each milker was provided with one milking machine.

The time required for milking operations of each cow was estimated as the average of total time taken for all the activities performed by the different milkers for a group of cows.

Manpower and electrical energy required for chopping green fodder was recorded in five sets of trials, viz, green maize with 12% and 20% dry matter, green jowar with 25% dry matter, mixed grass with 20% dry matter and oats with 12% dry matter. The chaffing was performed by power cutters operated by 15 hp electric motor. The chopped material was directly delivered to a tractor trailer through the delivery chute of the machine. Four to five workers were assigned for the chopping activity which included piling of fodder in the trailer and feeding of fodder, etc. The trailers used in the trials each had a capacity of 8.8 m^3.

The manpower needed for the transport and unloading of the fodder from chop cutter site to various sheds of the farm was recorded. Two persons were assigned for the job and total time taken from cutter site to the sheds and back was recorded. The electrical energy was estimated with the help of a three phase energy meter having a least count of 0.1 kW-h.

The manpower required for putting the oat silage and green maize with 25% dry matter in the feeding trough was estimated. A weighed quantity of silage was kept near the feeding trough and a single worker was assigned to put the fodder into the feeding trough and time was recorded with the help of a stop watch.

The energy required for the collection of dung manually by the belacha and by a bullock-operated dung cleaner with 180 cm wide blade were estimated. The bullock-operated dung cleaner required a pair of bullocks and two workers for its operation. Different size of paddocks were used for the observations.

The dung that accumulated at a place in each paddock was loaded manually into the tractor trailers. In the first trial, the time required for loading of the individual trailer was recorded and in the second trial total time required to fill 3 to 4 trailers along with intermediate slack time was also recorded.

The horsepower of an individual labourer was considered as 0.1 hp and horsepower of a pair of bullock was considered as 1 hp in the entire set of observations.

Results and Discussion

Observations in regards to the manpower and water requirements

Table 1 Water and Manpower Requirements for Washing of Lactating Cows (without Bedding Provided at Night)

No. of animals	Total water for washing (litres)	Water requirement (litres/animal/day)	No. of workers	Time (min)	Man-min per cow	Energy (hp-h/cow)
24	3 481.3	139.3	4	35	5.83	.0097
26	3 580.8	137.7	4	36	5.53	.0092
27	2 984.0	110.5	4	30	4.44	.0074
27	2 785.1	103.8	4	28	4.14	.0069
34	4 078.1	119.9	4	41	4.82	.0080
35	4 277.1	125.8	4	43	4.91	.0082
34	4 277.1	125.8	4	43	5.05	.0084
		122.6 ± 4.9			4.96 ± .219	.00826 ± .0004

Table 2 Water and Manpower Requirements for Washing of Lactating Cows (Provided with Bedding at Night)

No. of animals	Total water for washing (litres)	Water requirement (litres/animal/day)	No. of workers	Time (min)	Man-min per cow	Energy (hp-h/cow)
35	1 449.2	41.4	2	20	1.14	.0019
37	2 028.7	54.8	2	28	1.51	.0025
16	1 231.8	77.0	2	17	2.21	.0035
33	1 956.4	59.3	2	27	1.63	.0027
33	1 956.4	59.3	2	27	1.63	.0027
38	3 985.3	104.9	2	55	2.89	.0048
34	4 709.9	138.5	2	65	3.82	.0064
16	1 304.3	81.5	2	18	2.25	.0037
41	3 260.7	79.5	2	42	2.05	.0034
18	1 444.2	80.5	2	20	2.22	.0037
22	3 260.7	148.2	2	45	4.09	.0068
72	7 825.7	118.7	2	108	3.00	.0050
		86.1 ± 9.56			2.36 ± .265	.0039 ± .0010

for washing the cows are given in **Tables 1** and **2**. It was observed that water requirement for the washing of single cow was 122.6 ±4.9 litre/animal/day and manual energy required was 4.96 ± 0.219 man-min per cow. Bedding was not provided to animals at night. The water and manpower requirements while the animals were provided bedding at night was observed to be 86.1 ± 9.56 litre/animal-day and 2.36 ± 0.265 man-min per cow, respectively. The water and manpower requirements decreased significantly when bedding was provided to the animals.

Table 3 gives manpower and water required for washing of concrete cement floor of the milking byre. It was observed that 5.76 ± 0.041 litres of water was required for cleaning of each square meter of area. The time required for the cleaning of each square meter of area was 6.226 ± 0.205 sec and it was expected that one worker would clean 9.90 ± 0.3933 m^2 area per minute.

Giving shower to cows is an important requirement, particularly in summer. It was observed that 0.315 ± 0.013 man-min per cow was required for this operation **(Table 4)**.

Milking of animals was carried out three times a day. However, observations were taken only for the morning and afternoon milking. The data regarding evening milking was not undertaken under the course of study. Only final inference of the data are given in **Table 5**. The total number of observations and total animals considered under the different studies are also listed. The average time required for the machine milking of cows using the milking machine was 7.06 ± 0.03 min for the morning milking of cows. However, it was 14.37 ± 0.602 min per cow and 1.358 ± 0.119 min per kg cow was less for the afternoon milking due to the fact that milk yield was also less at that time. However, the average time required per kg of milk was greater for the afternoon milking as the other basic activities associated with the milking operation remained unchanged.

The average time per cow for the hand-milking was considerably higher than performing it by milking machine which was 14.37 ±

Table 3 Manpower and Water Requirement for Washing Floor

Total area washed (m^2)	Total water required (litres)	Water required per m^2 (litres)	Total time (seconds)	Time per unit area (sec/m^2)	Area per unit time (m^2/man-min)
219.46	967.7	4.41	1 045	4.762	12.60
219.46	1 365.8	6.62	1 475	6.721	8.93
219.46	1 183.4	5.39	1 278	5.823	10.30
219.46	1 098.61	4.98	1 281	5.837	12.04
149.85	814.9	5.44	880	5.873	10.22
149.85	879.7	5.87	950	6.340	9.41
149.85	928.8	6.20	1 003	6.693	8.96
149.85	926.0	6.18	1 000	6.673	8.99
149.85	976.9	6.52	1 055	7.040	8.52
149.85	780.6	5.21	843	5.626	10.67
149.85	883.4	5.56	900	6.006	9.99
149.85	1 015.8	6.78	1 097	7.321	8.20
		5.76 ± 0.041		6.226 ± 0.205	9.90 ± .3933

Table 4 Manpower Requirement for Showering of Lactating Cows during Summer Season.

No. of cows	No. of workers	Time (min)	Total man-minutes	Man-minutes per cow
62	2	21	42	0.355
14	2	3	6	0.429
62	2	9	18	0.290
14	2	3	6	0.429
20	2	4	8	0.400
10	2	3	3	0.300
14	2	2	4	0.286
26	2	5	10	0.385
62	2	9	18	0.290
14	2	2	4	0.286
62	2	9	18	0.290
28	2	5	10	0.357
21	2	4	4	0.190
14	2	2	4	0.286
62	2	9	18	0.429
14	2	3	6	0.429
30	2	5	10	0.300
62	2	9	18	0.290
62	2	9	18	0.290
10	2	2	4	0.200
26	2	4	8	0.308
63	2	9	18	0.289
63	2	9	18	0.286
				0.315 ± 0.013

Table 5 Manpower Required for Milking Operation

Detail of operation	Total number of observations	Cumulative number of cows	Average milk yield (kg)	Average time per cow (min)	Average time per kg milk (min)
Morning milking of cows by machine	48	468	7.43 ± 0.16	7.06 ± 0.14	0.98 ± 0.03
Afternoon milking of cows by machine	11	103	3.63 ± 0.22	4.72 ± 0.19	1.358 ± 0.119
Morning milking of cows by hand	5	373	4.55 ± 0.669	14.37 ± 0.602	3.23 ± 0.499
Morning hand milking of unweaned Buffaloes	3	33	3.51	13.19	3.76
Tying of cows in milking byre	17	343	—	20.26 sec ± 1.163	—
Untying of cows in milking byre	23	432	—	11.24 sec ± 0.901	—

0.602 min. The average time per kg of milk was 3.23 ± 0.499 minutes which was also considerably higher than machine milking. In case of unweaned buffaloes it was observed to be 13.19 min per buffalo and 3.76 per kg of milk.

The average time required for tying and untying of cows in the milking byre was observed to be 20.26 ± 1.163 sec and 11.24 ± 0.901 sec.

Final observations about the manual and electrical energy required for the chopping of the different types of fodder is given in **Table 6**. It was observed that 0.27 to 0.36 man-h were required for each cubic meter of chopped fodder. Since the output of power cutter may vary significantly with its bulk density, the data was recorded on volume basis for different types of fodders. It was found that for different crops viz, maize, oats, jawar (sorghum) and mixed grasses, the manpower requirement was almost comparable. The electrical energy required for the chaffing of maize and oats was observed to be 0.461 ± 0.0269 kW-h and 0.377 ± 0.0044 kW-h, respectively.

The energy required for some selected livestock farm operations are given in **Table 7**. These are the final observations made during the experiment. The manpower required per m^3 of fodder transport and unloading was 0.0793 man-h/m^3. The time required for feeding of fodder to animals was 3.205 min per quintal. Man-hour required for the collection of dung using the belacha was 35.84 ± 4.661 man-h per ha area. However, while the activity was performed with the help of a bullock-operated dung cleaner, it was found that 5.27 ± 0.71 man-h/ha and 5.27 ± 0.71 bullock-h/ha were needed. It was found that there was significant saving in the manpower as compared to cleaning of dung by belcha. The manpower required for the lifting of dung of wet and semi-dry consistency was 0.896 ± 0.082 and 0.532 ± 0.033 man-h/m^3 of dung. While idle time was also taken into account, the manual energy required for lifting wet dung was 0.756 ± 0.059 man-h/m^3.

Table 6 Energy Required for Chopping of Fodder

Crop	Number of observations	Moisture content % on wet basis	Energy per cubic meter of chopped fodder	
			Manual (Man-h)	Electrical (kW-h)
Maize	5	87 to 88%	0.270 ± 0.026	0.461 ± 0.0269
Oats	5	88%	0.356 ± 0.057	0.377 ± 0.0044
Maize	9	73%	0.310 ± 0.017	Not recorded
Jawar	4	65%	0.360 ± 0.030	Not recorded
Mixed grasses	12	76%	0.330 ± 0.062	Not recorded

Table 7 Energy Required for Other Selected Dairy Farm Operations

Manpower required for transport and unloading of fodder	0.0793 man-h/m^3
Time required for offering of silage to animals	3.205 min/q
Energy required for manual collection of dung through shovel	35.84 ± 4.661 man-hr/ha
Energy required for collection of dung through bullock-operated dung cleaner	5.27 ± 0.71 man-h/ha 5.27 ± 0.71 bullock-h/ha
Energy required on lifting of dung of wet consistency	0.896 ± 0.082 man-h/m^3
Energy required on lifting of dung of semi-dry consistency	0.532 ± 0.033 man-h/m^3
Energy required on lifting of dung of wet consistency including idle time	0.756 ± 0.059 man-h/m^3

Conclusion

The water and energy required for different dairy farm operations have been studied and efforts have been made to establish various management norms for effective utilization of manpower and other resources.

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Development and Evaluation of Mini-dal Mill for Villages

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Abstract

A socio-economic survey in India indicates that only 10% to 15% of pigeon pea dal required for consumption is processed in villages. The producer has to purchase dal by paying more, including his transportation. For this reason a mini-dal mill running on 1.0 hp single-phase electric motor was developed. Four units, viz. splitting, sieve, aspirator and polisher were provided to obtain polished dal from pigeon pea grains. Moreover, by changing of sieves, the same unit can be used for other pulses. The performance of a mini-dal mill was evaluated at the laboratory and the results are presented in this paper. The maximum milling efficiency was observed at 4.25 mm disc clearance with 45 kg/h capacity for pigeon pea. Similar value for green gram and black gram was obtained at 60 kg/h capacity. The respective recoveries obtained were 73.75, 85.50 and 84.63%.

