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VOL.29, NO.3, SUMMER 1998

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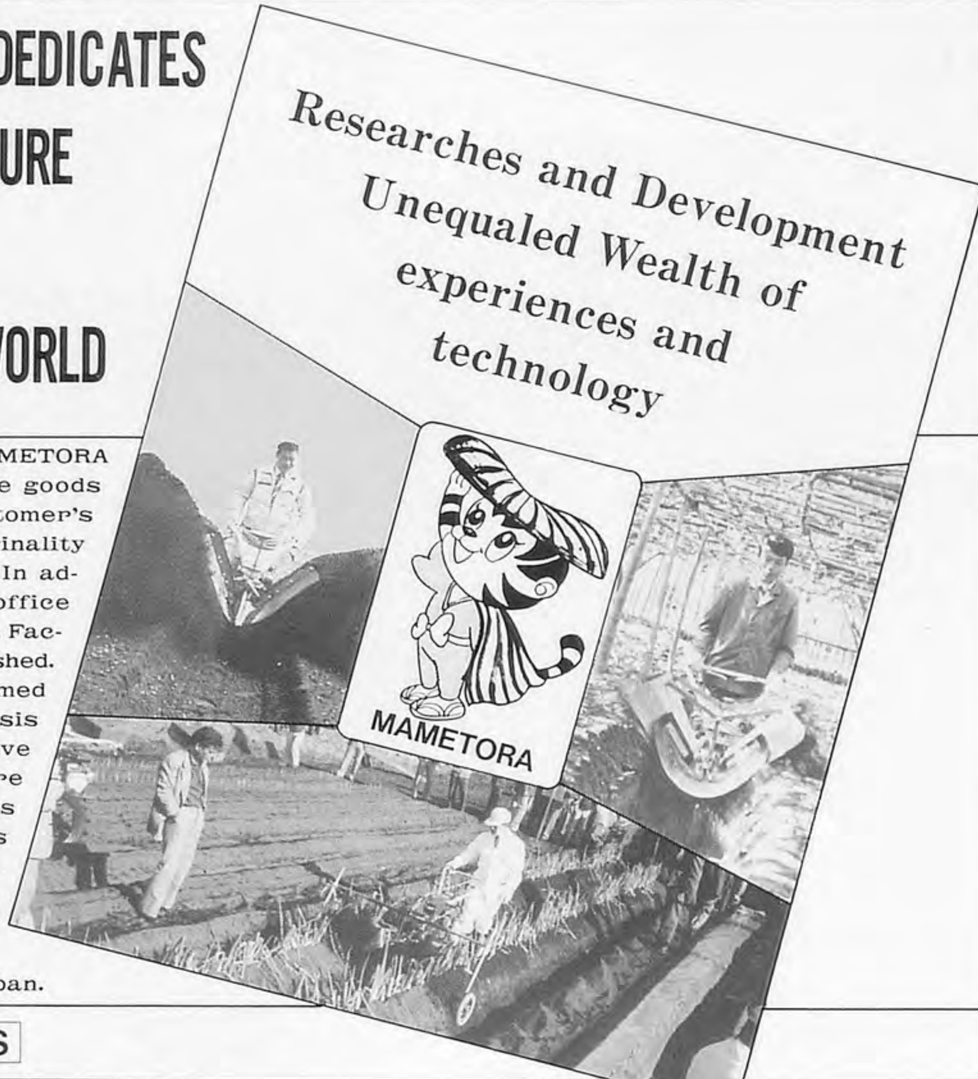

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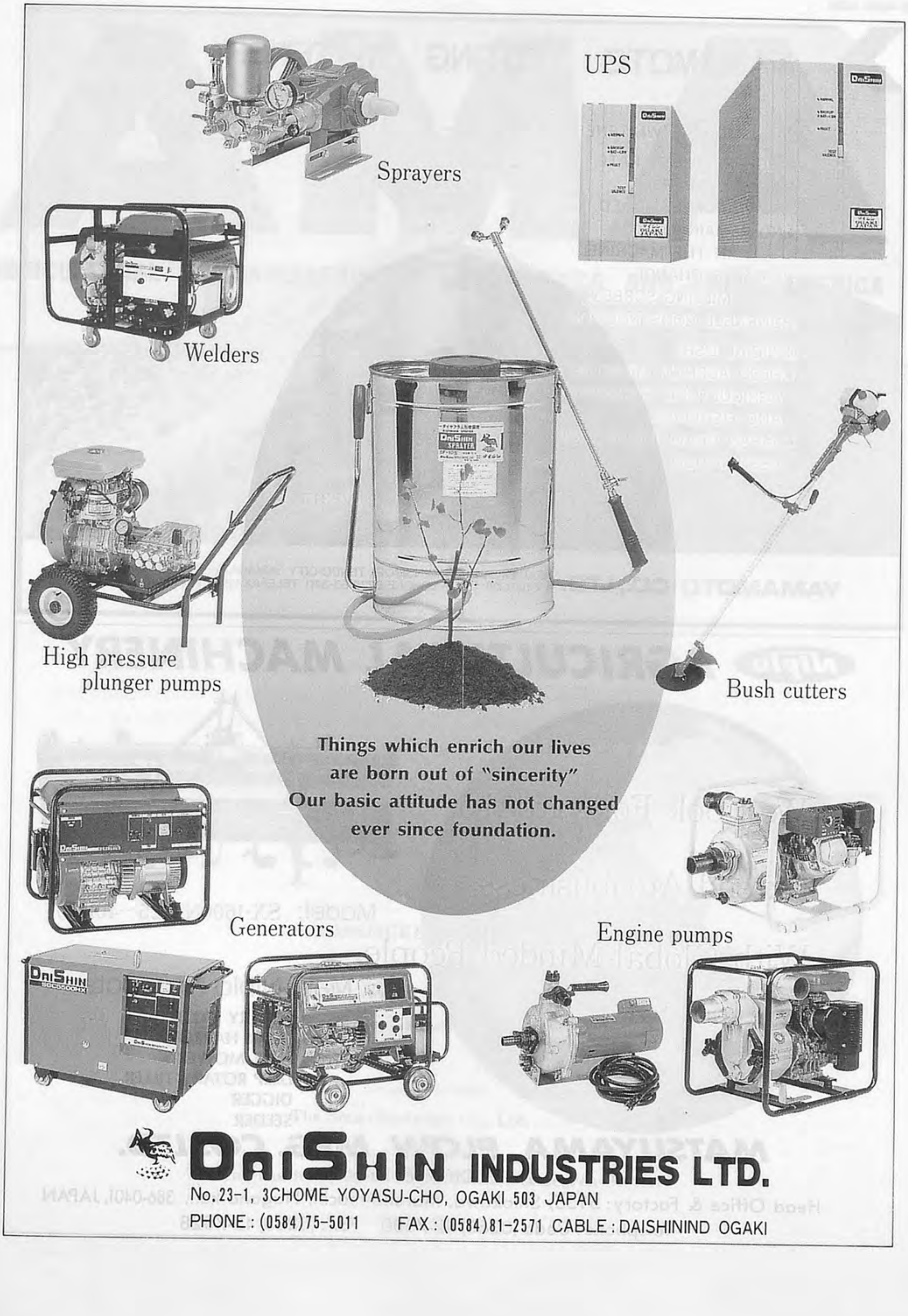
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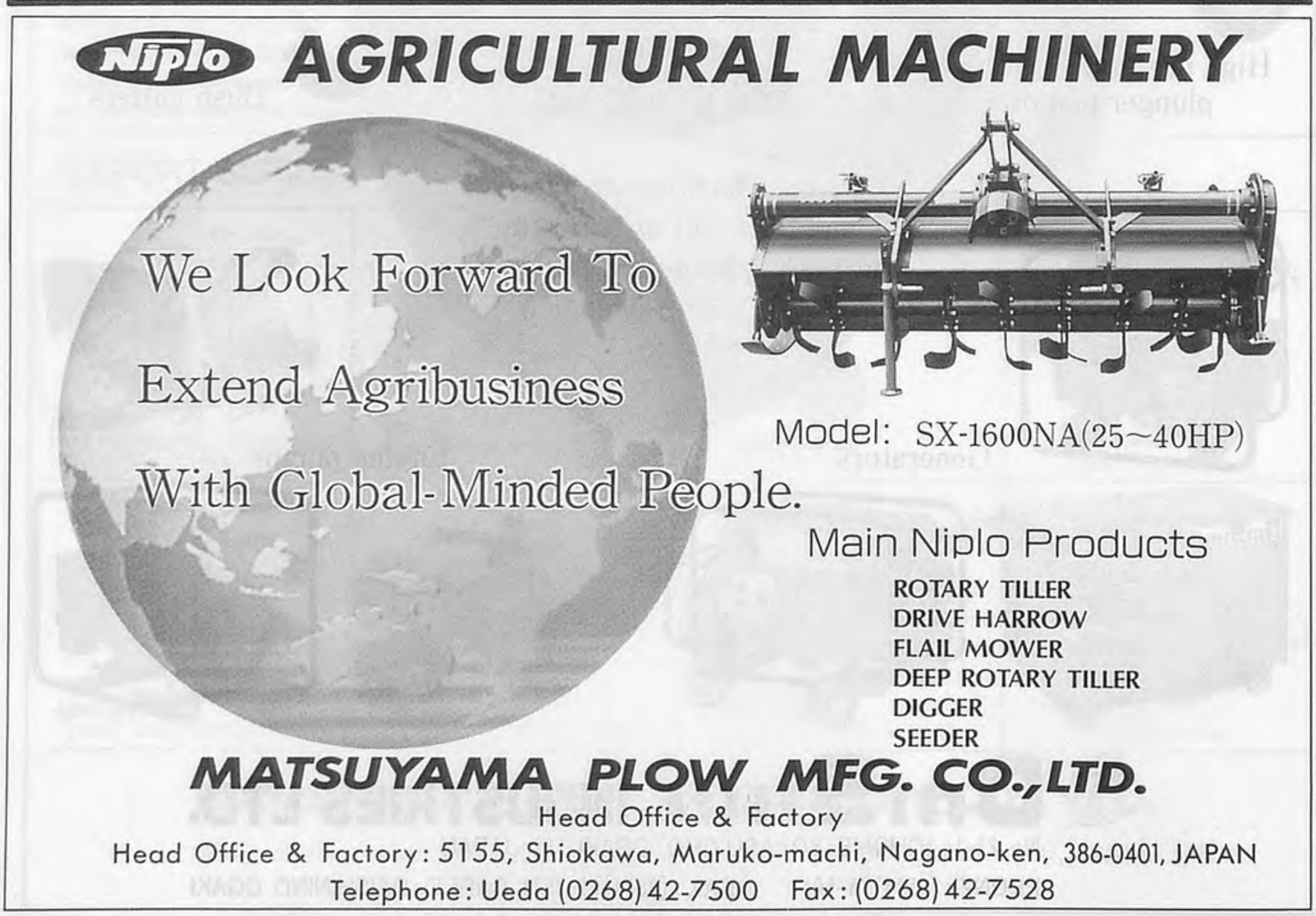

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EDITORIAL

Agricultural Mechanization in 21st Century

In a matter of 17 months from now, the 21st Century will be upon us. And as the millenium will be ushered in before long, some disturbing developments have recently emerged that affect the future of agriculture and farm mechanization, particularly in the Asian scenario. A number of Southeast Asian countries, for more than a year now, have been experiencing drought and its concomitant forest fires which are blamed on the vagaries of nature called "El Niño". The net result is food shortage, e.g., Indonesia which used to be a net exporter of rice is now in short supply of this staple by some 3.5 million metric tons. This condition is compounded by the financial crisis that has hit hard a number of Asian countries since last year, let alone some political problems that have surfaced recently.

Amidst these problems, how does the future of agriculture and farm mechanization look like? But, of course, governments have now choice but redouble their efforts to continue promoting agriculture and farm mechanization — not only to make up for food shortages but more importantly, to feed the burgeoning population that continues unabated in many Asian countries. To be sure, the demand for food in Asia is greatest in the world. The irony is that many of these countries are not prepared to meet the future's need for food. Mechanization of agriculture calls upon those countries to increase land productivity — given that other farm inputs such as high-yield crops, fertilizer, irrigation water and farm chemicals are available.

Bio-technology is yet another area of development in agriculture concerning genetic engineering or inter-changes of desirable genes, including the production of industrially useful raw materials. For example, some Japanese scientists have recently attempted to produce chemicals from silkworms which are originally intended for sericulture or the manufacture of silk. It looks like that new technologies are about to expand the horizon and possibilities of agriculture, even to transform farm lands into factories.

In the meanwhile, in most developing countries, farming continues to be traditional and very much a part of the local eco-system. One wonders whether traditional agriculture or global eco-system can be sustained even as farm mechanization needs to co-exist with new trends in technology development.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
July, 1998

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol. 29, No. 3, Summer 1998

Design, Development and Performance Evaluation of a Once-over Tillage Machinery Utilizing a Single-axle Tractor

by
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Abstract

This work involved the development and construction of a once-over tillage machinery combining the operations of tillage, planting, and applications of fertilizer and herbicide in one passs of a single-axle tractor. The tractor was calibrated to relate the ground travel speeds to the engine speeds to facilitate operator's convenience and economic use of the tractor.

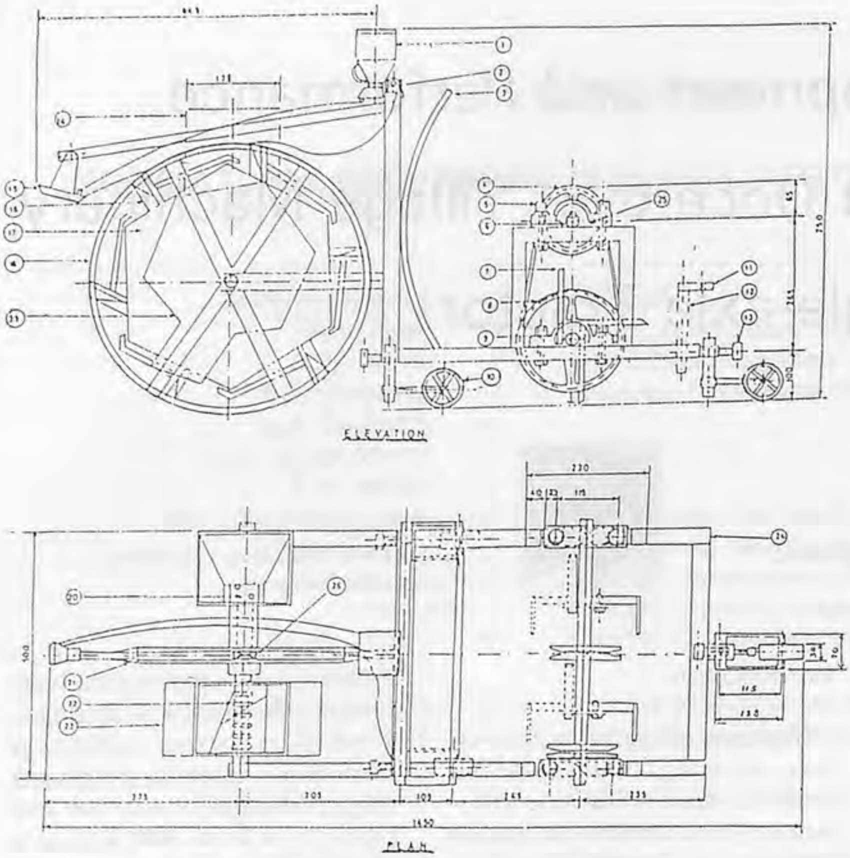
Field and laboratory tests were conducted using maize as the test crop. The mean penetration resistances for disc ploughing, disc harrowing, disc ploughing followed by disc harrowing and rotary tillage on sandy-loam soil were 0.38, 0.29, 0.41 and 0.36 MPa, respectively. A minimum of tillage operations reduced soil compaction and enhanced seedling emergence. The percentage of mechanically damaged seeds at travel speeds of 1.5, 2.5, 3.7 and 4.0 km/h were 0.75, 0.88, 1.38 and 2.38, respectively. There was no statistically significant difference in the visible seed damage of the machines tested.

Introduction

Agricultural mechanization has been receiving considerable interest in recent times due to increasing food demand and equally increasing population. However, short supply of appropriate tools and equipment is one of the major handicaps that have resulted in the inability of Nigerian agriculture to provide sufficient food, support agro-based industries and contribute to foreign exchange earnings through export. Abalu et al., (1981) for example, have put the present technical problems faced by Nigeria's agriculture as those associated with inappropriate technologies and cultural practices. The unit of land cultivated by an average Nigerian farmer rarely exceeds 5 ha (Anazodo, 1985) and the sophisticated farm equipment imported from Europe and North America are often uneconomical for the small-scale farmers.

The high growth rate of population of 3% annually (Ojanuga, 1984) and the attendant need to increase food production call for important timeliness in farm operations (land preparation, planting, fertilizer and herbicide applications) which must be mechanized if farmers are to produce crops efficiently. Onwuji (1983) developed a multi-operation cultivation machine incorporating moldboard ridgers mounted on tool bar and pulled by a Ford 1600 dual-axle tractor. The manufacturing and operating costs of the machine were thus high and not likely to gain widespread acceptance by Nigerian small-scale farmers on account of facilities for manufacturing and maintenance, heavy weight of the machines, small farm sizes and socio-economic conditions of the farmers. An alternative solution, therefore, is the use of rotary tiller with hoe tines for tillage operation and other integrated units connected to a single-axle walking tractor for power supply (**Figs. 1, 2, 3,** and **4**). The single-axle tractor has the advantages of light-weight and good maneuverability, suits the economic condition and management skills of most peasant farmers in Nigeria.

The main objectives of this study were to develop and construct a once-over tillage machinery to improve performance efficiency and to be within the technological level of the farmers in terms of repair and local manufacture.



ITEM NO.	DESCRIPTION	NO. OFF	MATERIAL
26	BALL BEARING	2	CROMIUM STEEL
25	BEARING HOUSING	2	MILD STEEL
24	MACHINE FRAME	1	ANGEL IRON
23	FERTILIZER DISTRIBUTOR HOPPER	1	16 GA B.I. SHEET
22	FERTILIZER AGITATOR COIL	1	ROUND SOLID IRON ROD
21	PUNCHING WHEEL	1	16 GA B.I. SHEET
20	SEED PLATE	1	HARD WOOD
19	FERTILIZER DISTRIBUTOR UNIT	1	HARD WOOD
18	SUPPORTING WHEET	1	16 GA B.I. SHEET
17	ROTARY PUNCH PLANTER	1	15 GA B.I. SHEET
16	ROTATING SEED FUNNELS	6	MILD STEET SHEET
15	CDA SPINNING DISC	1	PLASTIC
14	SEED HOPPER	1	16 GA B.I. SHEET
13	DEPTH CONTROLLER	1	ROUND SOLID IRON ROD
12	HITCH SUPPORT	1	ANGLE IRON
11	MACHINE HITCH	1	MILD STEEL SHEET
10	LAND WHEEL	2	MILD STEEL SHEET
9	M8 FLAT WASHER	8	MILD STEEL
8	DRIVEN PULLEY	1	CAST IRON
7	ROTARY TILLER KNIFE	8	MILD STEEL SHEET
6	POWER TRANSMISSION SHAFT	2	MEDIUM CARBON STEEL
5	M8x18 BLACK HEXAGONAL BOLT	8	MILD STEEL
4	DRIVER PULLEY	1	CAST IRON
3	PROTECTIVE SHIELD	1	16 GA B.I. SHEET
2	BATTERY CASING	1	PLASTIC
1	CDA SPRAYER TANK	1	TRANSPARENT PLATIC

Fig. 1 Design of the once-over tillage machine.

Fig. 2 Once-over tillage machine: W, rotary tiller unit with hoe tines; X, planter unit; Y, fertilizer applicator unit; Z, low-volume spinning disc CDA sprayer (Micron herbi).

Fig. 3 The once-over tillage machine on 7-hp single-axle (walking) tractor.

Fig. 4 Operation of the once-over tillage machine in an experimental field.

Materials and Methods

The once-over tillage machinery is a combined unit of a rotary tiller, a rotary injection planter, a fertilizer-applicator-band (FAB), and a controlled droplet application (CDA) herbicide applicator (Micron herbi) all mounted on the frame work of a single-axle walking tractor powered by a 7 hp Briggs and Stratton petrol engine. The rotary injection planter injects the seeds into the soil by a jabbing action and gently compacts the soil around the seed by means of a press wheel attached to the device. This equipment was originally designed by volunteers in the Technical Assistance, U.S.A. program, adopted in the region and is gaining popularity among farmers because of its precise seed metering and ease of operation. The manual planting method represents planting without any form of mechanical aid and involves dropping seeds into holes made with the heels, covering the seeds with soil and compacting the soil surrounding the seeds with the heels.

The ground in the experiment site is gently slopping and the texture of the soil surface is light with low water-holding capacity. The soil profile is characterized generally by a sand surface horizon underlying a horizon of clay accumulation with a weak sub-angular block structure, low cation exchange capacity (20-40 meg/100 gm of soil), high base saturation and pH, a reddish-brown to greyish-brown colour (resembling yellowish ferrallitic soils), formed from transported fine-grained loam material on broad gentle slopes in an undulating topography.

The Landmaster Lion single-axle tractor was fitted with a 7 hp Briggs and Stratton petrol engine which was calibrated to relate the ground speeds to engine speeds and positions of throttle lever. This was done for the operator's convenience. Throttle lever positions which correspond to tachometer speed readings of 800, 1 200, 2 400, 3 000, 3 400 and 3 500 rpm were properly marked. The tractor travel speed (m/s) was determined by measuring the time taken to cover a distance of 100 m on level ground with four replicate observations for each measurement. The three surface types used in the study were concrete floor, firm soil, and tilled soil. Linear regression analysis was performed on the data to relate engine speeds to travel speeds with the model:

$$y = ax + b \quad (1)$$

where

y = engine speed (rpm);

x = tractor foward travel speed (km/h);

a and b = empirical constants.

The performance criteria used were: seed metering; seed damage; seedling emergence; and ease of operation.

Field and laboratory tests were carried out to establish the machine's seed metering accuracy and determine the average number of seeds dropped per hill. At the end of each run on the field, the seeds deposited were dug out for examination. Spacings between hills were measured. A rotary injection planter was also used in the tests for comparison because of its popularity. Laboratory test was carried out on a flat piece of wood that was coated with grease to determine the performance of the machine's metering device under ideal conditions. For seed damage test, the machine was operated in the laboratory through a distance of 50 m. The percentage of cracked seeds, broken seeds and lost tip caps of the seeds were computed.

For the field test, land was prepared by using five tillage treatment as follows: disc ploughing (DP), disc harrowing (DH), disc ploughing followed by disc harrowing (DPH), rotary tillage (RT), and zero tillage (ZT) which were used in order to evaluate their relative performance under sandy-loam and clay-loam soils. Each tillage treatment was carried out on 30 m × 40 m plot. Disc ploughing tilled the soil to an average depth of 16 cm with a 3-furrow mounted disc plough coupled to a Steyr 8045 tractor while disc harrowing disturbed the soil to an average depth of 11 cm using an offset disc harrow coupled to the same tractor after ploughing. Both the first and the second treatments were combined to form the third treatment. A rotary tiller was used for shallow tillage at 6.8 cm depth. Zero tillage was done by planting the maize seeds directly into the soil without tillage operation. Analysis of variance (ANOVA) was performed by using the procedure for split-plot design as described by Cochran and Cox (1957).

The once-over tillage machinery and the rotary injection planter were run alongside with the traditional (manual) method of planting to evaluate the emergence of seedlings as influenced by the techniques of planting and tillage treatments on the two types of soil.

The three methods of planting were superimposed on the five tillage treatments at right angle and replicated three times, based on the practice being followed by the farmers that grow maize around the sites investigated. The rows were arranged across the slope. The crop row spacings, hill spacing, and depth of seed placement were 75 cm, 25 cm , and 3 cm, respectively.

Immediately after planting, pre-emergence herbicide (Primagram 500 fw) was sprayed using a knapsack sprayer at the rate of 4 ℓ/ha when soil moisture was adequate. However, the plots that received the once-over tillage machinery was treated by using the controlled droplet applicator which produced single droplet at about 1 mℓ per second flow rate giving droplets of 250-300 micron volume median diameter (vmd). Fertilizer (NPK 15-15-15) was applied at the rate of 400 kg/ha two weeks after planting in a ring of 10 cm radius and 2.5 cm deep around each stand according to local recommendations. Penetration resistance was measured with a penetrometer. The soil moisture content was determined in the laboratory on wet basis. Germination and emergence of seedlings were monitored after planting. Records of seedling emergence were maintained from the day of first seedling emergence until the emergence was completed.

Results and Discussion

During the tests of the once-over tillage machinery, it was observed that travel speeds lower than 0.5 km/h on the field were too low to support the field operations and the engine usually shut off after 17 minutes of operation. At travel speeds above 4.1 km/h, the operator had to run after the tractor. Hence, travel speeds between 0.5 and 4.1 km/h were used for field and laboratory tests. The results of the linear regression analysis that related engine speeds to travel speeds are shown in **Table 1**. The number of seeds dropped per hill and the distances between hills for the different machines used in maize cultivation are shown in **Table 2**.

The once-over tillage machinery showed better field performance than the rotary injection plant as regards their closeness to the agronomically recommended values. This was due to the uniform forward speed maintained by the once-over tillage machinery, seed delivery and placement accuracy and the presence of tiller unit which reduced the bounce problem. However, there was a noticed partial blockage of the spouts of the machines at a soil moisture content of 13% which implies a possibility of complete blockage of the spouts at higher soil moisture content. Choudhury (1985) experienced the same problem when evaluating similar planters.

The results obtained from the seed damage test conducted in the laboratory are shown in **Table 3**. There was no statistically significant difference ($p < 0.05$) in the visable seed damage of the machines as shown in **Table 4**. The differences arising among the means in the percentages of seed damage were not due to the differences in speeds and machines but just due to chance. The insignificant interaction between the treatments and the machines means that the seed damage was neither a function of the seeds nor the machines.

The once-over tillage machinery exhibited better metering efficiency and highest percentage of seedling emergence over the other machines as shown in **Figs. 5** and **6**. This may be explained by the fact that the once-over tillage machinery unit loosened the soil surface for easy penetration of seedlings. The slightly compacted soil underneath **(Table 5)** provided firm seed and moist soil contact. Harrison (1975) reported that soil compaction below the seed level improves germination.

The once-over tillage machinery had the advantages of light weight, adaptability to small farm areas and availability of local materials for fabrication. The ease of operation of the machine was due to the fact the tractor was calibrated to select the desirable travel speeds and that the operator acted more as control device than as source of power.

Table 1. Computed Linear Regression Coefficients and Their R^2

Surface Type	Gear		Value of Regression Coefficients a	b	Coefficient of Determination, R^2
Concrete floor	Low		708.0	−16.7	0.982
	Intermediate	I	406.0	971.0	0.611
		II	606.0	−527.0	0.986
		III	363.0	−73.4	0.949
	High		313.0	−187.5	0.989
Firm soil	Low		695.0	308.0	0.983
	Intermediate	I	630.0	196.0	0.990
		II	595.0	−9.5	0.990
		III	417.0	47.4	0.974
	High		368.0	−159.8	0.987
Tilled soil	Low		804.0	435.8	0.974
	Intermediate	I	635.0	485.8	0.969
		II	707.0	−25.0	0.974
		III	399.0	476.4	0.886
	High		378.0	40.1	0.984

Table 2. Comparative Performance of Once-over Tillage Machinery and Rotary Injection Planter

Parameter	Recommended values*	Values for Machines: Once-over machinery Field	Once-over machinery Laboratory	Rotary planter Field	Rotary planter Laboratory
Hill spacing (m)	0.25	0.31	0.32	0.44	0.27
Seeds/hill	1.00	1.20	1.21	1.32	1.24
Application rate (% total seeds planted):					
missed the hill	—	25.00	14.00	40.00	0.00
1 seed/hill	—	45.00	58.00	16.00	76.00
2 seeds/hill	—	14.00	18.00	24.00	24.00
3 seeds/hill	—	12.00	6.00	12.00	0.00
4 seeds/hill	—	2.00	1.00	8.00	0.00

*Source: Kim et al., (1984).

Table 3. Mechanically Damaged Seeds at Different Travel Speeds

Travel speed (km/h)	Seed dropped (No.)	Mechanically damaged seeds*: Once-over machinery (%)	Rotary planter (%)
1.5	200	0.750	1.000
2.5	200	0.875	1.125
3.7	200	1.375	1.500
4.0	200	2.375	2.500

*Mean of four replicates.

Table 4. Analysis of Variance of Effects of Travel Speed and Machine Type on Mechanically Damaged Seeds

Source of variation	DF	SS	MS	F-value
Replication	3	2.6250	0.8750	0.2721 (ns)
Treatment	3	12.0625	4.0208	1.2505 (ns)
Residual	9	28.9375	3.2153	
Machine	1	0.2813	0.2813	0.6208 (ns)
Treatment × machine	3	0.0313	0.0104	0.0230 (ns)
Residual	12	5.4375	0.4531	
Grand total	31	49.3750		
Grand mean		1.44		

ns = not statistically significant at 5% level.

Table 5. Analysis of Variance Table for the Effect of Planting Method/Equipment on Penetration Resistance

Source	DF	SS	MS	F-value
Replication	2	0.0075	0.0038	1.900 ns
Soil	1	0.2521	0.2521	126.030 *
Residual	2	0.004	0.0020	
Planting	2	4.8916	2.4458	4076.333 *
Soil × Planting	2	0.0796	0.0398	66.333 *
Residual	8	0.0051	0.0006	
Grand total	17	5.2399		

ns = not statistically significant at 5% confidence level.
* = significant at $p < 0.05$

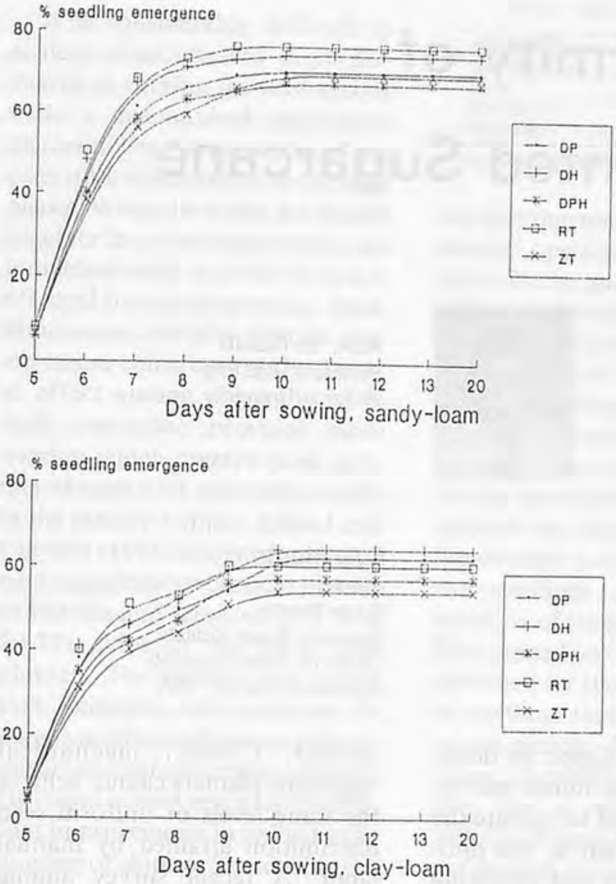


Fig. 5 Seedling emergence as affected by tillage treatments.

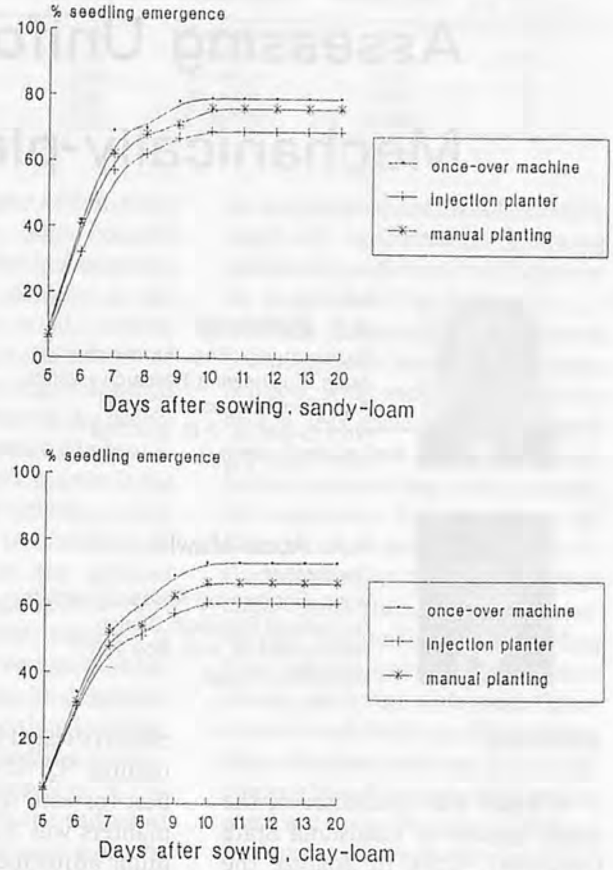


Fig. 6 Seedling emergence as affected by different methods of planting.

Conclusions

On the basis of the results in this study, the following conclusions were drawn:

1. The performance data of the once-over tillage machinery is in conformity with existing results in literature. As such, it has merits for further studies on certain soil-machine relationships that may be of special interest to researchers, designers and farmers.
2. A slight soil compaction below the planted seed helps in promoting seed emergence.
3. A once-over tillage machinery is likely a better solution to the problems of split traditional and mechanized systems of farming operations.

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Assessing Uniformity of Mechanically-planted Sugarcane

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Abstract

A study was conducted at the sugar Station of Louisiana State University, USA to analyze the performance quality of mechanical sugarcane planters. The main objective was to find out a practical method to assess the uniformity of mechanical planting of sugarcane. A systematic approach was developed to introduce an index for planting uniformity based on skips, acceptable and excessive distribution of seed-pieces. Acceptability of mechanical planter performance is largely affected by local conditions and cultural practices. Two criteria were considered for determining an index "U" to represent uniformity: 1. Consider various levels of seed pieces density and their contribution in forming the planted furrow, and 2. The effect of various levels of seed-pieces density on cane production.

In this respect, skips, sparse and excessive seed-pieces rates have varying degrees of effect on crop yield and cost of planting.

The method was used to assess the performance of four billet planters tested in Egypt. By determining "U" it was found that the best forward speed to operate the planters was 2.2 km/h. The optimum adjustments and operating conditions for planters were also determined.

Introduction

Sugarcane growers strive to plant a given rate of seed pieces represented by a number of cane stalks or cane sets placed parallel to each other in a planted furrow. In the past the rate of seeding was derived through farmers' experience. Uniform distribution of seed pieces is a key indicator of the quality of the planting operation. The uniformity of sugarcane seed pieces distribution during planting is essential due to the fact that sugarcane is not planted annually but three to five stubble crops may be harvested from a single planting. Skips or discrepancies in planting affect the yield each year until the cane is replaced. Total mechanization of sugarcane planting has not been completely successful. Current mechanical sugarcane planters cannot achieve the same levels of uniform seed distribution attained by manual labor. A recent survey among sugarcane growers in the United States showed a steady decline in the percentage of mechanically planted acres from about 75% in 1984 to about 55% in 1989. The major reason for the decrease in the use of mechanical planters was the dissatisfaction with the current planter's quality of performance (Waguespack and Jackson 1990).