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Introduction

India produces 1.39 million tonnes of pigeon pea every year out of which Maharashtra, Madhyapradesh and Uttar Pradesh together produce about 75% in equal shares (Singh and Jambunathan, 1982). Pigeonpea provides necessary protein supplement largely to the cereal-based diet of the Indian population in the form of "dal" or split pea. The recovery of dal from pigeon pea is very low due to the biochemical composition of the seed. The gums present in between the seed coat and cotyledons make it difficult to remove the husk. The dal recovery from pigeon pea by traditional methods at village level is at most 60%. Actually, in villages 10 to 15% of pigeonpea grains are converted into dal and rest of the produce is sold in the market at very low prices. The necessary quantity of ready-made dal is purchased at high prices from the urban sector. This indicates that a lot of potential was available for processing the pulses at village level. But the present methods of pigeon pea milling are time- and labour-consuming and are highly wasteful (Kurian and Pareria, 1968).

These considerations call for a small gadget for dehulling and splitting pigeon pea, particularly at village level where production and part processing can go simultaneously. Hence the development of such units was undertaken in Post Harvest Technology Scheme, Punjabrao Krishi Vidyapeeth, Akola. This has resulted into a PKV Mini-dal Mill which can work with 1.0 hp electric motor performing all the steps invovled in processing pigeon pea grain, including other pulses.

Materials and Methods

The PKV mini-dal mill was developed into four units, viz. splitting, sieve, aspirator and polisher. The complete dal mill is shown in **Fig. 1** and the units are described below.

Splitting Unit

A simple mini-grain mills run on 1.0 hp single phase electric motor was provided which has two emery discs, 200 mm diameter. One of the discs is fixed and the second is revolving, the clearance between them being adjusted by a screw mechanism operated by a

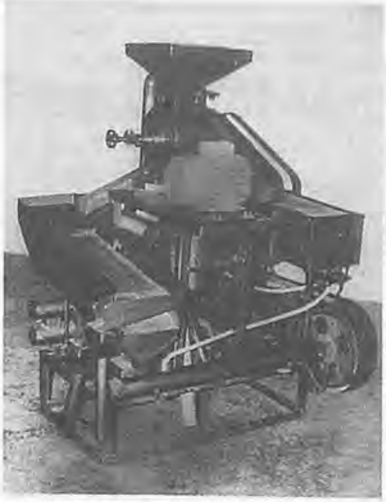

Fig. 1 PKV mini dal mill.

hand wheel. The capacity of splitting grain for this unit is 40 to 45 kg/h for pigeon pea and about 60 kg/h for green gram and black gram.

Sieve Unit

Two easily removable sieves are provided in the sieve unit which reciprocates to and fro with a specific eccentricity and frequency. The sieve unit is 155 mm wide and 470 mm long along a fixed slope towards outlet end. Different sizes of sieves are required for grains of different types and sizes. It separates the mixture into three parts each from individual outlet, i.e., lower for brokens, middle for dal and upper for mixture of husked and dehusked grains.

Aspirator Unit

This unit was developed with two blowers (aspirators) and a cyclone separator. The air flow velocity has been adjusted to such a magnitude that the aspirator separates only the husk and powder from the milled mixture and not the brokes and dal. Provision of one aspirator near to the outlet of the splitting unit makes it possible to provide dust-free operation. The second aspirator separates husk from dal moving from the polisher unit. Both aspirators are connected to a cyclone separator in order to divide the air out of the mixture of husk and powder and collect the latter without spreading in the atmosphere.

Polisher Unit

When polishing the dal is desired, it has to be rubbed alongwith oil and water. This arrangement is provided in the form of two-screw conveyors with closed casing, wrapped with good quality leather. The friction for dal between leather and inner surface of casing enables it to polish and remove the remaining husk which still adheres to the dal. A separate feed hopper is provided for this unit.

Power Transmission

A single phase 1.0 hp, 1 440 rpm electric motor is sufficient to provide power required for all the above units. The power from the prime mover is provided to a counter shaft which, in turn, supplies power to other moving components in requisite form and frequency using V-belt and pulleys. When milling green and black gram, the polisher unit is not required to be run for which one belt can be taken out from the pulley.

Test Procedure

Pigeon pea variety C 11 commonly grown in the Vidarbha region was obtained from the Central Research Station, Punjabrao Krishi Vidyapeeth, Akola for the study. It was well graded in order to obtain uniform size of the sample. The grain was soaked for 40 min, in 6% sodium bicarbonate solution then dried in waste fired dryer at 65° up to 10.5%-11.0% moisture content. The green gram and black gram were milled in the splitting unit of PKV mini-dal mill and analyzed for different fractions. The brokens and dal were separated by 1.00 mm and 2.48 mm mesh sieves, respectively.

The efficiency of the splitting unit was determined as an index performance of pulse splitting operation by using the following expression:

$$E = 100\,(1 - a_2/a_1)\,\{(b_2 - b_1)/[(b_2 - b_1) + (c_2 - c_1) + (d_2 - d_1)]\}$$

where,

E : milling efficiency, %

a_1 : percentage weight of whole pulse before milling

a_2 : percentage weight of whole pulse after milling

b_1 : percentage weight of whole pulse (dal) before milling

b_2 : percentage weight of whole split pulse (dal) after milling

c_1 : percentage weight of crushed pulse before milling

c_2 : percentage weight of crushed pulse after milling

d_1 : percentage weight of milling waste before milling

d_2 : percentage weight of milling waste after milling

The performance of the splitting unit was measured at five different clearances at an interval of 0.25 mm in terms of milling efficiency, feed rate and specific energy consumption for three pulses, i.e., pigeon pea, green gram and black gram.

The terminal velocity of the husk was determined by adjusting the aspirator size, its speed and air column. The air velocity of 2.05 m/sec has achieved to separate husk and powder at the rate of 99%.

The efficiency of the sieves was determined by putting only one sieve at a time inside the sieve unit and passing the mixture of known percentage of fractions over it. The efficiency was expressed in terms of percentage separation.

Results and Discussion

Table 1 Effect of Disc Clearance on Milling Efficiency, Feed Rate and Specific Energy Consumption

Grain used	Clearance (mm)	Feed rate (kg/h)	Milling efficiency (%)	Specific energy consumption (Wh/kg)
Pigeon pea	3.50	26.50	62.27	13.76
	3.75	30.60	66.39	11.15
	4.00	35.75	70.26	9.98
	4.25	45.10	72.75	8.18
	4.50	59.00	59.10	6.30
	4.75	66.30	18.72	5.82
Green gram	1.75	38.35	58.67	8.86
	2.00	42.40	67.30	7.57
	2.25	51.20	74.25	6.25
	2.50	60.00	85.50	5.53
	2.75	73.50	62.16	4.35
	3.00	81.32	21.63	3.93
Black gram	1.75	36.00	59.85	9.10
	2.00	40.60	65.70	7.88
	2.25	48.12	72.66	6.65
	2.50	59.80	84.63	5.35
	2.75	65.75	60.96	4.59
	3.00	81.00	20.25	4.11

Table 2 Performance of Sieve Unit in Percent

Particulars	Pigeon pea		Green gram		Black gram	
	Upper sieve	Lower sieve	Upper sieve	Lower sieve	Upper sieve	Lower sieve
Known refraction						
Gota	4.00	—	12.33	—	12.33	—
Dal	96.00	91.67	87.67	93.00	87.67	93.00
Broken	—	8.33	—	7.00	—	7.00
Separated by sieve						
Retained	11.75	92.43	20.93	93.68	21.21	93.46
Passed	88.25	7.57	78.74	6.32	78.79	6.54
Efficiency	91.91	90.87	90.20	90.47	89.87	90.20

Note: Values given are averages of three replications.

Table 3 Performance of Mini-dal Mill for Different Pulses

Item	Pulse used		
	Pigeon pea	Green gram	Black gram
Fractions after milling, %			
Dal (dehusked)	67.88	—	—
Dal (husked)	5.87	85.50	84.63
Total dal	73.75	85.50	84.63
Gota	1.43	—	—
Brokens	8.02	6.73	7.52
Husk + Powder	17.69	7.17	7.60
Capacity, kg/h	45.00	60	60
Specific energy consumption, kWh/q	1.90	1.50	1.50
Cost of milling, Rs/q (excluding pre-treatment)	17.40	11.60	11.60

The performance of the splitting and sieve units is presented in **Tables 1** and **2**. The milling efficiency of the splitting unit was observed along with feed rate and specific energy consumption for different clearances at an interval of 0.25 mm. The milling efficiency increased with an increase in clearance up to 4.25 mm for pigeon pea and 2.50 mm for green gram and black gram **(Fig. 2)**. Then it showed a declined trend and whole pulses started coming out. The specific energy consumption was reduced with the increase in clearance for all pulses **(Table 1)**. Thus, for maximum milling efficiency, the optimum clearance and feed rates were 4.25 mm and 34 kg/h for pigeon pea and 2.50 mm and about 60 kg/h for green gram and black gram.

Table 2 shows the performance of the two sieves used for the separation of different physical components of each milled pulse. For pigeon pea grain, 2.80 mm × 19.05 mm slatted sieve (upper) was provided for separation of "gota" and unhusked grain from the milled mixture. This sieve has an average efficiency of about 92%. The second sieve of 2.78 mm diameter was 91% efficient in separating dals from brokens. Green gram and black gram required sieve sizes of 2.40 mm × 19.05 mm (upper) and 1.98 mm diameter (lower) being small grain size. About 90% separation efficiency was achieved by these sieves for both types of grains.

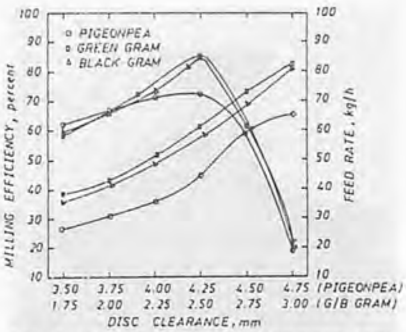

Fig. 2 Effect of clearance between two discs on milling efficiency and feed rate.

Table 3 shows the complete performance and economics of mini-dal mill. It was observed that the total recovery of dal was 73.75, 85.50 and 84.65% for milling pigeon pea, green gram and black gram, respectively. The cost of milling per quintal was Rs. 17.40 for pigeon pea (without pre-treatment) and Rs. 11.60 for green gram and black gram on the basis of prevailing market rates.

Conclusions

1. A maximum milling efficiency of 72.75% was obtained at 4.25 mm disc clearance and 45 kg/h feed rate for pigeon pea. At 2.50 mm disc clearance feed rate of 60 kg/h for green gram and black gram was observed with highest milling efficiency of 85.50% and 84.63%, respectively.

2. The highest aspirator efficiency (99%) was achieved at the terminal velocity of 2.05 m/sec.

3. Various sieve sizes for pigeon pea, green gram and black gram showed efficiency above 90%.

(Continued on page 68)

Prospect of Mechanized Cotton Production in China

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Abstract

China has a long history of cotton production. Its annual output of cotton amounted to 28 700 000 bales, accounting for 34.4% of the total world's output. In 1984-85, China ranked first in cotton production. But the cultivation of cotton in China had fallen in the last few years. This paper, as a result of investigation and research, holds that improving mechanization and raising labour productivity will help to stabilize and develop the cultivation of cotton again. The paper presents a system of measures to promote further the mechanization of cotton production in the country.

Introduction

China planted 5.34 million ha of cotton in 1990. But old China was seriously lacking in cotton. In 1949, before liberation, the annual total cotton output of the entire country was only 2 020 000 bales. By 1984-85, this figure increased to 28 700 000 bales. However, in the following years, the output could not be sustained.

At the present time, the supply of cotton has fallen short of world's demand. There are about 75 countries planting cotton, with China, the then Soviet Union and the United States producing about 60% of the world's cotton supply. The competition is proceeding seriously in cotton production and operation. It is predicted by the American Cotton Company that the annual total output of cotton all over the world in 1989-90 would amount to 81 800 000 bales, decreasing by 2 300 000, as compared with that of the previous year. The supply of cotton to the world's markets would be 113 700 000 bales, decreasing by 2 100 000 bales. But the quantity to be consumed would be 85 600 000 bales, increasing by 1 700 000 bales, as compared with the previous year. The store by year's end would decrease to 28 100 000 bales from 31 900 000 bales in the previous year.

The demand for cotton increases which results from people's having partiality for cotton fabrics. With the decrease of cotton output and the increase in demand, the textile industry would be influenced and threatened which would probably result in inflation.

In order to stabilize and develop the cultivation of cotton, good technical equipment is needed to meet the complex demand in the cultivation process. This paper presents plans for the development and use of farm machinery and tools for cotton production.

Status of Cotton Mechanization

Cotton fields are widely distributed in China, north to the Xinjiang's Manashi River valley, south to the Hainan Island, west to Kashi and east to the coast of the Yangtse delta and the Liaohe River valley, i.e., at 18-46° North latitude and 76°-124° East longitude. There are five great cotton growing areas: i) South China cotton area; ii) Yangtse valley cotton area; iii) Yellow River valley cotton area; iv) the Liaohe River valley cotton area (northern earliest maturing cotton area); and north-western inland cotton area.

The cotton output of the Yellow River valley accounts for about 60% of the total output of China which shows that the valley is good for growing cotton. And 30% of the total output comes from the Yangtse River valley — the main area producing quality cotton. There are two crops (cotton and grain) grown in a year. According to the distribution of provinces, cotton is produced with major concentration in the following five provinces: Shandong, Hebei, Henan, Jiangsu and Hubei which account for 80% of the total output.

As for cotton production mechanization, practices differ markedly by areas. In the Yangtse River valley, various kinds of machinery are used under different farming conditions. In Jiangsu Province, for example, there is a large population, less land that is criss-crossed by ditches, narrower roads and

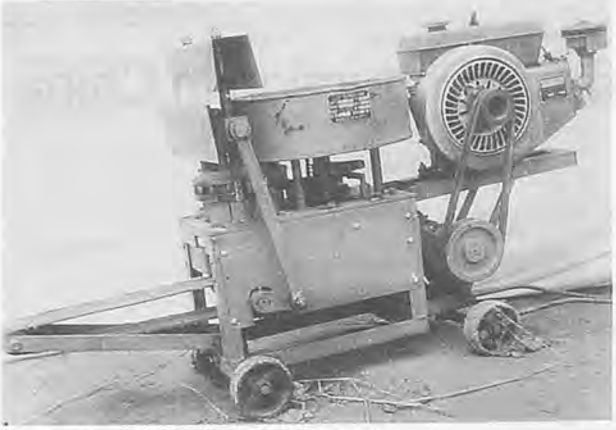


Fig. 1 Cotton nutritous earthen bowl-maker.

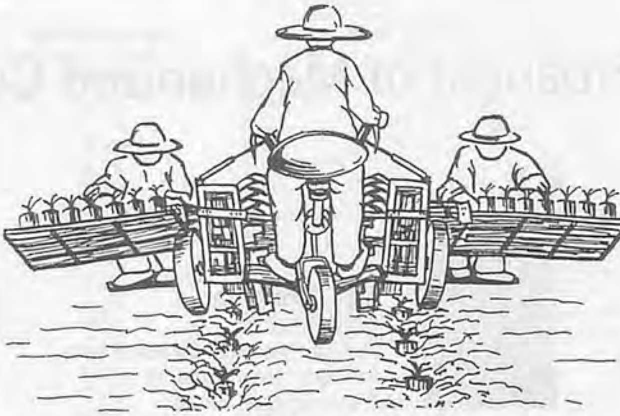


Fig. 2 Cotton seedling transplanter.

Fig. 3 Cotton field cultivator.

Fig. 4 Atomizing sprayer.

smaller plots. There often happens natural disasters: plague of insects, drought and flood. Under traditional farming methods and a crop of cotton and grain a year, various kinds and types of farm machinery are necessary to complete different farm operations. In this cotton growing area, the main farm machines and tools are walking tractors, cotton seedling transplanters and sprayers. Ditch diggers and atomizing sprayers are becoming popular. A great deal of successes on cotton field machinery research have been achieved. Some of them are shown in **Figs. 1, 2, 3** and **4**.

Shandong Province is an example of the Yellow River valley cotton area. This provincial cotton growing area and output account for more than one quarter of China's total production. The province is good for growing cotton and cotton produciton is developing rapidly. At present it has changed from one crop of cotton a year to two crops of cotton and a wheat crop raising its multiple crop index and expanding grain-cotton cropping areas. Cultivation methods in the Yangtse River valley should be introduced in this cotton area, bowl-making and transplanting technique should be popularized, and cotton seedlings with nutritious earthen bowls transplanted between rows of wheat. The main agricultural machines being used in this area are small 4-wheel tractors and their implements, and manpower and animal-power farm implements as well, for example, the knapsack sprayer, manpower and animal-drawn seeders and so on. What are being developed mainly are cotton precision seed drills, plastic film-covering machines and universal frames.

The Xinjiang Uygur Autonomous Region is the main area of the north-western inland cotton-growing region which developed rapidly in the 1980s. The cotton output increased by a big margin owing to the use of comprehensive measures to promote mechanization. About 60% of cotton production processes is done mechanically. An agricultural labour in this area manages 1.2 ha of cotton fields requiring an average of 240 workdays a hectare. One workday produces 3.27 kg of ginned cotton.

The mechanization of cotton production in this area is characterized by the following:

The mechanization of cotton sowing is preceded by the use of ground plastic film covering machines which influence the increase in cotton output. Of the many kinds and types of plastic film covering machines used, the simple one can only put plastic film on the ground, and the complex ones can continuously complete operations of furrow-digging, film-covering, film-pressing, hole-making, sowing, fertilizing and soil-pressing.

New high-yield varieties of cotton suitable for mechanization have been bred which are characterized by short straw, close planting and early maturing.

Mechanical weeding of cotton fields is needed only once or twice because of the application of a combination of mechanical and chemical measures, and simplification of field management.

Analysis and Recommendation

There are different machinery models and speeds in cotton-growing areas depending on different natural conditions, different bases and different demands in the three great main cotton growing areas of China: the Yangtse River valley, the Yellow River valley and the inland region.

The cotton-growing area of the Yangtse River valley is characterized by the following: more people, limited cotton fields and still in the process of developing farm mechanization

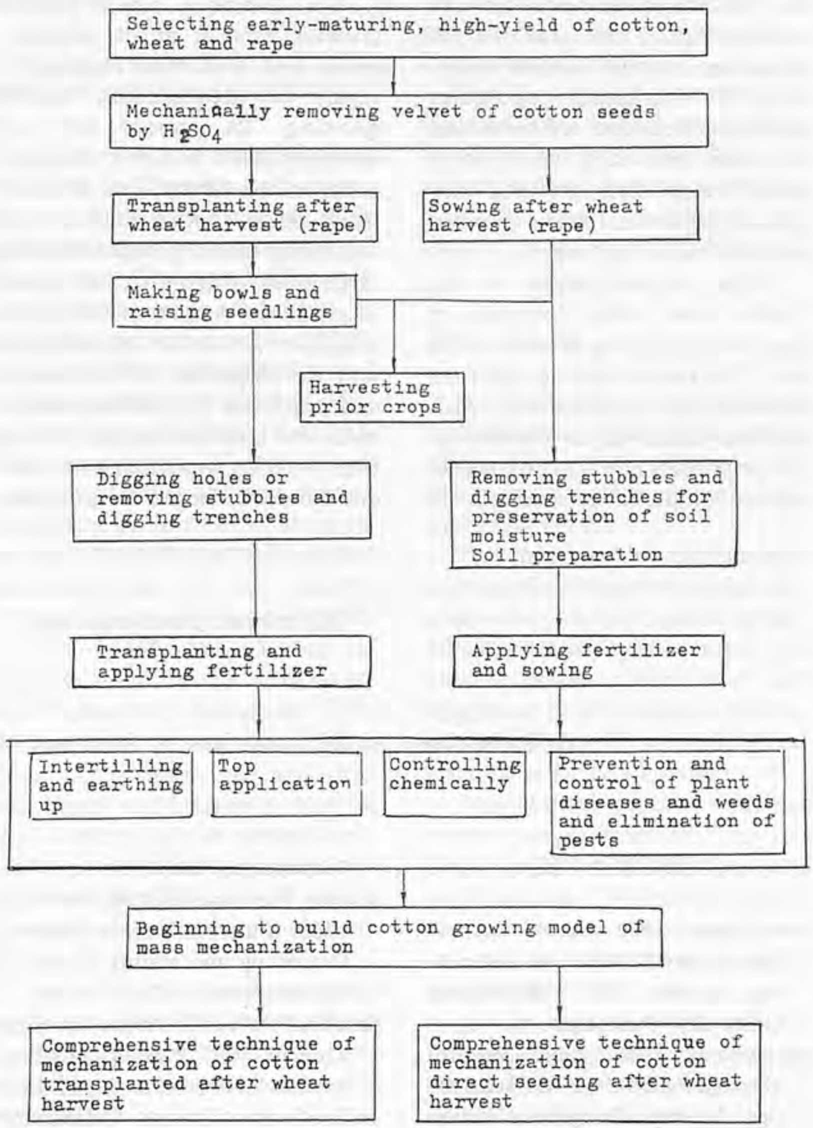
The present cultivative system in the valley is two crops/year: grain-cotton or grain-rapeseed. Roads are narrow, plots are small, ditches and streams are plentiful, and the natural environment is complex, which is why farm management on a large scale has not developed. Since the basis of mechanization is weak, it seems impossible for the area to fully develop mechanization of agriculture in the near future.

In view of the foregoing description of the efforts so far made by Chinese farmers in attempting to mechanize cotton growing, the proposed 10-step procedure is illustrated in the figure that follows:

Some basic requirements must be considered in the mechanization of cotton fields. As cotton fields are scattered transplanting is difficult to accomplish, particularly when intercropping or interplanting of wheat and cotton is done. Grain and cotton must be in a reasonable combination or sequence for a more effective farm management.

Technical measures must be taken so that farm implements and agricultural techniques must be compatible, mechanical engineering and biological engineering are researched cooperatively, development and research on farm implements are combined with breeding new crop varieties, mechanical measures are combined with chemical measures, and mechanical and direct sowing must be observed carefully in terms of efficiency in operation.

Selection of tractor size for cotton fields should be a question which claims precedence over all others. At the same time, necessary farm machineries and equipment as are necessary should be



designed and developed. In order to meet the growing demand for mechanization in the developed economic regions of China, farmers should make full use of and improve present farm implements and popularize actively qualified machines for digging trenches, removing stubbles, protecting plants, and intertillage. Mechanization and semi-mechanization, at the same time, should address shortage of labour for harvesting and sowing between summer and autumn.

The Yellow River valley cotton-growing area is characterized by a great plain, scanty rainfall and dry crop cultivation. In mechanization of agriculture, the area has an advantage over the Yangtse valley. With the increasing population and cultivated land are becoming less and less each year, there exists the problem growing only grain or cotton instead of growing each one after the other.

Farm mechanization in the Yellow River valley is similar to that in the Xinjiang inland cotton area. The main machine types are medium and small-sized, with medium machines as dominant. The important key is to popularize the technique of ground plastic film and to select and develop appropriate farm implements. The other is two crops a year, intercropping of grain and cotton or sowing cotton seeds between wheat lines. Because of great difficulties of cotton mechanization in early stage, small-sized and special purpose farm machines and tools must be combined with those of manpower, animal power and semi-mechanization for trench-diggers, seeders by manpower or animal power. After the first crop is harvested, the management of cotton fields will be the same as that of one crop a year.

The Xinjiang inland cotton growing area is in an advantageous and favourable position in terms of mechanizing cotton growing. Its present level of mechanization is higher than any other area in China. The development ahead should focus on the increase in labour productivity and large-sized, high-efficient farm implements. At present the stress should be put on the introduction and development of harvesters and machines for shelling cotton bolls and cleaning cotton. Plastic film covering machines and seeders should be improved and perfected, and multi-purpose machine units must be developed. The machines for collecting remnant plastic film on the fields should be improved so as to reduce the population of soil and the harm on crops by remaining film. Besides, greater attention should be paid to the processing machinery of cotton and its by-products so as to maximize the profits of cotton production.