This paper presents a method to assess seed piece placement uniformity of mechanically planted sugarcane based on the distribution of cane sets or stalks along a planted furrow. A method of assessing seed piece placement uniformity will assist manufacturers to identify modifications of the planter for better performance. Assessing seed piece placement uniformity will also provide a practical method to compare the mechanical planters and operating conditions in order to select the appropriate machine for the optimum operating conditions.

Review of Literature

It is considerably difficult to achieve constant seed piece discharge at varying forward speeds with a mechanical sugarcane planter due to the properties of the cane stalk which contains the seed pieces. When the stalks are placed together in a machine hopper, an individual stalk is involved and is affected by the other stalks. Stalk dimensions, weight, friction and curvature contribute to the mutual effect among the stalks. The stalk curvature provides more overlap which creates more contact of each stalk with other stalks in the planter hopper. Eiland and Clayton (1975) designed and tested a sugarcane prototype planter in Florida and reported 19.1% to 29.7% skips of the total area planted. The authors also stated that skipping will continue to plague mechanical planting due to the amount of extraneous materials found in seed material. Significant improvements in reducing the number of skips or in reducing the application rates do not seem feasible without reducing seed-piece length or increasing the planter's complexity. To keep application rates reasonable, workers will be required to follow a mechanical planter to fill planting skips and monitor row ends for excessive seed material deposited in the furrow. They added that with seed material at a value of $40 per ton, the additional labor cost per ha of approximately $12.5 can be justified.

It is difficult to design an efficient metering device to mechanically handle a uniform flow of individual cane stalks or cane sets to achieve uniform deposition of cane seed pieces as the planter moves forward and be adjustable to desired flow of the seed rate. Such mechanisms represent in holders or cells have been developed successfully for other crops that establish the concept of relating reasonable seed discharge with the planting machine advancment during operation. This concept controls the quality performance of the mechanical planters as discussed by Klenin et al, (1985). They indicated that the quality of planting seedlings largely depends upon the kinematics of the planting units. The kinematic index, λ, for the operation of a planter is the ratio of the linear velocity, u, of the extreme point of clamping of the seedlings and the ground speed, v, of the machine, $\lambda = u/v$. The speed of the bucket is governed by the average number of seedlings that can be deposited by the planter. The time interval, T (sec), between seedling deposition has a relationship $T = 2\pi R/zu$, where R is the radius of the bucket motion and z is the number of holders. If spacing between plants in the row is assumed to be a_s, the kinematics interrelationship is $\lambda = 2\pi R/za_s$. Klenin added that the value of λ may be unity in case where the linear velocity of the extreme clamping unit of the bucket would equal to the linear velocity of the machine, $u = v$.

Chaney et al, (1986) stated that most farmers in Louisiana aim for three to five parallel stalks in the planting furrow. Three stalks are adequate, but lack of uniformity may cause a problem, which is why farmers typically aim for three to five parallel stalks to avoid getting fewer than three stalks at any one point. They evaluated seed placement uniformity for manual and automatic control on the mechanical planter by counting the number of parallel cane stalks on the ground at 21 points spaced 3 m apart. They used the coefficient of variation as an indicator of uniformity (coefficient of uniformity). Planting uniformity collected by Chaney et al, is presented in **Table 1**.

Table 1. Planting Uniformity of Manual and Automatic Control on Typical Drum Planter

Sensor used	Feed speed	Drum speed	Mean count	Mean CV, percent
Manual (farmer)	Full	Constant	4.11	71
Manual (exp. station)	Full	Constant	4.52	59
Flap	Slow	Variable	2.56	95
Pressure	Full	Variable	4.69	50
Pressure	Full	Constant	4.98	45

Source: Chaney et al, 1986.

They explained that manual planting done on the Experiment Station with more twisted cane and a less experienced operator was slightly but not significantly better than planting with the farmer's operator. In operation, the dirt and trash accumulated on the flap, leading to a signal "enough cane" and thus no feeding occurred. The uniformity of feeding flap sensor got steadily worse during each run with a continuation of trash build up. The uniformity obtained with an automatic control based on pressure sensing was not significantly different than the uniformity obtained with a manual control feeding system. This means that the system using pressure sensors can replace the extra operator used with the manual controls with no loss of uniformity.

Parish et al, (1987) evaluated the field performance of eight mechanical planters and planting aids with manual and automatic controls. Their results indicated that hand planters placed the cane more uniformly than mechanical planters, and the modified Julian (chain) planter was not significantly different than hand planting. The good uniformity of the modified Julian planter may be the result of very high planting rate. Overall there were no significant difference detected between mechanical planters with manual controls and mechanical planters with automatic feed control. This finding verifies that an automatic feed system can be used with a labor savings of one person per planter and with no sacrifice in uniformity. The mean number of stalks placed in the furrow by each planter varied considerably, but the rate was a function of drum speed and ground speed on the mechanical planter, and the human variables in hand planting operations. It is viable that the farmer can control and should be independent of planter type. There were significant differences in planting rates expressed in both weight per ha and buds per ha. A total of 75 000 buds per ha is generally considered adequate.

A Systematic Approach to Assess Planting Uniformity

Sugarcane is mainly planted vegetativelly where the vegetative part of sugarcane found in the cane stem is placed along a furrow at different rates according to the region where the sugarcane field is. The cane stalk is the media which contain the buds and represents the sugarcane seed. The amount of seed is proportional to the stalk length within the same variety of a homogeneous sample. This is the reason why the cane seed rate, in a certain part of the planted furrow, is normally expressed as the number of parallel cane stalks or cane sets. The rate of seed may be identified as the total length of cane placed on a part of the furrow divided by the length of this part of the furrow (length of cane/length of furrow). The desired seed rate is different depending on environmental conditions, irrigation and/or the cropping system condition such as row spaces, soil types and method of harvesting.

The mechanical planters place cane stalks or cane sets along the furrow. The rate of seed pieces placed in the furrow may be zero in parts of the furrow or excessive in other parts. To facilitate assessing the uniformity of seed placed by a mechanical planter, it is necessary to classify and identify the possible categories of seed rate found in the mechanically planted furrow:

Desirable seed rate (SR_d) — The rate of seed in cane lines at which the grower tries to obtain (or it is the rate of seed at which the producer manually plants).

Acceptable mechanical seed rate (SR_a) — A range of cane lines the grower can accept with a mechanical planter (a range of seed does not significantly affect the crop production and/or planting costs).

Skips (SR_o) — The rate of zero cane lines.

Sparse (SR_l) — The rate of seed in cane lines lower than the farmer can accept.

Excessive (SR_e) — The rate of seed higher than the grower can accept.

Average seed rate (SR_{avg}) — The number of cane lines if the total amount of cane placed by the planter is redistributed uniformly in a planted furrow.

Analyzing the components of a mechanically planted furrow, any part of the furrow will contain one of these rates of seed. The importance of each seed rate will depend on the frequency and the length of the individual parts occupied with the same rate of seed. The ratio of the sum of the parts planted at any of these rates of seed to the full length of the furrow represents its contribution in forming the planted furrow. Summing up these ratios, the following relationship is obtained:

$$\frac{\Sigma LSR_o + \Sigma LSR_l + \Sigma LSR_a + \Sigma LSR_e}{L_f} = 1 \qquad (1)$$

The following two criteria were considered for determining an index to represent uniformity (U).

1. The uniformity index should consider each category of seed density and its contribution in forming the planted furrow.

2. The uniformity index should consider the effect of each seed density on cane crop production. In this respect, both sparse and the excessive seed rates are undesirable but they don't have the same effect on crop yield as skips.

According to these criteria the following steps were taken to calculate a uniformity index (U):

a. The ratio of the parts planted with no seed to the total length of the planted furrow ($\Sigma LSR_o/L_f$) will contribute uniformity with 0% of its value.

b. The ratio of the parts planted with seed below the acceptable rate ($\Sigma LSR_l/L_f$) will contribute uniformity with A% of its value.

c. The ratio of the parts planted within the acceptable range of seed ($\Sigma LSR_a/L_f$) will contribute uniformity with its full value.

d. The ratio of the parts planted at an excessive seed rate ($\Sigma LSR_e/L_f$) will contribute uniformity with B% of its value.

If the total length of the furrow is planted within the acceptable seed range, the uniformity index will be equal to unity. The more skips (SR_o) found in the furrow will reduce U where the reduction of U will equal the ratio of the total length of the skips to the total length of the furrow. The more contribution of SR_l and/or SR_e in the planted furrow, the more U will be reduced. A reduction in U will be proportional to the ratio of the length of the undesirable rates of seed to the total length of furrow. The unifromity index may be calculated as follows:

$$U = 1 - \left(\frac{\Sigma LSR_o}{L_f} + \frac{\Sigma LSR_l(A)}{L_f} + \frac{\Sigma LSR_e(B)}{L_f}\right) \qquad (2)$$

Where A% and B% are partial coefficients that determine the reduction in uniformity due to undesirable rates of seed. The values of A and B may differ depending on local environmental conditions where the field reflects the losses in production and/or additional cost due to planting more cane seed. The average seed rate is the total length of cane placed on a given length of the furrow divided by this furrow length. SR_{avg} may be calculated as the following:

$$SR_{avg} = (\Sigma LSR_o(O) + \Sigma LSR_l(l^-) + \Sigma LSR_a(a^-) + \Sigma LSR_e(e^-))/L_f \quad (3)$$

Where; l^- , a^- and e^- represent the average value of l, a and e and are calculated from the data.

Seed Qantity Calculation

Taking advantage of the SR_{avg}, equations 4 and 5 may be used to calculate the number of sets and the number of stalks placed within a planted area, respectively.

$$n_s = SR_{avg}(\frac{a}{l_s\ x}) \quad (4)$$

$$N_s = SR_{avg}(\frac{a}{L_s\ x}) \quad (5)$$

where:

n_s = Number of sets placed in an area "a".

N_s = Number of stalks planted in an area "a"

SR_{avg} = Average seed rate in cane lines (length of cane / length of furrow) if the total seed placed uniformly on the planted area.

l_s = Average set length (m)

L_s = Average cane stalk length (m)

a = Field area (m^2).

x = Distance between rows.

Equations 6 may be used to calculate the number of buds applied in certain area.

$$T_{NB} = n_B(\frac{SR_{avg}}{l_s})(\frac{a}{x}) \quad (6)$$

where:

T_{NB} = Total number of buds planted in certain area.

n_B = Average number of healthy buds per set.

The quantity of cane planted within a given area can be calculated using equation 7:

$$W = SR_{avg}(\frac{w}{1000})(\frac{a}{L_s x}) \quad (7)$$

where:

W = planted cane seed quantity in an area "a" (tons).

w = Average stalk weight (kg).

Application

The uniformity of set placement during the operation of four billet planters was reported in a descriptive method by Abdel-Mawla et al, 1991. The conditions under which these planters were tested used a desired seed rate, SR_d, of two continuous cane lines. A mixture of seed rates of one, two and three cane lines along a planted furrow may be an acceptable mechanical planter performance if the average seed rate is reasonable and the skips are negligible. The parameters to calculate unifromity are defined as follow: $SR_d = 2$, $SR_a = SR_d \pm 1$ (the range of the SR_a is from 1 to 3). $SR_e \geq 4$ cane lines and SR_l is absent. The value of A is not required for the calculations and the value of B was Determined to be 0.5. Accordingly equation 2 to determine uniformity index take the following form:

$$U = 1 - (\frac{2\Sigma LSR_o + \Sigma LSR_e}{2L_f}) \quad (8)$$

Calculating the uniformity index from the data according to the present approach, it was easy to determine that the maximum value of U was achieved at a ground forward speed of about 2.2 km/h for all the machines tested. **Figures 1** to **4** show the uniformity and seed quantity for each of the planters tested at speed of 2.2 km/h as affected by the other operating conditions or adjustments.

As indicated in the **Fig. 1**, the uniformity index, U, can be affected by machine adjustment as shown in the performance of the PTO-driven-cutter planter (PTO-DCP) where the high speed of the drum motivated the labor to feed more stalks, i.e., increasing SR_e with no reduction of skips. There was close comparison between the high SR_{avg} and SR_d and the 0.25 difference between and unity indicating low uniformity which may be due to gaps as well as excessive seed. The uniformity index was also used to identify the most appropriate adjustment of the metering device shaft speed of the automatic-drop planter (Auto-DP) as shown in **Fig. 2**. It also shows that the metering device shaft speed of more than 40 rpm did not improve U while SR_{avg} was within the reasonable range. Therefore, the ratio of skips did not decrease and a ratio of excessive seed occurred.

Another application of the uniformity index is to identify the optimum operating condition shown in the performance of the ground-wheel-driven-cutter planter (GW-CP) (**Fig. 3**). The uniformity index was improved by feeding the stalks two by two instead of one by one. SR_{avg} increased from less than 1 to almost 1.5 influencing a reduction in skips. With a low SR_{avg} the difference between the value of U and unity is due to skips. Another example is to calculate the uniformity index of the manual-drop planter (M-DP) where manual labor drop the seed sets with no device for cutting or metering. As shown in **Fig. 4**, U is steadily declined with an increase in the ground speed of the planter regardless of the value of SR_{avg}.

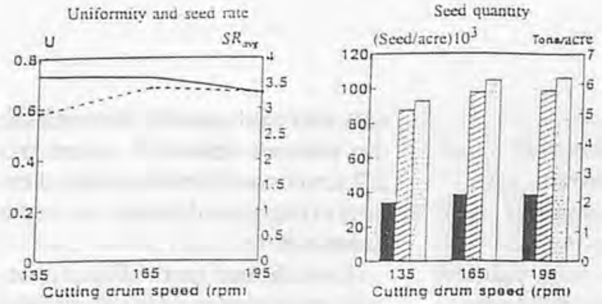

Fig. 1 Uniformity index and seed quantity as related to the rpm of the cutting drum of the PTO-driven-cutter planter.

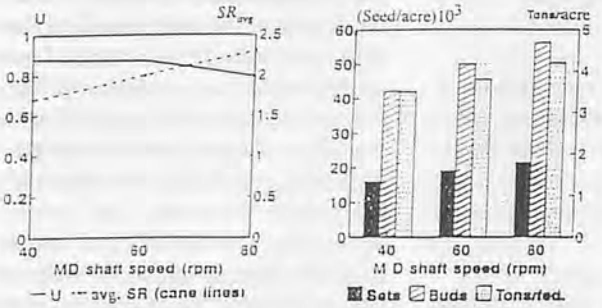

Fig. 2 Uniformity index and seed quantity as related to the metering device (MD) shaft speed of the automatic-feeding drop planter.

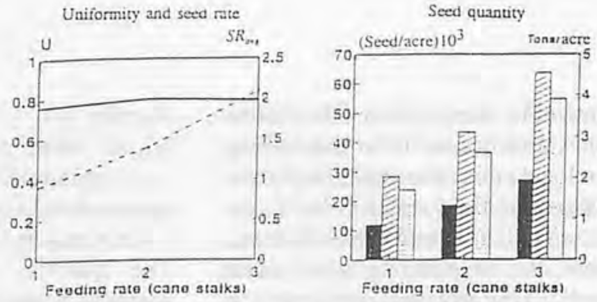

Fig. 3 Uniformity index and seed quantity as related to the number of stalks fed to the cutting mechanism of the ground-wheel-cutter planter.

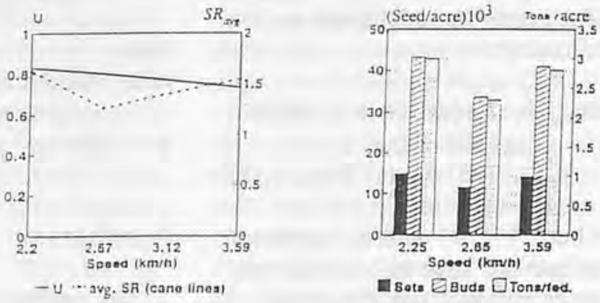

Fig. 4 Uniformity-index and seed quantity as related to the ground speed of the manual drop planter.

The forward speeds and sub-variables of the tested planter types at maximum uniformity are given in **Table 2**.

Table 2. Values of Maximum "U" and Corresponding SR_{avg} Achieved by the Tested Planters

Planter type	Forward speed (Km/h)	Sub-variable	U	SR_{avg}
PTO-DCP	2.45	*CD-rpm = 135	0.74	2.6
GW-DCP	2.60	*FR = 2 stalks	0.80	1.4
Auto-DP	2.20	*MD-shaft rpm = 40	0.88	1.7
M-DP	2.25	—	0.83	1.6

*CD: cutting drum, FR: feed rate, MD: metering speed.

Conclusion

A systematic approach was developed to assess uniformity of mechanical planting in sugarcane. Possible rates of seed-pieces found in a mechanically planted furrow may be skips, sparse, acceptable and excessive seed. Local conditions and agricultural practices determine the acceptability of the planter performance. An index "U" was developed to assess uniformity considering the contribution of various rates of speed-pieces placement rate on crop yield and planting costs. An average seed-piece rate SR_{avg} could be calculated as an indicator to the reason of the lack of uniformity.

An application of the approach using data available for testing billet planters in Egypt, showed that by calculating "U" the optimum adjustments and the most suitable operating conditions can be determined. By calculating SR_{avg}, the lack of the uniformity of the performance of the PTO-driven cutter-planter was due to both skips and excessive rate of seed-pieces. Skips were the main reason of low uniformity in the performance of the other tested planters.

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Comparative Profitability on the Use of Tractor vs. Animal Draft Power, Madhya Pradesh, India

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Abstract

The present study investigated the viability of tractorized vs. bullock-operated farms and utilization of tractor and bullock hours on and off the farm. The study focussed on the economics of owning and hiring a bullock pair and a tractor for farm operations. For this purpose, a sample of 40 farmers owning a total of 20 tractors and a similar number of farms using bullocks were selected randomly from 10 progressive villages in Shahpura block of Jabalpur District. Data for the year 1990-91 were collected by survey method.

The results of investigation amply demonstrated that the average size of operational holdings on the tractor-operated farms was substantially higher than those of the farms that use bullocks. Acquisition of tractor helps in timely accomplishment of farm operations and realization of higher cropping intensity which influences greater return per unit of area. Wheat, paddy and soybean were the important crops grown by the respondents which represented more than 70% of gross cultivated area of sample farms. A personally-owned tractor at the start is capital intensive but its operational cost was lower than the hiring rates of tractors per hour prevalent in the locality. Hence it was economical to own a tractor than to hire it. In the case of a pair of bullocks, it was more profitable to hire it than to own one. The hiring rates of bullocks pairs per hour per day were mostly conventional, disregarding the operational cost of a pair of bullock on the farm.

The tractor and bullock power is under-utilized at the existing use pattern, the main reason being that farms are small in size and scattered. The question of displacement of labour does not arise at all since tractors are mainly involved in preliminary tillage operation and hence there is no reduction of labour input in tractor farms. The use of tractors influenced the increased use of inputs, generating more employment opportunity through extensive as well as intensive utilization of land, expanded output and maximized net return. Therefore, tractor power is viable and more economical over the use of bullocks.

Introduction

The breakthrough in agricultural production in India was mainly a combined result of the adoption of high yielding crops, and increased use of fertilizer and irrigation water. Farm mechanization has played an important role in pushing the production frontier ahead. The tractor has since become a part and parcel of agriculture, replacing bullock labour as the latter is still economical. The tendency to replace the animal power by tractors has been increasing over time in spite of the fact that per hectare initial investment and annual operating expenses in the case of bullock power are much lower as compared to that of tractor. The land resources being scare in the country, there is need to release more land from fodder for the production of cash crops and pulses, etc. Therefore, it seems expedient to dispense with the draft cattle, particularly if a versatile tractor within reach of small farmers and other farm machineries are available to do all those jobs that the bullock does today.

In recent years, there has been a marked increase in the population of tractors in Madhya Pradesh: from 4.442 thousand in 1970-71 to 39.179 thousand in 1985-86. Various factors are responsible for this rapid increase, e.g., liberalized policies of agricultural financing facilities, and increasing quest among the relatively rich farmers for social status and more leisure time. An attempt is made in this paper to examine the comparative profitability of bullock- and tractor-operated farms.

Table 1. Bullock and Tractor Power Available in Madhya Pradesh, 1990

Characteristics	Chhatis-qarh plains	Baster plateau	Northern hills regions of Chhatis-qarh	Kymore plateau and Satpura hills	Vind-hyan plateau	Central Narmada valley	Gird region	Bundel-khand region	Satpura plateau	Malwa regions	Nimar valley	Jhabua hills	Madhya Pradesh
No. of districts	6	1	4	5	6	2	5	3	2	8	2	1	45
Net area sown (000 ha)	3 623	834	1 800	1 759	2 238	736	1 951	710	895	3 242	1 070	248	19 206
Cropping intensity (%)	126	104	118	117	108	117	108	119	117	123	109	111	117
No. of bullock pairs (000 ha)	960	246	688	644	470	146	510	287	246	563	234	126	5 120
No. of tractors	2 850	217	808	3 285	9 426	1 802	6 930	1 203	522	5 720	918	82	33 763
No. of pump sets	30 611	1 786	10 553	29 835	50 467	18 822	29 461	25 595	37 145	189 635	59 531	6 680	490 121
No. of bullock pair per thousand net area sown	265	294	382	366	210	199	261	405	275	174	218	363	267
No. of tractors per thousand net area sown	0.79	0.26	0.45	1.87	4.21	2.45	3.55	1.69	0.58	1.76	0.86	0.24	1.76
Ratio of cultivators to Agril. labourers	2.10	4.19	2.66	1.43	1.60	1.02	6.2	4.34	1.72	2.223	1.47	11.78	2.14

Materials and Methods

Mechanization in its broadest sense implies the use of mechanical contrivances which give an advantage in the use of power for work, be it human, animal or mechanical power. The nature and extent of mechanization may, thus, depend upon the availability of such mechanical contrivances for use in different operations in farming.

A sample of 20 farms using tractors and 20 other farms that use for farm power were randomly selected from 10 progressive villages of Shahpura block of Jabalpur district in Madhya Pradesh. In order to measure the economics of using tractor and bullock power, data and other information regarding land holding, cost of cultivation and production of crops, total employment for tractor- and bullock-operated farms and utilization of tractor and bullock pairs in hours were collected using the survey method. The standard procedure of calculating the cost of farming at actual and opportunity costs was adopted in estimating expenses and value of physical outputs of individual crops. The operational cost of a tractor and a pair of bullocks was determined considering the fixed and variable costs per year per hour. The fixed cost included depreciation interest on initial investment, taxes, insurance etc. The variable costs in the case of the tractor included fuel, and lubricants, minor repairs, driver wages, etc. For the pair of bullocks, the variable costs consisted of charges for feed and labour for upkeep and minor repairs for implements. The fixed and variable costs together represented the total operational cost per year per hour.

Results and Discussion

Availability of Tractor and Bullock Power

With increasing pace of modernizing agriculture, tractors have become popular which numbered over 53 thousand in 1990-91. The number of tractors was highest in Vindhyan plateau followed by Gird region, Malwa plateau with least in the case of the Jhabua region. The rich farmers in Vindhyan plateau appear to have gone for tractors to augment their social prestige rather than actually using them for what they are meant.

On the other hand, bullock power that is an essentially a part of Indian farming provides traditional farm power. **Table 1** shows that the largest number of bullock pairs are domesticated in the Chhattisgarh plains which account for nearly 18.75% of total for the state of Madhya Pradesh. This may be attributed to the vastness of the region that mostly covered by forest and grassland.

Irrigation pump sets provide sources of moisture for crops. Their numbers have since increased many fold considering that high-yield crop varieties and fertilizer, among other inputs, increase yields only when irrigation water is available. The total pumps identifiable into oil and electric pumps numbered 4.90 lakhs in 1990-91 39% of which are in Malwa Plateau or a ratio of 58 pumpsets per thousand of net sown area. In contrast there were only 2 pumpsets in Bastar plateau, lowest in all agro-climatic regions, during the study.

Economics of Bullock Use vs. Tractor Use on Farms

As shown in **Table 2**, paddy and soybean in kharif and wheat and gram in rabi were the major crops grown on the sample farms. The cropping intensity in farms that use tractors was higher than that in farms that derive power farm bullocks.

The economics of crop production using tractor and bullocks on actual farm costs and opportunity cost (rates of custom hiring) were determined. **Table 2** shows that the cost of cultivation of all the crops based on the opportunity cost of tractor hours was higher than that of the cost at actual farm cost of the tractor or bullock hours, the latter being the lowest for all crops. The cost of cultivation of crops based on the opportunity cost of bullock hours were the lowest for all the crops. The average of growing wheat was Rs. 3 078.15/ha.

The cost of production for all crops was higher on bullock-operated farms than that of

Table 2. Cropping Pattern in Bullock- and Tractor-operated Farms

Particulars	Kharif		Rabi		
	Paddy	Soybean	Wheat	Gram	Pea
Tractor-operated Farms					
i) Area (ha)	2.73	1.82	3.9	2.27	0.33
ii) Yield (kg/ha)	18.67	12.60	14.80	8.50	5.10
iii) Cost at (Rs. ha)					
a) Actual farm	2 230.90	2 470.90	2 280.50	2 143.15	1 480.00
b) Opportunity	3 346.35	3 292.10	3 078.15	2 678.94	1 972.00
iv) Cost of production at (Rs./Q)					
i) Actual farm cost	119.49	181.68	154.09	252.14	290.20
ii) Opportunity cost	179.24	242.07	207.98	315.17	386.66
Bullock-operated Farms					
i) Area (ha)	1.06	0.84	2.46	0.95	0.19
ii) Yield (kg/ha)	14.20	9.40	8.91	6.15	4.50
iii) Cost at (Rs. ha)					
a) Actual farm	1 881.50	1 593.30	1 455.20	1 630.98	1 251.90
b) Opportunity	2 340.80	2 159.18	1 773.98	1 852.20	1 677.15
iv) Cost of production at (Rs./Q)					
i) Actual farm cost	132.50	169.50	163.32	265.20	278.20
ii) Opportunity cost	164.84	229.70	199.10	301.17	372.70

Table 3. Average Value of Farm Assets Owned by Sample Farmers (Unit: Rs.)

Particular	Tractor-operated Farms		Particular	Bullock-operated Farms	
	Per farm	Per ha		Per farm	Per ha
Average size of holding	6.50	—	Average size of holdings	3.60	—
Value of tractor	160 000	24 615.38	Value of bullock (pairs)	10 000	2 777.76
Seed drill	7 500	1 153.84	Plough	1 500	416.66
Cultivators	5 100	784.62	Cultivators	1 250	347.22
Trolly	12 000	1 846.15	Cart	3 500	972.22
Other tools	8 000	1 230.76	Other tools	640	177.77
Total	1 926 065	29 630.75		16 893.6	4 691.63

Table 4. Comparative Operating Expenses of Tractor and Pair of Bullock on Sample Farms (Unit: Rs.)

Particulars	Tractor 35 H.P.	Bullock (one pair)
Initial cost	160 000	100 000
Number of hours use/year	965	860
Variable cost/year*	67 189.15	13 160
Fixed cost/year	16 000	1 316.00
Variable cost/hour	69.61	15.30
Fixed cost/hour	16.00	1.54
Total cost/hour	83.61	16.84
Ploughing cost/ha	252.27	404.38
Hiring rate/hour	100.00	8.75

* Includes depreciation, interest on working capital, labour wages, medical costs and minor repair.

tractor-operated farms based on actual cost of bullock/tractor hours. On operational cost basis, that of production per quintal of crops raised was higher in tractor-operated farms than that of bullock-operated farms. On actual cost basis, tractor-operated farms produced all the crops at much cheaper rate than that produced on bullock-operated farms due to the relatively higher yield rates per hectare for the farmer, better and timely operation.

Crop productivity per hectare on tractor-operated farms was significantly higher than that in bullock-operated farms. Thus, tractorization has proved to be profitable than bullock framing system in study area.

In terms of farm assets, **Table 3** shows that the average value of tractor-operated farms was Rs. 29 630.75/ha compared with Rs. 4 691.65/ha on bullock-operated farms due obviously to the nature of farm equipment possessed the two system of farming.

The operational cost per year and per hour for a 35-H.P. tractor and a pair of bullock was determined for the sample farm and presented in **Table 4**. The total operational cost per year covered both fixed and variable expenses and per hour cost was determined on the basis of actual number of hours, the tractor or bullock was used. The variable cost per hour was Rs. 69.61 and Rs. 15.36 in case of tractor and bullock pairs, respectively. The total cost per hour for tractor was Rs. 81.61 and for a pair of bullock was Rs. 16.84, nearly five times of the bullock labour cost. In terms of ploughing per hectare, the cost of operating the bullock pair was higher than of the tractor.

Comparing the operational cost per hour and the hiring rates prevalent in the locality, it was found that, in case of tractor, it is better to own one rather than hire it. For bullocks, hiring a pair was cheaper than per hour cost of maintenance. This is indicative of the relative profitability of owning and operating a tractor in comparison to owing a pair bullocks on labour cost per hour.

Utilization of Tractor and Bullock

The monthly utilization of tractor/bullock hours on the sample farm is presented in **Table 5**. These hours cover their use on the farm (both on own farm and hired out) and off farm for non-farm purposes.

It will be noted in **Table 5** that the maximum use of tractor hours on own farm was in the month of May when kharif season start followed by October (16.37%). These months accounted for nearly one-third of the total tractor hours utilized during the year. During the months of November, April and May most of the tractors could be seen on road or nearby markets for a variety of purposes. Non-farm work refers to social visits, general marketing, and religious trips to temple and places of repute. Nearly 70% of the total tractor hours were used

Table 5. Monthly Utilization of Tractor/Bullock

Month	Tractor Farm: Hours Worked on: Own farm	Tractor Farm: Hours Worked on: Hired out	Tractor Farm: Hours Worked on: Non-farm work	Tractor Farm: Total hours	Tractor Farm: Per-centage	Bullock Farm: Hours Worked on: Own farm	Bullock Farm: Hours Worked on: Hired out	Bullock Farm: Hours Worked on: Non-farm work	Bullock Farm: Total hours	Bullock Farm: Per-centage
May	140	50	18	208	21.55	165	25	30	220	25.58
June	45	8	—	53	5.49	52	15	14	81	9.42
July	—	—	5	5	0.52	—	—	—	—	—
August	—	—	—	—	—	—	—	—	—	—
September	20	12	6	38	3.94	15	—	—	15	1.74
October	105	38	15	158	16.37	110	—	—	110	12.79
November	40	11	12	63	6.53	50	—	32	82	9.53
December	80	14	9	103	10.67	64	—	15	79	9.19
January	55	6	4	65	6.74	42	—	16	58	6.74
February	43	15	10	68	7.05	60	—	12	72	8.37
March	88	25	13	126	13.06	40	—	8	48	5.58
April	60	14	4	78	8.08	62	29	4	92	11.05
Total	676	193	96	965	100	660	69	131	660	100
Average	70.05	20.00	9.95	—	—	76.74	8.02	15.23	—	—

Table 6. Economics of Hiring Out a Tractor/Bullock Pairs

Particulars	Tractor	Bullock
Productive life (h)	10000	10000
Actual utilization (h/year)	965	860
Total cost of tractor (Rs.)	160000	100000
Total variable cost (Rs./year)	67 189.75	13 160
Fixed cost (Rs./h)	16.00	1.54
Variable cost (Rs./h)	69.61	15.30
Total cost (Rs./h)	85.61	16.84
Existing hire charges (Rs./h)	100	8.75
Difference between hiring and operational cost (Rs./h)	14.39	8.09

on own farms. One-fifth of the tractor hours during the year were reported to be hired out to other farms.

Table 5 further shows a similar pattern followed for the utilization of bullock power, i.e., the maximum number of bullock hours were used in the month of May which accounted for 25.59% of the total hours used on the sample farms during the year. More than 76% of the total bullock hours used during the year was reported to be on own farm while only 8.02% was as hired out. About 15.23% of the bullock hours were used off the farm for social, religious and marketing purposes.

Table 6 gives the per hour operational cost of a tractor (35 H.P.) and a pair of bullock on the basis of actual cost, its use and the prevalent hiring charges per hour.

It is evident that the hiring charge for tractors was higher by Rs. 14.39 per hour than the actual operational cost per hour. Again it is economical to own a tractor than to hire one at exhorbitant hiring rates. The operational cost of tractor per hour was Rs. 54.06 against hiring rates of Rs. 100.00 per hour. The operational cost may be still lower if working hours are raised and vice-versa.

Table 6 shows that the operational expenditures on bullock labour exceeded the rates prevalent for hiring. The hiring rates were conventional disregarding the economics of maintaining a pair of bullocks; it is economical to hire bullock labour than to own one and maintain it on the farm provided the hiring rates continue to be the same. The higher operational cost of a pair of bullocks on the farm was mainly due to lower utilization of the bullock labour: only for 860 h (107.5 days) in a year, which mean that for nearly two-thirds of the work days in a year, bullock labour remained idle.

Policy Implications

Considering the size of holdings, availability of agricultural labour and yield rates of crops, tractorization in Jabalpur district seems to be a profitable proposition. On one hand, large size holdings with few agricultural labourers per ha, it is convenient to perform farm operations using a tractor timely and thoroughly.

Owning a tractor involves heavy financial outlay, hence not within the reach of common farmers. However, farmers do hire the tractor for timely completion of farm operations, specially field preparation and sowing. This leads to suggest that in view of very high hiring rates of tractor hours, the tractors may be owned and operated instead on cooperative basis. This will also result into better utilization of tractor and better performance of crop yields simultaneously. The replaced human labour through tractorization will release pressure on the supply of agricultural labour and spare few hands for other subsidiary occupations at the village level. Inspite of the several direct benefits of tractorization, bullock power cannot be completely ignored as it has numerous indirect advantages and is well woven with the farm business and farm family.

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Dynamic Response and Vibration Control at the Source in a Powered-knapsack Sprayer

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Abstract

This paper deals with the studies on the dynamic performance of a powered knapsack sprayer under field conditions. Vibrations and noise from the engine that drives the sprayer are transmitted to the body of the operator as a result of which he suffers a lot of discomfort, fatigue and hence loss of efficiency. The vibrations can be controlled at the source and this has been achieved by fully balancing the reciprocating inertia forces in the direction in which they are harmful to the operator. The effectiveness of the vibration control measure adopted has been evaluated and presented. Considerable reduction in vibrations transmitted to the shoulders of the operator also resulted in a great relief to him.

Introduction

Among other factors such as the use of seeds for high yielding crop varieties, fertilizers and timely irrigation, the application of pesticides has also played a significant role in increasing agricultural productivity in India in recent years. The application the pesticides needs an equipment which can be a foot-operated sprayer, powered knapsack sprayer or a tractor-mounted sprayer. Aerial spraying of crops is also possible, but it has only special applications where the farms are vast enough to justify the use of spraying aircrafts. Farmers with small landholdings find the knapsack sprayers easy to operate and handle. In order to increase the capacity of the knapsack sprayer, an engine-operated blower has built into the system which is mounted on the back and shoulders of the operator (**Fig. 1**).