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(Continued from page 64)

Development and Evaluation of Mini-dal Mill for Villages

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Some Aspects of Agricultural Mechanization in Turkey

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Introduction

Turkey is a developing country whose economy depends upon agriculture. The agricultural production potential in terms of soil, climate and water sources is great. According to 1987 agricultural statistics, sown area in Turkey is 18 781 000 ha, and fallow land is 5 574 000 ha. The distribution of land usage in Turkey, percentage distribution of field crops based on the production and area, percentage distribution of fruit production, and percentage distribution of vegetable production could show the basic character of Turkish agriculture (**Figs. 1-4**).

Turkey has nine agricultural regions with diverse climates. This provides a large variation in crops grown. Soon the irrigated land will increase significantly by the completion of a project called GAP.

All statistics show that agriculture is an important sector in Turkey like other sections. For this reason, new and improved technologies must be applied to agriculture and usage of agriculture machines and equipment must be increased, too. In this development, agricultural mechanization is going to play an important role. In this paper, the present situation of agricultural mechanization in Turkey is discussed.

Agricultural Mechanization

In order to increase the use of farm machineries and equipment in agriculture, the first attempts began at the turn of the century. Two hundred twenty one tractors were imported in 1924. During those years, majority of agricultural machineries and equipment used in Turkey's agriculture were imported (**Table 1**). The importation of agricultural machinery and equipment showed a big increase in 1950. Therefore, it may be said that agricultural mechanization in the country started to become popular in 1950.

After 1960, the number of imported agricultural machinery and equipment decreased. This development caused the production of some agricultural machinery and tractors to start in the country. At the present time 900 plants are producing agricultural machineries, six of which specialize in tractor manufacture (**Table 2**).

Determining the agricultural mechanization requirements for a country is a rather difficult task. Agricultural mechanization level is determined in terms of kW/ha, ha/tractor, number of tractor/1000 ha, present mechanical power/total power, and equipment weight/tractor.

For Turkey, the number of tractors, agricultural mechanization level in terms of kW/ha, and average tractor power are given in **Table 3**. Some machines per tractor are given in **Table 4**.

Conclusions

Agricultural mechanization level in Turkey is increasing and is higher than the world average. The average tractor power is likewise increasing.

This indicates that the machineries for field crop production are used widely. As horticulture is also very important in the country, the use of suitable machineries and equipment in horticulture, including small- and medium-sized tractors must be increased.

The total equipment weight per tractor ranges from 2.5 t to 3 t. This weight is lower than the world average. The major equipment include tractor plough, trailers, and machines used for crop protection.

In agriculture, the use of mechanical power in Turkey is about 77% (Tekinel, 1988).

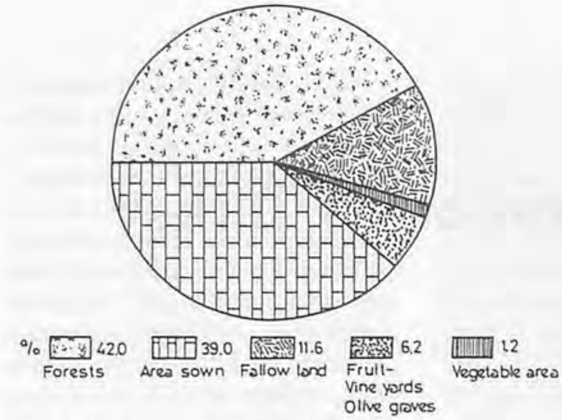

Fig. 1 Land usage in Turkey (Anon., 1987).

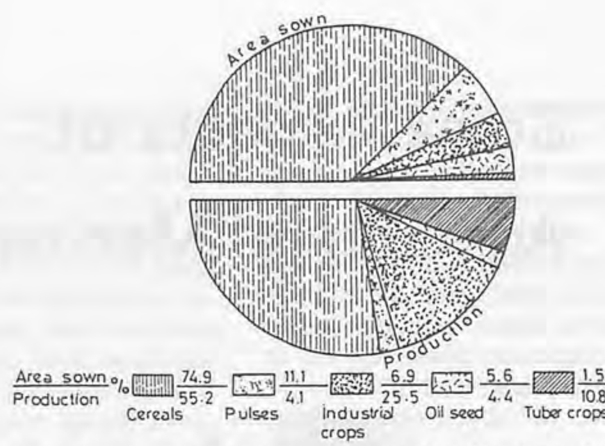

Fig. 2 Percentage distribution of field crops based on the production and area (Anon., 1987).

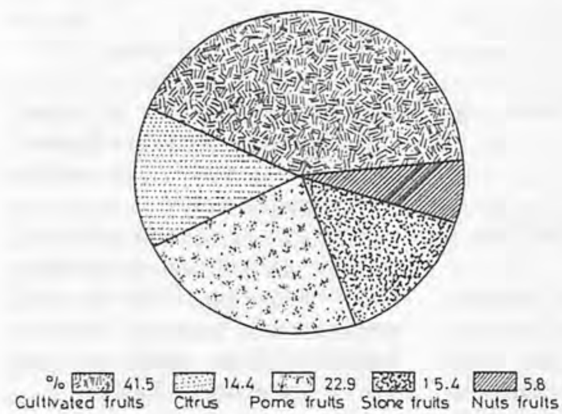

Fig. 3 Percentage distribution of fruit production (Anon., 1987).

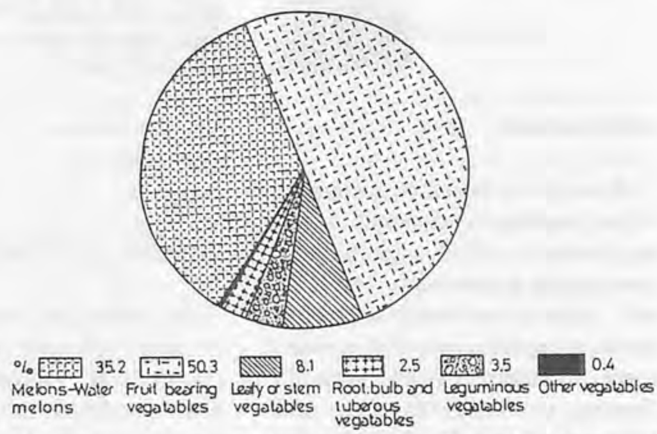

Fig. 4 Percentage distribution of vegetable production (Anon., 1987).

Table 1 Weight of Imported Agricultural Machines and Equipment Between 1923 and 1960 (ÖZMERZI, et al 1982)

Year	Weight of Imported Agricultural Machinery and Equipment (t)
1923	1 324
1927	4 750
1940	2 986
1950	3 000
1960	7 000

Table 2 Percent Distribution of Tractors Manufactured in Turkey, 1987

Tractor Power (kW)	Percent Distribution
8.1-17.7	1.3
18.4-25.0	1.5
25.8-36.8	26.4
36.8 <	70.8

Table 4 Some Equipment per Tractor

Equipment	Percent/ Tractor
Tractor plough	90
Reversible tractor plough	4
Disc type tractor plough	11
Rotary cultivator	3
Cultivator	40
Tined harrow	56
Thinning machine	12
Drill machine	11
Combine drill machine	13
Fertilizer	24
Trailer	93

Table 3 Number of Tractors, Agricultural Mechanization Level and Average Tractor Power, 1960-1985

Year	Number of Tractors	Average Tractor Power (kW)	Agricultural Mechanization Level (kW/ha)
1960	42 136	24.3	0.04
1965	54 668	25.9	0.05
1970	105 865	27.4	0.27
1975	243 066	28.3	0.27
1980	436 369	36.3	0.59
1985	583 947	37.7	0.96

(Sabanci, et al, 1988)

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Implications and Prospects of Farm Mechanization in Pakistan

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Abstract

This paper describes the present status of farm mechanization, implications and future strategies of adopting the mechanical technology for boosting agricultural production. Tractor and field labour population is increasing whereas bullock power is decreasing with the passage of time. Fragmentation of land into small pieces has been found a major constraint in the adoption of agricultural mechanization. By the year 2009, the total available power per hectare is expected to be 1.47 horsepower which is quite adequate. In order to implement this technology, custom hiring services should be encouraged to provide adequate and timely services to the small farmers who cannot afford to own farm machineries.

Introduction

Pakistan's population is 105.5 million of which 70% resides in rural areas depending mostly on agriculture for their livelihood. The present population growth rate of Pakistan is 3.1%, which will grow to about 145 million by the year 2000, an alarming situation in relation to the country's food producing potential. The share of agriculture in Pakistan's GDP has declined from 53% in 1944-50 to 26.8% in 1988 but still agriculture is a dominant sector in Pakistan's economy (Pakistan Statistical Year Book, 1989). It absorbs 51.5% of the total labour forces of the country. In fact, the importance of agriculture will continue to grow due to the following reasons. First, a higher agriculture production is necessary to ensure adequate food supply for a growing population at reasonable prices. Second, it provides raw materials for expanding industries. Third, it contributes significantly to the balance of payments. The most important of all is that it consistently employs a much larger proportion of the labour force than its contribution to national income.

Agricultural productivity depends upon biological, hydrological, chemical and mechanical inputs. Very little attention has been paid to the mechanical input in the past. New ideas always face bitter opposition in the beginning. Therefore, farm mechanization in Pakistan had a late start and registered slow progress because the planning and development bureaucrats made policies of restricting mechanization based on the apprehension that it would displace farm labour and bring about problems of unemployment. Even the international agencies like the FAO and the World Bank advocated caution and recommended that small farmers should not be encouraged to purchase tractors. Tractors were imported in limited numbers and their assembly and production in Pakistan remained a debatable issue until 1970. However, upon realizing of the importance of mechanical cultivation, new policies were made for the importation of tractors. Mechanization as a whole enhanced farm incomes, manpower productivity and generated employment. Total employment in agriculture increased from 9.8 million in 1965 to 13.5 million in 1988. (Pakistan Statistical Year Book, 1989).

Despite the use of high yielding crop varieties, better chemical and management of irrigation water, the agricultural productivity in Pakistan is still three to four times less compared with developed countries (Agri. Statistics of Pakistan 1988-89). It may be pointed out that all the inputs depend upon each other to increase crop yields. Since the areas under cultivation could not be significantly increased attention has to be given to adopting mechanization in addition to the use of improved seeds, fertilizers and plant protection measures to increase crop yields.

Present Status

Source of Farm Power

Three modes of power are available on the farm, viz; animal power, human labour and tractor power.

Animal power — Animals are considered to be inefficient and an inadequate power source. A bullock generates only 0.5 hp for 8 hours continuous operation of the field work. Due to their limited power and inefficiency, the growth rate of draft animals is negative. The growth rate of draft animals was determined by employing Shryoch equation (1976) taking into account 20 years data from 1960 to 1980 and is expressed as follows:

$$A_i = A_o e^{rt} \quad \text{............} \quad (i)$$

where,

A_i = work animals in the next census year, numbers

A_o = work animals in the previous census year, numbers

t = time in years between diferent periods

r = growth rate, in decimals

The growth rate of draft animals was $r = -4.34 \times 10^{-3}$ for the period 1972-80. Using equation (i) it can be predicted that the number of draft animals will be 5 902 086 head in 1990, a 7.4% decrease as against 6 381 317 head in 1972 (Pakistan Census of Agriculture, 1972, 1980). Considering the average hp of one work animal being 0.5 the power available at present from work animals on the farm is 2.95×10^6 hp.

Human labour power — Human labourers are also considered to be inadequate and inefficient source of farm power. A normal man generates only 0.1 hp for 8 h continuous field operation. However, the growth rate of farm labour is positive and was r = 0.02239 from 1981 to 1989. Using equation (1), considering labour instead of animals, 14 131 198 in 1990, a 22% increase as against 11 552 190 in 1981 (Pakistan Statistical Year Book, 1989). Taking into account an average hp of one human labour being 0.1, the human power available at present is 1.413×10^6 hp.