Although the powered knapsack sprayer has become popular because of its increased capacity, the effectiveness of spraying and lower operational cost vis-à-vis other sprayers, the operator is subjected to severe mechanical vibrations — an important factor in total environment (Bansal, 1988). The operator is also exposed to excessive noise generated by the engine and the blower. The noise accelerates fatigue and affects the sensitivities and reaction rates of human operators (Griffin, 1990). Defects in spinal cord due to vibration become apparent only after a long period and the operator is not able to connect his health problems with the poor design of the equipment that he uses (Huang and Suggs, 1967). It is known that the effect of vibration on operator in the tranverse direction is far less severe as compared to that in the vertical and the longitudinal direction (Gupta, 1979). These directions are indicated on **Fig. 1**.

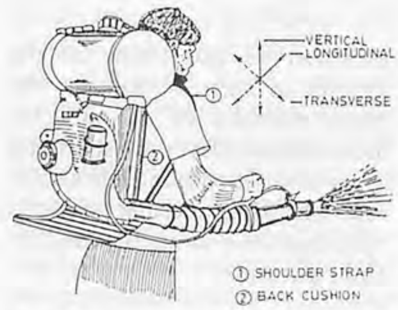

Fig. 1 Back mounted powered knapsack sprayer and directions in which oscillations were measured.

Description of Powered-knapsack Sprayer

An isometric view of an APSEE BOLO motorized knapsack sprayer is shown in **Fig. 2** with identified various parts. Specification of the model Villiers L 34 two-stroke Agro-industrial engine that runs the blower follows: bore, 35 mm (1.38 in); stroke, 35 mm (1.38 in); capacity, 34 cc (1.07 cu in); power output, 1.2 bhp at 5 500 rpm; weight (dry), 4.3 kg (9.5 lb); and ignition: flywheel magneto. The engine is

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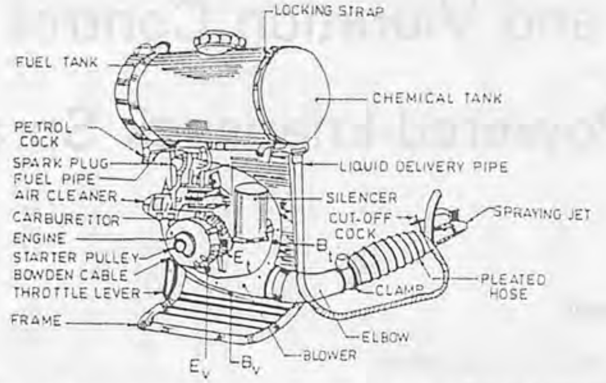

Fig. 2 Motorized knapsack sprayer fitted with Villier L 34 engine E_v, E_t, B_v and B_t were the stations for vibration measurements.

mounted on the frame of the sprayer in such a way that the piston executes its to -and- fro motion above the crank shaft and in a vertical direction. The axis of rotation of the crank shaft is horizontal and along the longitudinal direction.

Source of Vibrations and Their Transmission to Operator

There is an inherent problem of imbalance in a reciprocating engine. The reciprocating masses of the piston and other parts are only partially balanced as a normal practice. That being so, the magnitude of imbalance is reduced in the vertical direction and an equal amount is introduced into the transverse direction. The operation of the sprayer thus generates periodic vibration primarily at the frequency of oscillation of the piston which is also equal to the revolutions per second of the crank shaft. The excitation forces in the vertical direction are transmitted to the shoulders of the operator on which the cushioned straps support the sprayer. The excitation force in the transverse direction and the moments about the transverse and the vertical axis are transmitted to the back of the operator through the back cushion. Any rotating imbalance arising from the impeller of the blower also gives rise to the transverse and vertical excitation force components.

Balancing for Vibration Control in Vertical Direction

In order to determine the amount of additional balance necessary for fully balancing of reciprocating masses, it is essential to find out the total mass of reciprocating parts of the engine. This comprises a full mass of piston, piston-rings, bearings and the gudgeon pin, and a fraction of the total mass (76.4 g) of the connecting rod, which is considered to be effectively reciprocating together with the piston. The amount of reciprocating masses has already been determined by balancing the mass on both sides of the crank shaft where the big-end bearing supports the connecting rod, was first found. The weights of the effectively reciprocating and revolving mases of the connecting rod were 32.7 g and 43.7 g, respectively, by using a method presented by Bansal (1985). The total weight of the reciprocating parts, including 71.0 g of the piston assembly, is thus $= 32.7 + 71.0 = 103.7$ g.

The existing partial balance of the engine was found by statistically balancing the crankshaft to which the balance weights are added diametrically opposite to the big end bearing. The partial imbalance was 1 500 g-mm. The crank radius being 27.5 mm, the reciprocating and rotating imbalances were $103.7 \times 17.5 =$ 1 814.75 g-mm and $43.7 \times 17.5 =$ 746.75 g-mm, respectively. These give a total imbalance of 2 579.5 g-mm in the vertical direction. As 1 500 g-mm is the amount of existing partial balance, the additional balance required is $2\,579.5 - 1\,500 = 1\,079.5$ g-mm. For complete balance, two masses of 10.8 g and 6.6 g were mounted at radii of 27.0 and 120.5 mm on the starting pulley and the blower, respectively. The planes in which the pulley and the blower are located are 101.6 mm and 37.5 mm from the centre of the big end bearing, such that these planes are 139.1 mm apart. However, in a modified design of the engine, the counter-balance masses at the crank shaft should be increased to balance the remaining imbalance of 1 079.5 g-mm.

Dynamic Performance Studies

The dynamic performance studies on the knapsack sprayer were conducted by mounting the sprayer on the back of an operator, as done while actually spraying in the field. Vibration levels were measured at various locations on the sprayer and body of the operator, both before and after incorporating the design change/balancing. Noise levels were measured close to the ear of the operator. The fuel tank and the pesticide tank were kept filled up to about 50% of the full capacity throughout the study. The operator weighed 53 kg and stood at

163 cm bare-foot. Vibration levels were measured by running the sprayer at two different speeds of 4 000 rpm and 5 000 rpm. The maximum permissible speed recommended for the sprayer is 5 500 rpm. A B & K vibration and noise measuring equipment was used.

The vibration levels were recorded at station E_v and E_t on the engine in the vertical and transverse directions, respectively. Measurements were also made at stations B_v and B_t on the blower casing in the vertical and transverse directions. The locations of these stations together with the directions in which the vibration levels were recorded are shown on **Fig. 2**. Vibration levels were also recorded on the sprayer frame and the shoulders of the operator.

Results and Discussion

The results of the dynamic performance studies are presented in **Figs. 3** to **6** and in **Table 1**.

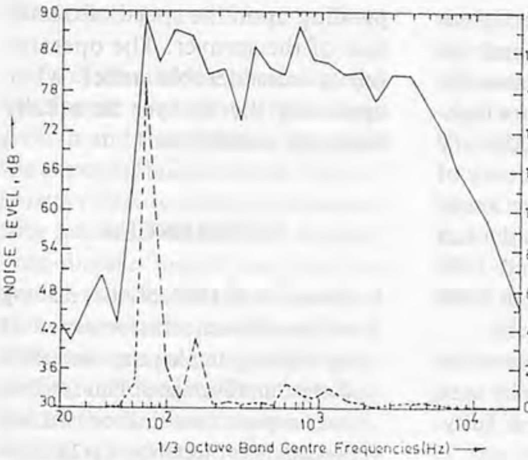

Fig. 3 Frequency analyses of noise and vibration of powered knapsack sprayer (-------, vibration level; ______, Noise level).

Figure 3 presents the frequency analysis of vibration and noise levels of an existing sprayer measured at its frame and close to the ear of the operator, respectively. The highest peak response values, both for noise and vibration, correspond to the firing frequency of the engine. Besides combustion, exhaust air intake and mechanical noise generated by the engine, the wide band aerodynamic noise emitted by the blower is also quite high and extends over a wide frequency range covering up to 10 KHz, as compared to the vibration level that is significant (16 m/sec^2, peak value) only in a narrow frequency band centered around the firing frequency of the engine. The overall noise level recorded close to the ear of the operator is of the order of 93 dB(A), which is considerably above the safe limit of 90 dB(A) for exposure duration of 8 hours a day, 5 days a week.

Figures 4 and **5** show the 1/3 octave band frequency analyses of the vibration levels (acc. m/sec^2) measured on the engine and the

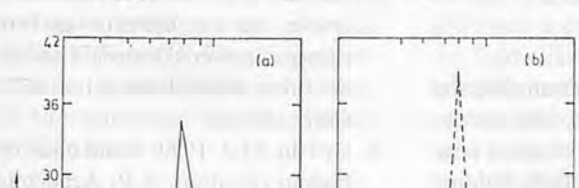

Fig. 4 Frequency analyses of the vibration levels of the sprayer measured at (a) station E_v (vertical) and (b) station E_t (transverse) on the engine operating at 5000 rpm (______, engine partially (60%) balanced; ------, engine fully (100%) balanced).

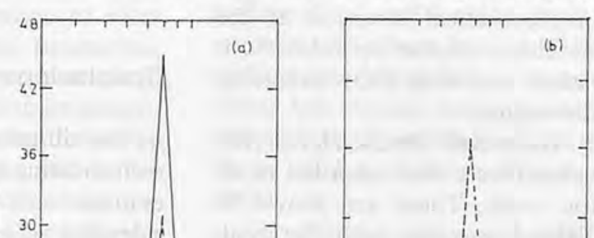

Fig. 5 Frequency analyses of vibration levels of the sprayer measured at (a) station B_v (vertical) and (b) station B_t (transverse) on the blower casing while the engine operated at 5000 rpm (______, engine partially (60%) balanced; ------, engine fully (100%) balanced).

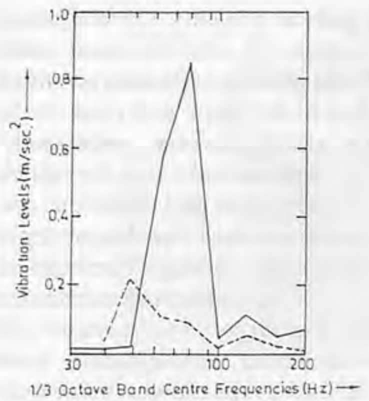

Fig. 6 Frequency analyses of the response measured at the shoulder of the operator while the engine operated at 4000 rpm (______, engine partially (60%) balanced; -------, engine fully (100%) balanced).

Table 1. Peak and Overall (Lin) Values of Vibrational Response (m/sec^2) and Their Changes

Station	RPM	Peak response: Existing balance 60%	Peak response: Fully balanced 100%	Percent response change (−, +)	Overall response: Existing balance 60%	Overall response: Fully balanced 100%	Percent response change (−, +)
Engine							
Vertical	4 000	31.0	18.0	−42.0	36.2	23.1	−36.0
E_v	5 000	34.9	19.8	−43.3	49.0	31.0	−42.5
Transverse	4 000	8.6	22.0	+156.9	15.7	27.9	+36.1
E_t	5 000	14.0	39.0	+178.5	20.0	46.0	+121.1
Blower							
Vertical	4 000	26.0	22.0	−15.4	39.0	34.0	−11.7
B_v	5 000	44.0	17.0	−29.5	52.0	34.9	−33.0
Transverse	4 000	8.5	31.0	+100.0	18.5	30.0	+62.0
B_t	5 000	11.7	24.8	+112.0	22.0	39.0	+77.2
Operator							
Shoulder	4 000	0.82	0.21	−74.0	1.62	1.20	−26.0
	5 000	0.25	0.12	−52.0	0.76	0.47	−38.0

blower casing, in the vertical and the horizontal directions, both before the after fully balancing the engine. The high response peaks occur at firing frequency which corresponds to the engine speed of 5 000 rpm. The vibrational response sufficiently below and above the firing frequency is very low and was thus not recorded. **Figure 6** shows the frequency analysis of the response measured in the vertical direction at the shoulders of the operator both before and after fully balancing the engine.

The overall vibration levels (Lin values) were also recorded in all the cases. These are shown in **Table 1** together with the peak values both when the engine was only partially balanced (60%, existing) and when it was fully balanced (100%, modified). The engine speeds were 4 000 and 5 000 rpm.

Comparison of the peak and the overall values shows a considerable reduction in vibration levels in the vertical direction. These reductions are up to 43% at the engine and 33% at the blower casing. There is, as expected, considerable increase in the vibration levels in the transverse direction as measured on the engine and the blower. The vibration levels at the shoulders of the operator are highly dependent upon the speed of the engine and hence the frequency of excitation. An overall reduction of vibration level at the shoulder has been recorded at 38% and 26% and the engine operated at 5 000 and 4 000 rpm, respectively.

The operator really experienced a considerable relief when he used the sprayer running in a fully-balanced condition.

Conclusions

The vibrations generated by the reciprocating engine of the sprayer in the vertical direction are considerably reduced by fully balancing the reciprocating and rotating parts of the engine and the sprayer. This also results in a reduction of vibrations transmitted to the shoulders of the operator. Vibrations transmitted in the vertical direction are most harmful and cause excessive human fatigue. The balancing resulted in 33% and 43% overall reduction in vibration levels on the blower casing and the engine, respectively. The vibration at the shoulders of the operator was reduced by 26% to 38%, depending upon the speed of operation of the sprayer. The operator felt a considerable relief while operating the sprayer in a fully balanced condition.

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Simulation Modelling for Crop-disease Spraying Management

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Abstract

Two simulation models were developed: one for wheat crop growth and the other, to simulate the exponential growth of *Septoria tritici* disease on the upper-most four leaves of wheat. The coupled crop-disease model was used to predict crop losses and to compare and analyze the cost/benefit of different spray strategies for controlling the disease. The three control methods: insurance treatment, routine spraying and managed disease control were not economically viable under the assumptions used and gave average extra costs of 44%, 17% and 8.9%, respectively, when compared with the value of the untreated simulated crop yield loss.

Introduction

The crop production cycle is a chain of biological and physical processes linked together in which a crop canopy captures solar radiation from the sunlight and converts the energy into dry matter which is accumulated and produces a harvestable yield. The relationships between the product and the inputs are not simple, because of the large number of complex and interdependent processes which take place during the production cycle. A general representation of the bio-physical process is given by the following:

$$Y = fX^{\cdot}$$

where

Y = the yield of the crop (usually the economic yield)

$X^{\cdot}$ = $(x_1, x_2, ..., x_n)$ is the quantity of resources used in growing the crop.

f = a production function

Agricultural machinery is one of the inputs which the farmer uses in the exploitation of solar energy during crop production and there are certain operations in the field, like planting irrigation, spraying and harvesting have to be carried out correctly and in the right time in order to create the best environment for crop growth and harvest at its optimum quality. One of the targets of the mechanization in agriculture must be to provide a measure of feedback control into the transformation process so that the inputs can be manipulated more effectively to exploit changes in the environment and give a crop output of more predictable quantity and quality (O'Callaghan, 1991).

Pests and diseases may reduce crop growth and yield at any level of production. Estimation of such yield loss is found to be essential in any system of crop production because they form the basis for an economic cost/benefit analysis of control measures.

In U.K. winter cereals are subjected to attack by many diseases, but the potentially most damaging of wheat foliar diseases are the *Septoria* ones (Thomas et al, 1989). They cause considerable reduction in yield and many fungicides have become available for control of such diseases. In 1984 the net loss from the application of the three spray programme on winter wheat was estimated at £35 million (Cook and Jenkins, 1988), while in 1993 although about £136 million was expanded on fungicides, but disease induced yield loss in England and Wales still cost about £63.5 million (Blakes, 1993).

The effective timing and application of inputs such as spraying and other cultural and specific management practices for a crop is largely dependent on a reliable understanding of the whole crop production system.

Developments are taking place in decision support systems which can help in disease management and proper timing of treatments (e.g., Anon, 1986, Webster and Cook, 1986, Rabbinge and Rijselijk, 1983). Simulation modelling is becoming more important for better management of crop production systems by predicting the general processes of crop growth and giving insights on the critical times and operations to be implemented. This can help in proper control over the inputs and could lead to better decisions in response to conditions in the field which may, consequently, reduce the total cost of crop production. There are now many crop models which are designed to be used as tools for the evaluation and management of various kinds of crop production options (e.g., Jones and Kiniry, 1986, Williams et al, 1989, Djurle and Yuen, 1991, Kiniry et al, 1992, Jones et al, 1992).

The Crop Model

A relatively simple crop model SODCOM (O'Callaghan, 1994a) which is diagrammatically presented in **Fig. 1**, has been built up from a number of processes integrated together on a daily basis describing the fundamental relationships for canopy leaf area, light interception, photosynthesis, dry matter production and partitioning in relation to crop phenological development. The model calculates the potential growth and yield under ideal conditions without limitations of nutrients and water and free from weeds, pests and diseases.

The crop model was modified for Riband wheat cultivar using several crop parameters to convert solar energy into daily photosynthate which is divided between respiration and plant biomass. The net assimilate which produced every day is partitioned to different plant organs and the proportion allocated varies with the development stage of the crop.

The major phenological stages expressed as a function of thermal time and the energy conversion and dry matter partitioning factors are shown in **Table 1**.

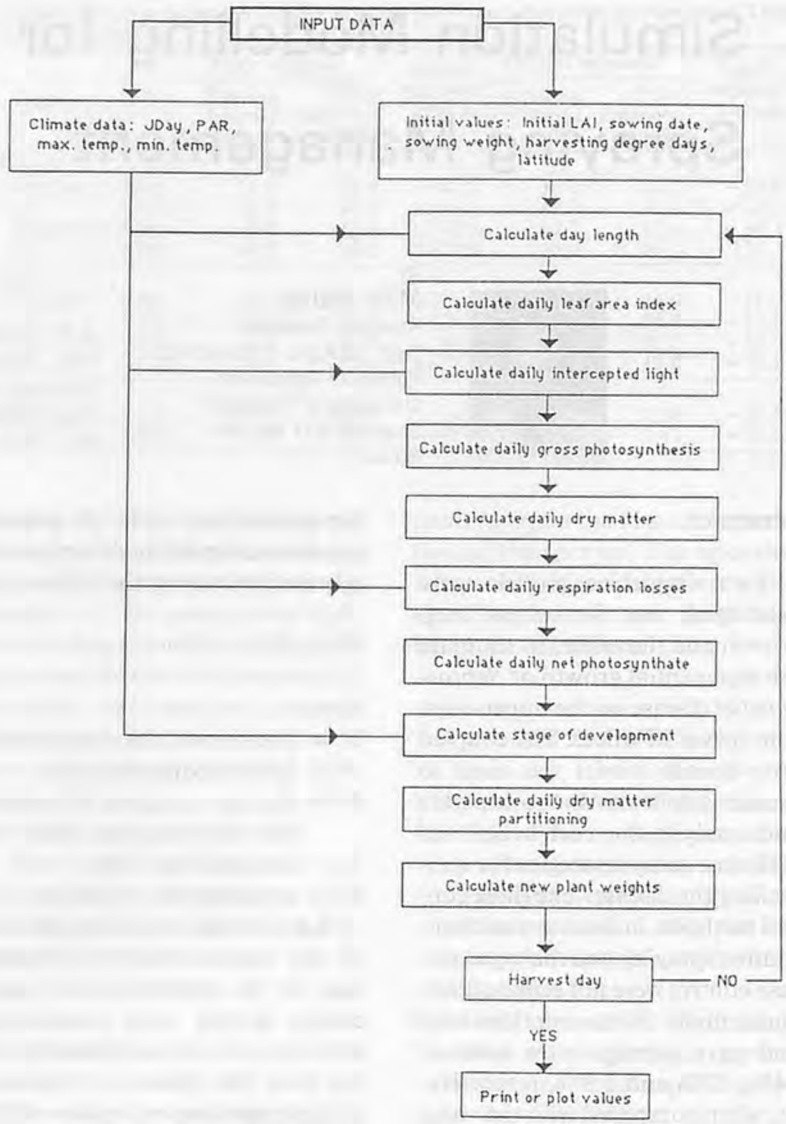

Fig. 1 General flow chart of crop growth model.

Table 1. Major Phenological Stages and Energy Conversion and Dry Matter Portioning Factor of Wheat Crop

Extinction coefficient	0.440				
Maximum rate of leaf photosynthesis	1.111 mg m^{-2} j^{-1}				
Initial light use efficiency	0.009 mg j^{-1}				
Growth respiration coefficient	0.340				
Maintenance respiration coefficient	0.002 (pre-anthesis)				
	0.001 (post anthesis)				
Co_2 conversion factor	0.650				
	Dry matter partitioning factors				
	leaf	stem	root	ear	grain
Emergence to double ridge	0.55	0.1	0.35	0.0	0.0
Double ridge to terminal spikelet	0.40	0.4	0.20	0.0	0.0
Terminal spikelet to anthesis	0.30	0.3	0.10	0.3	0.0
Anthesis to maturity	0.0	0.0	0.0	0.0	1.0

Base temp. 0°C.
Source: Weir etal, 1984.

A typical plot of the simulated growth and distribution of dry matter over the different organs of winter wheat plant (C.V. Riband) at Cockle Park Farm, Northumberland, U.K. is shown in **Fig. 2**.

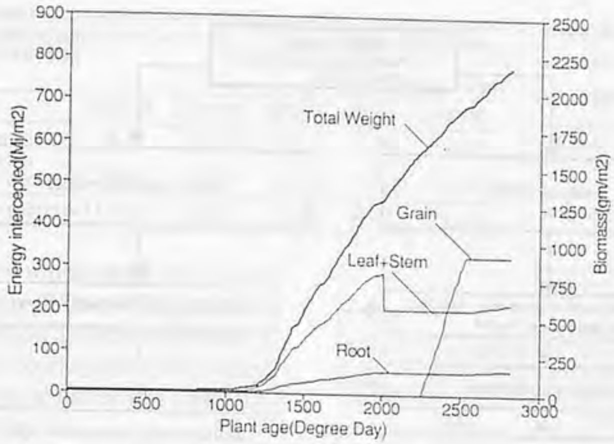

Fig. 2 Simulation of winter wheat in Northumberland, 1991-92.

Septoria Disease Modelling

The Field Trial

In the absence of enough quantitative information on the descriptive epidemiology of *Septoria tritici* foliar disease in the U.K., a field experiment was conducted for better understanding of the development of the disease on a wheat crop and as a means of generating data which could help in developing a predictive model of the disease. The trial was based on two sowing dates (early and late sown) and two cultivars of winter wheat, one is highly susceptible to the disease (Riband) and the other is less susceptible (Apollo). Both cultivars were either sprayed with the fungicides Radar (Propiconazole) and Impact Excel (flutriafol + chlorothalonit) as shown in **Table 2**, or left untreated. Each treatment was replicated three times giving a total of 24 plots.

Table 2. Fungicides Application Schedule for Early and Late Sown Winter Wheat Crops at Cockle Park Trail Farm, 1991/92

Item	Fungicide name	Date of spraying	Application rate
Early sown	Radar	Jan. 13	0.5 L/ha
	Radar	March 5th	0.5 L/ha
	Impact Excel	April 9th	2.0 L/ha
	Impact Excel	May 14th	2.0 L/ha
	Impact Excel	June 19th	1.0 L/ha
Late sown	Radar	March 5th	0.5 L/ha
	Impact Excel	April 9th	2.0 L/ha
	Impact Excel	May 14th	2.0 L/ha
	Impact Excel	June 19th	1.0 L/ha

The progress of the disease in the upper most four leaves of the untreated early-sown Riband cultivar is shown in **Fig. 3**.

Development of the Disease Model

The amount of the disease as represented by pycnidia numbers collected on the upper-most four leaves of the untreated Riband cultivar was used for building a model describing the development of the disease (O'Callaghan, 1994b). In the predictive model, the growth of the disease in each leaf layer was developed as a function of thermal time and represented by an exponential population growth model as follows:

$$N_t = ne^{rt}$$

where,

N_t = number of pycnidia at time t in degree days

n = initial number of pycnidia on a leaf layer

r = relative growth rate of the disease

The Crop-disease Models Interaction

The effect of the predicted septoria development on the simulated crop growth was found by correlating the percentage of leaf areas infected by the disease, which was collected from the field trial, with the simulated disease levels on each of the upper-most four leaves ($r^2 > 0.90$). From these correlations the following regression equations were derived and used in the coupled crop-disease model

$$Y_{t1} = 13.28\ (0.66)\ N_{t1} + 0.20$$
$$Y_{t2} = 8.51\ (1.01)\ N_{t2} + 5.31$$
$$Y_{t3} = 10.66\ (0.47)\ N_{t3} - 1.09$$
$$Y_{t4} = 17.01\ (1.21)\ N_{t4} - 5.71$$

Where 1, 2, 3, 4 denote leaf numbers of the crop considering the flag leaf 1. Y_t is the calculated percentage of leaf area infected at time t. N_t is the simulated amount of disease on the leaf at time t. The standard error of N_t coefficient is within the brackets.

The disease was assumed to have been distributed uniformly

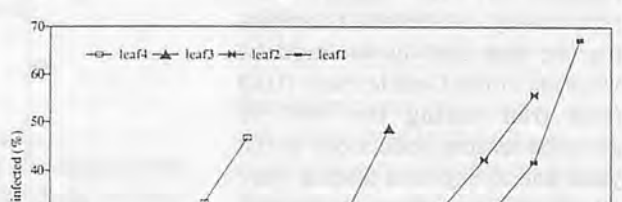

Fig. 3 Progress of Septoria disease severity over uppermost four leaves of winter wheat crop, 1991-92.

over the field (Show and Royle, 1987). The proportion of the leaf area index of the crop covered by the disease at any time was calculated as the average leaf area on the upper most four leaves and is referred to as disease factor (df) in the model

$$df_t = (T_{t1} + T_{t2} + Y_{t3} + T_{t4})/4$$

The effects of an attack of Septoria disease on the growth and yield of a wheat crop was estimated by incorporating the simulated disease into the wheat crop growth as shown in **Fig. 4**. In the first instant, the effects of the simulated disease were introduced into the crop model through reductions in the photosynthetically active leaf area affected by the disease. This approach produced only a small reduction in the final yield. However, metabolic effects of the disease on the crop were taken into account by modifying the gross photosynthetic rate (P_{gt}) in the crop model by the ratio of the uninfected leaf area to the total leaf area as follows:

$$\text{New } P_{gt} = P_{gt} (1 - df_t)$$

Where New P_{gt} is the infected gross photosynthetic rate at time t in degree days.

The simulated above-ground biomass and grain yields were reduced by 9.3% and 11.3%, respectively, as a result of combining the crop and disease models, whereas in the Cockle Park (UK) field trail during the 1991/92 growing season, reductions in the yield due to Septoria disease were 10.6% in the total dry matter and 12.1% in grain yields. The simulated effects of the crop-disease linked model on biomass and grain yields of winter wheat are shown in **Fig. 5**.

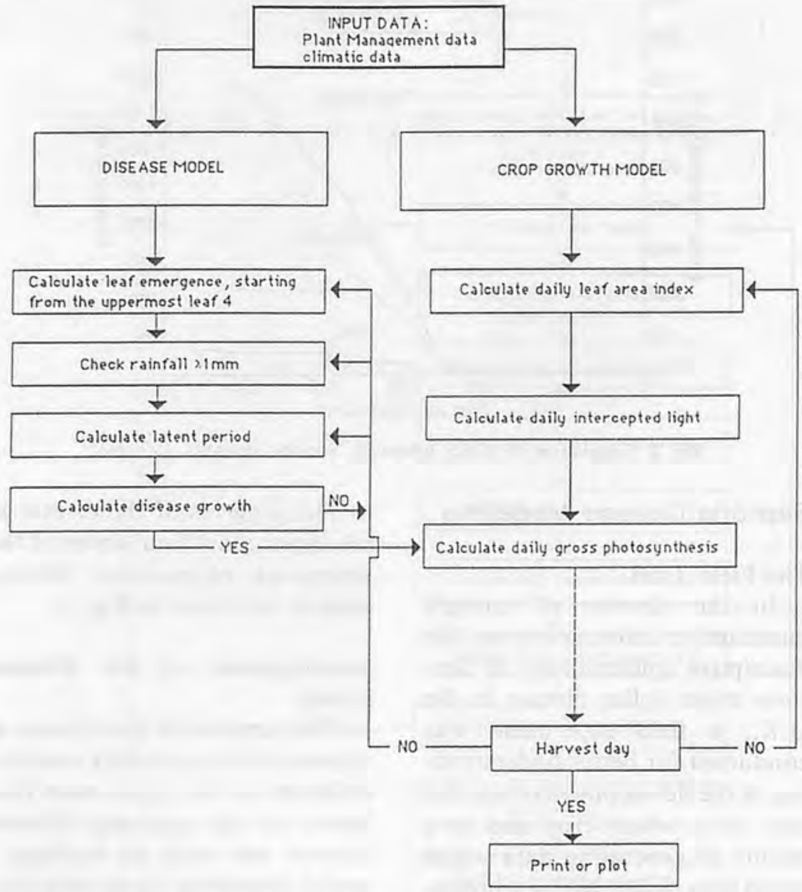

Fig. 4 Flow diagram to show how crop growth and disease development models are dynamically linked.

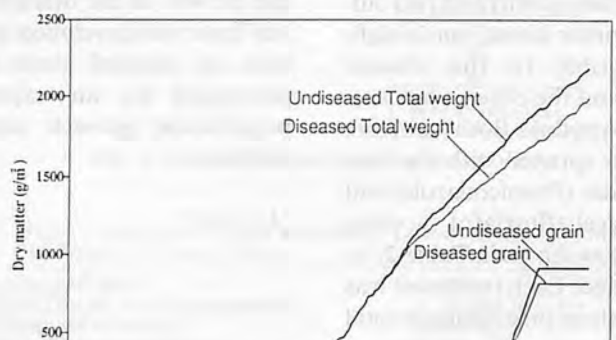

Fig. 5 Simulated effect of Septoria disease on total dry weight and grain yield of winter wheat crop, 1991-92.

The Cost/Benefit Analysis of Spraying

The coupled crop-disease model was used for analyzing and comparing the cost/benefit of different Septoria disease control strategies during five growing seasons (1987/88-1991/92) at the Cockle Park farm. Using weather data from the site and crop sowing dates, it was possible to pin-

Table 3. Simulated Grain Yields in Winter Wheat Crops Free of and Infected with *Septoria Tritici* at Cockle Park Farm, 1978-1992

(Unit: t/ha)

Item	1987/88	1988/89	1989/90	1990/91	1991/92
Disease free	8.77	8.27	7.51	8.50	9.15
Infected with Septoria disease	7.82	7.12	6.35	7.54	8.12
Yield loss (percent)	10.80	13.90	15.40	11.30	11.30

Table 4. Estimated Percent Losses in Yield Due to Wheeling Damage

Previous wheeling marks	Growth stage	Spray boom width		
		10 m	15 m	20 m
Wheel marks present	GS 31	0.0	0.0	0.0
	GS 39	1.7	1.3	1.8
	GS 59	3.5	2.6	1.7
No wheel marks	GS 31	0.0	0.0	0.0
	GS 39	3.5	2.6	2.7
	GS 59	7.0	5.3	3.5

Source: Webter & Cook, 1986.

point how much yield loss would have occurred due to Septoria disease infection as shown in **Table 3**.

The following spraying schedules were compared for control of the disease:

(i) Insurance spraying based on calendar dates with treatments applied four times during the growing season.

(ii) Routine spraying based on predetermined specific crop growth stages in which treatments were applied at the three growth stage, stem elongation (GS. 32), flag leaf emergence (GS. 39), and ear emergence (GS. 59).

(iii) Managed disease control (M.D.C., Anon, 1986).

In costing the different control methods, the total cost of a treatment was taken to include the chemical cost, spray application cost and the estimated value to yield loss due to wheeling damage.

The following assumptions were made in calculating the cost of the different treatments:

a) The same three chemicals were used during the five growing seasons with the same application costs; Radar at a cost of £20/ha, Spark 45 (Prochloraz) at £24/ha and Impact excel at £22/ha.

b) Spraying was done by a contractor, using a ground spraying machine of 12 m boom width and charging £11/ha (Nix, 1991).

c) Tramlines (wheeling marks) were present in the crop during spraying and the wheeling damage was estimated by interpolating losses in yield from **Table 4**.

The spraying costs which were calculated for the different control approaches in each of the five seasons and the values of the simulated yield losses without treatments are presented in **Table 5 (a, b, c, d)**. The average costs of each approach to disease control compared with the value of mean yield loss in an untreated crop are summarized in **Table 6**.

Table 5. Calculation of Costs of Spray Treatment for Different Septoria Control Strategies in Each of Five Growing Seasons, 1987/88-1991/92 at Cockle Park Farm

A. Insurance control using calendar dates

Item	1987/88	1988/89	1989/90	1990/91	1991/92
	£	£	£	£	£
Application costs	44.0	44.0	44.0	44.0	44.0
Wheeling damage costs	38.7	35.2	31.4	37.3	40.2
Chemical costs	86.0	86.2	86.0	86.0	86.0
Total costs	168.7	165.2	161.4	167.3	170.2

B. Routine spraying at specified growth stages

Item	1987/88	1988/89	1989/90	1990/91	1991/92
	£	£	£	£	£
Application costs	33.0	33.0	33.0	33.0	33.0
Wheeling damage costs	38.7	35.2	31.4	37.3	40.2
Chemical costs	66.0	66.0	66.0	66.0	66.0
Total costs	137.7	134.2	130.4	136.3	139.2

C. Managed disease control (MDC)

Item	1987/88	1988/89	1989/90	1990/91	1991/92
	£	£	£	£	£
Application costs	22.0	22.0	22.0	22.0	22.0
Wheeling damage costs	38.7	35.2	31.4	37.3	13.4
Chemical costs	42.0	42.0	42.0	42.0	22.0
Total costs	102.7	99.2	95.4	101.3	46.2

D. Estimates of no-treatment costs based on simulation model

Item	1987/88	1988/89	1989/90	1990/91	1991/92
	£	£	£	£	£
Yield loss x wheat price*	104.5	126.5	127.6	105.6	113.3

*: Assumed at £110/t.

Table 6. Mean Costs of Different Spraying Approaches to the Predicted Yield Loss in an Untreated Wheat Crop at Cockle Park Farm, 1978/88-1991/92 Growing Seasons

Item	Insurance	Routine	M.D.C.	Untreated
Mean cost (£)	166.6	135.6	89.0	115.5

Discussion

The increase in the input costs to farmers, the demands of consumers for less chemical residues in food crops and the pressures to minimize environmental pollution and damage, all point to the need to achieve satisfactory yields with reduced amounts of chemical inputs.

Two simulation models were developed: one for crop growth that was driven by the quantity of solar radiation intercepted by the crop canopy, and, the other, for *Septoria tritici* development on the upper-most four leaves of a winter wheat crop. The two models were linked together, in the first instant by considering only the physical effect of a reduction of the active leaf area of the crop and was found to underestimate the reductions in yield. This could be attributed to the availability of excess leaf area at the time of infection (Djurle and Yuen, 1991). Further losses could be explained metabolically as a reduction in gross photosynthesis, an idea used by Rabbinge (1982) in SUCROS model.

The coupled simulation model of Septoria disease in winter wheat was used for analyzing and comparing the cost/benefit of different disease control strategies during the growing seasons 1987/88 to 1991/92 under the environmental conditions of Cockle Park farm in the U.K. The analysis was done by simulating yield loss due to the disease and comparing the values of yield loss with the costs of spraying.