Tractor power — This is considered to be an efficienct source of power on the farm. There are five makes and models of tractors which are assembled/manufactured in the country as follows: Massey Ferguson, Fiat, IMT, Belarus and Ford. The growth rate of tractors in the agricultural sector in different periods is given in **Table 1**.

At present tractors employed in the agriculture sector number 249 005 units. Keeping in view the cumulative average horsepower of one tractor being equal to 50 (Sheikh, 1984), the power from farm tractors is 12.45×10^6 hp.

A comparison of available farm power in the country at the present time is shown in **Table 2**.

A calculation of area commanded by tractors and work

Table 1 Growth Rate of Farm Tractors, 1960-90

Period	Growth rate (%)
1960-1968	28
1968-1975	11
1975-1980	20
1980-1984	12
1984-1986	9
1986-1988	8
1988-1990	6

Source: Report of the National Commission on Agriculture, 1988.

Table 2 Comparison of Available Power in Pakistan Farms

Source of power	Power (hp × 10^6)
Work animals	2.95
Labourers	1.41
Farm tractors	12.45
Total	16.81

As the total available farm power is 16.81 × 10^6 hp and the total cultivated area is 21.00 × 10^6 ha, the average hp available per farm is only 0.80.

Table 3 Basic Statistics on Farm Power

Average field capacity of one tractor = 40 ha
Population of tractors in agri. sector = 249,005 units
Area commanded by tractors (I × II) = 9.96 × 10^6 ha
Number of work animals, in pairs, in the agric. sector = 2,951,043 head
Average field capacity of a pair of bullocks = 1.5 ha
Area commanded by bullocks (IV × V) = 4.4 × 10^6 ha
Total area commanded by bullocks and tractors (III + VI) = 14.36 × 10^6 ha

animals in 1990 is shown in **Table 3**.

Out of the 330 150 tractors imported into the country up to 1989 only 238 000 were actually working on the farms in that year. About 28% of the total balance have been written off and others were working in the non-farm sectors. It has also been seen that farmers are giving up bullocks at a rate higher than the rate of acquisition of tractors according to the 1980 census of agriculture. Only 67% of all farms had bullocks while tractors were owned by only 2.3% of the total number of farms. The latter figure is increasing every year. The practice of hiring out of tractors is becoming popular so that the farmers who do not own tractors are also able to get their field cultivated by hiring tractors from others.

Farm Machinery

There are nearly 462 agricultural machinery manufacturers in Pakistan; 11 are large, 40 medium and the rest small. Eighty seven percent of these manufacturers are within the Punjab Province. The assets (excluding land and building) of a small manufacturer are limited to Rs. 0.5 million whereas the medium manufacturers have assets of Rs. 0.5 to Rs. 5.0 million and are fabricating 5 different farm machines. The large manufacturers have an asset of Rs. 5.0 million (Ahmad, 1985). The farm machines/implements currently manufactured in the country are: tractor-drawn implements, wheat threshers, rice hullers, groundnut shellers, maize shellers, cane crushers and a whole range of farm implements. The industry has done well on its own although most of the manufacturers do not have access to the latest technology (National Commission, 1988).

Tillage implements — The tillage implement mainly used at present is the cultivator while disk plow, M.B. plow, and disk harrow are also used to varying extent. Some progressive farmers use a wide range of implements.

Tillage requires maximum energy amongst all agricultural operations, hence the most expensive operation in agriculture. At present 249 005 tractors are directly involved in agriculture. With an annual use of tractor for 350 h in tillage, the total cost of fuel required annually in the country is Rs. 1 743 million (hourly consumption of diesel oil is assumed 5.0 litres and price per litre is assumed Rs. 4.00).

Planting equipment — A few years back, Korean transplanters were imported for use in various districts of the Punjab by a team of experts of the Department of Agriculture, Govt. of the Punjab and the University of Agriculture, Faisalabad. The machine was modified according to the condition of the soil but did not prove its worth due to its high cost of operation and with no increase in yield (Sheikh, 1984).

Animal-drawn seed drills are used on a limited scale. Most farmers sow their crops either by broadcast or through "pora" (seeding one by one in rows). Large farmers use seed drill. It is estimated that crops sown with efficient seed drill can increase crop production by 10% (Rajput, 1988).

Harvesting and threshing equipment — More than 100 firms are manufacturing wheat threshers in the country. Their production is estimated at about 6 000 threshers per year. Sufficient capacity for the production of wheat threshers is available in the country which is mainly located in the Punjab.

The large-scale rain damage to the ripened crop of wheat in 1987 changed the outlook of the combine harvesters, especially among the large farmers who have shown ready acceptance of combine harvesting due to their high efficiency and economical operation. At present there are about 578 combines working in Pakistan (Cheema, 1989). Few mechanical cotton pickers were imported as an experiment for adoption of this technology. However, up to the present time, they have not been successful. The bumper crop of cotton of the last decade created some problems in the manual picking of cotton and many farmers interviewed said that the cost of using mechanical pickers for cotton is prohibitive (National Commission, 1988).

Implications

The farm machinery manufacturing capability of the country is not fully utilized. Some areas require strengthening or improvements. The research and development (R&D) facility is almost non-existent in this industry. There are only a few large farm machinery manufacturers who have separate R&D sections in their premises, whereas the rest of manufacturers do not have even a qualified person on their staff who can read a drawing or consult a reference book or a guide on design.

Some of the major problems are:

1. Availability of farm power has been generally inadequate, especially if one keeps in mind all the operations like subsoiling, ridging and weeding which need to be done to raise crops properly.
2. Selective mechanization was both essential and unavoidable.
3. Tractor imports were recommended but benefits of mechanization were not reaped by the small and medium

farmers who contribute 65% to agricultural production (Pakistan Statistical Year Book, 1989).

4. It was thought earlier that tractorization was synonymous to mechanization. Very little attention was, therefore, given to the development and introduction of appropriate implements to go with the tractors. Censequently, the only widely used implements /machines with the tractor today are the narrow tine cultivators, rear blade, trolley and wheat thresher. For this reason about Rs. 1 743 million is expected to be spent during 1990 in the use of cultivators for the seedbed preparation which is a huge amount for one operation of crop production.

The following are the major implications restricting the introduction of mechanization in its true sense in the country:

1. High initial cost and manufacturing of basic tillage implements (disk harrow, M.B. plow, disk plow);
2. The benefit cost ratio of farm mechanization is very low presently as compared with all other inputs in agriculture;
3. Selection of equipment is difficult and frustrating;
4. Small- and medium-sized land holdings prohibit the purchase of implements;
5. Loan/credit facilities are not readily available and are of high interest rates.
6. Repair and maintenance facilities are very limited.
7. Lack of trained manpower (skilled operations) for the efficient operation of agricultural machinery.
8. Remote villages do not have electricity, hence repair problems are enormous.
9. Combine harvesters in their present form have a serious drawback of wasting wheat "bhoosa" (chaffed straw) which is used as feed for the animals.

Custom Hiring Services

About 65% of the cultivated area in the country is operated by small- and medium-sized farmers (Pakistan Statistical Year Book, 1989). Most of these farmers cannot justify owning a tractor. Most of them would find it uneconomical to own a complete range of mechanized equipment, including items having seasonal use of a few days in a year. This suggests that there is a great scope of custom hiring services in the agriculture sector. To provide adequate services to the farmers of far-flung areas, the government should give incentives for setting up workshops at Markaz level (7-8 villages) on private basis. These workshops should be financed by the government on easy recovery loan basis. This will help in providing repair facilities to the local farmers and readily available agricultural machinery on custom-hire basis. This will attract positive contribution for raising the average national yield of crops is 3-4 times less compared with developed countries.

Future Outlook

Farm power in Pakistan is likely to increase in order to meet power needs of various equipment on the farm. Ridge sowing is known to conserve water and to increase yields. Planting of sugarcane in ditches with subsequent green-ridging gives the plant a firm base thus reducing lodging, conserves water and is conductive to higher yields. Similarly, sowing of cotton on the slopes of ridges in saline soils reduces the adverse impact of salt water. Sowing of crops in line with seed drills not only gives a better crop stand and even spread of plant population but also facilitates weeding and interculture. Use of power sprayers help in more effective application of pesticides.

Using equation (1) and the data available from different sources, projections were given for the power available from the three modes of power on the farm up to the year 2010. Best fit curves were developed using the computer Stat package. It is predicted from **Fig. 1** that there will be one tractor for every 40 ha of farm land

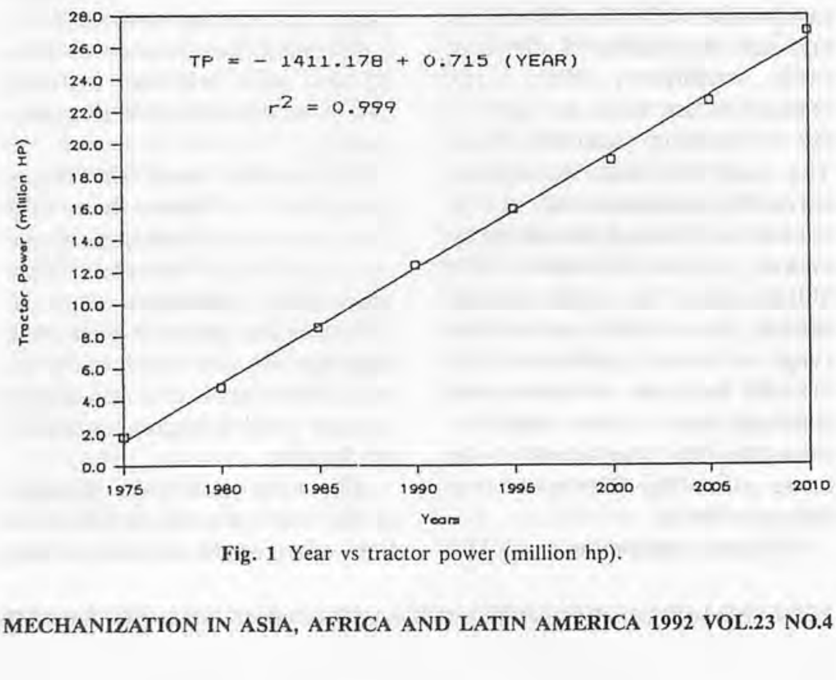

Fig. 1 Year vs tractor power (million hp).

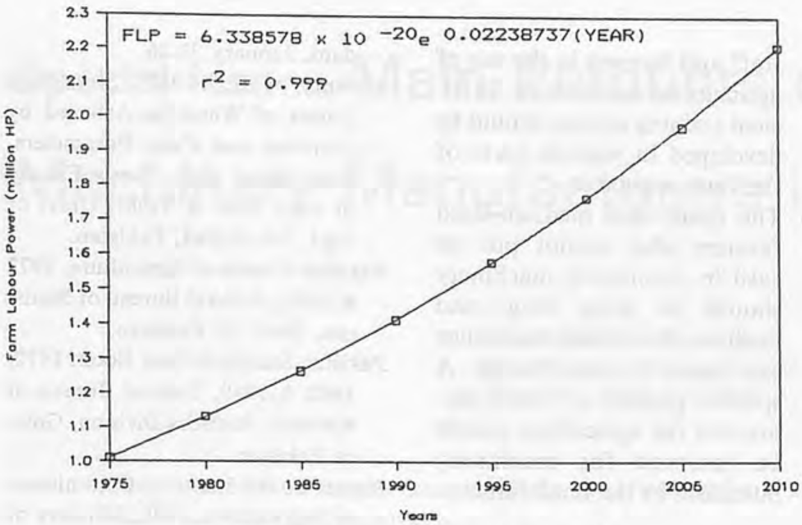

Fig. 2 Year vs farm labour power (million hp).