The insurance treatment policy and the routine spraying at the pre-specified growth stages were found to give average extra costs of 44% and 17%, respectively, greater than the value of the simulated yield loss due to the actual predicted disease epidemic. The managed disease control (MDC) approach may give an average return of 30% on the assumption that the spray treatment give complete yield response. Experimentally, (Cook and Jenkins, 1988; Cook and Thomas, 1990) found about 10% yield increase attained when a two-spray programme was used. If the same yield response was assumed for the MDC system, which in most years of the present study was found to require two sprayings, then the cost of spraying was higher than the value of the yield reduction, giving a loss of about 9%. Therefore, under the assumptions used in calculating the costs of spray treatments, none of the control approaches was economically viable.

It can be concluded that:

Estimating the profitability of the use of fungicides on cereals is difficult because of the assumptions that have to be made and the different factors have to be considered, however, the timing of control of an outbreak and its severity are important.

Simulation modelling can help as a decision support system for disease management and for optimizing the economic benefits from disease control, by allowing a cost/benefit analysis of a fungicide treatment to be made at early stages during the growing season.

The dynamic crop-disease coupled model can play an effective role in avoiding unnecessary treatments and reduce the amounts of chemicals to be used, which could help in increasing the profit margins of the farmer and in protecting the environment from contaminations.

Simulation modelling is a powerful method of transferring advances in biological information for use by engineers in bringing about technological improvements in crop spraying and management. Future improvements may be achieved by collecting more information for selectively applying the spray where it is needed and based on sensors which detect patches of disease infections in the field.

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Selected Design and Operational Parameters of Serrated Tooth-type Bruising Mechanism of a Straw Combine

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Abstract

Wheat straw combines are being used increasingly to salvage leftover wheat straw in grain combine harvested field by farmers in the states of Punjab, Haryana and Western Uttar Pradesh. The serrated tooth-type bruising cylinder has been mostly used in these straw combines. The effects of various design and operational parameters like blade angle (6° to 10°), concave bar spacing (8 mm to 14 mm), cylinder speed (23.96 m/s to 30.83 m/s) and feed rate (15 to 21.5 q/h) on the performance of serrated-tooth type bruising mechanism were studied. These experiments indicate an optimum combination of blade angle, 10 degrees; concave bar spacing, 11 mm; cylinder speed, 23.96 m/s; and feed rate, 21.5 q/h. Optimization of results was considered in terms of net specific fuel consumption and straw quality. The quality of bruised straw was determined on the basis of average straw length and split straw percentage.

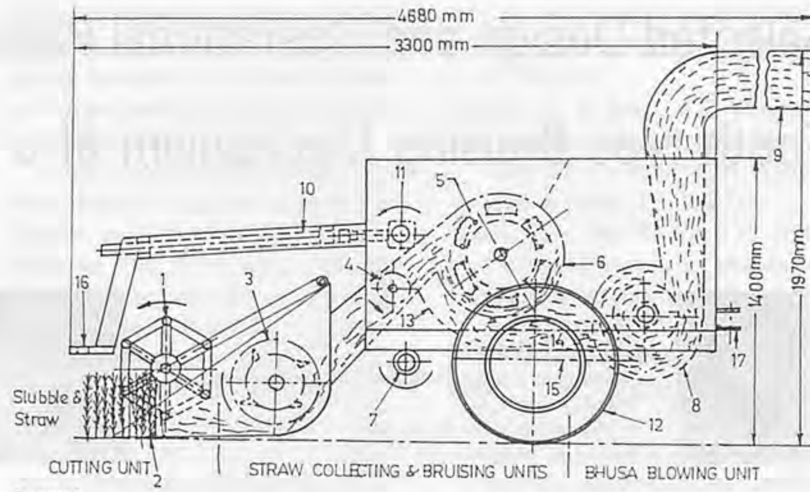
Introduction

Grain combines have helped in timely harvesting and saving of grain losses even as they have limited acceptability due to loss of wheat straw or "bhusa". Wheat straw is extensively used as cattle feed for milch animals in India. With the use of grain combines, this important cattle feed is left in the field. To collect and bruise the wheat straw and stubbles left behind after wheat harvest with grain combines, local manufacturers in Punjab have devised a wheat straw combine. The device recovers the wheat straw left behind in a combine-harvested field i.e., cuts the stubbles, converts them into finely bruised straw called *tibbin* or *bhusa* and then collected in a trailer attached behind the straw combine.

The straw combine essentially consists of four units, viz, stubble cutting unit, feeding unit, straw bruising unit, and bhusa blowing unit with transportation trolley. A straw bruising unit is an important unit of a straw combine. The serrated tooth-type bruising unit is mostly used in the straw combine for bruising the wheat stalks. Several alterations of bruising drum are currently in use. No systematic research study has been reported on the bruising mechanism of straw combine. Studies are, therefore, needed to investigate the effect of different operational and design parameters on the performance of the straw combine as determined by net specific fuel consumption and straw quality.

Literature Review

Burrough (1954) observed that the power consumption for various components like reel, cutter bar, threshing drum, cleaning and separating system for a feeding rate of 27 q/h were 0.3, 0.7, 2.4, 1.1 and 0.3 hp, respectively. Reed et al. (1970) concluded that the straw length before threshing was not an important factor. The resulting length after threshing were 25.4 cm and 20.2 cm, when the mean straw lengths before threshing were about 63.5 cm and 30.5 cm, respectively. Wrubleski et al. (1981) concluded that the combine cylinder used 68 to 82% of the total power for wheat. They also observed that energy requirements increased as the harvest rate increased for a given loss level, independent of machine configuration. Verma et al. (1992) found that the average field capacity of the straw combine varied between 0.24 and 0.4 ha/h. They mentioned that the height of cut varied between 5 and 7 cm and the straw output ranged between 15 and 25 q/h. Ahuja et al. (1993) studied the performance of straw combine operated with a 45-hp tractor at an average speed of 4 km/h. The combine recovered 18.0 q/ha bruised straw as compared to 35-40 q/ha obtained with manual harvesting and conventional thresher system. Other research workers have conducted studies on various aspects of threshing by threshers and grain combines. But local manufacturers are using several alterations of bruising mechanism for better performance of straw combine. One such unit of straw combine with serrated-tooth type bruising mechanism was tested in terms of net specific fuel consumption and straw quality.



Legend
1. Reel 2. Cutter bar 3. Auger 4. Feeder 5. Straw bruising drum
6. Concave 7. Counter shaft 8. Aspirator blower 9. Adjustable blower duct
10. Input shaft 11. Gear box (bevel gear) 12. Pneumatic tyre wheels
13. Sieve 14. Grain sieve 15. Grain tray 16. Hitch hook 17. Trolley hook

Fig. 1 Side view of straw, combine showing material flow from reel to trolly.

Experimental Straw Combine

A straw combine manufactured by M/S standard combine was used for the present study. The combine (**Fig. 1**) consists of a conventional cutter bar of 2 150 mm cutting width, auger platform and reel chain conveyer, bruising drum, and a bar sieve shaker. The reel of straw combine has usually a smaller diameter as compared to the reel in grain combine. The straw bruising drum (diameter, 64 mm) consists of serrated-tooth cylinder with a concave. In bruising system the straw was not allowed to escape from the top of the concave as in a grain combine. The whole length of the straw passes through the concave which after bruising is reduced in size. The materials passing through the concave are subjected to the aspiration action of the blower (520 mm diameter), with 4 trapezoidal shape blades. The finally bruised straw is blown into the trolley which is hooked at the back of the machine. The trolley is covered with a canvas cloth that tethered with trolley to collect the straw. The rear side of the trolley is covered with an iron net i.e., *jalli* so that air is blown off from the rear side and the bruised s traw is stored in the trolley. The machine is operated by SWARAJ-855 tractor of 55 hp (SAE). The power is transmitted from the tractor P.T.O shaft to the main drive of the straw combine through the universal telescopic coupling i.e., shaft.

Experimental Procedure for Testing the Straw Combine

The basic design of the combine, the overall dimensions of cutter bar and reel, blower (size and location) diameter and width of bruising drum and concave clearance (front 21 mm and rear 20 mm) were kept constant during the experiments. The range of selection of levels of independent variables was made on the basis of previous studies carried out on the straw combine and the parameters used by different straw combine manufacturers. The levels of different independent variables for serrated tooth type bruising drum are given in **Table 1**.

V-pulleys of sizes 16.51 cm, 20.32 cm and 24.13 cm with transmission ratios 2.38:1, 1.95:1, and 1.62:1 were selected to vary the speed of the rotation of the bruising cylinder. The feed rate was varied by changing the forward travel speed of the tractor. The selected forward speeds were 2.0 km/h, 2.5 km/h and 3.0 km/h for evaluating the effect of feel rate on straw combine performance. The tractor was operated in L-I and L-II gears at throttle speed between 1 400-1 800 rpm according to the proper correlation between forward travel speed of the tractor and drum speed. Wheat crop of variety CPAN - 3002 was used for the operation of straw combine. The wheat crop had an average length of cut equal to 223 mm (C.V. = 15.8%) and an average stalk density of the

Table 1. Levels of Different Independent Variables for Serrated Tooth-type Bruising Drum

Variables	Level I	Level II	Level III
Blade angle (D)	D1 = 6°	D2 = 8°	D3 = 10°
Concave bar spacing	C1 = 8 mm	C2 = 11 mm	C3 = 14 mm
Cylinder speed (S)	S1 = 715 rpm (23.96 m/s)	S2 = 865 rpm (28.98 m/s)	S3 = 920 rpm (30.83 m/s)
Feed rate (F)	F1 = 15 q/h	F2 = 18 q/h	F3 = 21.5 q/h

crop was 412 stubbles/sq.m (C.V. = 11.2%).

The average moisture content of the straw was 6.33% on dry basis (C.V. = 13.2%). Fuel consumption was measured by fuel flow meter attached to the rear guard of the tractor. Net fuel consumption is equal to the difference of the total fuel consumption for the operation of straw combine minus the fuel consumed during the idle run (no cut). The net specific fuel consumption is the ratio of the net fuel consumption to the average feed rate. Straw quality was determined on the basis of average straw length and split straw percentage. Samples collected from the trolley for each experiment were thoroughly mixed.

The mean length (mm) and standard deviation were recorded for each sample which is the average straw length. Straw sample (approximately wt. 100-200 g) was sorted manually for unsplit straw to determine the split straw percentage. The average length of straw ≤25 mm with C.V. ≤40% together with splitting of straw ≥ 92-95% with C.V. ≤40% was considerd acceptable quality.

The feed rate (F) of crop was estimated as follows:

$$F(kg/h) = w * l * v$$

where

w = wt. of crop per unit area (Kg/sq.m)

l = effective width of cut (1.83 m)

v = forward travel speed (m/h)

The factorial (3^4) randomized block design (RBD) was used to conduct the experiments and test the significance of the variables and their interactions.

Results and Discussion

Net Specific Fuel Consumption

The effect of the four variables viz; blade angle (D), concave bar spacing (C), cylinder speed (S) and feed rate (F) were significant at 5% level. The concave bar spacing was the most significant parameter affecting the net specific fuel consumption. An increase in concave bar spacing caused the reduction in net specific fuel consumption (**Fig. 2**). The maximum reduction of net specific fuel consumption was 0.912 cc/kg at cylinder speed of 920 rpm i.e., 30.83 m/s and blade angle of 6° with the increase in concave bar spacing from 8 mm to 14 mm. Reduction in net specific fuel consumption with an increase in concave bar spacing was due to the lesser resistance offered to the movement of straw at wider concave opening sizes which allowed the materials to pass through relatively easily.

An increase in the threshing cylinder speed also increase the net specific fuel consumption (**Fig. 3**)

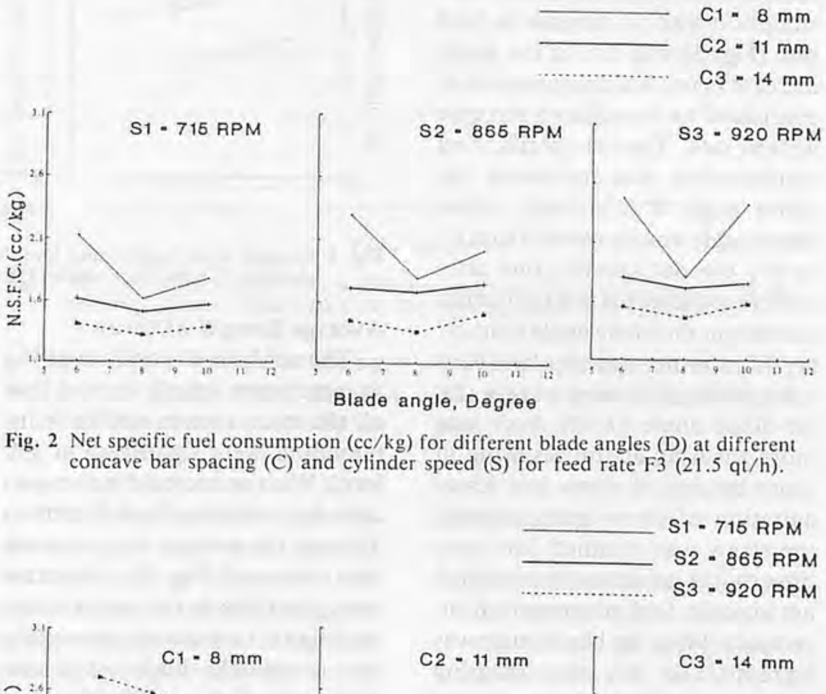


Fig. 2 Net specific fuel consumption (cc/kg) for different blade angles (D) at different concave bar spacing (C) and cylinder speed (S) for feed rate F3 (21.5 qt/h).

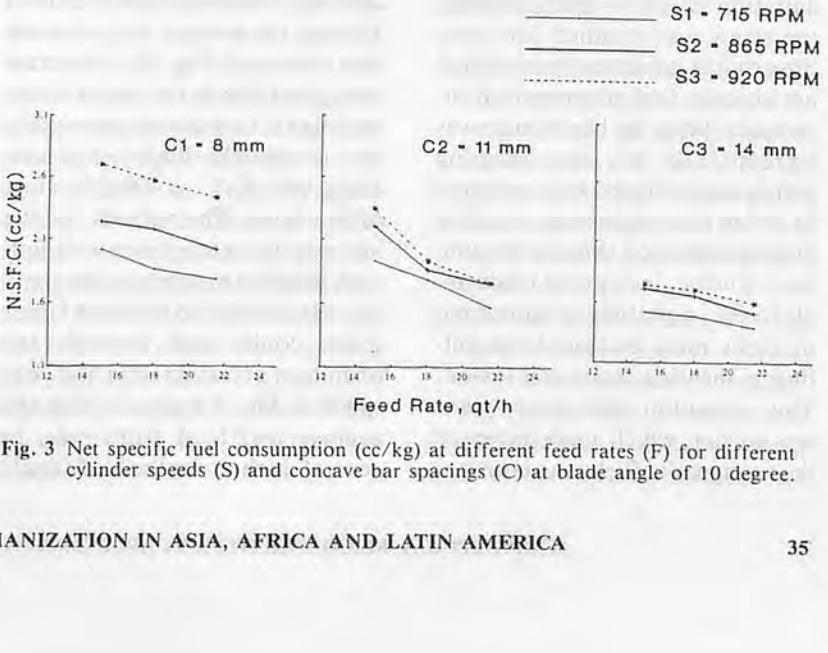


Fig. 3 Net specific fuel consumption (cc/kg) at different feed rates (F) for different cylinder speeds (S) and concave bar spacings (C) at blade angle of 10 degree.

at any fixed value of blade angle (D), concave bar spacing (C) and feed rate (F). At higher cylinder speed, increased impact energy due to finer straw (i.e., less average length of straw) and better splitting resulted in higher net specific fuel consumption. At all settings of the blade angle (D), concave bar spacing (C) and cylinder speed (S), net specific fuel consumption was minimum for high feed rate of 21.5 q/h.

The minimum reduction in net specific fuel consumption was 0.129 cc/kg at concave bar spacing of 14 mm and cylinder speed of 715 rpm i.e., 23.96 m/s with an increase in feed rate from 15 q/h to 21.5 q/h. There was always an increase in net fuel consumption with an increase in feed rate. But reduction in net specific fuel consumption with an increase in feed rate (**Fig. 3**) was due to the lesser increase in net fuel consumption as compared to the relative increase in feed rate. The net specific fuel consumption was minimum for blade angle 8°. Initially, when blade angle was increased from 6° to 8°, the net specific fuel consumption decreased but on further increase in the blade angle from 8° to 10°, the net specific fuel consumption again increased (**Fig. 2**). At blade angle of 6°, there was more shearing action resulting in more cutting of straw but lesser agitation of straw mass. Hence, the straw was retained for more time on the concave due to which net specific fuel consumption increased. When the blade angle was increased to 8°, the shearing action was reduced but agitation of straw mass increased resulting in lesser retention time on the concave. Further increase in blade angle to 10°, agitation or movement of straw mass increased but cutting or shearing action was lowest. Thus retention time on concave was greater, which again increased the net specific fuel consumption.

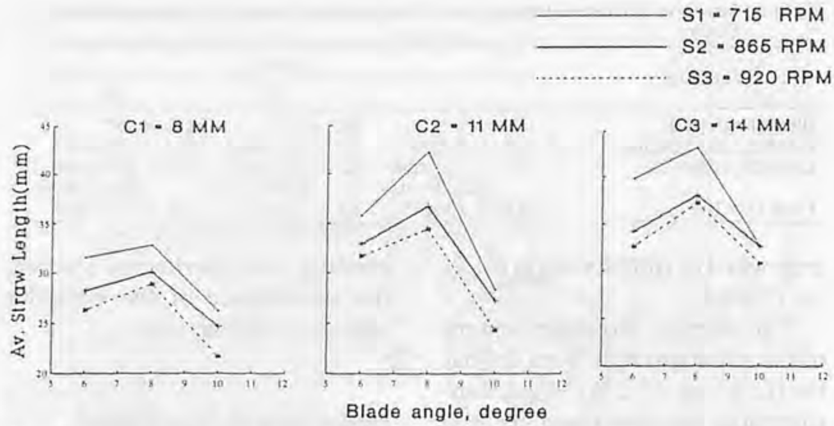


Fig. 4 Average straw length (mm) for different blade angle (D) at different cylinder speed (S) and concave bar spacing (C) for feed rate F3 (21.5 qt/h).

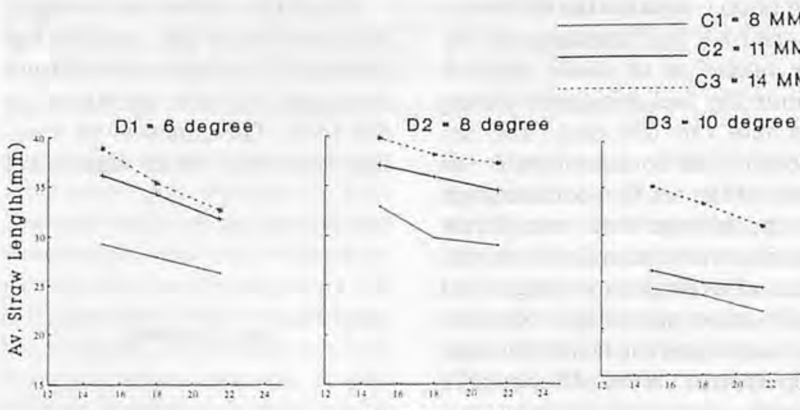


Fig. 5 Average straw length (mm) for different feed rates (F) at different concave bar spacings (C) and blade angles (D) for cylinder speed S3 (920 RPM).

Average Length of Straw

The analysis of variance of the average straw length showed that all the main factors and their interactions were significant at 5% level. With an increase in the concave bar spacing from 8 mm to 14 mm, the average size of straw also increased (**Fig. 5**). The straw sizes available at the concave bar spacing of 14 mm was not within the acceptable limit (≤25 mm along with C.V. ≤40%) in most of the cases. The reasons for the increase in average straw length with increase in concave bar spacing was due to the fact that larger straw could pass through the openings at larger concave bar spacing. **Fig. 4** indicates that the average length of straw was, in general, highest for the blade angle of 8° amongst the blade angles studied. The minimum straw size was available at blade angle of 10° even for concave bar spacing of 14 mm which was within the acceptable range of straw (≤25 mm along with C.V. ≤40%). The effect of blade angle on average straw length can be explained in a similar way as that for the net specific fuel consumption. Increase in cylinder speed resulted in reduction of average straw length (**Fig. 4**). The reduction in average straw length was due to more cuts/impacts per unit time at higher cylinder speed. Thus, higher impact energy was imparted to the c rop materials, which in turn resulted in finer straw available at higher cylinder speeds. **Fig. 5** shows that finer straw was available at higher feed rates. The minimum reduction in average straw length with feed rate was 2.5 mm for concave bar spacing of 8 mm and blade angle of 10°. The reduction in average straw size with feed rate was due to the fact that at higher feed rates, the straw was properly compressed and resulted in minimal movement. Energy transfer to a compact mass would also be greater at higher feed rates because of less crop slippage.

Split Straw Percentage

The analysis of variance for split straw percentage as affected by blade angle (D), concave bar spacing (C), cylinder speed (S) and feed rate (F) shows that all the main factors were significant at 5% level. The blade angle (D) was the most significant parameter affecting the split straw percentage. Minimum splitting of straw was obtained for blade angle 8° (**Fig. 6**) and in most of the cases was not within the acceptable range of splitting (≥95% along with C.V. ≤40%). The maximum straw splitting ranged from 95 to 99% that was obtained with blade angle of 10°. Straw splitting obtained for blade angle 6° was also within the acceptable range of splitting (≥95% along with C.V. ≤40%). The effect of blade angle on split straw percentage can be explained by shearing action and straw movement i.e., agitation affecting the crop retention time on the concave. With an increase in concave bar spacing, splitting of straw decreased (**Fig. 7**). At large concave bar spacing of 14 mm with blade angles of 6° and 8°, the splitting of straw was not within the acceptable range of splitting (≥95% along with C.V. ≤40%). The reduction in splitting at higher concave bar spacing was due to less retention time of the straw on the concave as they could pass through concave opening relatively faster. **Fig. 6** indicates that an increase in cylinder speed caused better splitting of the straw. Splitting was within the acceptable range (≥95% along with C.V. ≤40%) at higher cylinder speed at any setting of concave bar spacing for blade angle of 6° and 10°. The increase in straw splitting at higher cylinder speed was due to high impact levels imparted by the bruising cylinder at high cylinder speeds. The increase in feed rate contributed to increasing the splitting of straw (**Fig. 7**). The maximum increase in straw splitting was 6.74% at concave bar spacing of 14 mm and blade angle of 10°, when feed rate increased from 15 q/h to 21.5 q/h. The increase in splitting was due to the vigorous rubbing and agitation amongst different layers of the straw at high feed rate.

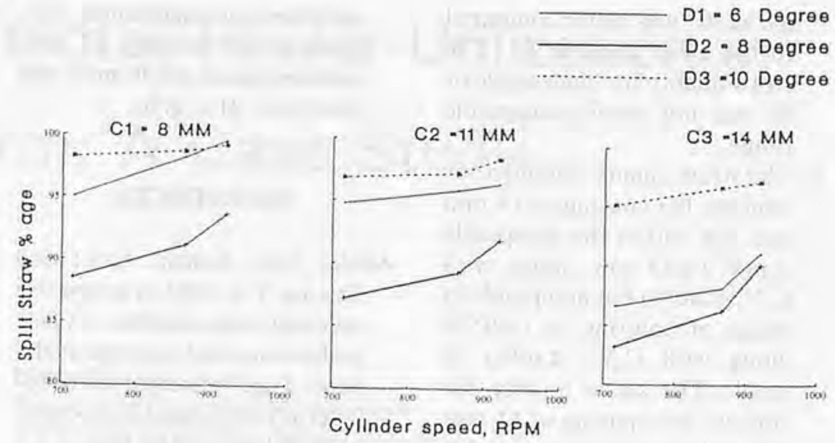


Fig. 6 Split straw percentage (%) for different cylinder speed (S) at different blade angle (D) and concave bar spacing (C) for feed rate F3 (21.5 qt/h).

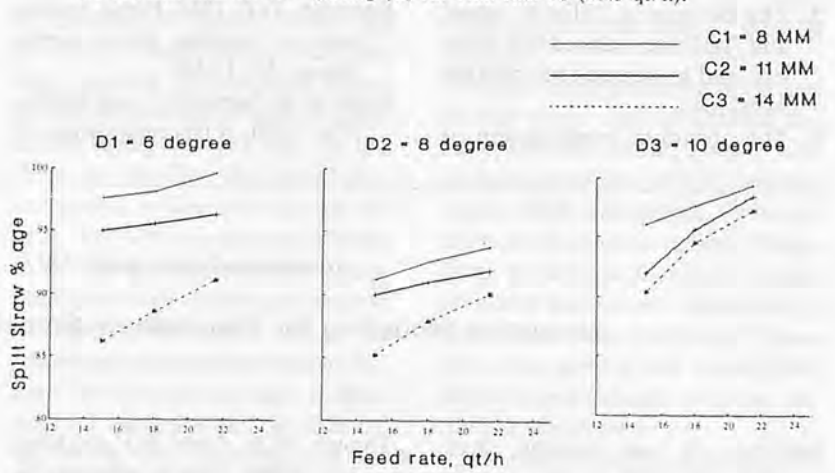


Fig. 7 Split straw percentage (%) for different feed rates (F) at different concave bar spacings (C) and blade angles (D) for cylinder speed of S3 (920 RPM).

Conclusions

1. The net specific fuel consumption for the blade angle of 8° was lowest as compared to blade angles of 6° and 10°. The net specific fuel consumption for blade angle at 10° was lower relative to the blade angle of 6°.
2. The net specific fuel consumption decreased with an increase in concave bar spacing and feed rate, hence also increased with the increase in cylinder speed.
3. The straw quality for blade an-

gle at 10° was better compared to the blade angle at 6°. The straw quality for blade angle of 8° was not within acceptable range.

4. The straw quality obtained for concave bar spacing of 14 mm was not within the acceptable range (≤25 mm along with C.V. ≤40%) but acceptable in range of splitting at (≥95% along with C.V. ≤40%) of straw. The straw quality for concave bar spacing of 11 mm was well within the acceptable range.
5. The increase in cylinder speed and feed rate reduced the straw size and increased the splitting of straw.
6. The optimum combination of variables was: blade angle, 10°; concave bar spacing, 11 mm; cylinder speed, 23.96 m/s; and feed rate, 21.5 q/h.

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Pattern of Tractor Power Utilization in a Fodder Farm: A Case Study

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Abstract

Efforts were made to determine the monthly pattern of tractor power utilization in a fodder farm. The basic purpose of the investigation was to use this information to reduce the down time of machinery during peak demand periods and to adhere to the maximum with the timeliness of farm operations by arranging the repair and maintenance activities during lean periods of tractor demand. The pattern of tractor power utilization for agricultural field operation, fodder transport, dung - transport from livestock farm, miscellaneous activities and total tractor power demand were studied. A study of the annual contribution of different horse power tractors viz. 30 to 35 hp, 45 to 55 hp, 60 to 75 hp and more than 75 hp on these operations were also analyzed.

Introduction

The demand for tractor power utilization varies during the year in every farm. The tractor power requirements vary depending upon farm size, cropping pattern, weather conditions, type of agricultural operations and many such other factors. Therefore, the study of the pattern of the monthly utilization of tractor power may be useful in many ways. It will not only provide information about the different kinds of tractor operations being carried out in the farm but also give details of tractor power utilization during the year, size of tractors being utilized in different types of operations, maximum and minimum periods of tractor demands, etc. The generated information may be utilized for the scheduling and planning of agricultural operations. Moreover, one can organize the preventive maintenances of tractors and machinery very effectively during the lean periods of demand.

In the present study, efforts were made to study the pattern of the tractor power utilization in the fodder farm of the Indian Veterinary Research Institute, Izatnagar. The entire 160 ha land of the fodder farm was exclusively cultivated for the production of fodder crops like maize (*Zea mays* L) Sorghum (*Surghum vulgre*), oats (*Danthonia* species), Berseem (*Triforium alexandrinum*), etc. This entire crop was harvested for the feeding of about 1 000 head of adult cattle. The different activities like seedbed preparation, transportation of fodder, transportation of dung from dairy farm and other miscellaneous activities were arranged through 14 tractors ranging in size between 35 hp and 100 hp.

The fodder production reports of the farm were evaluated for May, 1989 to March, 1993. It was revealed that the period between April, 1989 and March, 1990 was the best production period. Therefore, it was considered as a period when maximum timeliness of operations was fulfilled. Therefore, this period was undertaken for the present study with the following objectives:

1. To study the monthly pattern of tractor power utilization on different farm operations.
2. To determine the maximum and minimum periods of tractor utilization.
3. To study the annual use of different sizes of tractors in various farm operations.

Materials and Methods

The information was collected from the log books of 14 tractors deployed in the 160 ha fodder farm of the Indian Veterinary Research Institute. Dung was transported from the livestock farm of 1 000 head of cattle. The information gathered pertains to the type of agricultural operation, hours of use, horse-power of tractor and month of use. There were one 100 hp, one 75 hp, eight 48 to

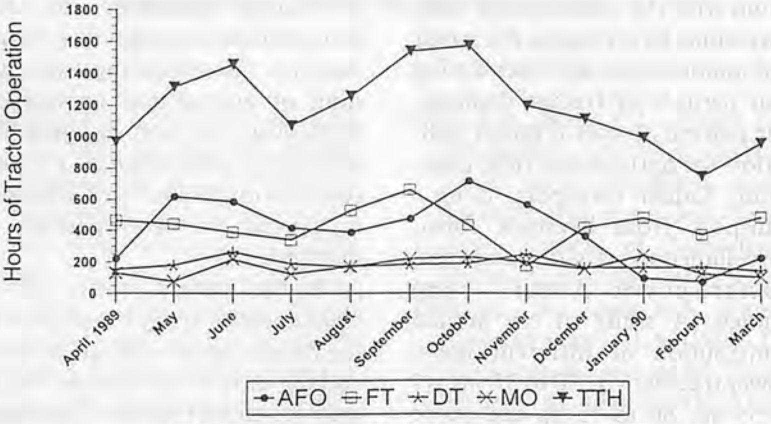
Table 1. Monthly Pattern of Tractor Power Utilization on Various Farm Operations (Unit: hours)

Month	Agricultural field operations	Fodder transport	Dung transport	Miscellaneous operations	Total
April, 1989	220.5	465.0	153.0	128.0	966.5
May	617.5	442.5	179.0	76.0	1315.0
June	586.0	389.5	264.0	216.5	1456.0
July	417.5	341.5	189.0	124.5	1072.5
August	390.0	529.0	170.0	170.0	1259.0
September	476.5	662.5	182.5	219.5	1541.0
October	717.5	436.0	190.5	231.0	1575.0
November	568.0	176.5	251.0	201.0	1196.5
December	366.5	422.0	169.0	156.5	1114.0
January, 90	99.5	484.0	165.5	245.0	994.0
February	76.5	376.0	169.0	127.0	748.5
March	225.0	486.5	144.0	102.5	958.0

*Tractor hours are irrespective of tractor size.

Table 2. Annual Use of Different Tractor Size in Various Farm Operations (Unit: hours)

Type of form operation	Size of Tractor				Total
	up to 30-35 hp	between 45-55 hp	between 60-75 hp	more than 75 hp	
Agricultural field operation	526.0 (11.05%)	2005.0 (42.11%)	1183.5 (24.80%)	1046.5 (21.98%)	4761.0 (100%)
Fodder transport	1658.5 (31.82%)	2745.0 (52.68%)	649.0 (12.45%)	158.5 (3.04%)	5211.0 (100%)
Dung collection	104.0 (4.72%)	2077.5 (93.31%)	45.0 (2.02%)	— —	2226.5 (100%)
Miscellaneous	918.0 (45.96%)	981.0 (49.11%)	93.0 (4.66%)	5.5 (0.28%)	1997.5 (100%)



TTH) = Total Tractor Hours, FT = Fodder Transport, AFO = Agricultural Field Operations, DT = Dung Transport and MO = Miscellaneous Operations

Fig. 1 Monthly pattern of tractor use.

65 hp and four 30 to 35 hp tractors in the fodder farm. The work done by these tractors was grouped into four activities, namely; agricultural field operations (seedbed preparation and sowing activity); fodder transport operation; transport of dung from livestock farm; and miscellaneous activities. These tractors were classified into four groups by size: 30-35 hp, 45 to 55 hp, 60-75 hp and 100 hp.

Data was collected for the monthly tractor utilization on these activities irrespective of tractor horse-power. Data was also compiled for the utilization of each tractor group on these activities.

Results and Discussion

Data are compiled in **Table 1** about the monthly use of tractors in various agricultural operations from April, 1989 to March, 1990. The tractor hours referred to in the table are irrespective of tractor size and provide total hours of tractor operations in a particular operation. The total monthly tractor hours of operations were compiled.

The total demand for tractor working hours for agricultural field operations flactuated between 76.5 h per month (for the month of February) and 717.5 per month (for the month of October). There was another demand peak in the month of May touching to 617.5 h per month **(Fig. 1)**. The reason for the maximum tractor requirement in May and October was basically due to seedbed preparation requirement coupled with sowing operations of summer and winter fodder crops in the same farm.

This demand was at low levels in most parts of the year, particularly from June to September and November to April. This may be the period where one can take care of the major repair and maintenance activities of the equipment plus other developmental activities in the farm. The low tractor demand periods may be utilized effectively for the upkeep of equipment to reduce the downtime of machinery during the demand periods.

The monthly demand for tractor working hours varied from 144 to 264 h on dung transport operation. Logically, the output of dung from the livestock farm should have been almost constant and as such there should have a fixed tractor demand on this operation. This variation concides with the peak tractor demand for agricultural field operations.

The tractor demand for fodder

transport operations varied from 176.5 to 662.5 h per month. The peak demand periods were in September and between January and March. There was almost no control over this demand as all the available crops were to be harvested.

The total demand for the tractor working hours in the fodder farm varied from 748.5 to 1 575.0 h per month. The periods of peak demand were in June and between September and October.

An analysis was also made on the annual use of different sizes horse power tractors in various farm operations (**Table 2**). The share of tractor use of sizes between 30 and 35 hp; 45 and 55 hp; 60 and 75 hp and more than 75 hp on agricultural field operations were 526.0 h (11.05%); 2 005.0 h (42.11%); 1 183.5 h (24.8%); and 1 046.5 h (21.98%). The use of 30 to 35 hp tractor was minimum.

In the case of fodder transport the use of the tractors was 1 658.5 h (31.82%), 2 745.0 h (52.58%), 649.0 h (12.45%) and 158.5 h (3.04%) in that order. The use of 45 to 55 hp tractor was maximum in fodder transportation from the farm.

For the transport of cow dung, a tractor of 45-55 hp range was used for 2 077.5 h which was 93.31% of total annual use. Therefore, it can be considered that this tractor size was most suitable for the purpose.

The miscellaneous operations were mainly carried out by the tractors of 30 to 35 hp and 45-55 hp range. Percentage-wise, these were 45.96 and 49.11, respectively.

Conclusion

The monthly pattern of tractor power utilization of a farm should be readily available for the planning of various activities of the farm. It will not only help in the completion of various farm work with timeliness of operations but planning and scheduling of maintenance operation of equipment will be also easier. The annual use of various sizes of tractor on different agricultural operations may be helpful for the selection of tractor size, too. ■■

Design of a Belt Thresher for Cowpea Beans

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Abstract

A conventional cylinder and concave thresher cannot be used to thresh cowpeas (*var.* Minica), due to the sensitive pericarp of the beans and their brittle nature. Based on results of tests for modulus of elasticity, threshability and aerodynamic lift, a prototype thresher was designed, transported to Guyana and tested *in situ*. This paper reports on the design of the thresher, the experimental results and its actual performance.

Introduction

The need for small-farm mechanization in developing countries has been growing in recent years. It is imperative that these countries be fairly self-sufficient in food. In Guyana, which has vast agricultural lands, small farms are increasing, as is the cultivation of legume crops, including cowpeas (*vars.* Minica # 1, Minica # 4 and Blackeye - California varieties).

Mechanically-assisted threshing of grain and seed crops has been utilized for many centuries all over the world and many developments have been made in this process. Many other studies have been carried out on the cylinder and concave thresher in the combine rather than as a stand-alone, stationary unit. [Harrison, 1992; Norris and Wall, 1986; Deere, 1973; Neal and Cooper, 1970; Arnold, 1964]

Initial investigations employing a spike tooth cylinder and concave thresher originally designed to handle rice was used in Guyana to thresh cowpeas but excessive damage occurred in the form of split beans and pericarp removal. Therefore, a new design concept was sought.

Details design, fabrication and testing of a belt-type thresher for cowpeas (*var.* Minica) were the principal goals of this study. Emphasis was placed on obtaining threshed beans with minimal damage at an efficient rate. A probability model was developed for belt threshers to confirm the physical findings but is not reported in this paper.

Design of the Machine

Selection of Threshing Mode and Mechanism

Threshing food grains and beans may be implemented using one of several modes: impact, rubbing, squeezing, or a combination of the three [Kepner *et al.*, 1978]. Of these three, the rubbing mode was chosen for the design based on the physical characteristics of the pods and the results from the impact analyses using Minica # 1 beans [Allen, 1993]. The rubbing action simulated manual separation of the pods and thus it was felt that this action would produce threshed beans with minimal damage.

Belt and Threshing Section Parameters

In order to select the type of belt for the design, a small belt thresher simulator was built [Allen, 1993]. Based on availability, low cost, effectiveness, applicability and durability, a semi-rough, rubberized canvas conveyor belt was selected from the wide selection of available belts of varying roughness, pattern and materials.

The length of the threshing bet was determined primarily on the basis of the simulations done with a belt simulator [Allen, 1993]. These results reveal that approximately two to three passes of the 0.5 m long simulator belt were needed to completely thresh the crop, and thus the belt length was estimated at 1.5 m. However, the need for an entrance length acting as a platform for feeding the crop between the belts **(Fig. 1)** led to the decision to make upper belt 0.2 m shorter to provide for this. The width of the threshing belts was chosen equal to the width of commercially available conveyor belts, 0.76 m. The effective length of the belt was 1.3 m. In order to achieve a high production rate, the speed of the threshing belt system was chosen such that it would have the capability of being tested at

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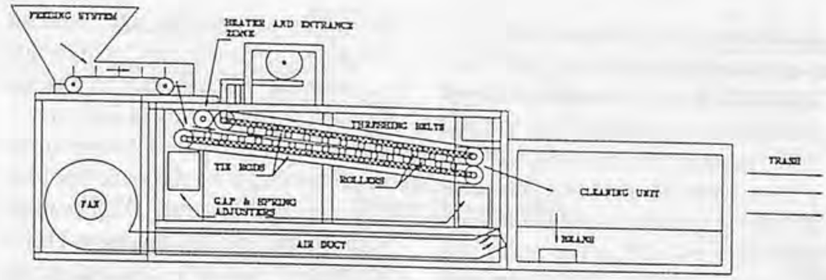

Fig. 1 Schematic of the Cowpea bean thresher.

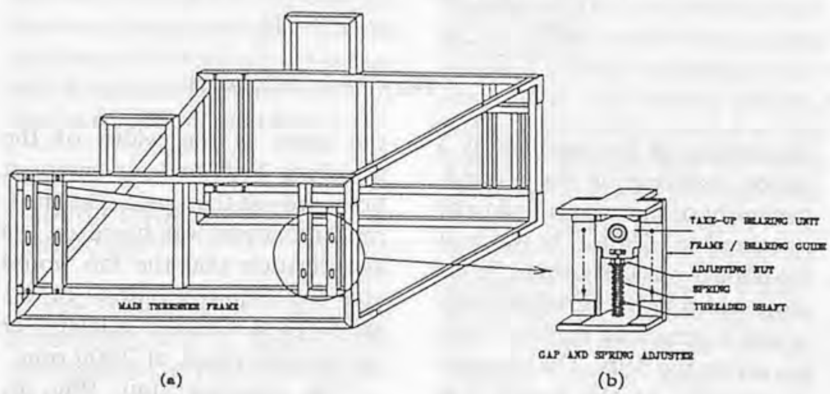

Fig. 2 Main thresher frame and gap and spring adjuster.

high speeds and relative velocities, but with an acceptable residence time for the crop. To provide the rubbing action, the upper belt was adjusted to move slower than the lower belt. The assumed optimum crop slip relative to the belt as determined from the simulations was 0.3. The range of belt linear speeds finally used during the commissioning were: for the upper belt +0.43 to −0.96 m/s; and for the lower belt +1.6 to +8 m/s where the positive sign indicates motion in the direction of the crop.

Due to their width and length, the threshing belts had to be supported along their span to prevent them from becoming concave when the crop entered the threshing zone. To provide this support, the upper half of the lower belt and the lower half of the upper belt each had a roller bed comprised of 20 mm diameter mild steel shafts. The shafts had bronze bushings at their ends which were pressed into a 50 mm × 100 mm section of hard wood board which extended along the length of the thresher belts, and was attached to the tie rods. **Figure 2a** shows the layout of the frame for the main threshing section.

Power Required to Drive Threshing Belts

From experiments with the belt simulator it was found that the energy required to slide the belts over each other with a crop mat of approximately 20 mm and a compression 'F_c' of 98 N was, on average, 3.3 Nm for a 0.5 m long by 0.18 m wide semi-rough top belt. Allowing for a safety factor of 1.5, the average energy per unit area 'E_a' used to slide the belts under those conditions was 55.6 Nm/m^2. Scaling up for the prototype size and maximum velocity, the maximum power requirement for each of the threshing belts was, therefore, calculated from the above to be 2.4 kW. Taking into consideration the entire unit, that is, both threshing belts, the feeding unit, and the cleaning unit, a total power requirement of 5.8 kW was ascertained. A 6.6 kW single cylinder gasoline engine was selected as the power supply.

Precompression of Threshing Belts

The belt thresher simulator [Allen, 1993] revealed that it was necessary to have some degree of force/compression on the crop while it was being threshed by the rubbing action. Also, the belts should not contact each other when empty to reduce wear on the belts. A further requirement was that the gap should be adjustable.

The results of the threshing belt simulations [Allen, 1993] were used to determine the force of compression required and this was calculated to be 538 N which is equivalent to 318 N/m^2 of pressure on the crop mat. Four springs at the corners of the lower belt provided this force.

The gap and spring adjuster were designed as one unit and were located on the lower belt. Self-aligning take-up bearing units with a 2.5 kN radial load capacity at 1 750 rpm were selected. The springs selected to provide this precompression were medium pressure 50% deflection - 100 mm (4″) free length - 1.9 kN load at 50% deflection. The take-up bearing unit was located at the centre of a special frame for the gap and spring adjuster **(Fig. 2b)**.

Beater

A finger-type beater was installed at the entrance section of the threshing belts to aid in the feeding of the pods into the gap between the threshing belts and to provide a few light impacts to the crop mat. Several different types of beaters (fingers and bats) and material types were tested; rubberized canvas, ductile metal and finally mild steel fingers (#8 mild steel welding rod, 3 mm diameter). The fingers were riveted to a 3 mm thick aluminum flat bar

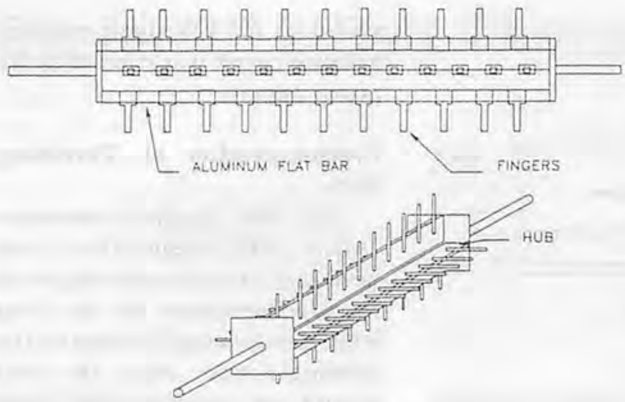

Fig. 3 Beater bar details.

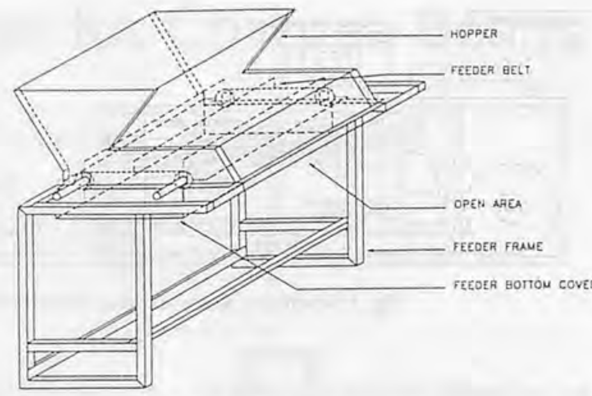

Fig. 4 Feeder sub-assembly.

which was then bolted onto a specially designed hub (**Fig. 3**). The beater spanned the entire width of the threshing belts and had an average diameter of 0.14 m.

Feeding Section

The feeding system composed of a hopper and racked conveyor (**Fig. 4**) was designed to deliver a mat of crop of a uniform thickness to the threshing belts at a uniform controllable rate. A racked conveyor belt moving in a closed conduit (to restrict the height to which the crop was heaped between the racks) was selected for the feeding mechanism. The racked conveyor was simply a fairly rigid conveyor belt with 90° angle aluminum sections riveted at fixed intervals across its width. The vertical dimension of the hopper had to be restricted due to the relatively large height of the threshing unit. The height at which the crop had to be delivered to the threshing section was 0.76 m above the ground due to the length and tilt of the threshing belts; and in order to facilitate the loading of the machine by a person standing on the ground, the height of the hopper had to be restricted to 1.38 m. The width of the hopper was designed to be the same width as the threshing belts to aid in achieving uniform feeding across the belts. The volumetric capacity of the hopper was 0.1 m^3, equivalent to approximately 2 bags (standard 40 kg (100 lbs) sugar or fertilizer bags) of lightly compressed crop. To facilitate easy shipping of the machine, the entire feeding unit was assembled on a separate frame (**Fig. 4**) connected to the rear of the threshing unit.

Cleaning System

A squirrel cage, centrifugal fan (**Fig. 5**) using backwards facing blades and an arithmetic spiral housing was designed to fit within the existing structure at the rear of the machine, under the feeding unit. The width at its output was the same as the width of the threshing belts and air enters at both ends of the shaft. The theoretical analysis was based on the specification that the fan would give the required output of 1.1 m^3/s (10 m/s outlet velocity) at an impeller speed of 2 000 rpm.

The cleaning unit (**Fig. 6**), located at the front, exit end of the threshing unit comprised of a rectangular housing open at the front rear, and closed on one side with the other being half open. A 20 mm square mesh "Vexar" sieve was installed on the inside just below the level of the threshing belts extending half-way along the length of the housing to the edge of the threshing belts. The upper end of the frame of the sieve was agitated by a pair of cams to provide a sifting action to the screen. The air flow from the cleaning fan was channelled through a chute to the front of the machine where the cleaning unit is

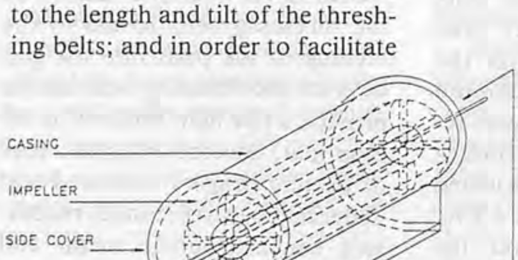

Fig. 5 Fan design details.

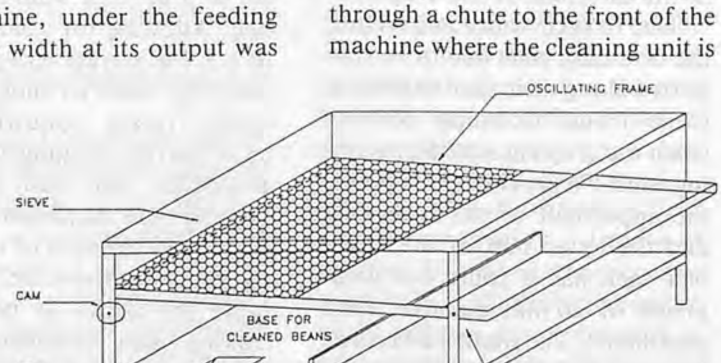

Fig. 6 Cleaner sub-assembly.

located. An adjustable baffle at the exit of the chute provided a means of varying the air flow.

In operation, as the threshed crop exited the threshing section and fell through an air stream, the lightweight threshed pods and chaff were blown off at the rear of the cleaner. The threshed beans and most of the unthreshed pods fell onto the agitated sieve where the beans passed through while the pods were bounced off at the rear end due to the hopping action of the front end of the sieve.

Experimental Testing Procedure

The objective of the main experiments was to quantify the performance of the threshing section, i.e., the threshing efficiency and damage.

Before any of the tests were carried out, about 40 kg of the Minica # 1 crop were sun-dried for a few hours for many days. This daily drying was necessary in order to extract the moisture that the crop picked up during the night since the pods were not stored in an enclosed building. Following drying, the crop was brought under the shed where the machine was located and 1.3 kg samples were weighed for testing.

The main machine variables were belt-speed and gap settings, although the beater speed was adjusted by 20%. The gap at the entrance to the thresher belts and the speed of the feeder belt remained constant during the tests. The minimum gap, 1 mm, at the exit (lower) end of the thresher belts was such that the belts just did not touch. Other lower end gaps tested were 2 and 3 mm. The maximum value chosen was approximately 50-60% smaller than the nominal width of a typical bean (7 mm). The belt speed range for both thresher belts was noted.

After measuring and recording the speed of all the shafts using a digital tachometer, the basket containing the sample was emptied into the centre of the hopper. The machine was then allowed to run until all the crop exited from the threshing belts. All the materials that passed through the sieve, and the material that fell at the end of the sieve in the re-threshing zone of the cleaner were collected and weighed. All the unthreshed pods lost out of the feeding section, those from all the sections of the cleaner, and those that may have been blown off with the trash were then collected, separated and weighed to give the mass of unthreshed pods. The beans collected in the cleaning section were then visually inspected for any damage (split and/or depericarped). The damaged beans were separated and weighed.

The moisture content of the crop was measured on a wet basis using ASAE Standard S358.2 for the pods and S352.2 for the beans [Hahn and Rosentreter, 1986].

Experimental Results and Discussion

Statistical Analysis

Of the 39 tests carried out, 23 were selected for the statistical analysis which had a reasonably constant moisture content, spring load setting, mass feed rate, upper end gap, beater speed and crop type. The threshing efficiency was the dependent variable and the residence time, relative celocity and lower gap were the independent or predictor variables.

The relative velocity (RV) was found by taking the difference between the peripheral velocity of the lower and upper belts. The residence time (TD) was determined by dividing the length 'l_c' over which the two threshing belts contacted the beans by the average velocity 'AV' of the threshing belts in which the assumption is made that the slippage of the beans is the same at their interface with both the upper and the lower belts. The average velocity (AV) was the numerical average of the two belts. The threshing efficiency (η) was calculated as the ratio of the mass of the threshed crop to the mass of the total crop, corrected for the portion that escaped at different points through the machine.

Results of Statistical Analysis

The statistical model achieved using relative velocity, lower gap, and residence time as independent variables gave the following regression equation.

$$\mu = 85.3 + 0.934\,(RV) + 2.18\,(TD) - 15.2\,(LGAP) \quad (1)$$

$R^2 = 0.519$ $\sigma = 2.4$ p-value $= 0.003$

where:

μ - theoretical threshing efficiency from the regression (%)

RV - relative velocity of the threshing belts (m/s) [range 1.5-4.5 m/s]

TD - residence time of the crop between the threshing belts (s) [0.5-4 s]

LGAP - the gap between the lower end of the threshing belts (m) [1 mm-3 mm]

σ - standard deviation

R^2 - correlation coefficient

This equation holds true for the following values of the other variables:

Moisture content - 13.5 ± 0.1% (w.b)

Upper end gap - 6 mm

Beater speed - 508 ± 60 rpm

Feeder speed - 32 ± 7 rpm

Figure 7 shows a plot of experimental and theoretical (statistical model) efficiencies versus the relative velocity for mean values of lower end gap and residence time. **Figure 8** shows similar plots of residence time for mean relative

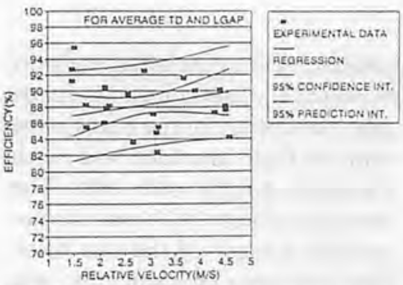

Fig. 7 Experimental and theoretical (statistical) efficiency for variation in relative velocity.

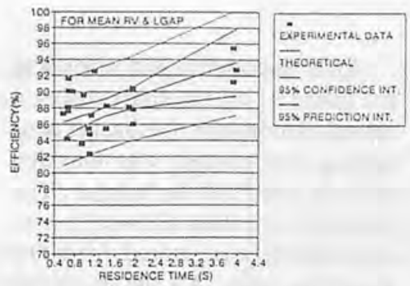

Fig. 8 Experimental and theoretical (statistical) efficiency for variation in residence time.

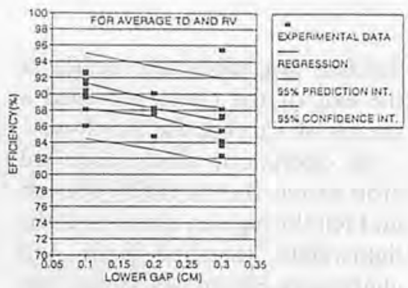

Fig. 9 Experimental and theoretical (statistical) efficiency for variation in lower end gap.

velocity and lower gap and **Figure 9** lower end gap for relative velocity and residence time. All three graphs have the confidence and prediction bands shown.

Experimental Test Results

The experimental results of the commissioning tests led to several conclusions being drawn with respect to the machine and the effectiveness of the individual parts of the belt thresher.

Effectiveness of threshing belts — The commissioning tests demonstrated that the threshing belts were very effective. It was also observed that the beater alone could not have threshed the Minica #4 beans.

In order to determine the effectiveness of the belts length, in one series of tests the lower gap was fixed at a constant value of 3 mm, to cause minimal amount of damage and the upper gap was then reduced from 50 mm to 6 mm, thus increasing the length of belt over which the crop was rubbed. The beater speed was also kept constant. It was found that, with the reduction of the upper end gap, the number of unthreshed pods decreased significantly with an estimated increase in efficiency from 25% to approximately 70%. Thus it was evident that the effective length of the threshing belts was very significant.

Effectiveness of the beater — Two commissioning tests runs aimed at determining the effectiveness of the beater. One used the beater while the other did not, with the result that the number of unthreshed pods increased when the beater was taken out of operation. Thus the pre-cracking that the beater imparted on the pods was useful in terms of increased efficiency. This agreed with the simulations carried out on the belt simulator [Allen, 1993]. However, its observed effectiveness was not as significant as that achieved when the upper gap was reduced.

Overall performance — With the optimal settings of the machine and the correct moisture content, the machine performed at 80-90% efficiency with negligible damage for Minica #1 and 55-70% efficiency with 2-10% damage for Minica #4. When the Minica #4 beans were dried moisture contents between 11 and 14%, excessive damage was encountered. The red coat of the beans became brittle and rubbed off (depericarped) very easily. This case of depericarping was even evident when manually rubbing the beans. Thus when the crop was passed between the semi-rough top, threshing belts, several of the beans depericarped. With the correct beater speed and lower gap setting, this was the only damage that was imparted to the beans by the thresher. In order to reduce this damage, the belt gaps had to be increased. This increase caused a reduced threshing efficiency for an acceptable percent damage. Thus different optimal settings are required for Minica #1 and #4 beans.

Conclusions

A "Belt Type Stand-Alone Thresher" was designed, built and tested for Minica beans. As a result of the commissioning studies and the field testing of the machine, the following conclusions are made.

1. The Belt Type Thresher provides the necessary threshing action to split open dry, mature cowpea (*var.* Minica) pods to release the beans.
2. The machine is not capable of threshing Minica beans with the vines still attached.
3. The threshing efficiency for pods only is significantly increased if the pods are cracked by a beater before passing through the belt threshing zone.
4. The residence time is one of the most significant parameters affecting the performance of the thresher. Thus the longer the threshing belts, the better will be the threshing efficiency, given that the other parameters are set at acceptable levels.
5. Threshing effectiveness is significantly better with the crop at moisture levels below 13% (w.b). Therefore, pre-dryig the crop enhances threshing.
6. The existing cleaning system separated the beans from the pods mainly by a sifting action rather than by aeration of the pods.

(Continued on page 54)

Global Assessment of Power Threshers for Rice

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Abstract

Harvest is a crucial time for rice farmers everywhere. They are anxious to reap the rewards for their season's effort. The harvest is more of a bottleneck in the humid tropics for rice growers facing a complex of weather and labor issues. Rice is a highly vulnerable crop once it reaches maturity. Delays mean serious losses in volume and quality. Power threshers have played an important role as the forerunners of labour-enhancing techniques in the riceworld. For low-income farmers with fields that are very small or difficult to access, "Western-style" threshers are inappropriate and even the small-sized but more sophisticated of the Japanese harvesting equipment range have not been adopted. Rising labor costs and manpower scarcities for harvesting have hastened the development of a wide range of small thresher designs across the riceworld in the last 40 years. In this paper, a classification and the overall characteristics of various types of power threshers are presented as a set of baseline data and to assist in future thresher designs. The advantages and drawbacks of several types are compared. Trends in the Japanese farm machinery market are analyzed to provide instructive lessons. Characteristics that accentuate cultural or regional differences between power threshers are presented.

Acknowledgements: This is a summary of information some of which is included in the "Rice Harvesting Manual", prepared for publication by the International Rice Research Institute, PO Box 933, Manila, Philippines. The author wishes to record his gratitude to Yoshisuke Kishida and staff at Shin-Norinsha's FMIRC for much valuable data that was used in the preparation of graphs presented here.

Introduction

Threshing machines have had a long and proud history in the industrialized world. Completely outdated now, in their heyday they were as important as they were large. Old threshing machines can still be seen at showdays. They are an impressive sight, especially when driven by a steam traction engine connected by an enormous belt drive to the thresher. But they are now only nostalgic museum or showtime pieces in the Western world. By contrast, in developing countries there are places where small-area* farmers do their threshing using muscle power — either human or animal — for example by foot treading or by bundle-beating. Big Western-style threshers and combines are not unknown, but they are considered too costly and heavy, or ill-suited to small and inaccessible paddy fields. Rising labor costs and manpower issues intensified with rapid industrial growth during reconstruction after World War II, and from the 1950s Japanese farmers siezed upon small power threshers. Korea and Taiwan rapidly followed, then China, India and other Asian countries, but with major cultural and regional differences in design and usage.

*'Small-area' refers to individually-owned farms that make up the greater proportion of the landholdings in rural-based societies, especially in Asia where a land holding is typically about a hectare in size. The degree of mechanization on such farms varies greatly, from nothing much more than a sickle, hoe and hand sprayer, to Japan's farmsteads, which are still around a hectare, but each with their own matching-sized tractor, tillers and thresher or even a small combine harvester.

Overview: Power Thresher Classification

Table 1 sums up the categories of power threshers. Some definitions are in order: A *stationary thresher* is one that is transported or carried to the threshing site, by contrast to a *self-mobile* or *trailed* unit that can be driven or towed in to the field.

A *head-feed* thresher is one that deals only with the panicles of the rice bundles, which may be presented to the threshing elements by hand or by a mechanical conveying device or feeder chains. A *throw-in* thresher is one in which the whole crop material is fed into the thresher feed opening. *Through-flows* are usually thresher designs in which the crop enters the threshing zone tangentially and in one pass. By contrast, in *rotary* and axial-flow threshers,

Table 1. Classification of Rice Threshers

Usage Type Classification	Basic Features
1. By mobility	Stationary, trailed, or self-mobile
2. By method of driving	Hand, foot treadle or prime mover
3. Prime mover type	Animal power, IC engine, tractor PTO, electric, direct-coupled or belt-driven
4. By manner of crop feeding	Head-feeding or throw-in
5. By feeder type	Hand feed, bundle feed, mechanical conveyor or bundle tie-cutter, metered
6. Head-feed type	Hold on, mechanical feeder chain
7. By crop flow path	Through-flow (tangential feed or end-feed), axial flow or rotary threshingand separation
8. By number of drums or cylinders	Single or multiple
9. By type of threshing elements	Wire loop, pegs or spikes, rasp-bars or hammers/blades
10. By concave type	Open, closed, peg, bar or mesh
11. By method of cleaning	Thresh only or thresh and clean
12. By method of grain collection	Container, bagging or bulking

the crop can be driven around the rotor or threshing drum up to a dozen times in its passage through the machine.

Head-feeding vs Throw-in Threshers

With a head-feed thresher, the heads are brought to bear against the rotating beaters while the straw is deliberately held back. Head-feeding is achieved by the straw being gripped either by hand, or mechanically by a pair of feeder chains. Head-feed threshers have remained popular where the straw has commercial uses. In pre-war Asia treadle powered threshers with wireloop drums were popularized. The next step was to put a power unit on these machines to rotate the same drum, or series of drums on a common shaft. These were hand-fed machines. Mechanized crop feeders came next. In Japan for example, highly sophisticated head-feeding power threshers are still marketed, and although their numbers are steadily declining, they are the main type. Most of the Japanese-manufacturered head-feed threshers are mounted on self-mobile rubber-tracked crawler undercarriage — machines that are just one or two steps away from being complete small combine harvesters. Around 11 400 threshers were produced in 1994 in Japan; this should be compared with an output of 61 200 head-feed combines. The peak year, therefore, for power threshers was 1968 when 366 000 were sold (Shin-Norinsha's FMIRC, 1996).

Since the straw is not processed through the cylinder of a head-feeding thresher, the straw is retained undamaged and the specific power requirement is low.

The drawbacks of the head-feed thresher are precisely linked with the concept of head-feeding. This type of thresher cannot digest all of the straw; the grain heads or panicles are not always uniformly presented and losses can be much higher if the operator is careless. The alternative is the throw-in thresher-the whold bundle is fed in to be processed: heads, straw, and sometimes the band as well.

Throw-in threshing takes more power, but a modest increase in engine power is usually not too costly. If the power is available, a very significant increase in throughput and field workrate is possible with a throw-in thresher especially if the drum has sufficient inertia. Practically all the threshers used in the Western world farming in earlier times were throw-in types, some being quite capable of digesting the binder twine around the sheaves as well, while others had special twine-cutting or twine-separating and feed evener attachments.

Chinese Threshers

Treadle-operated threshers are still to be found in China, but the same type of hold-on thresher with wire loop cylinder driven by electric motor is far more widespread. The Chinese have introduced rural electrification to an extent unprecedented in history. It is not uncommon to see a thresher brigade man-handling their sled-mounted thresher over to a power pole switch from the overhead power line in remote fields, far from any buildings. professor Ma Ji, formerly of CAAMS, and originator of the vertical-type reaper and vertical axial thresher, reports on an 18-meter wide electric-powered thresher at a commune threshing site.

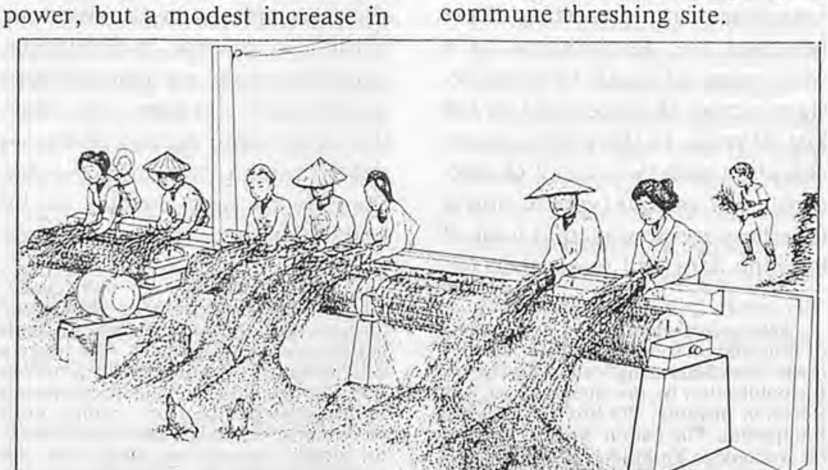

Fig. 1 Widest threshing cylinder.

This wire-loop thresher is six meters in extent. It is driven by an electric motor through a belt pulley to three drums on a common axle. This thresher was sighted by a UN team in Hua Shan Commune, Guangdong Province, China. (Drawing at IRRI by F. Jalotjot, derived from a photo in UN/FAO Bulletin No. 50, 1977). Actually, if it cam eto record-breaking, the award for the widest would have to go to the State Farm in a Chinese Province where Professor Ma Ji, formerly of CAAMS, reported that as many as ten drums have been motor-driven on a common axle 18 m wide (Ma Ji, Pers. Comm., 1996) (**Fig. 1**).

An early form of throw-in power thresher in China in the 1960s utilized a conical housing wrapped around the beating cylinder of the thresher. The crop worked its way around the rotor towards the discharge by virtue of the increasing radius of the cone envelope or housing. The conical shape imparted an axial component of movement as the crop was driven around the rotor towards the discharge. Conical threshers emerged at Tian-Jing State Farm around 1958 following electrification because the hold-on threshers could not do a thorough threshing job in japonica rices. After first-stage threshing with wire-loop rotors, the material was put through the conical thresher. By 1965 the conical design had earned a place in its own right as a rice thresher (Ma Ji, Pers. Comm., 1996). These types are still in use (Zhang Bao Zhao, pers comm, 1996). A drawback of the conical thresher is that without guide vanes the feed opening is of necessity restricted in width, or else serious backfeeding at the inlet would occur. There are other interesting designs produced in China, such as twin-drum through-flow types, vertical-shaft models and fan-type power threshers. Power thresher usage is gradually declining, however, with the rise in demand for combine harvesters, the effects of farm privatization and emergence of contract harvesting.

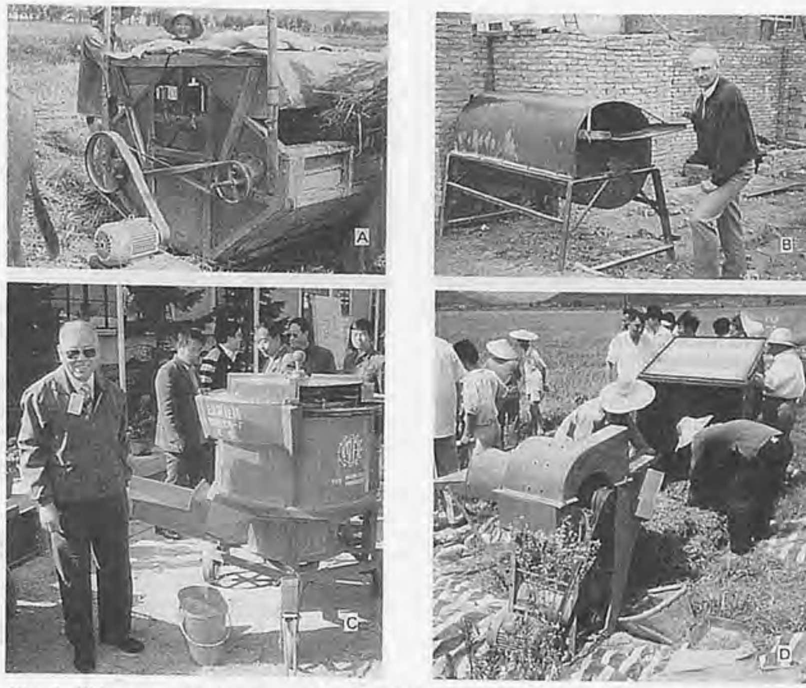

Fig. 2 Chinese power threshers. (A). Double feed head thresher; this machine is driven by electric motor and operators at either side hold bundles against the two counter-rotating wire loop cylinders. The thresher is sled-mounted and pulled to the field site by a draft animal (Photo courtesy Professor Zhang Bao Zhao, China National Rice Research Institute, Hangzhou, 1996). (B). Conical thresher design seen near Shejiazhang, shallow cone moves material around the beater drum which drives grain through concave. (C). Vertical axial flow power thresher with developer Professor Ma Ji, formerly of CAAMS, Beijing. (D). Compact cantilever shaft-mounted fan-type thresher seen in operation near Hangzhou (Author photos).

IRRI's Axial Flow Threshers

IRRI's axial flow thresher program came at a propitious time and was influential on machine adoption in the riceworld.

The axial principle had been around for a long time but it took a sustained and well-managed program led initially by Dr Amir U Khan, to assist small-scale manufacturers in developing countries to take up the challenge of fabricating threshers using this principle. The axial design has persisted because it is a more compact and effective method of threshing than tangential throughflow - if straw damage can be tolerated. The axial is also very tolerant on thresher clearances, which almost eliminates the need for concave adjustment and for close drum/concave tolerances - important factors for fabrication in less well-equipped workshops.

Fig. 3 Jaspe's light steel thresher from Pavia, Iloilo, Philippines. Modelled on IRRI's TH7 design, this particular make attracts sales by virtue of a high straw-throwing capability; 6.5-14 hp diesel, 1-2 t/h capacity, depending on engine used. Thresher weighs 160 kg without engine and can be carried on bamboo poles by 2 to 4 men (Company literature).

Fig. 4 Thailand has several manufacturers of truck-mounted threshers. There are a range of models made, for example, by Kaset Patana at their Pitsanoluke factory, requiring 75 to 150 HP (56-90 kW). They can be equipped with a power feeder, tailings return, full grain cleaning system and conveyor to sacking chute. Capacity is around 3 t/h clean paddy for the 75 HP model, up to 7-12 t/h for the KPF-8 powered by a 150 HP engine. The largest model has an 0.5 m diameter rotor 2.3 m long (Photo provided by the Company).

Fig. 5 Vietnam. This is a locally-built axial flow thresher being transported by canal barge to a field site on the Mekong Delta, South of Cantho (IRRI photo by Thomas Hargrove).