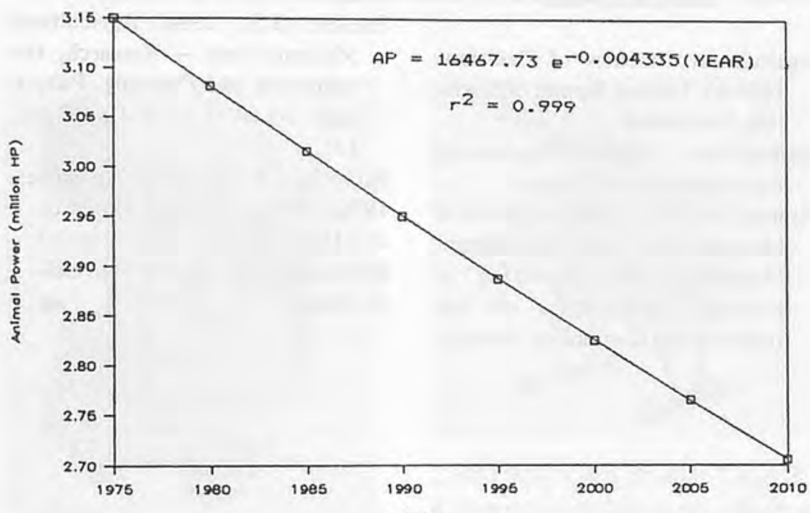

Fig. 3 Year vs animal power (million hp).

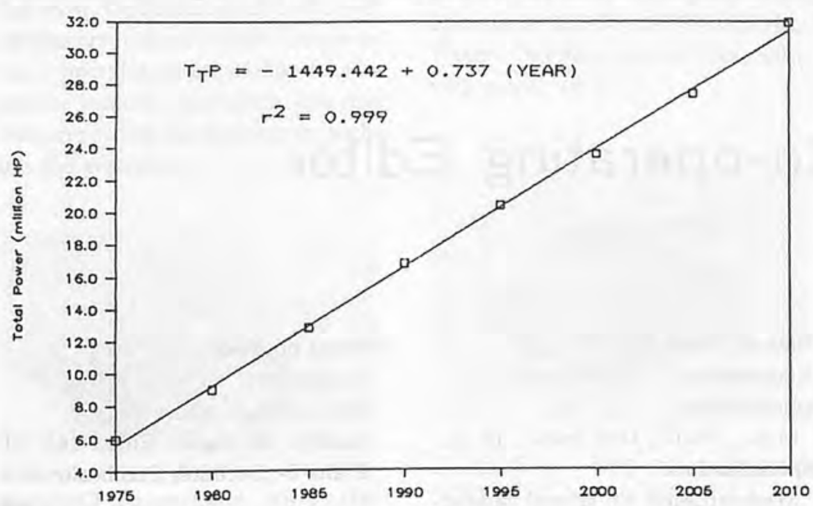

Fig. 4 Year vs total power (million hp).

by the year 2009 which is the actual requirement. Total tractors working in the agriculture sector by that year will be 525 000. On the other hand, power from human beings will also increase, i.e., more employment on the farm will also be created (**Fig. 2**). Nevertheless, power from the farm animals has shown a decreasing trend, therefore, draft animals will contribute little towards the total power available on the farm (**Fig. 3**). Total power trend from the three sources is shown in **Fig. 4**.

Keeping in view the problems encountered in the introduction of mechanical power, emphasis should be given to the following points in order to achieve the future targets:

1. Tractor companies in the country should be encouraged to diversify their output by producing large and small tractors (not less than 50 hp) in response to market demand, including a full range of agricultural implements and tractor attachments.
2. Manufacturers of agricultural machinery should be assisted by the Government by:
   i. Carrying out a survey to identify their problems.
   ii. Establishing development projects to assist in marketing the manufactured units.
   iii. Making farm machinery manufacturers eligible for special lines of credit, especially, for small agro-industries.
   iv. Arranging for technicians from abroad.
   v. Establishing demonstration and testing farms.
3. Agriculture machinery should be free of restrictions. A reasonable level of protection should be provided to the local industry by imposing variable import taxes on items being manufactured locally. The im-

port of tools and components meant for manufacturing agricultural machinery should be allowed liberally without import duties.

4. Most of the modern farm machineries are designed and manufactured abroad. Research in Pakistan should be done to test the suitability and applicability of imported farm machinery to Pakistani conditions and, whenever possible, to adopt them for local use. The Farm Machinery Institute (FMI) at NARC and AMRI at Multan should be strengthened and farm machinery research farms should be established in each of the four provinces in order to identify the peculiar regional needs. There should also be effective arrangements for diseminating the research findings to the farmers and to the agricultural machinery manufactures.
5. Due attention should be given for the training of technical staff and farmers in the use of agricultural equipment. Sufficient training centres should be developed in various parts of the four provinces.
6. The small- and medium-sized farmers who cannot put up cash in purchasing machinery should be given long- and medium-term credit which they can repay in installments. A specific portion of credit earmarked for agriculture should be reserved for machinery purchases by the small farmers.

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Special Issue: Main Products of Agricultural Machinery Manufacturers in Japan

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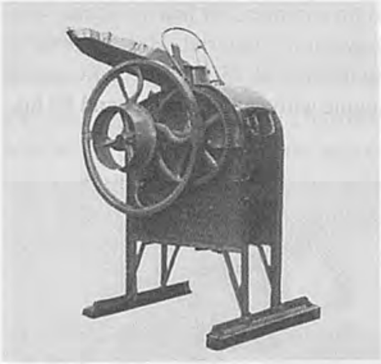
Introduced here are the main products of agricultural machinery manufacturers in Japan with a number of photographs.

The products are developed and improved for both foreign and domestic markets. For further information please refer to the manufacturers contained in the directory.

The ARIMITSU Greenhouse Sprayer. Operators safety and labour savings are realized because the equipment operates automatically from a remote location, uniformly spraying micron particle size droplets throughout the greenhouse.

BUNMEI Sugarcane Harvester NB-11. The small walking type harvester.



CHIKUMA Corn Sheller Type 3. Removes kernels from corn-cobs by a short time. Capacity: 750-1, 125kg/h, Power r'd: 1-2 PS, R.P.M.: 300-500, Size in mm: 1,015H x 575W x 1,010L, Weight: Net 90kg Gross 130kg, Shipping meas.: 18 cft.

DAISHIN Engine Pumps "CORAL" Model SCL-50. Suitable for general purpose pumping, irrigation, water carting in agriculture, water transfer over long distances, public works, etc. Max. total head: 32m (105ft). Suction lift: 8.5m (28ft). Max. capacity: 520ℓ/min. Standard capacity: 15m-210ℓ/mm. Engine power: 3.1-3.5HP.

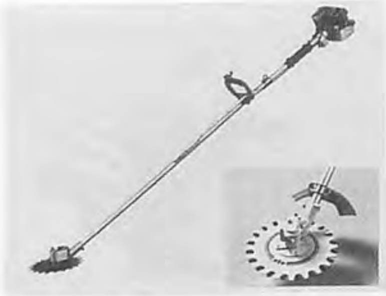
ISEKI Tractor Landmax 1085. Mounted with 108 HP (6,494cc) Diesel engine. The 6-cylinder, well-balanced engine runs without noise and dynamically performs any type of work.

ISEKI Combine Frontier HL500.

Super Rolling mechanism always controls the position of the body at level by the help of sensors. Working width: 1,650mm-1,700mm (5 row). Engine power: 50HP (2,600cc).

KIORITZ Battery-powered U.L.V. Sprayer (Shoulder type) ESD-5. A compact and lightweight battery-powered U.L.V. Sprayer providing easy portability combined with high performance. It is designed for use in environmental hygiene control such as malaria prevention, etc. in addition to general-purpose applications. Operates on six 1.5 V batteries. A rechargeable battery pack can also be used.

KOBASHI Rotor KA Series with 4-point auto-hitch. Working width: 220cm. Required tractor horsepower: 50-65.



KOMATSU ZENOAH Reciprocator SGC220DL. Engine: 22.5cc, Dry weight: 6.5kg, Cutting Blade: 230mm, 20-toothed, heat-treated steel blade.

KUBOTA M8580 Tractors. Built to handle a variety of agricultural applications, including field operations, heavy-duty front loader work in barnyards and other farm work. Designed to turn tighter, lift heavier loads, and move more material. Has a powerful liquid-cooled direct injection diesel engine with four cylinders and 80 hp.

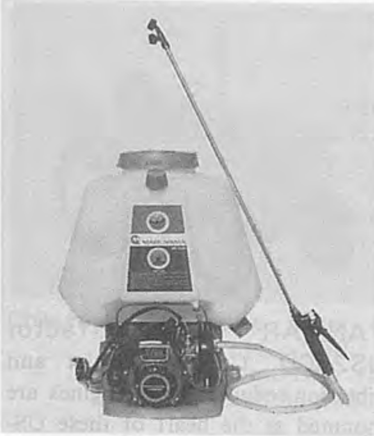
KUBOTA Diesel Tractor B20. Provides power and versatility for a variety of heavy-duty jobs, including loader, backhoe, and box scraper work, and still retains all the benefits of a compact tractor. Engine (Model D950-A-T): Water-cooled, 3-cylinder, 20hp. Total weight: 930kg.

KUBOTA Zero Diameter Turn. Auto Assist Differential, 4WD Front Mower Model FZ2100.
Engine: 4 cycle, liquid-cooled diesel, 20hp. Total weight: 680kg.

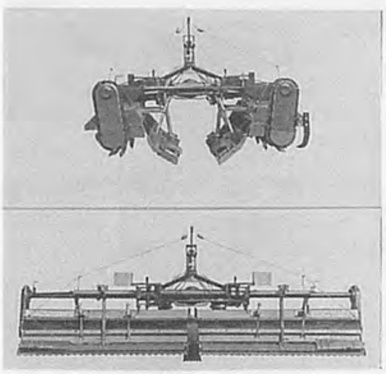
MAMETORA Power Cultivator SRV4V. Wide range use: cultivation to riding, Mounted with 7 PS engine.

MAMETORA Vegetable Transplanter TP-3V. This machine is available in both pot and soil block in seedling transplanting. Application: all vegetable nursery.

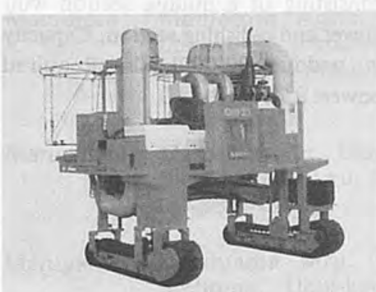
MARUSHICHI Rice Whitening Machine Echo-Star M3. Double jet suction mechanism. Law breakage rate and power. Power: 2.2kW, Capacity: 180-240kg/h.



MARUYAMA Portable Power Sprayers MSO55D. Engine: Air-cooled, 2-cycle, output 22.6cc, Pump: Suction capacity 5.1ℓ/mm, max pressure 25kg/cm^2, Weight: 8.5kg.

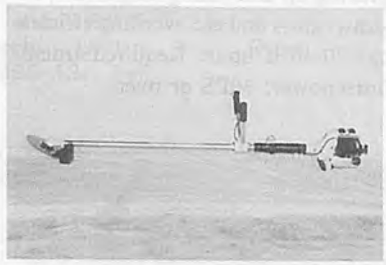


NIPLO Wing Harrow HW-4101B folded by hydraulic power for transport. Working width: 417cm; Required tractor horsepower: over 50.

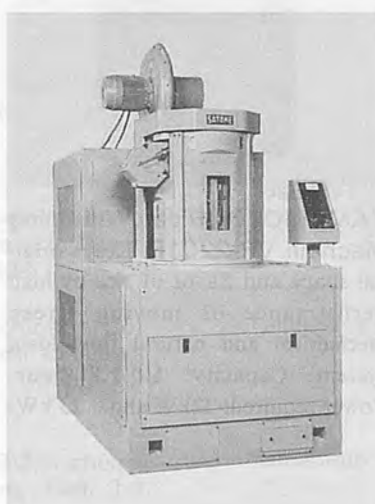


OCHIAI Riding Type Tea Picking Machine OM-25. Full working width cutter bar. Stepless speed control. Water-cooled Diesel engine 28.5PS.

OREC Power Cultivator AR700. Wide range use: Cultivation to riding. Mounted with 7 PS ~ 7.5 PS engine.



ROBIN Brush Cutter Model NBT415. 2 cylinder engine makes the operation easy and comfortable (low noise and vibration). Rotational speed of blade 4000-6000rpm.



SATAKE New Rice Whiteness, Abrasive and Friction types, have high recovery, uniform & gentle milling, less installation space and high capacity. Model: VRM8A (Abrasive type) & VMA8A (Friction type) Capacity: 8 to 10 mt/h brown rice.

SATAKE Color Sorters with their quality optics and high-grade electronics allow the operator to make efficient separator on the basis of color. Model: GS40AG/AK/AP, GS60AG/AK/AP, GS80AG/AK/AP and CS500B. Major Application: Rice, wheat, coffee, corn, sunflower, beans, spices, etc.

SASAKI Fertilizer Spreader BF-300. The lever type action controls the amount of application with high accuracy. Application width: 10-12m. Hopper capacity: 300ℓ. Required tractor horsepower: 20-50PS.

SHIZUOKA's Single Kernel Moisture Tester CTR-800E for rough rice, brown rice, wheat and barley.

STAR Mini-Roll Baler MRB 0810. Automatic pick-up, rolling and ejection. One bale every 30 seconds. Handy bale size (50cm in diameter and 70cm long). Required tractor horsepower: 18-30 HP.

SUKIGARA Double Row Cultivator Model TBC. The row width can be controlled easily and quickly by adjusting each bolt at the left and right of tool bar. Row width: 600-900mm. Suitable working speed: 3-5km/h. Power required: 11-20HP.

TACHIYAMA ROLL BALER RB904. Working width: 900mm, picking up and baling long straw, cut straw, grass and etc. working efficiency: 20-40 a/hour. Required tractor horsepower: 30PS or over.

YAMAMOTO Rice Whitening Machine VP-2201F. Keeps original shape and flavor of rice by high performance of moving screen mechanism and natural flow-down system. Capacity: 1.0-1.8t/hour. Power required: 22kW and 0.23 kW.

YANMAR Diesel Tractor US250D. Compact, quiet and vibration-reduced diesel engines are mounted at the heart of these US-series tractors. Engine: vertical, 4-cycle, water-cooled 25HP/2600 rpm. Weight: 916 kg Transmission: gear shifting F8 × R2 Drive system: 4-wheel drive.

YANMAR Rice Huller/Polisher Mill Mate YHP800. This machine is a complete direct-through rice mill consisting of a hulling section winnower and polishing section. Capacity in paddy 800-900kg/h. Required power: 15-18HP.

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The ABSTRACT 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. The requests from the readers for publishing the whole contents among the articles introduced here may also be sent to editorial staff. Regarding the article of many requests, the publication of whole contents will be reconsidered.

ABSTRACTS

013

The KSU Date-palm Service Machine Portable Units Design and Test Programme: S.A.A1 Suhaibani, A.S. Babeir, Assoc. Professor, respectively, College of Agriculture, King Saud Univ., P.O. Box 2460, Riyadh 11451, Saudi Arabia; M.L.A. Bascombe J. Kilgour, Senior Lecturer in Farm machinery Design at Silsoe College, Silsoe Campus, Silsoe, Bedford, MK45 4DT, U.K.

The presence of field irrigation channels restrict the free movement of a date-palm service machine recently developed for mechanizing activities associated with date-palm trees in Saudi Arabia.

The design of a pair of portable bridge units to be used to enable the service machine to cross over irrigation channels is described, together with a test programme.

The bridge units constructed from rectangular hollow section in grade 43C steel proved to be satisfactory in carrying the maximum design wheel load of 30kN over a maximum clear span of 2 meters with an acceptable maximum deflection.

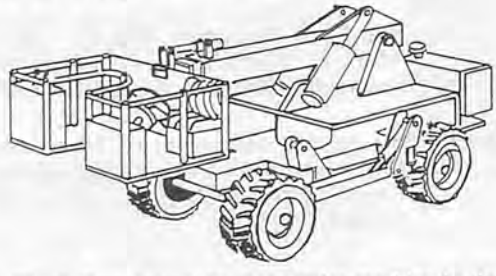

Fig. 1 Prototype palm tree service machine in the transport position.

015

Studies on Moisture Reduction during the Cooling of Heated Wheat: A.K. Gupta, Research Engineer, Dept. of Processing and Agricultural Structures, Punjab Agric. Univ., Ludhiana 141004, India J.L. Woods, Senior Lecturer, Univ. of Newcastle-upon-Tyne, NEI 7RU, England.

Dry-aeration experiments were conducted on wheat at an initial moisture content of 16% and 12% (w.b.). The grains preheated to temperature of 80, 60 and 40°C were put into a well insulated aluminium cylinder and aerated at airflow rates varying from 60 to 960m^3/h/m^3 of grain. An airflow rate of about 120m^3/h/m^3 was found to be optimum for maximum moisture reduction during cooling which was 0.25 to 0.65% (d.b.) per 10°C temperature difference. It was noticed that moisture reduction during cooling also depends on initial moisture content of the hot grains.

016

Effect of Harvesting Stage on Yield Potential of Soybean: B.B. Saxena, Scientist S-2, Central Institute of Agric. Eng., Nabi Bagh, Berasia Road Bhopal 4620188; T.P. Ojha, Deputy Director General (Eng.), I.C.A.R., Krishi Bhavan, New Delhi; A.C. Datta, Assoc. Prof., Agric. Eng. Dept. I.I.T., Kharagpur, Midnapore (WB), India.

Soybean (Glycine max.) is a rich source of protein (40%) and oil (20%), and is considered to be an appropriate substitute to other pulses for vegetarian persons. The stagnant production of pulses (about 11 million tonnes), high cost of animal protein and increasing demand of protein requirement due to current population growth challenged the consensus amoung agricultural engineers and scientists to increase production of soybean through harvest and-post harvest operations. The global annual production of soybean in 1985-86 was 94.12 million tonnes in which India contributed 1.1 million tonnes (1.16%) only. Though the pulses are very important dietary constituents in India, the ratio of legume to cereal has decreased from 0.17 in 1951-52 to 0.10 in 1979-80 (Pushpamma and Chittemma, 1981) and per capita consumption of pulses also declined from 60 g/day in 1951 to 30 g/day in 1981 against the minimum requirement of 85 g/day per capita.

Harvesting crops at proper time ensures minimum damage and less of grain during threshing, and other lesses in subsequent handling and processing operations. Norman (1967) reported that the soybean grain contains 65% moisture at maturity and it abruptly declined to 10-15% in 1-2 weeks just prior to harvest. Further, this plant dries up in a short span of time resulting in the possibility of shattering of grain and pods in field and damage of grain during harvesting and transport (Saxena,

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1987). Therefore, such a crop requires more careful handling during harvesting and threshing operations. Hence the harvesting of crop at proper time and suitable moisture content became necessary in order to achieve higher and better quality grain without significant loss in yield. Keeping this in view, it was felt necessary to study the influence of harvesting period on yield and grain quality of soybean and to predict experimental yield potential model.

For the above study, two varieties of soybean, namely, Jawahar soybean-2 and 7244 designated, respectively, as JS-2 and JS-7244, popular in Madhya Pradesh were taken. Each variety had different characteristics. The JS-2 variety is early maturing and more susceptible to shattering than that of JS-7244. Further, JS-7244 is relatively late maturing than JS-2 but both show almost equal yield potential.

Field experiments were conducted during June to November of 1984 and 1985 at the research farm of Central Institute of Agricultural Engineering (CIAE), Bhopal. In each year, one-half ha of land was prepared following the standard practices. Line sowing was done in July with 4-row animal-drawn seed drill. Ten dates of harvest from date of sowing (DAS) like 70, 75, 80, 85, 87, 90, 93, 96, 99 and 102 nd for JS-2 and 10 other dates as 85, 90, 95, 100, 103, 106, 109, 112, 115 and 118th for JS-7244 were selected. Soybean crops from $10m^2$ area were harvested manually on the aforesaid DAS for each variety. Pod and grain moisture content (w.b.), grain yield, shattering losses were noted for all DAS. Shattering losses and yield at 8% m.c. were calculated for the purpose of comparison.

Statistical analysis carried out on both varieties indicated that there is a significant variation in grain yield for the range of DAS for both JS-2 and JS-7244 varieties. The yield ranged from 8.30 to 14.82 q/ha for JS-2 and that of JS-7244 variety varied from 8.67 to 14.75 q/ha. The optimum harvesting period was statistically determined as the period when crop could be harvested without significant loss in yield. Considering this, analysis of the data shows that the crop could be harvested between 85 and 93 DAS for JS-2 and 110-112 DAS for JS-7244 varieties without significant loss in yield at 5% level. It was further noted that the yield decreased rapidly beyond 93 DAS and beyond 112 DAS, respectively, for JS-2 and JS-7244 varieties. The reduction in yield beyond 93 and 112 DAS was probably due to heavy shattering losses for excessive drying of pods in the field. The average moisture content during the optimum harvesting period (85-93 DAS for JS-2) ranged from 40.21 to 20.54% and that for JS-7244 (100-112 DAS) ranged from 42.5 to 16.45%.

The second-order polynomial of DAS with yield potential was found to fit for both varieties. However, this model could explain 89 and 95% of total variation, respectively, for JS-2 and JS-7244. Less predictability of the model than the maximum was due to the reduction in yield beyond 93 and 112 DAS which were affected by sharp increase in shattering losses.

039

Comparative Performance of Power Tiller and Bullock-drawn Tillage and Sowing Equipment: A.C. Varshney, Project Coordinator, Power Tiller Scheme; Suresh Narang, Scientist S-2, Power Tiller Scheme; A.K. Misra, Scientist S-2, Crop Production Eng. Div., Central Institute of Agric. Eng., Bhopal, India

A study was conducted to evaluate the performance of power tiller rotavator and seed-cum-fertilizer drill and bullock-drawn blade harrow and seed-cum-fertilizer drill on sorghum (Sorghum vulgare Pers.) and bengalgram (Cicer arietinum L.) respectively, during Kharif (rainy) and Rabi (winter) seasons. The mean weight diameter of soil aggregates was comparable in rotatilling twice and blade harrowing thrice treatments but there was a saving of 46.39% time in seedbed preparation by rotatilling twice in comparison with blade harrowing thrice. The maximum yield of sorghum and bengalgram was found in rotatilling twice treatment. Seed-cum-fertilizer drills operated by power tiller and bullocks did not show effect on yeild of bengalgram.

047

Off-road Performance of Bicycle Wheels with Special Emphasis on Rolling Resistance: Md. Syedul Islam, Sr. Agric. Engineer, Farm Machinery and Postharvest Technology Div., BRRI, Gazipur, Bangladesh; C.D. Watt, Lecturer, Dept. of Agric. Machinery Eng., Silsoe College, Bedford, MK45, 4DT, U.K.

The field performances of bicycle wheels were studied by two methods, namely; the strain gauge and the cone penetrometer method. The tests were conducted on three typical surface conditions, viz. compact soil, loose soil and grass field. The test variables were wheel diameter, tyre inflation pressure, load and speed. The rolling resistances measured by strain gauge method were higher than those predicted from cone penetrometer method.

048

Development of Curve Numbers for Different Land Use Patterns in the Himalayan Catchment of Ramganga River in India: Rajat Kumar Mehta, Asst. Prof. (Agric. Eng.), Crop Res. Stn., Ghaghraghet, N.D.U.A.T., U.P., India; Ghanshyam Das, Prof. and Head, Dept of Soil and Water Conservation Engineering, College of Technology, G.B. Pant Univ. of Agriculture and Technology, Pantnagar, India

The Soil Conservation Service (SCS) method is most widely used for soil moisture accounting and estimating runoff amounts from agricultural watersheds. The soil moisture accounting and volume of runoff depends on both meteorologic and watershed characteristics. Curve number for prevalent land uses were developed through an interaction technique for Marchula watershed of Ramganga catchment by using daily rainfall data as the input and runoff as the output. The watershed was divided into sub-areas of Thiessen polygons to estimate the runoff. The results of all the selected storm events were varified with measured data and found to be satisfactory.