Fig. 6 A self-mobile Vietnam thresher, "Tien Thanh" brand, this unit has a four wheel drive undercarriage made up from parts of imported secondhand vehicles. With 15 HP diesel engine, capacity is around 2.4 t/h. A contractor operating this machine in 1993 charged 4% of the crop, with the help of two workers provided by the farmer (Photo from Mekong Delta by author).

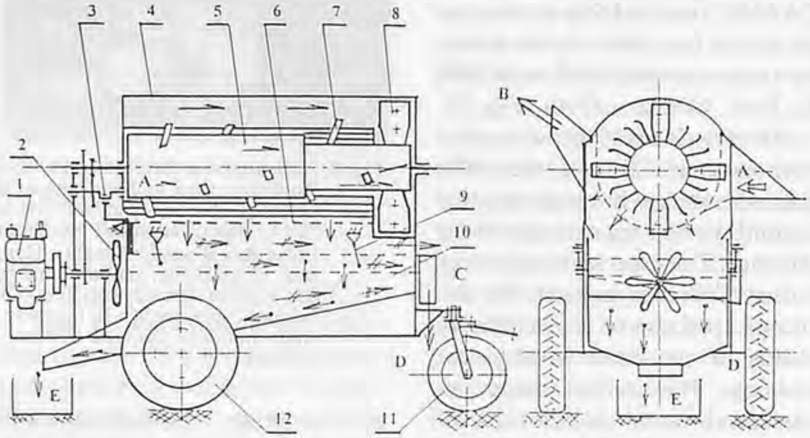

Fig. 7 Inset shows the rotor configuration in the 'Tien Thanh Works' axial-flow thresher. The stepped-diameter rotor of 0.3 and 0.4 m dia, 1.6 m long, carries just 16 bolted-on threshing elements. These were shaped from old vehicle spring steel; a classic case of war vehicle material turned to peaceful purposes. (Source: Hien et al, 1994).

Local demands for threshing equipment have made unprecedented production of power threshers possbile in many developing countries, where the thresher is the first stage in the mechanization process. Axial flow designs range from small completely hand-portable units of around 200 kg/h capacity to Thailand's truck-mounted machines capable of 10-12 tonnes/h with mechanical feeders.

Vietnam Strikes Out on its Own

Vietnam recently joined the world's top three rice-exporting nations. Dr PH Hien of the University of Agriculture and Forestry, Ho Chi Minh, sees a connection between the popularization of power thresher in the Mekong Delta and the fact that most of Vietnam's export grain come from that region. Certainly the country's initial export thrust could never have happened without the widespread adoption of threshers. By 1990, the government estimated that there were 1 000 thresher manufacturers in the Mekong Delta alone and that they had built in excess of 50 000 units.

An interesting feature of the Vietnam threshers is the absence of guide vanes and, unlike axial designs elsewhere in Asia, they use fewer specially-shaped thresher blades made from flattened leaf springs bolted onto the rotor. These blades are so shaped to drive the crop towards the discharge end.

Indian Throw-in Threshers, and Bhusa

Some of the power threshers produced for the Indian market utilize the axial-flow principle. They differ from those in SE Asia, in that Indian farmers want cereal straw — wheat straw in particular — to be chopped up finely for use as animal feed. This feed from wheat straw, called *'Bhusa'*, has in some seasons almost as much value as the grain. To achieve a simultaneous threshing and straw-chopping action, all of the crop material has to pass through the concave and the rotor is equipped with hammer blades similar to those deployed on a hammer mill. Often a fan is mounted integrally on the rotor axle to provide the air blast for the cleaning system underneath the concave, along with a heavy flywheel or two, to maintain momentum for the chopping action. Needless to say these are not manually-portable machines.

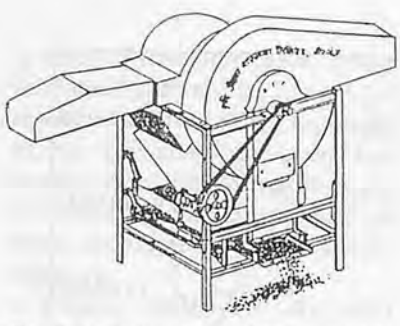

Fig. 8 An Indian power thresher model. The rotor shaft carries not only the threshing elements which mill the straw, but a heavy flywheel (or even two) and a co-axial centrifugal fan. Needless to say these threshers are heavy, not manually-carried, and are restricted to use mainly in wheat. Paddy straw is not usually required to be chopped up, in fact the straw is more often wanted intact so it can be used for thatch or matting etc. Some users object to axial-type threshers because they can damage the straw excessively.

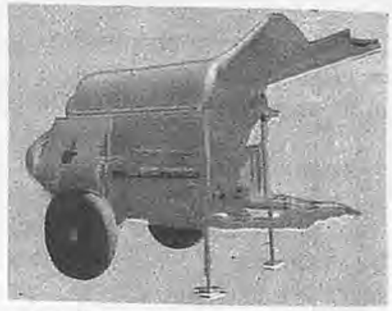

Fig. 9 This thresher, made by the Union Tractor Workshop in New Delhi has an end-feeding axial-flow rotor of 0.6 m diameter, 1.07 m long. Powered by 5 HP electric motor (3.5 kW), the unit has an advertised capacity of 500 kg of paddy per hour, but performance is higher in wheat (Company literature).

Fig. 10 Nile Delta farmers using an Egyptian-built dual-mode thresher for their paddy harvest. Capacity is around 1 t/h of rice and the drive power comes by belt from a tractor of typical size 65 HP. (Photo courtesy of Amir Khan).

Dual-mode All-crop Thresher

Where wheat and paddy are grown in rotation, such as in Egypt, parts of China and in India, farmers need threshers capable of use in either crop with a minimum of modification.

That would not pose too great a difficulty, except that in Western Asian countries and in Egypt, chopped wheat straw is quite valuable as stockfeed for cattle and camels. Threshers with rotors having milling hammers and otherwise strengthened and suitably designed to produce stockfeed have been matched to the need. This finely-chopped wheat straw is called *'Bhusa'* (India) or *'Tibn'* (Egypt). These machines do not perform well in fibrous-strawed crops like rice, soybeans or sunflower. Conversely, axial-flow threshers designed optimally for paddy do not make fine-chopped fodder from wheat straw. Dr. Amir Khan has been involved in the further development, commercialization and popularization of dual-mode thresher design and manufacturing in Egypt. The work there was initially conducted around the 'Turkish' wheat thresher. In 1988 it was found that if the louvers over the rotor of an axial-flow thresher of the beater type could be made adjustable, then dual-mode operation became practicable. A set of adjustable louvers inside the cover of the thresher drum can be fixed at 90° to the rotor axis and the straw outlet blanked out for work with wheat in the beater mode. For threshing paddy, the louvers are set at 75° to the rotor axis and the straw outlet door opened for separated straw discharge (Khan, 1990).

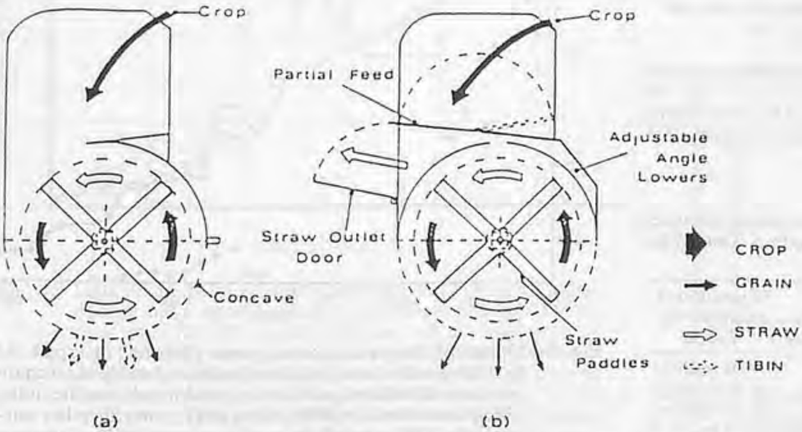

Fig. 11 Inset shows the insides of a dual-mode power thresher (Khan, 1992).

Europe's Votex Ricefan and Lova Threshers

The Government of the Netherlands has for some years encouraged thresher design as a form of foreign assistance to developing countries. A tangential-flow thresher, made by Vogelzang Andelst B.V. called the *Votex Ricefan*, a throw-in thresher has some novel features. The principal goal of this machine was portability and simplicity, with an eye to local production in developing countries.

The basic *Ricefan* thresher has one moving part, the comjbined threshing cylinder/thrower/cleaning fan. Rethreshing is needed with only one pass. By contrast, the Lova thresher from Italy's Lova combine works is a large and sophisticated trailed thresher, costing around $22 000 for 1 t/h capacity, compared with an IRRI-type of similar capacity at $2 000 in the Philippines.

Examination of the Japanese Machinery Market

Power threshers were precursors in the mechanization of Japanese agriculture. Farm equipment market trends in Japan, where the Government and Shin-Norinsha's Farm Machinery Industrial Research Corporation (FMIRC) have maintained invaluable and detailed records of the industry, are instructive for developing countries with similarly-small area rice farms. Unlike those in Western economies, average farm size in Japan is 1.4 ha.

There was a rapid escalation in power thresher numbers in the 1950s, which peaked in 1968, by which time two out of every three farms had a power thresher, and this was a decade ahead of the take-off in power tiller sales, and 20 years ahead of the emergence of wheeled tractors.

When the inevitable decline

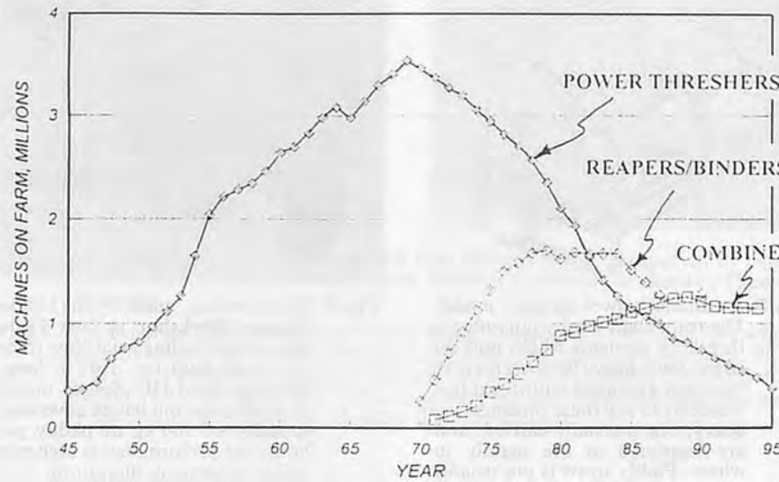

Fig. 12 Harvesting machines on farms in Japan from 1950. (Graphs plotted by the author from data provided by FMIRC, Tokyo, Japan).

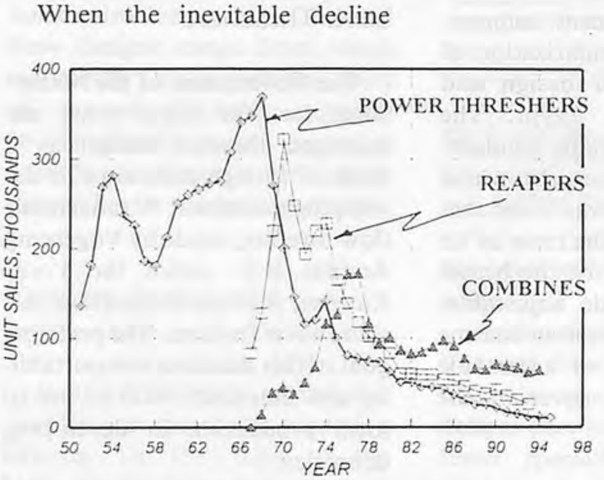

Fig. 13 Market trends of Japanese harvesting machinery (plotted from FMIRC data). Note the successive rises — first the power thresher to a peak in 1968, then the binders/reapers which peaked in 1970. The peak for combines came in 1977.

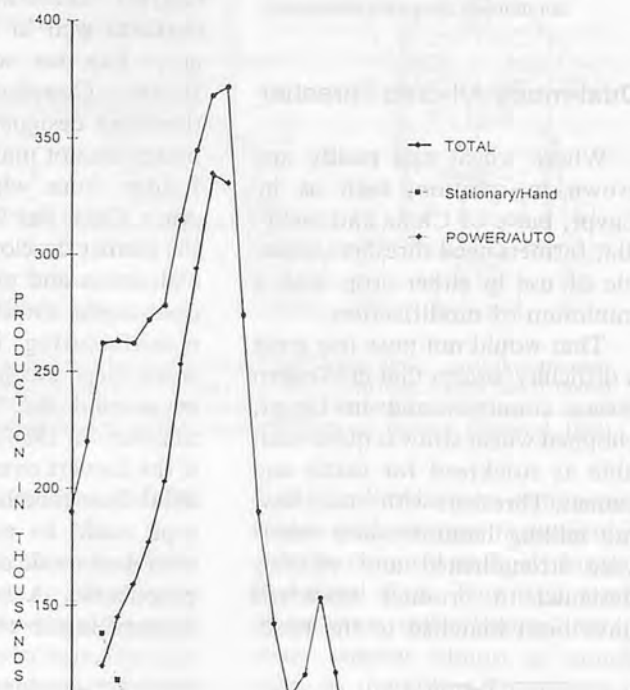

Fig. 14 Details of the production of power threshers in Japan. At first these were hand fed, but the chain headfeed mechanism soon dominated, as did the trend to self-mobile units, which accounted for 99% of the 1993 power thresher output, only 0.8% were of the stationary type for the Japanese market.

Table 2. Estimated Number of Threshers in Some Asian Countries, Power Threshers of All Types, Including Tangential, Axial-flow and Head-feeding Type

Country (Source of data)	Year Reported	Annual Production (Estimate for 1996)	Cumulative Number on Farms
China (BAEU)	1992	200 000	5.9 million
India (BKS Jain)	1996	525 000	2.35 million
Japan (FMIRC)	1995 Peak in 1968	11 000 372 363 produced	0.38 million 3.5 mill peak in '69
Vietnam (UAF)	1990	5 000	>50 000

in sales of threshers came, it was mirrored by the rise in demand for small combines on Japanese farms. Nowadays there are less farms, but, on avergage there is a combine on almost half of them (combine population 1.15 million).

Power threshers are still produced - in 1994 one-fifth as many as small combines into a steadily-shrinking market. There have been sweeping shifts from hand-feed to mechanical head-feed, and from stationary to self-mobile types.

Quantitative Assessments of Power Threshers

Information from commercial sources on 54 recent power threshers from 11 countries across the rice world has been accumulated to enable graphs to be made of power versus throughput and, in the case of axial-flow threshers, versus rotor width. Least-squares regression yields the result that for this group of machines as a whole, specific power (power requirement per unit of throughput, also measured by the slope of the regression line Power (kW) = 6.125*Throughput (t/h) + 0.53 for the data subset) was 6.125 kWh/t of rough rice grain throughput.

For the axial-flow threshers only, the slope coefficient for the trend for throughput versus rotor size was 4.79 t/h per meter of rotor length, and 5.98 kWh/t of throughput. For the head-feeding threshers only, the power versus throughpult coefficient, specific power, was 3.05 kWh/t, or one-half of the characteristic for the threshers as a whole. This is to say that a head feed thresher only needs falf the power of the other types as a whole. This type of compact power thresher was not intended for capacities much above 1 t/h, because the feed tray is usually manually loaded.

A qualification: The thresher performance parameters plotted here (with a few exceptions) are from commercial sources and are not from independent field test data. As such, they are intended to be indicative of the power and throughput performance of each type of thresher. They cannot be considered precise, but trend data, and maximum power demands only. The most economic in terms of power is the head-feed type of thresher, but these are restricted in capacity by the feeder. In order to attain higher capacities, e.g., above 2 t/h of grain throughput, throw-in or whole crop power threshers in rice must have a power feed mechanism. Apart from that, power feeders are safer than manually-fed threshers.

Unless the feed apron is of sufficient length, there is always a

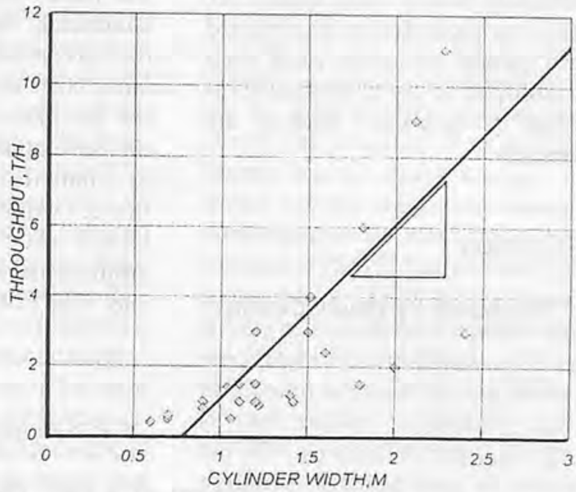

Fig. 16 Axial-flow power thresher characteristic plot of throughput versus rotor length. Correlation coefficient was R^2 = 0.607 for the prediction equation Throughput (t/h) = 4.79*Rotor Length(m) - 3.75.

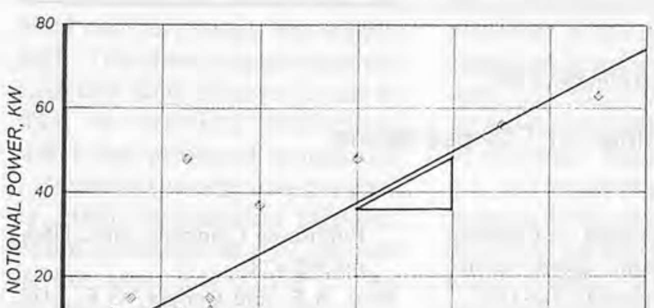

Fig. 15 Data on 54 different power threshers has been accumulated here and a regression line fitted to generate a slope coefficient of 6.125 kW (or 8.2 HP) per t/h of rough rice; ie 6.125 kWh/t, this can serve as a guide to specific power demand for Asian threshers in rice. This graph was derived from commercial information on 54 different power threshers from 11 countries across the riceworld. Correlation coefficient was R^2 = 0.865 for the prediction equation Power (kW) = 6.125*Throughput(t/h) + 0.53.

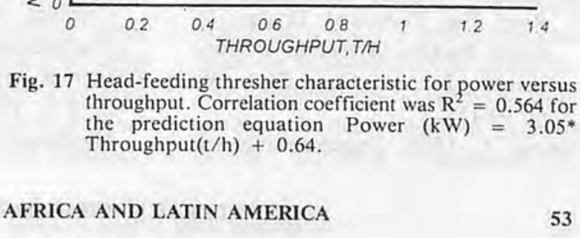

Fig. 17 Head-feeding thresher characteristic for power versus throughput. Correlation coefficient was R^2 = 0.564 for the prediction equation Power (kW) = 3.05*Throughput(t/h) + 0.64.

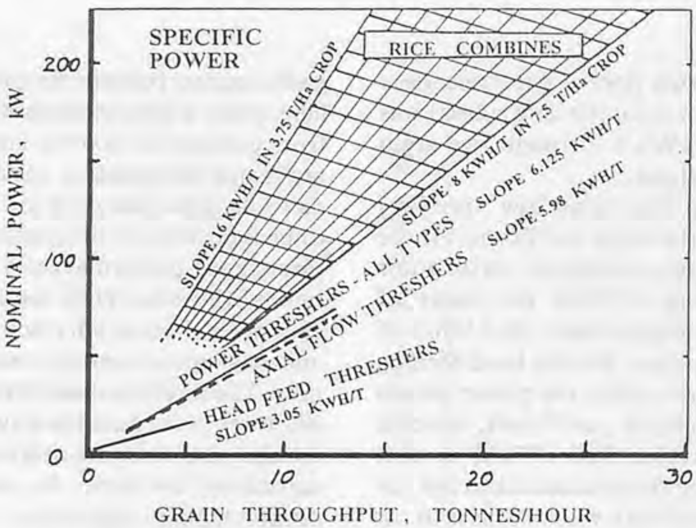

Fig. 18 Roundup of three types of power thresher characteristics, versus the combine characteristics out of an assessment of 70 combines from across the rice world; the slope characteristic for the set of combine data becomes 8 kWh/t in a 7.5 t/ha crop for a combine with 7 m front operating at 5 km/h.

risk of the operator getting a hand or arm pulled in to the drum or rotor. The Indian milling-type threshers, which make Bhusa, are the most hazardous in that regard and Indian standards have been established to try to minimize injuries to operators feeding the thresher.

Summary

Threshing by power threshers accounts for the bulk of the rice crop prolduced in developing countries. Even though many of the paddyfields are still cut by handsickle, threshers help alleviate the harvest-time bottleneck. Rising labor costs and manpower scarcities for harvesting have hastened the development of a wide range of small thresher designs across the rice world in the last 40 years. IRRI's axial flow thresher program came at a propitious time and was influential on machine adoption in a number of countries.

The axial flow thresher design has persisted because it is a more compact and effective method of threshing than tangential throughflow, where straw breakup can be tolerated. Axial flow threshers have not caught on in places like Japan however where the straw is wanted largely intact and Japonica varieties predominate. Japanese harvest equipment market trends are instructive in showing how machinery choices have shifted over time in a small-area farming setting. In Japan as elsewhere, power threshers were the precursors to mechanization.

Local demands for threshing equipment have made unprecedented production of power threshers possible in many developing countries. The thresher has proven to be an item that is needed and can launch indigenous manufacturing capabilities. Graphs and parameters provide guidelines for power thresher development. ■■

(Continued from page 46)

Design of a Belt Thresher for Cowpea Beans

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Design and Performance Evaluation of a Small-scale Conduction Type Grain Dryer

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Abstract

In order to reduce the mildew losses on grains, on the basis of the results of test and optimizing analysis of the first dryer, a new type of grain dryer with high temperature, quick drying was developed in the light of the present economic and technical conditions of the vast countryside in South and East China. A quality test of dried rice, performance test and production test were carried out. The dryer is easy to operate and works reliably. The qualities of rice dried by the dryer were found comparable with those of sundried rice. Moreover, the head rice percentage was slightly high. Therefore, it was concluded that this kind of dryer could be used in practical production, which has profound significance for solving the perennial problem of grain deterioration in developing countries due to delayed drying, especially during the wet season.

Introduction

Drying is one of the most critical rice post-harvest technologies. Grain deterioration due to delayed drying is still very serious in developing countries, especially in tropical and subtropical regions. The grain dryers and drying technology are still neither sufficient nor efficient in developing countries. In the course of developing mechanization of agriculture, Western Europe, North America, Japan and the former Soviet Uniot laid much stress on the development and application of dryers. In China, studies on grain dryers were begun later than other agricultural machinery. The number and types of grain dryers in existence are few. Sundrying of grain is still the predominant method for drying grain and other crops in the vast countryside. The grain dried by means of dryers is less than 2% of the total output. However, if the typhoon hit or it rains continuously, the germination, and mildew and rot losses of grains due to delayed drying are very serious. According to statistics, the losses of grain deterioration are 5-18 million t every year in China[1], which not only affects grain output and income of peasants, but also harms peoples health directly. So, it is indispensable to dry grain with dryers.

China is one of the most important rice bowls in the world. However, the grain dryers developed before were costly, large scale and low utilization ratio, and they do not suit present economic and technical condition and production scale of the farmers. This study aimed to solve the perennial problem of grain deterioration due to delayed drying, especially during the wet season, by providing the mass of farmers with a multi-purpose dryer which is simple, inexpensive and practical.

Hall (1961)[2], Chancellor (1968)[3] studied conduction drying of grains. Their studies had shown the potential of using high temperature, quick-drying of grains without significant damage to the grains. Besides, Jindal and Obaldo (1986)[4] found that high temperature (100-140°C) quick-drying of high moisture paddy had the effect of thermal disinfestation and could improve the storability of the paddy. Arboleda, J.R. (1974)[5] concluded that high temperature, quick-drying of paddy would have a parboiling effect that gave high milling recovery.

In view of the above-mentioned indings, we developed a conduction type, continuous flow drum dryer with high temperature, quick-drying in 1989. The single-factor tests to study the influence of the main technical parameters on the performance of the dryer, the quadratic orthogonal rotary combination tests and regression analysis to establish the quantitative relationships between the technical parameters (such as average drum surface temperature, cylinder rotation speed and feeding speed of grains) and performance indexes (such as heat consuming rate, average amount of moisture removed per hour, grain quality after drying and moisture content reduction rate per pass), the optimization calculations to make the dryer do better dry quality and drying efficiency, and the theoretical analysis of the forces applied to grains and motion locus of grains to calculate the retention time and contact heating time of grains in the dryer were carried out[6, 7]. We found the optimal combinations of the main technical parameters as follows: cylinder rotation speed was 8-10 r/min; cylinder surface temperature was 180-200°C; and the quantity of grains fed per hour was 230 kg.

On the basis of these research results, a second dryer was developed, and the performance and the production tests were carried out.

Working Principle and Design of Dryer

Working Principle

The burning of fuel directly heats the cylinder. The grains absorb heat and moisture evaporates when in contact with the inner surface of the cylinder and move in the dryer. Meanwhile, the air in the dryer is also heated. The hot-air, which acts as the drying medium, continuously heats grains and takes away moisture from grains. Not only conduction heating but also convection heating in the dryer take place. Moreover, the convection was sufficient to carry away the moisture as rapidly as vaporization occurs. In this way, grain could be dried quickly.

Design Criteria

In the light of the present economic and technical conditions of the vast countryside in South and East China, the design criteria followed were:

1. *High quality of dried grains* — The grain drying should be accomplished without damage to the grains. The grain should be uniformly dired, the quality of which should equally match that of sundried grain.

2. *Small scale* — It should be suitable for the small scale of farming in the South and East China. The throughput capacity of the dryer should be about 1 ton per workday.

3. *Simplicity* — The designed dryer should be simple such that it can be manufactured by local farm machinery factories, and operated and maintained by farmers without any special training.

4. *Low cost* — In order to reduce the cost of construction and maintenance, the availability of construction materials, power and fuel materials should be available locally. The dryer should be manually or mechanically operated according to different local conditions. The fuel of the dryer can be either coal or agrowaste materials, such as soybean stalks, corn cobs, rice strains, firewood, jute stem, etc.

5. *Mobility* — A movable dryer should conveniently supply service for several farmers, minimize transport cost of grains and reduce grain losses.

6. *High technical efficiency* — The dryer should reduce the moisture content of grains to a level that will arrest deterioration (18-20% for paddy). Meanwhile, the dryer should have a high thermal efficiency.

7. *Multi-purpose* — The dryer should also be used to dry other grains or other agricultural products in addition to drying paddy.

Structure and Main Technical Parameters of Dryer

Structure

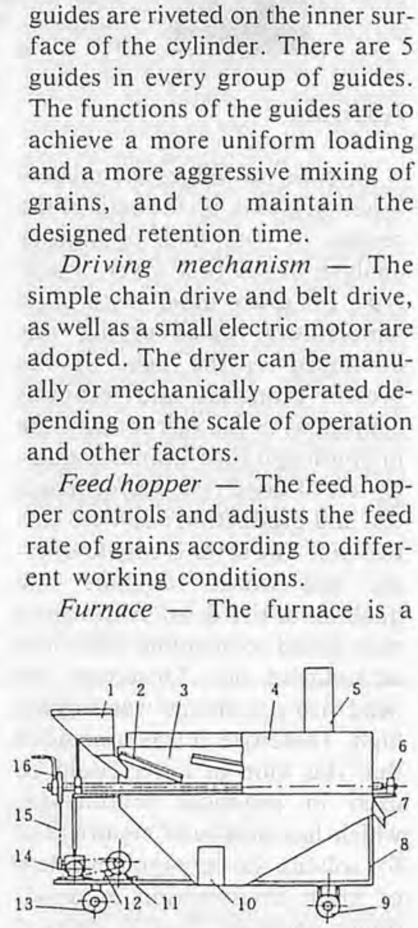
The dryer consists mainly of the drying cylinder, the feed hopper, heating furnace, main frame, transport wheels and the drive mechanism **(Fig. 1)**.

Drying cylinder — The cylinder is supported by two bearings on the main frame with on inclination of 1.5°. Four groups of guides are riveted on the inner surface of the cylinder. There are 5 guides in every group of guides. The functions of the guides are to achieve a more uniform loading and a more aggressive mixing of grains, and to maintain the designed retention time.

Driving mechanism — The simple chain drive and belt drive, as well as a small electric motor are adopted. The dryer can be manually or mechanically operated depending on the scale of operation and other factors.

Feed hopper — The feed hopper controls and adjusts the feed rate of grains according to different working conditions.

Furnace — The furnace is a



Legend:
1. Feed hopper
2. Guide
3. Drying cylinder
4. Cover
5. Chimney
6. Bearing
7. Outlet
8. Frame
9. Transport wheel
10. Furnace
11. Motor
12. Belt
13. Pilot wheel
14. Deceleration mechanism
15. Chain
16. Driving handle

Fig. 1 Schematic drawing of dryer.

simple enclosure under the cylinder, the heat insulating cover of which is made of asbestos in order to concentrate the heat.

Transport wheel — The transport wheels renders the dryer easy to transport from one area to another.

Main Technical Parameters

On the basis of the test and theoretical analysis, the dryer was improved and manufactured. The main structure and technical parameters are as follows:

Lengh × width × height = 2 65 mm × 764 mm × 1 880 mm;

Diameter of cylinder × length = 450 mm × 1 660 mm;

The inclination of cylinder = 1.5°;

The spiral angle of guides in front and rear section = 60°;

The spiral angle of guides in center section = 7.5°;

The cylinder surface temperature = 180-200°C;

The quantity of grains fed per hour = 200 kg;

The rotation speed of cylinder = 10.37 r/min;

The throughput capacity with moisture reduction rates of 8% = 100 kg/h.

Table 1. Measured Results of Performance Tests

Item	1st Test	2nd Test	Average
Initial grain temperature (°C)	34.2	34.5	34.4
Grain temperature after drying (°C)	62.6	63.2	62.9
Environmental temperature (°C)	35.0	35.0	35.0
Relative humidity (%)	78.0	77.0	77.5
Puffing rate (%)	0	1	0.5
Initial moisture content (%)	22.18	22.12	22.15
Moisture content after drying (%)	20.07	19.93	20.00
Moisture content after cooling (%)	17.91	17.83	17.87
Firewood consumed (kg)	10.05	10.19	10.12

Table 2. Performance and Economy Indexes of Dryer

Indexes	Results
Moisture reduction rates (%)	4.28
Heat consuming rate per kg moisture evaporated (kJ/kg)	7482.13
Mechancial energy consuming rate per kg moisture evaporated (kJ/kg)	76.96
Total energy consuming rate per kg moisture evaporated (kJ/kg)	7 559.08
Cost of heat consuming (US$/kg)	0.00057
Cost of total energy consuming (US$/kg)	0.00060
Drying cost of 1 kg grains (US$/kg)	0.00341
Throughput capacity of dryer with the moisture reduction rate of 1% (kg/h)	856.0
Drying intensity ($kg \cdot m^{-3} \cdot h^{-1}$)	20.36

Table 3. Measured Results of Production Test and Performance and Economy Indexes of Dryer

Item	Results
Initial moisture content (%)	26.47
Moisture content after 1st pass drying (%)	23.625
Moisture content after 1st cooling (%)	21.36
Moisture reduction rate of 1st pass (%)	5.11
Moisture content after 2nd pass drying (%)	18.42
Moisture content after 2nd cooling (%)	16.94
Moisture reduction rate of 2nd pass (%)	4.42
Puffing rate of two passes drying (%)	2.00
Total moisture reduction rate (%)	9.53
Heat consuming per kg moisture evaporated (kJ/kg)	9118.11
Throughput capacity of dryer with the moisture reduction rate of 1% (kg/h)	875.1

Tests and Analysis

Performance Test

The performance test was done in the Experimental Farm of Zhejiang Agricultural University. The test rice was the early *indica* variety, and fuel used was the firewood with a calorific value of 15 910 kJ/kg.

The main performance indexes of the dryer have met the design requirements. The drying cost of 1 kg grains is only US$0.0034 (including the wages of operators), which is cheap enough to be accepted by the farmers. The puffing rate is only 0.5%, which showed that the high temperature, quick-drying has no significant damage to the grains dried. The dryer gave a throughput capacity of more than 1 t per workday, if the grains require reducing moisture content to 8%. The dryer is suitable to the present production scale of the farmers in South and East China.

Production Test

To verify the performance test results and to test the reliability of the dryer, a production test was carried out. The 2nd pass drying was done after two h of the 1st cooling. The fuel used are stems of jute with a calorific value of 15 366 kJ/kg.

The grains used in this test had a very high initial moisture content of 26.47%. The results of production test showed that the high wet grains could be dried to a designed level of moisture content in two passes of drying, which would arrest deterioration (approximately 18-20% for paddy).

Most of the performance and economy indexes (such as moisture reduction rate, and throughput capacity) tallied with the results of performance test. However, the heat consuming rate was increased from 7 559.08 kJ to 9 118.11 kJ. This is because that the stem of jute is easy to be burned, the furnace door would be frequently opened to add the stem of jute, and the loss of heat increased. Moreover, the dryer has never broken down in the production test and the more than 2 years of utilization.

Quality Test of Dried Grain

The effects of high temperature quick-drying with different numbers of pass and the final drying

Table 4. Effects of the Number of Drying Passes and the Final Drying Method on Rice Quality

Number of drying passes	Final drying method	Brown rice recovery	Milled rice recovery	Head rice percentage	Whiteness degree
Sundried		80.10	71.96	64.58	86.5
1 Pass	Shaded dry	81.00	71.56	66.84	83.0
2 Passes	Shaded dry	80.30	71.40	67.04	80.00
1 Pass	Sundry	80.20	72.50	65.24	85.5
2 Passes	Sundry	80.00	71.74	64.98	84.7

method on grain quality were investigated by analyzing the quality of grain it dried. The grains were milled by an experimental huller and an experimental mill. The brown rice recovery, milled rice recovery, head rice percentage and the whiteness degree were tested in the light of the State Standard of China (**Table 4**).

It could be observed from **Table 4** that the number of drying passes and the final drying method did not show any significant effect on the brown rice and total milled rice recoveries. As compared with sundried rice, the head rice percentage of grains dried by high temperature, quick-drying was raised slightly. It may be explained by the fact that vitamin B in the grain has been diffused into the endosperm under high temperautre and the gelatinization effect has caused cementing of the grain cells, which results in reducing breakage[8]. On the other hand, the whiteness degree was slightly lower which was suspected to be caused by some chemical reactions that may have taken place during the high temperature, quick-drying. Further study on the mechanism should be dońe later.

Conclusions

(1) The high temperature, quick-drying of high moisture grains to a level of moisture content that would arrest deterioration immediately after harvest was a viable technique for grain quality preservation, which would contribute to solving the perennial problem of grain lost due to delayed drying.

(2) The high temperature, quick-drying method did not show any significant effect on brown rice recovery nor total milled rice recovery. Moreover, the head rice percentage was raised slightly, compared with that of sundried rice.

(3) The performance and economy indexes of the developed dryer are in accord with the demands of design criteria. The dryer was a simple structure, low cost, convenient to use and maintain, high throughput capacity, versatile, and reliable. It not only could dry paddy, corn, wheat and other grains, but also could be used to dry or roast peanut, tea, melon seeds, beans, etc.

(4) This drum grain dryer is suitable not only for the vast countryside of China, but also the rural area in tropical and subtropical regions of developing countries.