069

Selected Technical Specifications of Agricultural Tractors Affecting Tractive Performance in Wetland Cultivation (Puddling): J. Prasad, Sr. Scientist (Farm Machinery and Power) and Head, Instrumentation and Data Processing Div., Central Institute of Agric. Eng., Nabibagh, Berasia Road, Bhopal, India

Puddling of soil, in the presence of standing water in the field, is an essential operation for the paddy cultivation. The power sources for puddling include draft animals, power tillers and tractors. The tractors are increasingly being used for puddling with either double cage wheels or with paddy disc harrow and rotary cultivator in combination with half cage wheels. All the tractors manufactured presently are not recommended for wetland cultivation (puddling). Even those tractors which are recommended for wetland cultivation sometimes lack in adequate traction and need effective sealing arrangements and face other problems such as prematured damage of critical components and immobility during puddling operation. this paper highlights some important technical requirements which should be taken into consideration to improve trafficability and performance of tractors under wetland conditions.

073

Effect of Plant Characteristics on Mechanical Cotton Picking in Rahad Project, Sudan: Mamoun I. Dawelbeit, Sr. Res. Scientist, Agric. Res. Corp., Rahad Research Station, Elfau, Sudan

Two experiments were conducted comparing mechanical picking at four plant populations (62,600, 113,300, 141,200, and 160,700 plants/ha) and evaluating the performance of mechanical picking on two varieties of medium staple acala cotton (Sudac-K and Barac (67)B). Results show that plant population affected plant characteristics such as height of the first fruiting node, plant height and resulted in higher weight of picked cotton. However, machine and overall efficiency were not affected by plant population.

The total weight of picked cotton was affected by variety while mechanical and overall efficiencies were not.

Grades of hand-picked cotton were higher than those machine-picked regardless of plant population or variety. Grades and fiber properties of machine picked cotton were not affected by population or variety.

102

Shallow Wells in Coarse-textured Valley Bottom Soils: P.N. Vine, Lecturer, Dept of Physics, Univ. of the West Indies, Saint Augustine, Republic of Trinidad and Tobago; E. Okoro, Federal Agric. Coordinating Unit, P.M.B. 2277, Kadna, Nigeria; T.T.K. Amachree, Stella Aris College, Port Harcourt, Nigeria

Many rural dwellers use unlined pits as wells. Experiments were conducted on the effects of well diameters from 0.10 to 0.80 m and drawdown depths from 0.30 to 0.90 m, and of different well structures and linings, in a valley bottom seasonal wetland in south-western Nigeria having coarse-textured soils. The different structures and linings consisted of a bamboo-lined trench; unperforated or perforated single drum-lined wells; and unperforated or perforated twin drum-lined wells in which two drums 1 m apart were linked underground by a pipe. Recharge rate was little affected by well diameter, drawdown depth, well structure or lining, ranging from 2 to 9 L/min. This rate favoured intermittent rather than continuous emptying The unperforated single drum-lined well (using a 220 L steel oildrum with both ends removed) was found to be the most appropriate to reduce major problems of unlined pits, including continual wall collapse, infilling, turbidity and entry of persons with infections. ■■

The General Body Meeting of the AAAE
December 7, 1992
Bangkok, Thailand

The General Body (GB) meeting of the Asian Association of Agricultural Engineers (AAAE) is scheduled to be held on December 7, 1992, the first day of the International Agricultural Engineering Conference at the Asian Institute of Technology, Bangkok, Thailand.

At the GB meeting it is planned to recognize those members who generously contributed their time and money for AAAE to become a reality. The members who have contributed tremendously to the Association by recruiting new members will also be recognized during this meeting. In addition to technical paper presentations on 8 and 9 December 1992, a Symposium on Prospects of Agricultural Mechanization in the Asian Region is being organized by the AAAE in collaboration with the Club of Bologna's Regional Forum of Asia and Oceania. The Management Committee of the International Commission of Agricultural Engineering (CIGR) will also meet on December 9, 1992 during the international conference.

The Third Postharvest Convention
March 31-April 1, 1993
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Day 1 Quality Conservation in Harvested Perishables
Day 2 Storage of Durables without Spoilage

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Agritech Spring '93 is the showcase for Israel's world-renowned agricultural technology. It is the tri-annual event for Israel's dynamic, inventive and solution-oriented manufactures and agronomists to exhibit what they do best: new ideas, the latest technology, and the solutions for today's farmer.

Organized by the Ministry of Agriculture, the Israel Export Institute and the Kibbutz Industries Association, **Agritech Spring '93** promises to be the largest and most varied Agritech exhibition yet. Thousands of visitors from over 115 countries have already shown an interest in the exhibition.

Agro-technologists, scientists and engineers from Israel's Research and Development Centers will be displaying the imaginative technology that will meet demands for the ever increasing yields and environmental concerns of the future.

Agritech Spring '93 is also the venue for the 6th International Conference of Water and Irrigation, the 3rd Seminar on Greenhouse Technology and the 1st Seminar on Agro-Ecology.

Israeli agricultural technology is deeply involved in the needs of farmers, and that's why Israeli equipment across the globe is increasing yields and profits while cutting operating costs.

Agritech Spring '93 features the very latest Israeli technology for field and fruit crops, poultry and dairy farming, greenhouse growing, aquaculture, and many other branches of modern agriculture. These include irrigation and fertigation technology, advanced tillage and minimum tillage equipment; planting and transplanting systems; efficient plant protection and spraying systems; milking systems; harvesting systems; sorting; packing, and transportation equipment.

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Agritech Spring '93 Organizing Committee
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Tel: 972-3-5142830
Fax: 972-3-5142881

EXPO 93
July 25-27, 1993
Louisville, KY, USA

EXPO 93 will be held in Louisville, Kentucky USA, on July 25-27, 1993. EXPO is recognized throughout the world as one of the largest lawn, garden and power equipment exhibitions.

XII° C.I.G.R. World Congress and AgEng '94 Conference
August 29-September 1, 1994
Milano, Italy

The XII CIGR Congress will be held simultaneously with AgEng '94 (the biennal conference of EurAgEng, the European Society of Agricultural Engineers) and will be divided into two parts.

The first part will cover the Agricultural Engineering strategies related to the changing social and economic conditions of world agriculture and to the increasing demands for environmental protection. This is in accordance with the new role of CIGR as world organization assembling all Regional and National Societies of Agricultural Engineering, as well as individual members, societies, research centres etc..

The second part will follow the traditional schemes of the AgEng conferences, which started in Cambridge in 1984 and dealt with the state of the art in the different areas of Agricultural Engineering Research and Development.

For information contact:

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Papua New Guinea/IRRI Sign Technical Cooperation Agreement

Los Baños, Philippines — The Government of Papua New Guinea (PNG) and the International Rice Research Institute (IRRI) have agreed to work together over the next five years to build up PNG's rice research capabilities.

PNG Minister of Agriculture and Livestock Roy Evara and IRRI Director General Klaus Lampe signed a memorandum of agreement for scientific and technical cooperation on September 22 at the IRRI research center in Los Baños.

"Rice is increasingly becoming a staple food in PNG, home to approximately 3.8 million people," Minister Evara said. National production is 1,000 tons, less than 1% of rice consumption levels. In 1991, the mountainous archipelago imported almost 160,000 tons of rice at a cost of about US$40 million.

"We want to encourage small landowner and commercial production," Evara explained.

"Both the PNG and IRRI will seek donor funding so that seed, training, and technical expertize to help PNG move toward rice self-sufficiency can be mobilized," said IRRI Director General Lampe. "We will give high priority to establishing rice research capability to develop rice varieties with the eating quality that the Papua New Guineans prefer."

A.G. Rijk, New Chief for the Agricultural Engineering Service FAO/UN

In March 1992, Dr. Adrianus G. Rijk has joined FAO HQs in Rome as Chief of the Agricultural Engineering Service. He succeeds Mr. R.C. Gifford who retired in December 1990. Prior to rejoining FAO, Dr. Rijk worked in the Agriculture Department of the Asian Development Bank in Manila since 1981.

His overseas career began in 1975 in an FAO project in Thailand. From 1977 to 1979 he worked for FAO in Nepal, and after that as an international consultant, prior to joining the ADB. He holds a degree from an Agriculture College, an M.Sc degree in Agricultural Engineering with a specialization in tropical agriculture, and a Ph.D from Wageningen University, The Netherlands.

He has also written a book on Agricultural Mechanization Policy and Strategy. On the family farm in the Netherlands he acquired practical farming skills. He is a member of the American Society of Agricultural Engineers, The Netherlands Institution of Agricultural Engineers, and the Asian Association for Agricultural Engineering.

Dr. A.M. Michael Joined as Vice-Chancellor, Kerara Agricultural University, India

Dr. Michael has joined as Vice-Chancellor, Kerara Agricultural University, Vellanikkara, Thrissur, Kerara State from July 1992, on a five year tenure.

He has been assisting AMA as a co-operating editor since 20 years and will continue to do so.

Incidentally it may be mentioned that he is the first Agricultural Engineer to be appointed as Vice-Chancellor of the University.

They have a full-fledged College of Agricultural Engineering at the University. Kerara is located in the humid tropical region. Plantation crops, spices, paddy and tuber crops are the main crops of the State. ■■

INSTRUCTIONS TO AMA CONTRIBUTORS

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

Criteria for Article Selection

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

a. are written in the English language ;
b. are relevant to the promotion of agricultural mechanization, particularly for the developing countries ;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission ;
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 ;
f. are typewritten, double-spaced, under 4,000 words (approximately equivalent to 8 pages of AMA-size paper) ; and those that
g. are supported by authentic sources, reference or bibliography.

Rejected/Accepted Articles

a. As a rule, articles that are not chosen for AMA publication are not returned unless the writer(s) asks for their return and are covered with adequate postage stamps. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but requires revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
c. "The AMA does not pay for articles published. However, the writers are given collectively 5 free copies (one copy air-mailed and 4 copies sent by surface/sea mail) of the AMA issue wherein their articles are published. In addition, a single writer is given 25 off-prints of the article and plural writers are given 35 off-prints (also sent by surface/sea mail)"

Procedure

a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article may be sent directly to the AMA Chief Editor in Tokyo.
b. Contributors of articles for the AMA for the first time are required to attach a passport-size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

Format/Style Guidance

a. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features :
   i) a brief and appropriate title ;
   ii) the writer(s) name, designation/title, office/organization ; and mailing address ;
   iii) an abstract following ii) above ;
   iv) body proper (text/discussion) ;
   v) conclusion/recommendation ; and a
   vi) bibliography
b. The pages must be numbered (Arabic numeral) successively at the top center. Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
c. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
d. 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.
e. 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).
f. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
g. Convert national currencies in US dollars and use the later consistently.
h. Round off numbers, if possible, to one or two decimal units, e.g., 45.5kg/ha instead of 45.4762kg/ha.
i. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers . . . , or Five tractors . . ." instead of 45 workers . . , or, 5 tractors.

Co-operating Editors


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A M Hossay


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D K Some


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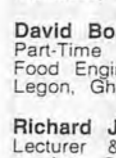
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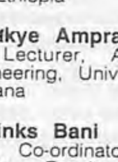
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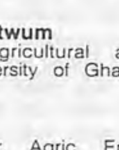
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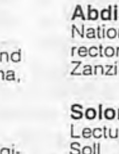
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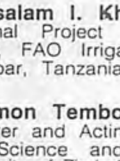
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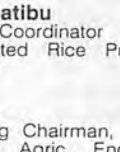
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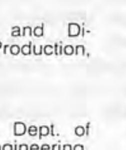
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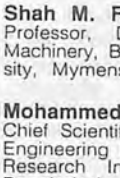
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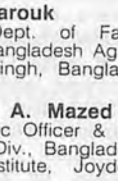
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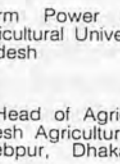
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BACK ISSUES

(Vol. 22 No. 1, Winter 1991 ~)

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA
(Vol. 22, No. 1, Winter, 1991)

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA
(Vol. 22, No. 2, Spring, 1991)

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA
(Vol. 22, No. 3, Summer, 1991)

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA
(Vol. 22, No. 4, Autumn, 1991)