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Design of Solar Dryer for Dates

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Abstract

A solar dryer is designed to dry dates under controlled and protected conditions. A prototype of the dryer is constructed to be used in experimental drying tests. This paper describes the design considerations followed and presents the results of calculations of design parameters. To dry a daily batch of 100 kg of dates from 49% wet basis to 21% w.b. in a drying time of 9.8 hours under average ambient conditions of 32°C air temperature and 65% relative humidity with incident solar radiation of 22.5 MJ/m^2/day, a minimum of 16 m^2 solar collector area is required. The ambient conditions are for July, August and September. The prototype dryer is sized to have a minimum collector area of 1.6 m^2.

Introduction

Date palm is a major crop grown in Oman for both local consumption and export (OMAF, 1990). Dates are sun-dried by farmers in the open air to preserve them before they are processed, packaged, sold or consumed. During open air sun-drying uncontrolled weather conditions reduce the drying efficiency and the products become contaminated (Sodha, et al, 1987).

The use of fossil fuel or electrical energy in artificially heated air drying is costly. The use of solar energy in drying under controlled conditions will improve product quality and reduce the cost of drying (Sodha, et al, 1987). The development of a solar cabinet dryer designed to provide solar drying under controlled and protected conditions was, therefore, undertaken with the aim of reducing the time span required to dry a specified quantity of dates and improving the quality of the dried product.

The specific objectives of the project are the design of the solar dryer, the construction and testing of the dryer for drying dates and the compilation of technical and cost data for the use and management of the dryer. This paper reports on the design of the dryer for conditions in the Sultanate of Oman and the construction of a prototype dryer for experimental drying tests.

Conditions in Oman

The Sultanate of Oman is located between longitudes 52 and 60° East and latitudes 16 and 26° North. The climate zone is dry tropical characterized by extreme heat at high sun season around June and coolness at low sun period around January. Summer climate in Northern Oman is one of the hottest in the world and the temperature as high as 55°C have occurred (OMAF, 1989b). Summer months run from April to October. The maximum average temperature during June is 40°C (OMAF, 1989b). The intense heat from solar radiation provides solar heat for drying.

The growing of dates in Oman takes place mainly on the Northern Coast (Batinah) and in Central Oman (Interior). The common date varieties produced are Fardh, Hillali, Khalas, Khusab, Khuneezi, Mabsli and Naghal. Dates are harvested at moisture contents ranging from 34 to 74% wet basis (OMAF, 1991). The average moisture content at harvest for 16 varieties grown in all date producing areas is 49% w.b. The desired moisture content for storage is 21% w.b. or below (King and Bolin, 1972). Date production levels range from 2 to 4 t/ha and 4 to 8 t/farm or holding per year, the average farm size being two hectares (OMAF, 1989a). Date harvesting period is from April to October with the peak period being July to September.

Design Features of the Dryer

The solar dryer has the shape of a home cabinet with tilted transparent hinged top. The angle of slope of the dryer cover is within 30° for the latitude of location (Sodha, et al, 1987). The dryer is set on casters to make it mobile. It is provided with air inlet and outlet holes at the front and back, respectively. The outlet vent is at a higher level. The vents have sliding covers which control air inflow and outflow.

The movement of air through the vents, when the dryer is placed in the path of airflow, brings about a thermosiphon effect which creates an updraft of solar heated air laden with moisture out of the drying chamber. The source of air is natural airflow. When the front vent is connected to a self-propelled blower, forced air may be used. An electrically powered fan may also be used at either of the vents to provide forced air stream.

Solar Dryer Design Considerations

In the design of a solar dryer, design conditions or assumptions and calculations have to be established. Design considerations and steps followed for the determination of design parameters include:

1. *Harvesting time to establish the period during which drying is needed.* The period reflects ambient temperature and relative humidity conditions.
2. *Quantity of product to be dried at a given time and initial and final moisture contents of the product for the calculations of moisture to be removed.* The amount of water to be removed from the product, m_w, in kg is estimated from the following expression:

$$m_w = \frac{m_p(M_i - M_f)}{100 - M_f} \quad (1)$$

where m_p is the mass of product, kg; M_i is the initial moisture content, % wet basis and M_f is the final moisture content, % w.b.

3. *Sunshine hours for the selection of drying time.* Average drying rate, m_{dr}, kg/h is determined from mass of water to be removed by solar heat and drying time.
4. *Ambient air temperature, air relative humidity and temperature of drying air.* These are for the determination of initial and final humidity ratios from Enthalpy-Humidity ratio (h-w) diagram (Sodha et al, 1987) and sorption isotherm (Ayranci et al, 1990). Airflow rate required, m_a, kg dry air/h is then calculated from the following expression (Sodha, et al, 1987).

$$m_a = \frac{m_{dr}}{W_f - W_i} \quad (2)$$

where m_{dr} is the average drying rate, kg water/h; W_i is the initial humidity ratio, kg water/kg dry air and W_f is the final humidity ratio, kg/kg dry air. Volumetric airflow rate, V_a in m^3/h, is obtained by dividing m_a by density of air which is 1.1 to 1.2 kg/m^3. For high sugar content foods the maximum temperature of drying air allowable ranges from 65 to 70°C (Sodha et al, 1987).

5. *Daily solar radiation to determine energy received by the dryer per day.* From the total heat energy, Ein kJ, required to evaporate water and net radiation received, the solar drying system collector area, A, in m^2 can be calculated from the following relationship (Sodha et al, 1987):

$$E = m_a(h_f - h_i)t_d \quad (3)$$

$$A = \frac{E}{I\eta} \quad (4)$$

where h_f is the enthalpy of drying air in kJ/kg dry air; h_i is the enthalpy of ambient air, kJ/kg dry air; t_d is drying time in hours; I is the incident radiation, MJ/m^2/day and η is the collector efficiency, 30 to 50% (Sodha et al, 1987). From the collector area, bin area or dimensions can be determined.

6. *Wind speed for the determination of air vents area or dimensions.* The air vent area is obtained by dividing volumetric airflow rate by wind speed.
7. *Air pressure head and power.* Air pressure head, H in m, is used for the determination of air pressure, P_a N/m^2, i.e., air driving force per unit area. The relationship for determining the air pressure is (Wieneke, 1980):

$$P_a = g(\varrho_1 - \varrho_2)H \quad (5)$$

where g is the acceleration due to gravity, in m/s^2, and ϱ_1 and ϱ_2 are densities in kg/m^3 of ambient and warm air, respectively. The product of P_a and V_a gives the air power, A_p in watts.

Design Calculations

To carry out design calculations and size of the dryer, the design conditions and assumptions applicable to Oman are required. The conditions and assumptions summarized in **Table 1** are used for the design of the date dryer.

From the conditions, assumptions and relationshps, the values of the design parameters are calculated. The results of the calculations are summarized in **Table 2**.

Table 1. Design Conditions and Assumptions

Item	Condition or Assumption
Location	Batinah Coast (Seeb - 23°35′N, 58°17′E)
Crop	Dates
Variety	General
Drying period	July to September
Harvesting days	60 (20 days/month)
Quantity of crop to be dried for season	6 t
Daily drying batch (loading rate)	100 kg
Initial moisture content (moisture content at harvest), M_i	49% w.b.
Final moisture content (moisture content for storage), M_f	21% w.b.
Drying time (sunshine hours) t_d	9.8 h
Ambient air temperature, T_{am}	32°C (Average for July to September)
Ambient relative humidity, Φ_{am}	65% (Average for July to September)
Maximum temperature allowable, T_{max}	70°C
Incident solar radiation, I	22.5 MJ/m²/day (Average for July to September)
Collector efficiency, η	30%
Wind speed, S_w	2.5 m/s

Table 2. Values of Design Parameters

Parameter	Value	Data or Equation Used
Initial humidity ratio, W_i	19 g water/kg dry air 0.019 kg/kg d.a.	T_{am}, Φ_{am}
Initial enthalpy, h_i	80 kJ/kg d.a.	T_{am}, Φ_{am}
Final enthalpy, h_f	120 kJ/kg d.a.	T_{max}, W_i
Equilibrium relative humidity, Φ_f	60%	M_f, Isotherm
Final humidity ratio, W_f	0.032 kg/kg d.a.	Φ_f, h_f
Final operating temperature, T_f	42°C	Φ_f, h_f
Mass of water to be evap, m_w	35.4 kg	1
Average drying rate, m_{dr}	3.6 kg/h	m_w, t_d
Airflow rate, m_a	276.9 kg da/h	2
Airflow rate, V_a	249.5 m³/h	m_a, air density
Total energy requirement, E	108 545 kJ/day	3
Solar collector area, A	16 m²	4
Vent area	0.03 m²	V_a, S_w
Air pressure, P_a	0.7 N/m²	5
Air power, A_p	0.05 watt	P_a, V_a

Prototype Dryer

A prototype solar cabinet dryer so sized that it is 1.6 m (5 ft, 0 in) long, 1.0 m (3 ft, 0 in) wide and 1.03 m (3 ft, 4 in) high at the back and 0.5 m (1 ft, 6 in) high in front is constructed (**Fig. 1**). There is a rear air vent located 0.1 m (4 in) below the back top edge (**Fig. 2**). The solar collector surface of the drying chamber is 1.6 m² and is 0.2 m (8 in) from the bottom of the dryer. The collector area of the prototype is calculated on the basis of a loading rate of 10 kg per day. The collector surface is the drying floor. It is constructed from corrugated metal sheet and insulated underneath (**Fig. 3**).

The dryer is set on four casters to make it mobile. The total cost of the dryer is US$413 (Rial Omani 160). It is to be used in experimental drying tests.

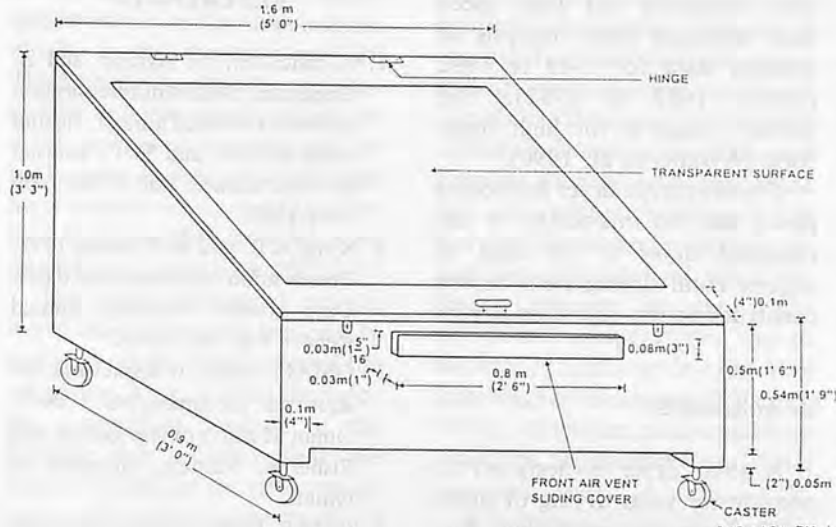

Fig. 1 Solar cabinet dryer (closed).

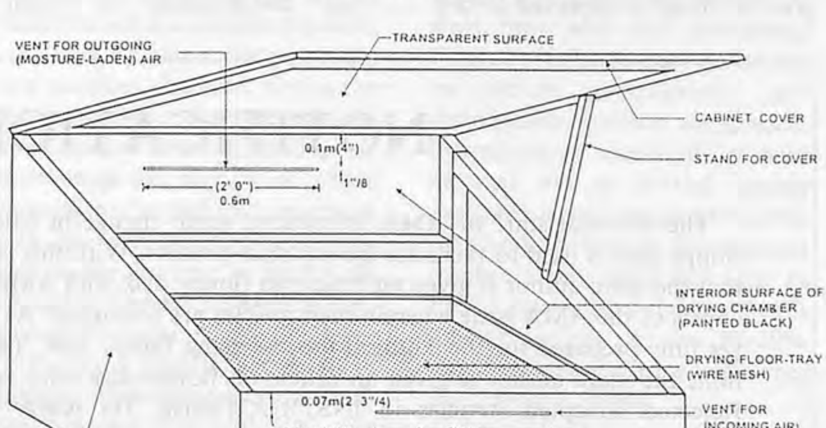

Fig. 2 Solar cabinet dryer (opened).

Discussion

The daily drying batch of 100 kg has been obtained by considering a farmer who harvests 6 t of dates during the harvesting season and dries them over 60 harvesting days. This figure matches the current drying practice of farmers. They dry batches of 100

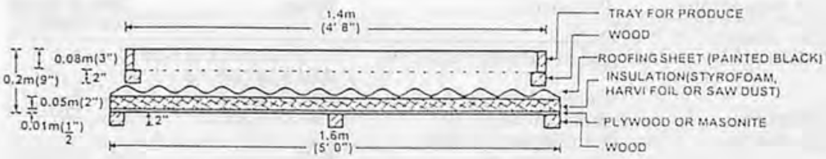

Fig. 3 Drying floor section.

to 200 kg in 14 to 21 days. The controlled drying with the solar dryer in 10 hours will reduce the drying time to 2 to 3% of the open air sun drying time and result in improvement in the quality of the dried material.

The meteorological data used, namely; air temperature, relative humidity, sunshine hours, incident solar radiation and wind speed were obtained from analysis of weather data for 1988 to 1992 (OMC, 1988 to 1992). The isotherm used is for high sugar food (Ayranci et al, 1990).

The prototype dryer is a scaled down size, to one-tenth, of the designed dryer to be used in experimental drying tests before constructing the full scale dryer.

Conclusions

A solar dryer is designed to provide for solar drying of dates under controlled conditions. The designed dryer with a collector area of 16 m^2 is expected to dry 100 kg of dates from 49% wet basis to 21% w.b. in 9.8 hours under ambient conditions during harvesting period from July to September. A prototype of the dryer with 1.6 m^2 solar collector area is built for use in experimental drying tests.

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The editorial staff of AMA introduced some change in editorial policy in 1994 in which floppy disk is used to facilitate the editorial process. With this change in policy, it was decided that the main author is given an article on floppy disk with AMA true format other than 5 free copies of the AMA issue wherein their articles are published. As of now, however, we have not yet fully prepared for the editorial process using floppy disk. Therefore the sentence "In addition, the main author is given an article on floppy disk with AMA true format." in item C, Rejected/Accepted Articles in INSTRUCTIONS TO AMA CONTRIBUTORS should be omitted and reprints of the article will be sent to each author as before.

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Top-bin/In-bin-counterflow Drying of Paddy

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Abstract

Paddy or rough, unmilled rice is difficult to dry with high-temperature air because of the susceptibility of rice kernels to fissure. A new in-bin high-temperature drying system has been developed specifically for medium-capacity paddy depots in China. The system consists of a series of three drying bins and two storage bins. Each drying bin contains a top-bin dryer and an in-bin-counterflow dryer. Thus, the paddy is dried in six stages, with tempering after each high-temperature drying stage. The throughput of the system is 12 tonnes of wet rice per hour in reducing the moisture content from 24% to 13%. The system is operating near Shanghai, China.

The world production of paddy has been relatively stable—i.e., between 400 and 430 million metric tons (MMT) annually (USDA, 1993); the largest producer is China with 180-185 MMT per year followed by India with 105-110 MMT. Although Thailand and the U.S.A. are relatively small producers with 17-20 MMT and 6-7 MMT of paddy, respectively, they are the largest rice-exporting countries with 1992 exports of 4.7 MMT and 2.4 MMT on a milled rice basis. China's rice export is increasing and is expected to reach 1.0 MMT (milled) soon.

Due to the decrease in per capita rice consumption, China at present is storing about 25 MMT of rice, or roughly 20 percent of the annual domestic consumption. The bulk of the rice stored in China is of relatively low quality, and is exported as low-quality rice to Africa at low prices. High-quality rice is sold at a premium, mostly in the domestic market. The main difference between high-quality and low-quality rice is the difference in the percentage of brokens (in general, in world trade high-quality rice is considered to have less than 10% brokens, low-quality rice more than 20%).

The price-differential on the world market between low-quality and high-quality rice is about $100 per tonne. Thus, it is essential for the competitive position of the Chinese rice industry that the general quality of the rice crop be upgraded from low-/intermediate-quality to high-quality. Improvement of the rice drying and storage facilities will accomplish this task.

Along with the color and cooking qualities, the head yield is the major quality characteristic of milled rice which is defined as the percentage (by weight) of whole kernels in a lot milled from rough rice. In a well-designed rice drying system the decrease in head yield should be limited to 3-4 percentage points (Brooker et al., 1992).

Paddy is usually harvested in China at an average moisture content between 20% and 26%, wet basis, depending on the type and variety of paddy and location where the crop is grown. Rapid drying after harvest is essential in preventing the wet rice from discoloring and deteriorating. Proper drying is required to limit the percentage of broken kernels after milling.

In Southeast Asia and China much of the paddy produced is sun-dried, a labor-intensive practice of spreading the moist rice kernels in a thin layer 3-5 cm thick on hard soil or concrete floor, and exposing them to the energy of the sun. Intermittent stirring of the rice layer increases the drying rate and the uniformity of the layer-drying process. Frequently the rice-kernel temperatures rise to 60-70°C, resulting in fissuring (cracking) of the kernels (Suhargo, 1993). Milled rice produced from sun-dried paddy, therefore, has a low head yield.

Bin-drying of paddy is practiced in many rice-producing areas. The paddy can be dried in steel bins with full perforated floors or in flat storage structures in which appropriate air-distribution systems are placed. Drying can be accomplished with natural air at initial paddy moistures as high as 23-24% if the relative humidity of the ambient conditions is sufficiently low. In the humid tropics the practice is limited to rice in the 17-20% moisture content range (Bowrey and Driscoll, 1986).

The use of high temperatures in conventional in-bin rice drying systems is restricted because of the destructive effect of overdrying on rice quality. This paper describes the design of a new concept of in-bin paddy drying which allows the use of moderately-high air temperatures. The system consists of a combination of top-bin and in-bin counterflow dryers arranged in series.

Top-bin and In-bin-counterflow Drying

The complete drying system consists of a hopper-type receiving bin, three top-bin intermittent-flow/in-bin continuous-flow drying bins, and two in-bin aeration/storage bins, arranged in series. Each drying bin contains a top-bin (TB) dryer in the top of the bin, and an in-bin counterflow (IBCF) dryer at the bottom of the bin. Thus, high moisture content grain is subjected to six drying and one aeration treatments dring the drying/aeration process. **Figure 1** shows the layout of the system. This system has been built at the Shanghai Twanjie Sha State Farm on Chongming Island near Shanghai, China.

In a conventional top-bin maize dryer, the perforated drying floor is located near the roof of the bin; the depth of the grain layer is limited to 0.3-0.5 m. Wet maize is augered into the top of the bin and is spread by leveling rings to the desired uniform depth. A high airflow rate (40-50 m^3/min-t) combined with the relatively shallow grain-layer results in fairly uniform drying of the layer. After the maize in the overhead drying system has dried at 60-70°C for 30-90 min, it is dumped to the bottom of the bin via a large number (30-48) of dump gates built into the top-bin drying floor. Since the dumping of the partially-dried maize through the dump spouts is accomplished in a minute or less, the time between batches is restricted only by the filling time of the TB dryer. **Figure 2** shows a schematic diagram of a conventional top-bin dryer.

On the other hand, the in-bin counterflow dryer is a continuous-flow drying system. A thin-layer (0.1-0.15 m) of warm, partially-dried rice, located just above the perforated floor, is removed from the grain mass via an on-floor tapered auger as soon as the paddy has dried to a preselected moisture content level. The auger is of special design so that the wet rice remaining in the bin moves downward at a uniform rate. The hot rice is transferred by the tapered auger to a transport auger for conveying to another bin. The tapered-auger start/stop action is controlled by a temperature sensor; the rotation of the sweep auger stops when the controller senses that the next thin layer of paddy has not yet reached the preselected moisture content level. The airflow in a conventional in-bin counterflow dryer is 5-10 m^3/min-t, the inlet air temperature 25-75°C. **Figure 3** shows a schematic diagram of a conventional in-bin counterflow dryer.

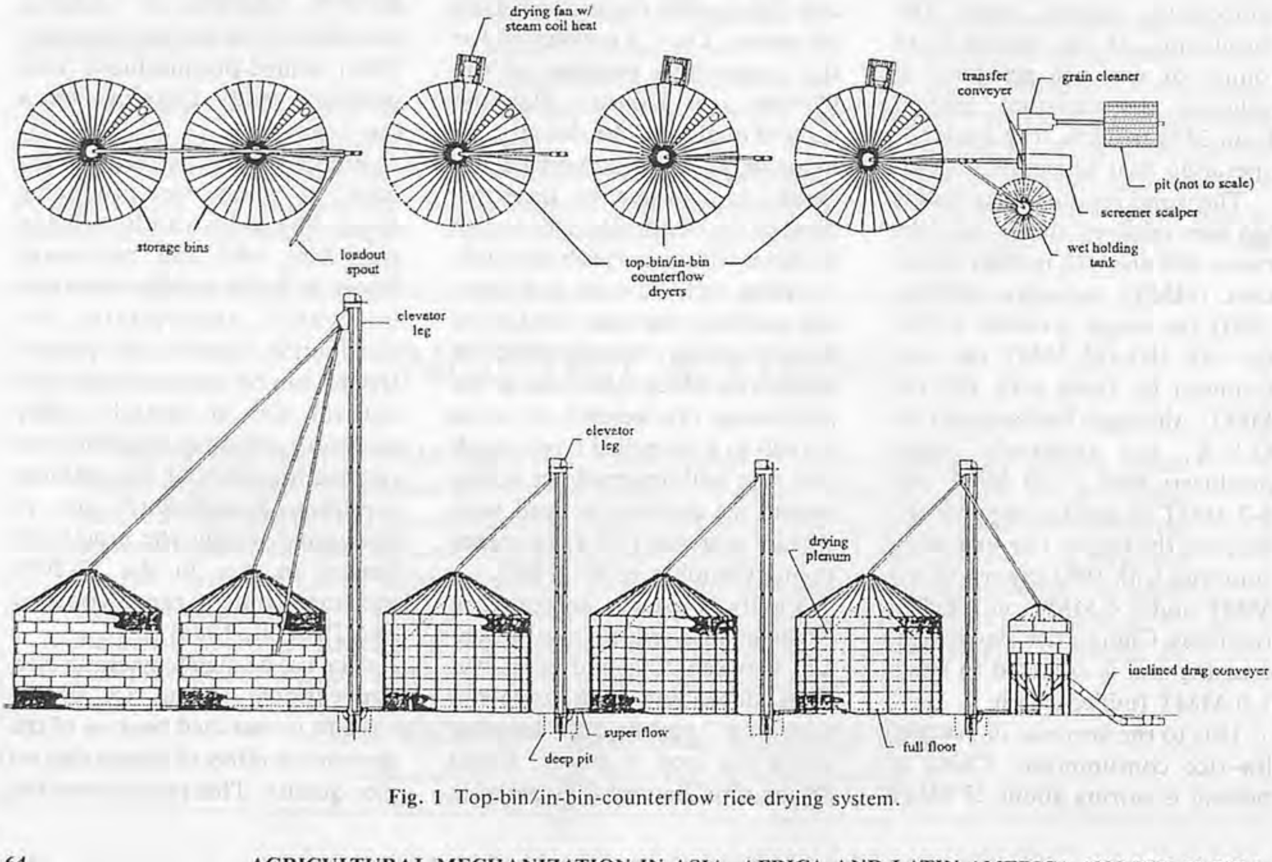

Fig. 1 Top-bin/in-bin-counterflow rice drying system.

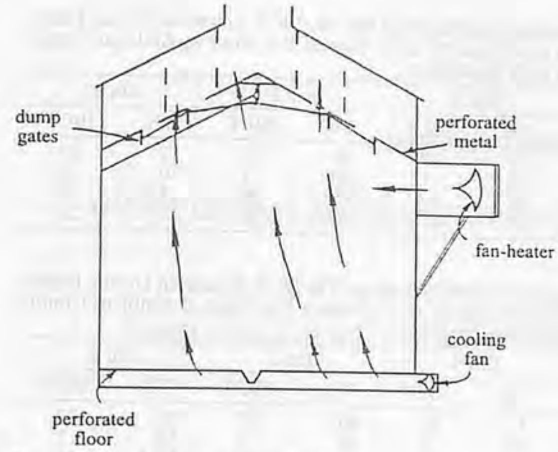

Fig. 2 Top-bin grain drying system.

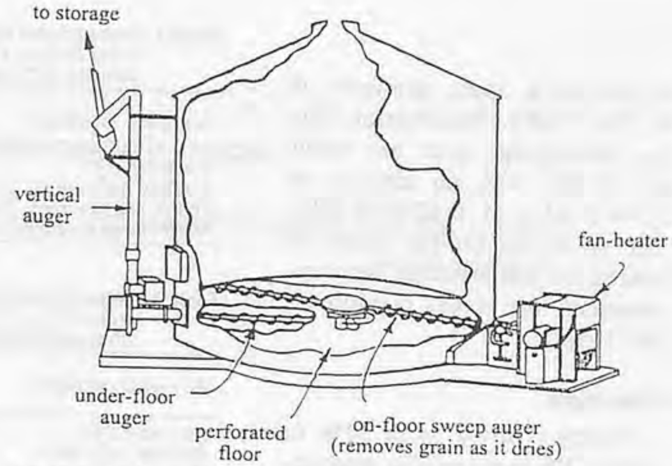

Fig. 3 In-bin-counterflow grain drying system.

Theory

The TB/IBCF drying system can basically be considered as a series of six top-bin/in-bin-counterflow dryers. In the system's design, the output of the first top-bin dryer model becomes the input to the first in-bin counterflow dryer model. And, the output of the first in-bin counterflow dryer model becomes the input to the second top-bin dryer model, etc. Thus, proper matching of the throughputs of the dryers is essential. The design of the system requires simulation models of two basic dryer designs, i.e., of the top-bin dryer and of the in-bin counterflow dryer.

Top-bin Dryer Model

The top-bin dryer is of the fixed-bed dryer type. An updated version of the Michigan State University (MSU) fixed-bed model was used to simulate the top-bin grain drying process (Bakker-Arkema, 1984; Brooker et al., 1992). The model is derived by writing energy and mass balances over a differential volume within the grain layer:

$$\frac{\partial T}{\partial z} = \frac{-ha}{G_a c_a + G_a c_v H}(T - \theta) \quad (1)$$

$$\frac{\partial \theta}{\partial t} = \frac{ha}{\varrho_p c_p + \varrho_p c_w M}(T - \theta) - \frac{h_{fg} + c_v(T - \theta)}{\varrho_p c_p + \varrho_p c_w M} G_a \frac{\partial H}{\partial z} \quad (2)$$

$$\frac{\partial H}{\partial z} = -\frac{\varrho_p}{G_a}\frac{\partial M}{\partial t} \quad (3)$$

$\frac{\partial M}{\partial t}$ = a paddy thin-layer drying equation (4)

Equations (1) through (4) constitute the simulation model for the drying of a fixed bed of grain. The thin-layer drying equation of Wang and Singh (1978) for long-grain rice was used.

In-bin-counterflow Dryer Model

The in-bin counterflow dryer can be simulated with a fixed-bed model (equations 1-4) if modifications are made to account for the paddy being lowered in the bin over a discrete distance, after each cycle of grain removal. The intermittent counterflow characteristic of the process is modeled by shifting the known conditions of the grain in the simulated bed downward by a distance equal to the thickness of the removed layer of the dried grain (Marks et al., 1993).

TB/IBCF Drying System Model

In each of the bins, the top-bin and the in-bin counterflow models have to be linked not only because of the coupled outlet-TB/inlet-IBCF conditions but also because the outlet air from the IBCF dryer is mixed with the ambient inlet air of the TB dryer. Thus, the TB inlet-air conditions are found by a search of the operating conditions of the two dryer models, and of the fan characteristics of the TB and IBCF systems. Since the airflow rate of the IBCF system is only about 10% of that of the TB dryer, the effect of the IBCF dryer on the inlet temperature/humidity conditions of the air in the TB dryer is small.

A disadvantage of coupling the TB and IBCF dryers in one bin is the negative effect of the TB fan (i.e., the static pressure) on the airflow rate through the IBCF grain bed. The IBCF fan not only has to overcome the airflow resistance in the IBCF bed but also the operating static pressure of the TB fan.

TB/IBCF Drying System

Design

The top-bin/in-bin-counterflow rice drying system is illustrated in **Figure 1**. It consists of three 7.3 m drying bins and two 7.3 m aeration/storage bins. Each of the top-bin dryers is supplied with two 12.0 kW fans with an output of 11.3-9.0 m^3/s of air in the static pressure range of 0.25-0.65 kPa. The fans on the in-bin counterflow dryers have a power rating of 2.4 kW and supply 2.8-2.4 m^3/s

of air at a static pressure of 0.12-0.37 kPa. The aeration fans on the storage bins are rated at 4.0 kW with an airflow of 5.7-4.2 m^3/s at 0.12-0.50 kPa. The air in the top-bin dryers is heated by steam-heated heat exchangers; the steam pressure is 241 kPa.

Operation

Paddy is dried from 24% to about 13% (wet basis) at a capacity of 12 t/h in the TB/IBCF drying system. The approximate conditions for operating the system at 27°C and 65% relative humidity are tabulated in **Table 1**, and for the 27°C and 95% humidity in **Table 2**.

The grain-depth in the top-bin dryer is 0.3 m in each drying bin, and 1.5 m in the in-bin counterflow dryers. At a capacity of 12 t per hour, the tempering time between the TB and IBCF drying treatments is 7.5 h. The total drying time in the system for rice being dried from 24 to about 13% is 27 h.

The top-bin dryer temperatures in the three bins decrease, i.e., from 52°C to 46°C to 41°C. The air-temperature in the IBCF dryers is 27°C in each of the bins. The airflows in each bin are 50 m^3/min-t and 1 m^3/min-t in the TB and IBCF dryers, respectively.

There is a significant change in the moisture extraction of the system if the ambient relative humidity changes from 65% to 95%. Under the less humid conditions, the moisture decrease in the successive drying stages is 4%, 1%, 3%, 1%, 1.5%, and 0.5%, resulting in a final moisture content of the paddy of about 13% **(Table 1)**. Under less favorable drying conditions (i.e., of 95% humidity) the final moisture content is 15% **(Table 2)**.

The average paddy temperatures are little affected by a change in the ambient conditions; the grains never exceed an average temperature of 41°C, and are thus expected not to decrease in head yield by more than 1-2 points.

For the paddy grains to reach the same final moisture content at 95% humidity as at 65% humidity, the grain flowrate through the system has to be decreased from 12 t to 9 t/h. The approximate operating conditions for this case are tabulated in **Table 3**. The average paddy temperatures are slightly higher when the system operates at 9 t/h compared to at 12 t/h.

Table 1. Approximate Operating Conditions of the TB/IBCF System in Drying Paddy from 24% to 13% at a Capacity of 12 Tonnes Per Hour at Ambient Conditions of 27°C and 65% Humidity

Air/grain condition	Bin 1		Bin 2		Bin 3	
	TB	IBCF	TB	IBCF	TB	IBCF
Air temp (°C)	52	27	46	37	41	27
Airflow (m^3/min-t)	50	1	50	1	50	1
Outlet MC (average, %)	20	19	16	25	13.5	13
Outlet temp (average, °C)	41	27	39	38	37	28

Table 2. Approximate Operating Conditions of the TB/IBCF System in Drying Paddy from 24% to 13% at a Capacity of 12 Tonnes Per Hour at Ambient Conditions of 27°C and 95% Humidity

Air/grain condition	Bin 1		Bin 2		Bin 3	
	TB	IBCF	TB	IBCF	TB	IBCF
Air temp (°C)	52	27	46	27	41	27
Airflow (m^3/min-t)	50	1	50	1	50	1
Outlet MC (average, %)	21	20	17.5	17	15.5	15
Outlet temp (average, °C)	41	28	40	29	37	29

Table 3. Approximate Operating Conditions of the TB/IBCF System in Drying Paddy from 24% to 13% at a Capacity of 9 Tonnes Per Hour at Ambient Conditions of 27°C and 95% Humidity

Air/grain condition	Bin 1		Bin 2		Bin 3	
	TB	IBCF	TB	IBCF	TB	IBCF
Air temp (°C)	52	27	46	27	41	27
Airflow (m^3/min-t)	50	1	50	1	50	1
Outlet MC (average, %)	19.5	18.5	15.5	14.5	13.5	13
Outlet temp (average, °C)	43	28	41	30	39	31

Conclusions

A new rice drying system has been designed consisting of a series of top-bin and in-bin-counterflow dryers followed by several aeration/storage bins. The system has particularly advantageous features for the drying of paddy because of the step-wise drying characteristics and the built-in tempering stages. The system appeared to also have advantages for the drying of wheat and maize because of the excellent control capabilities, and the after-dehydration storage capability.

List of Symbols

- a specific surface area, m^2
- c specific heat, J $kg^{-1}{}^\circ C^{-1}$
- h_{fg} heat of desorption of water, J/kg
- h grain bed heat transfer coefficient, J $m^{-3}{}^\circ C^{-1}$
- t time, s
- δt time increment, s
- δx depth increment, m
- G mass flow rate of air, kg $m^{-2}s^{-1}$
- H absolute humidity of air, kg/kg dry air
- M moisture content of grain, decimal dry basis, kg/kg dry matter
- T air temperature, °C
- z depth in bed from inlet, m
- q grain temperature, °C

Subscripts

- a dry air
- p dry grain
- v water vapor
- w water (liquid)

(Continued on page 70)

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Development and Performance Evaluation of Bullock-drawn Groundnut Diggers


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India

Abstract

Four different types of bullock-drawn groundnut diggers, namely; two-row ridging type, ridging type with semi-circular blade, V-type blade and ridger type were developed. Testing of these diggers was done for power requirement, effective field capacity, field efficiency, labour requirement, pod losses, digging efficiency, performance index and economics of digging. Effective field capacity and digging efficiency were high in the case of V-type blade and ridger type, respectively. The maximum digging efficiency of 92.0% was found for the ridger type under an optimum speed of 1.9 km/h. The performance index was maximum for the semi-circular blade as 0.170. As compared to manual uprooting, the performance of these bullock-drawn diggers was satisfactory and economical. However, the ridger type was most sutable. The use of these diggers are within reach of small and marginal farmers growing groundnut crop on a commercial basis.

Introduction

The traditional method of harvesting groundnut by digging the ridges with the help of small hoes or "phowra" is very labour intensive. This process is carried out at a soil moisture content of 12 to 15%. So in a very short period of time groundnut must be harvested. Not only in manual digging are many pods spoiled, but also the harvesting cannot be completed in time bringing the problem of land preparation for the next crop. The different types of bullock-drawn groundnut diggers, namely; two-row ridging type, ridging type with semi-circular blade, V-type blade and ridger type were fabricated and were tested in the Government agricultural farm, Khurda, Orissa.

Materials and Methods

Two-row Ridging Type

The two-row ridging type groundnut digger with its component parts rests on a main angle iron frame with the support of two iron plates **(Fig. 1)**. A 25-mm rod is kept parallel to the wheel shaft for digging tool arrangement. In this rod a mild steel plate is attached wherein a series of holes are made. There are two tynes made from high carbon steel of

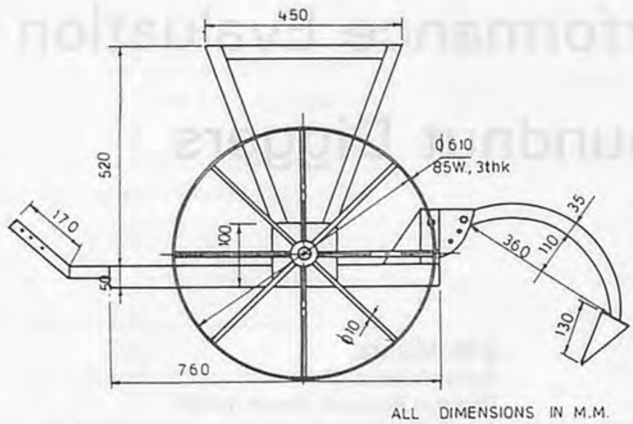

Fig. 1 Two-row ridging type groundnut digger.

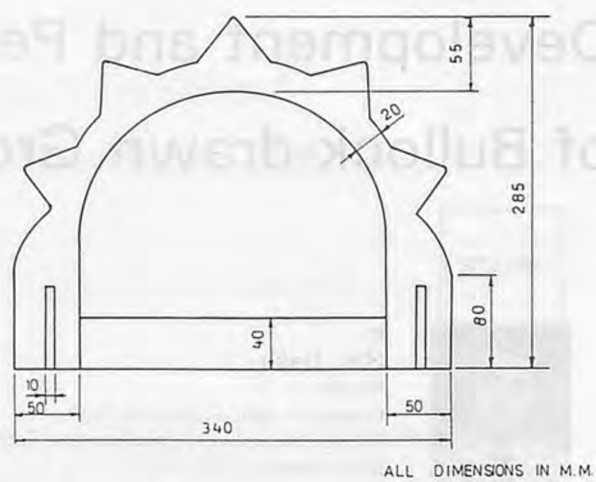

Fig. 2 Ridging type semi-circular blade groundnut digger.

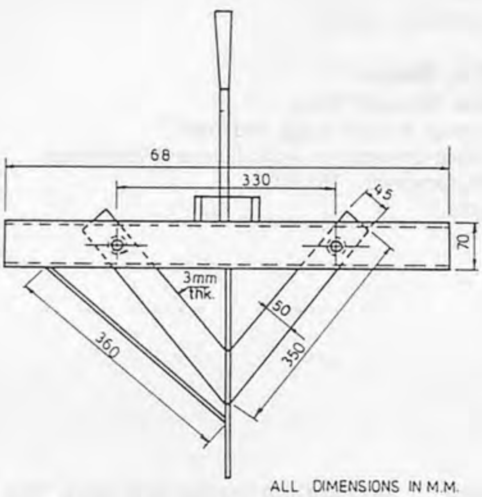

Fig. 3 V-type digging blade groundnut digger.

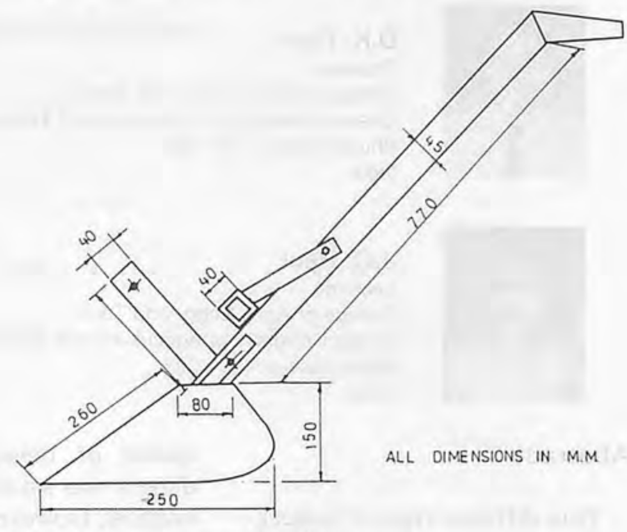

Fig. 4 Ridger type groundnut digger.

size 35 × 10 mm. These tynes are fitted with plates with the help of nuts and bolts of size 0.95 cm at the one end. On the other end of the tyne, a 10 mm size V shaped cutting tool is attached. The internal angle is designed at 65°. Two 61 cm ground wheels are attached to either side of the main frame. Two iron plates are welded on the front side of the main framed for hitching arrangement.

Semi-circular Blade Type

Except for the digging blade, all other parts remain the same as those of the two-row ridging type (**Fig. 2**). The digging blade is attached at the back side of the ridging type groundnut digger with the help of two tynes. A semi-circular m.s. blade of 4.5 cm wide and 6 mm thick is provided having inner radius of 19 cm. The blade is provided with triangular spikes of 5 cm long with 6 cm wide and placed throughout the outer curvature of the blade. This arrangement ensures the penetration of the spikes more at the centre causing the whole vines with the pods uprooted.

The V-type Blade

This bullock-drawn groundnut digger has a main frame, digging tool arrangement and hitching mechanism (**Fig. 3**). The main frame has 4 mild steel plates of size 67 cm × 6 cm × 5 mm which are welded together. This frame has a number of holes at required distances to fix the cutting tool. Over the frame, the handle is fixed with the support of two iron flats. The digging blade consists of two 34 cm long 45 mm × 10 mm mild steel flat. This is designed for V-shaped with an internal angle of 85°.

The Ridger Type

The digging blade is made of mild steel plate of size 3 mm and is made ridger-shaped having an internal angle of 50° (**Fig. 4**). On this blade there is m.s. plate frame over which the handle is fixed. A beam made of wood of size 245

× 6 × 4 mm is attached to the frame.

These diggers were tested in the field for ICGS-44 variety of groundnut for power requirement, effective field capacity, field efficiency, labour requirement, pod losses, digging efficiency, performance index and economics of digging. The moisture content of pod, vine and soil were determined by air oven method on dry weight basis. Draft, power requirement and effective field capacity were measured during the test. The pods left on the surface within the soil and damaged pods were collected separately from specified areas to determine the losses.

Results and Discussion

Table 1 shows the average values of power requirement, field capacity, field efficiency, losses, digging efficiency and performance index of each digger. The average draft is higher for two-row ridging type and semi-circular blade than for the V-type blade and ridger type which is due to a wide cut. The maximum average power requirment of 0.48 hp was recorded for the two-row ridging type digger which might have been influenced by the highest draft of 85.5 kgf. The effective field capacities of the two-riding type and of semi-circular blade are 0.057 and 0.046 ha/h and those of V-type blade and ridger type were 0.06 and 0.058 ha/h, respectively. This variation is due to the fact that the latter two types were operated at higher speeds than the former two. Accordingly, the field efficiencies of the former two types were 70.771 and 89.32%, respectively.

The variation in digging efficiency with respect to speed of operation of different diggers are shown in **Fig. 5**. The average digging efficiency is lower for the two-row ridger type and semi-circular blade than other two types. This is due to the fact that the former two type of diggers experienced clogging problem due to high width of cut and a greater number of spikes. The optimum operating speed of different diggers to achieve maximum digging efficiency are found in **Fig. 5** and presented in **Table 2**.

The performance indices (PI) of the four groundnut diggers were evaluated considering the quality of digging, quantity of digging and power requirement for the operation. The PI of two-row ridging type and semi-circular blades are found to be higher than those of the other two diggers. This is due to the wide cut and greater quantity of groundnut dug per metre run for the former two diggers. In the case of the ridger

Table 1. Average Values of Power Requirement, Losses, Field Efficiency, Digging Efficiency and Performance Index of Different Diggers

Type of digger	Speed km/h	Draft Kgf.	Metric horse power	Effective field capacity ha/h	Theoretical field capacity ha/h	Field efficiency %	Labour requirement man ha/h	% of exposed pod loss	% of unexposed pod loss	% of undug loss	% of total loss	Digging efficiency %	Width of cut cm	Performance index
Two-row ridging type	1.51	85.5	0.48	0.057	0.081	70.82	52.57	10.0	12.0	6.6	28.6	71.4	54	0.163
Semi-circular blade	1.55	72.3	0.42	0.046	0.080	56.81	66.67	12.4	16.1	7.3	35.8	64.2	52	0.170
V-type blade	1.74	66.8	0.43	0.060	0.078	76.71	50.73	7.6	10.9	1.3	19.8	80.2	45	0.094
Ridger type	1.86	57.0	0.39	0.058	0.065	89.32	52.18	3.6	5.5	0.8	9.9	90.1	35	0.095

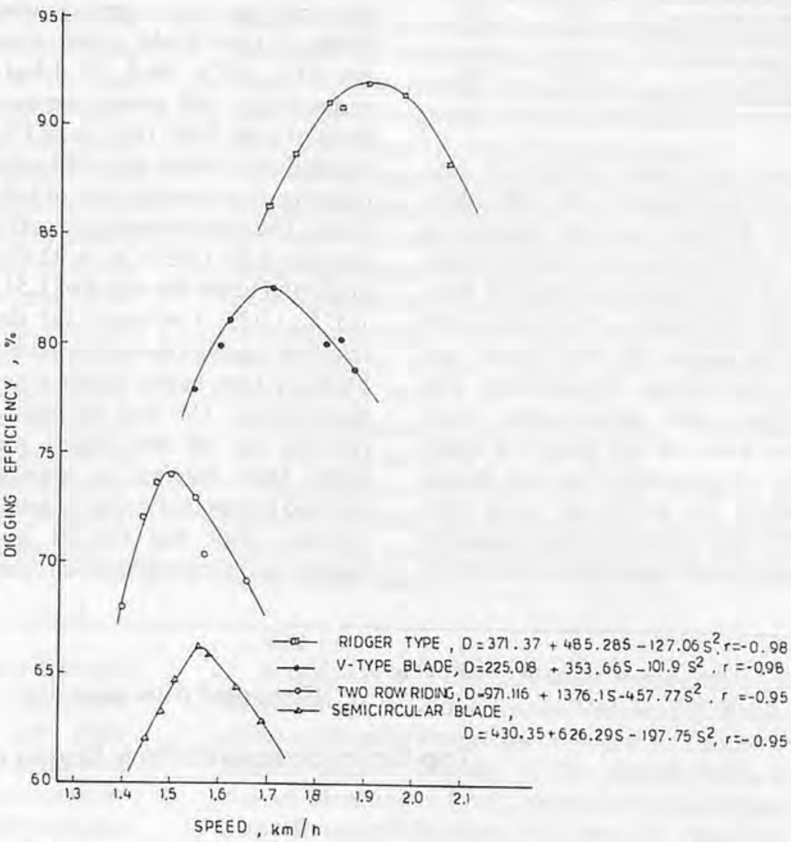

Fig. 5 Variation of digging efficiency for different speed of operation of different diggers.

Table 2. Optimum Speed for Maximum Digging Efficiency of Different Diggers

Type of digger	Speed km/h	Digging efficiency (%)
Two-row ridging type	1.51	74.3
Semi-circular blade	1.575	65.5
V-type blade	1.725	81.9
Ridger type	1.90	92.0

Table 3. Effective Field Capacity and Cost of Operation of Different Diggers

Method of digging	Average effective field capacity (ha/h)	Cost of operation per ha (US$)
Two-row ridging type	0.057	5.93
Semi-circular blade	0.046	7.33
V-type blade	0.060	5.37
Ridger type	0.058	5.42
Manual uprooting	0.0075	6.97

type, the field efficiency was recorded highest at 89.32% while the PI was recorded highest at 0.1770 for the semi-circular blade. The field efficiency and PI were recorded lowest at 56.81 and 0.094 in the case of the semi-circular and V-type blades, respectively. The digger with semi-circular blade had wider cut and hence the quantity of groundnut dug was higher which was attributed to its high PI. The effective field capacity and cost of operation of different digging methods are compared and presented in **Table 3**. The cost of operation for the manual digging method was US$6.97/ha which is higher than all the diggers except with that of the semi-circular blade. The effective field capacity of this said digger is much higher than the manual method.

Conclusion

The average draft for the two-row ridging type, semi-circular blade, V-type blade, ridger type are 85.5, 72.3, 66.8, 57.0 Kgf, respectively, and power requirement of 0.48, 0.42, 0.43, 0.39 PS, respectively, which are within the capacity of an average pair of bullocks. The maximum digging efficiencies of 74.3, 65.5, 81.9, 92.0% are found under the speed of 1.51, 1.575, 1.725, 1.90 km/h for the two-row ridging type semi-circular blade, V-type blade, ridger type, respectively. The cost of operation/ha for all the diggers are lower than digging by manual method except in the case of semi-circular blade but the PI was highest in the case of semi-circular blade. The effective field capacity of all the diggers are found to be higher than the manual uprooting method. The performance of these developed diggers is satisfactory and should be suitable for harvesting bunch varieties of groundnuts in sandy loam soils.

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Top-bin/In-bin-counterflow Drying of Paddy

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ABSTRACTS

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.

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Water and Fertilizer Use in Saudi Arabia: Al-Jaloud, Ali A., Associate Professor, Research Institute of Natural Resources & Environment, King Abdulaziz City for Science and Technology, P. O. Box 6086, Riyadh 11442, Saudi Arabia.

Saudi Arabia is a vast, arid country occupying almost 80% of the Arabian peninsula and extending from 16 to 32° North latitude and from 36 to 56° East longitude. The total area is about 2.2 million Km^2 and represents about 5% of the arid zones of the world (Bashour, et al. 1983). Nearly 27 million hectares (ha) is cultivable but only about 1 272 million ha are currently under cultivation. The whole country lies in the semi-arid region with an evaporation rate exceeding that of rainfall in general (Bashour 1987). Thus, all major farmed areas are under irrigation and water is applied in large farms through central pivots. One pivot system, depending on the arm length, supports around 50-80 ha.

The country's main source of income is oil. During the 1970's the Saudi economy experienced an average growth rate of 9.6% pa, the fastest in the world according to the World Bank Atlas. Evidently, this rate was too high to be sustained, especially considering the recent oil price fluctuations.

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Loading Simulation of Drawbar for a Tractor-trailer System Part I Steady State Condition: Al-Jalil, H.F., Associate Professor, N.H. Abu-Hamdeh, Assistant Professor, Z.M. Al-Hawery, Graduate Student, respectively, Agricultural Engineering and Technology Dept., Jordan University of Science and Technology, P.O. Box 3030, Irbid, Jordan.

The mechanics of a tractor-single axle trailer system moving at uniform motion up and downhill, was theoretically simulated. A computer program was developed to analyze the system to predict the effect of both the trailer loading weight and the slope angle on the tractor stability, traction ability, and drawbar loading. The results showed that the tractor becomes unstable when towing a trailer weight of 3 750 uphill at 28° slope angle. Insufficient traction occurs at slope angles ranged from 15° to 18° corresponding to trailer weight of 3 750 to 750 kg. The parallel component of drawbar pull reached a maximum value of (17 318) N when the trailer was pushing the tractor downhill at 30° slope angle. The perpendicular component showed similar maximum values for both uphill and downhill motions of the system.

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Evaluation of Final Seedbed Preparation for Some Crops in Sudan Gezira Vertisols 1. Some Aspects of Tractor-Implement Performance: Sheikh El Din Abdel Gadir El Awad, Associate Prof., Agric. Engineer, New Halfa Research Station, P.O. Box 17, New Halfa, Sudan.

Field test for tractor-implement performance, to 20 cm ploughing depth, under dry, heavy clay soil, indicated that five-body ridger with 60 cm spaced ploughing bodies to give sixty cm ridges was found to be superior over 4-body ridger with 80 cm spaced ploughing bodies to give 80 cm ridges. The former was resulted in 1.26 m/s actual speed, 10% wheel slip and rate of work of 1.09 ha/h. While the latter was resulted in 0.9 m/s actual speed, 31% wheel slip and rate of work of 0.84 ha/h.

According to slip % the two types of ridger indicated no effect on soil compaction, in comparison with disc plough (20% wheel slip) and scarifier (22% wheel slip).

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Evaluation of Final Seedbed Preparation for Some Crops in Sudan Gezira Vertisols 2. Evaluation of Ridging Practices on Irrigated Cotton in Sudan Gezira: Sheikh El Din Abdel Gadir El Awad, Associate Prof., Agric. Engineer, New Halfa Research Station, P.O. Box 17, New Halfa, Sudan.

Four ridging practices for cotton were evaluated technically, economically, and agronomically. These were 80 cm and 60 cm ridges with and without green ridging. The experiment was of randomized complete block design with four replications. 60 cm ridges with and without green ridging were resulted in significantly higher plant population and with similar cotton yield. 80 cm ridges with and without green ridging were resulted also in similar cotton yield, i.e. the green ridging had no effect in increasing cotton yield for any ridges system. However, 60 cm ridges system with and without green ridging were resulted in higher cotton yield compared to 80 cm ridges with and without green ridging.

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Evaluation of Final Seedbed Preparation for Some Crops in Sudan Gezira Vertisols 3. Effect of Wheat Seeds Coverage on Crop Establishment and Yield in the Gezira: Sheikh El Din Abdel Gadir El Awad, Associate Prof., Agric. Engineer, New Halfa Research Station, P.O. Box 17, New Halfa, Sudan.

Four methods of wheat seeds coverage, after manual broadcasting in the Gezira, were evaluated. These were coverage by 4-body ridger with 80 cm spaced ploughing bodies, coverage by disc harrow, and coverage by 5-body ridger with and without mouldboards, with 60 cm spaced ploughing bodies. The experiment was of randomized complete block design, with four replications. Means over three years showed that 60 cm spaced ploughing bodies, without and with mouldboards to give 60 cm spaced ridges, were increased the yield by 15% and 14%, respectively, compared to 80 cm spaced ploughing bodies, to give 80 cm spaced ridges; and also increased the yield by 11% and 10%, respectively, in comparison with coverage by the disc harrow.

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Development of a Potato Seed Cutter: Shafi, Ahmad, Assistant Professor, Dept of Basic Engineering; J.K. Sial, Professor and Chairman, Dept. of Basic Engineering; and Muhammad Iqbal, Assistant Professor, Dept. of Farm Machinery and Power, respectively, University of Agriculture, Faisalabad, Pakistan.

A mechanical seed cutter has been developed by the Department of Basic Engineering, Faculty of Agriculture Engineering and Technology for farmers which find great difficulty while cutting potato tubers for seed purposes manually. Machine is semi automatic and fabricated with local available material and workshop. The machine has given excellent results. Seeds cut by machine were found seven times cheaper than that by manual cutting. However, machine can be made fully automatic by designing feeding system only. ■■

International Conference on Engineering in Agriculture

September 27-30, 1998
Perth, Western Australia

The Australian Society for Engineering in Agriculture is convening the eleventh biennial conference on engineering in agriculture from September 27-30, 1998. This conference is entitled "International" and will attract technical and research delegations not only from the South Pacific but also from the Indian-rim countries, Asia, Europe and South Africa. This conference is endorsed by the Institution of Engineers, Australia (IEAust), the Asian Association for Agricultural Engineering (AAAE), the International Commission of Agricultural Engineering (CIGR), and the American Societyof Agricultural Engineers (ASAE).

The Conference will be held at the University of Western Australia, Perth. Western Australia is the nation's largest state, occupying almost one third of the Australian continent. The emergence of Western Australia as a major source of agricultural products was accompanied by a strong reputation in sustainable agricultural research which led to the development of vast areas of the state which previously thought to be unsuitable for farming.

The theme of the conference is "Engineering Better Agricultural Environments." The aim of this international conference is to advance the fields of agricultural engineering for sustainable agricultural resources and production by providing a forum for the sharing of current expertise between researchers to enhance the communication and collaboration of researchers within Australia and with those from other countries.

Conference Secretariat

At this point in time, correspondence relating to the conference, including proposals for papers should be addressed to the conference secretariat: Mohammad Amjad, Secretary, 1998 International Conference on Engineering in Agriculture. 712 Murray St. West Perth, WA 6005. Tel (+61) 8 9321 3340, Fax (+61) 8 9481 4332 e-mail: Contact WestAust@eol.leaust.org.au

International Conference on Peri-Urban Vegetable Production in the Asia-Pacific Region for the 21st Century

September 29-October 1, 1998
Bangkok, Thailand

Peri-urban vegetable production which occurs in the 'green belt' zones surrounding large population centers is the primary source of perishable and off-season fresh vegetables for urban dwellers. Questions are being raised about the ability of the current vegetable systems to respond to the food needs of the rapidly expanding urban populations. Due to migrations from rural areas, urban populations are growing at a much greater rate than the overall population. Meeting the demands for perishable fresh vegetables by this burgeoning urban population poses major challenges for agricultural research.

Objectives:

1. To focus attention on the increasing demand for peri-urban vegetable supplies.
2. To learn through shared experiences more about current production practices and constraints.
3. To stimulate interest in research and research support to help make peri-urban vegetable production systems more sustainable and environment friendly.

Program:

The program will consist of two days of presentations and discussions followed by a half day excursion to see peri-urban vegetable production and wholesale vegetable markets in the vicinity of Bangkok.

For additional information contact:
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EIMA — International Agricultural Machinery Manufacturers Exhibition

November 14-18, 1998
Bologna, Italy

The first exhibitors have already begun reserving space at the 29th edition of EIMA, Italy's international agricultural machinery fair to be held in Bologna on November 14-18.

Organized by UNACOMA Service srl with the Bolognafiere fair authority, EIMA offers farmers, agro-industry, livestock raisers, park managers and gardeners one of the world's major exhibitions of the machinery they need.

Last year, the fair attracted 1 479 exhibitors of whom 357 from thirty-six foreign countries, and they exhibited over 17 000 models. Over 110 000 visitors passed through the turnstiles. Exhibitors used up all the 104 000 square meters of covered and airconditioned exhibition on offer. This year, a further 22 000 sq.m will be available in the new pavilion built by the fair authority. This should give some exhibitors better showing space, make things more comfortable for the visitors and enlarge the facilities for companies showing their goods to agriculturists, sub-contractors and other businessmen.

This year's fair will maintain the traditional 14 product groups, including the machinery for park management and gardening on show in EIMA Garden. The exhibition will also maintain its traditionally sober and rational style: no advertising, just explanatory panels to introduce the machines on show and enable the visitors to find what they want easily.

Vast and varied as it is, EIMA represents a particularly important sector of Italian industry. With 890 000 tonnes of machinery produced in 1997 for a value of 11 370 billion lire (about $6.3 billion), Italy's agricultural machine makers rank after only the United States in the world, more or less equal second with Germany. A full 64% of their output is exported, to 180 countries, producing a trade surplus of 4 900 billion lire.

At EIMA 98, the wider public will be admitted for the first three days, and the other two will be reserved to the professionals. Thirty official delegations attended last year, and a large number is expected this year too, to compare technical, economic and policy notes.

EIMA will be organizing a calendar of meetings and debates on various aspects of agricultural mechanization and the short and medium-term scenarios. Then, the international experts belonging to the Club of Bologna will be assessing strategies for technological development and the spread of the various types of machine. The club's agenda will cover new techniques and methods of earth working and official assessment tests for tractors and agricultural machines designed to develop efficiency, quality and safety while offering a great range of choice to farmers and sub-contractors.

Contact: EIMA - 00161 Roma (Italia) - via Lazzaro Spallanzani, 22/a. Tel: 06/44298.1 - Telefax: 06/4402722
Internet: http:/www.smart.it/EIMA, e-mail: eima@unacoma.it

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4. International Conference on Housing, Engineering and Environment in Livestock Farming

March 9-10, 1999
Freising-Weihenstephan, Germany

Call for Papers

The papers should deal with production processes and developments which allow to fullfil main requirements of the future:

- best economic results,
- high product quality,
- environmental protection and
- an ethically and ethologically sensible animal production.

Theatre presentations of 20 minutes each will be followed by 10 minutes of discussion. Supplementary plenary papers and posters are planned. The conference will last 2 days. The conference applies to scientists, engineers and manufacturers who develop and distribute new techniques as well as to farmers and consultants as users of latest scientific results.

Conference Languages: German, English (no simultaneous translation available)

Main Topics:

1. Ethological and Physiological Basis for Developments in Animal Husbandry
2. Production Technology and Automation
3. Agricultural Construction
4. Assessment of Housing Systems
5. Environmental Engineering in Animal Production
6. Product Development, Marketing and Service

For any information concerning registration and general information please contact:
Dr. Manfred Schurig, Bayer. Landesanstalt für Landtechnik, Vöttinger Str. 36, 85354 Freising. phone: +49 81 61/71 34 51, fax: +49 81 61/71 43 63 (http://www.tec.agrar.tu-muenchen.de/tagungen.html)

International Symposium — Dust Control in Animal Production Facilities

May 30-June 2. 1999
Jutland, Denmark

The symposium will start on Sunday 30 May by the Mayor's welcome and end at Wednesday, 2 June, in the Scandinavian Congress Center, near Aarhus City Center.

The purpose of the symposium is for the participants to exchange information on the latest development on dust measurement and control abatement of dust, animal welfare and health, human health risks and the epidemiological function of dust particles related to animal production.

The symposium will be organized by the Danish Institute of Agricultural Sciences, DIAS, and it will be guided by an international scientific committee.

Scientific programme

The following topics will be discussed at the symposium:

- Sources of dust and characterization of dust
- Measurement of dust concentration and particle sizes
- Dose response and control standards
- The impact of dust on animals
- Health risks for humans

- Effect of dust emissions on the environment
- Modelling of dust concentration distribution indoors and in the surroundings
- Dust reduction techniques

Call for papers

Abstracts not exceeding 300 words should be submitted before 1 September 1998. Notification of acceptance for oral or poster presentation will be given before 1 December 1998. Manuscripts for accepted papers must be submitted before 1 April 1999. The proceedings will be available at the symposium.

For additional information contact:

Scientific Secretariat
Att.: Søren Pedersen, Danish Institute of Agricultural Sciences, Research Centre Bygholm, P.O. Box 536, DK-8700 Horsens, Denmark. Phone: +45 75602211, Fax: +45 75624880, E-mail: Soeren. Pedersen@agrsci.dk
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The XIV Memorial CIGR World Congress 2000

November 28-December 1, 2000
University of Tsukuba, Tsukuba, Japan

The XIV Memorial CIGR World Congress 2000 will be held in Tsukuba, Japan, on November 28 - December 1, 2000. The Congress will cover a wide range of agricultural engineering fields, which are expected to become more and more important in the 21st century.

The Congress is organized by the Japan Assolciation of International Commission of Agricultural Engineering (JAICAE) sponsored by International Commission of Agricultural Engineering (CIGR)

The official language of the Congress will be English.

Topics and Call for Papers

The Congress will focus on the follwing areas, and contributions in those and related areas are appreciated. A person intending to give an oral or poster presentation at the Congress is requested to submit a one-page abstract (A4 size, approximately 500 words) to the International Program Committee of the Congress no later than December 31, 1999. More detailed information and the presentation application form will be included in the Second Announcement.

- Regular technical sections
  Land and water use
  Farm buildings, equipment, structures, and environment
  Equipment engineering for plant production
  Rural electricity and other energy sources
  Management, ergonomics, and systems engineering
  Processing
- New agricultural technology in the 21st century
  Informatics, life support systems and plant factories
- Global agriculture in the 21st century
  Paddy field agriculture, upland field agriculture, small-scale farming
  Sustainable bio-production and processing

Second Announcement and Further Information

The second announcement for the Congress will be issued in October 1999. It will contain a paper presentation application form and registration form as well as details about the tour, accompanying person's program, and accommodations and travel information. Additional information on the Congress site, maps, and updates on the scientific programs will be available through the World Wide Web.

URL: http://bee2.en.a.u-tokyo.ac.jp/cigr2000/

Farmer's Flexible Tool

Scientists, engineers and other experts are always in the quest for innovations, developments, indigenization of products, machines, process, system etc.; pertaining to Industries. The farmer Produces the most precious food grains to the entire world population. He is not given due consideration in terms of making his work simpler, modifying his hand tools and safety in the farms.

The innovation proposed in this paper is about the hand tool in the hands of farmers, feeding into the mouths of billions of people.

There are many common hand tools. The spade is used worldover mostly by farmers and also by construction workers. Even if the machines are doing some of the farm works, ultimately the farmer has to use his hands with this tool in some way or other. Some of the purposes for which the spade is used are:

1. for digging the soil
2. for levelling the loose soil
3. for scrapping the grass etc.
4. for watering the fields

For doing the above jobs, farmers need spades of different angles (angle between the metal plate and the handle). Even to do the same job like digging the soil and doing earth work in general, different people get accustomed to different angles. If a new spade is purchased and if the angle is different from the one he was using earlier, it is very inconvenient to work with and in the process of working accidents do happen. A spade where the angle can be varied to 4 different values will be a boon for the farmers and the other people who work with this tool.

Some works need shoveling when some material is to be displaced to a different location or to be loaded or unloaded. For such work again a different tool is needed. The tool described in this paper takes care of the function of a shovel also.

To the metal plate top edge, a mild steel plate with 5 holes spaced suitably is welded.

The holes are numbered 1,2,3,4 and 5 as given in the **Fig. 6**. A similar but small plate with two holes at the same spacing is fixed to the handle or the ring holding the handle. These holes are marked as A and B. **(Fig. 6)**

With the help of two bolts and nuts if the holes 1 and 2 are made to coincide with A and B and fastened we get an angle of 10°. If we make the holes 2 and 3 coincide with A and B, we get the angle 27°. Similarly with 3 and 4 the angle will be 42° and 3 and 5, the angle will be 85°. In this arrangement we get all the acute angles convenient to work as a spade.

The first angle namely 10° will be used for scrapping. 2nd and 3rd namely 27° and 42° will be for earthwork and digging. The 4th angle namely 85° will be helpful in digging the hard soil and cutting the roots or levelling the loose soil etc.

If we reverse the direction of the piece with holes A, B and fix with 3 and 5 we get almost 180°. This will make the tool to be used as a shovel. In all the above cases, the handle can either be wooden or thin metal pipe as per the requirement.

The drawings showing the tool in the shape of spades in the increasing angles are shown from **Fig. 1** to **Fig. 4** and that as shovel in **Fig. 5**. The enlarged drawing showing the arrangement of holes A and B and 1,2,3,4 and 5 is given in **Fig. 6**.

The cost aspect for making this modification is too little. The extra mild steel plate weighs only 200 gms. costing negligible extra amount. If a

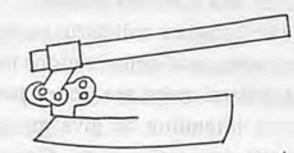

Fig-1

Fig-2

Fig.3

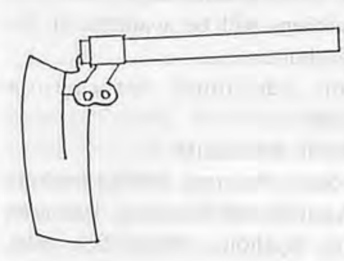

Fig-4

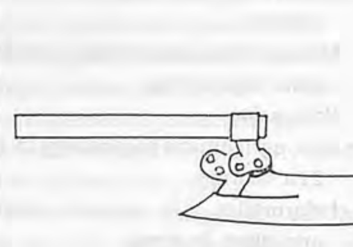

Fig-5

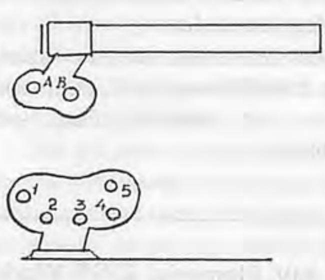

Fig-6

zig is made the holes can be made easily. The cost of making the holes as well as welding to the tool will again be small. If the pieces can be mass produced, the whole modification will increase the cost by 10 to 15% only in comparison with the conventional fixed angle spade. There is lot of flexibility in this tool and the same tool can be used for several functions. All that the user has to do will be removing the 2 bolts and again refixing to the different setting. The rural people particularly the farmers will welcome such a hand tool used day in and day out for all purposes by them. The cost aspect is very much encouraging. The overall weight is almost same as conventional one.

The spade population in the world will be about 100 millions. If this improvement in its design is taken to the villages world over it will definitely reduce the fatigue of the farmer, reduce farm accidents and improve the productivity level in the farm sector.

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Rice Inspection Technology

(Japan)

The textbook "Rice Inspection Technology," is a product of the Grain Inspection Technology Cooperation Promotion Project, one of the ODA projects of the Japan Food Agency for 1995-1997. The book is a companion volume to its Japanese edition.

Recently there has been remarkable economic development in the developing countries, especially in Southeast Asia. As a result of this development, there has been a shift of population from farms to cities, centers of commerce and industry, accompanied by higher standard of living. It is said that today half of the world's population lives in cities. For this reason, a change has occurred in the consumption pattern of rice, which is a staple in many countries. Specifically, more rice is now distributed as a commercial product, and people are now demanding rice of higher quality and good taste.

In order for rice to be distributed smoothly as an appealing product both domestically and internationally, guarantee of quality is important, as is price. Rice must receive fair inspection based on recognized public quality and packaging standards, so that the consumers can be assured that good quality rice will be supplied in sufficient quantity. In rapidly fluctuating economic and social conditions, in order to assist countries that are seeking to improve their rice standards and inspection methods, as well as countries which are attempting to establish standards and inspections for rice for the first time, this book has been prepared to introduce the rice quality standards, inspection methods and inspection equipment which the Japan Food Agency has developed and maintained for many years.

Rice inspection does not involve merely classifying rice into grades and determining the price. If rice is not matured, or becomes damaged, in the production process, it will be impossible to improve its quality after it is harvested. About all that can be done then is to remove damaged grains and brokens. A rice inspector is in a special position in which he can see the quality of the rice, point out probles in the rice growing and in drying and storage of the rice after it is harvested, and suggest improvements. We believe that standards and inspection methods should be used so that inspectors' opinions will be fed back to rice growers and also consumers' opinions will be fed back to the rice milling plants. Consequently, chapters on the effects of drying, storage and rice milling operations on rice quality, and on inspection equipment and packaging, have been added to the chapters on standards and inspection administration. Each chapter was written by a leading expert on that subject in Japan. There is some duplication of subject matter among the chapters, but each chapter is independent of the others, so the duplication has been left as a convenience to readers.

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Drying and Storage of Cereal Grains

(USA)

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by B.K. Bala

This book has been written primarily for undergraduate and graduate students in agricultural engineering. It is the outcome of several years of teaching and research work carried out by the author.

The book covers a very wide spectrum of drying and storage studies which is probably not available in a single book. Chapters 1 to 8 deal with air and grain moisture equilibria, psychrometry, physical and thermal properties of cereal grains, principles of air flow, and detailed analyses of grain drying and chapters 9 to 13 deal with temperature and moisture in grain storages, fungi and insects associated with stored grain, design of grain storages, and a comprehensive treatment of modern grain storage systems. Chapter 7 and chapter 10 have been primarily devoted to the application of simulation techniques using digital computers. A good number of problems have been solved to help understand the relevant theory. At the end of each chapter unsolved problems have been provided for further practice. An extensive bibliography will help the reader to find detailed information on various topics of his interest.

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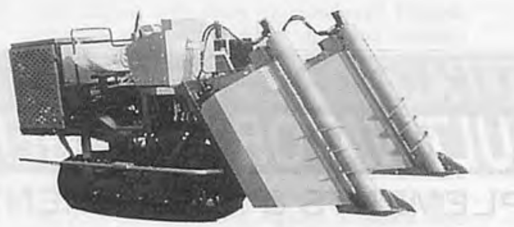

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