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Edited by

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EDITORIAL

CIGR (International Commission of Agricultural Engineering) 2008 Conference was successfully held in Iguassu Falls City, Brazil from August 31st to September 4th. It was combined with the special meeting of the Brazilian Society of Agricultural Engineering and more than one thousand papers were submitted. Only selected papers were presented at the several thematic conferences. Other papers were presented at poster sessions. The number of participants as well as papers exceeded one thousand. Due to respectful efforts by organizers, the conference was very well organized with an effectively arranged program.

It was impressive that most research papers dealt with the problems originated on the practical side of farming and contained ideas that seemed to be useful for the solution to current problems, while much research in advanced nations has sometimes been less related to practical issues of farming. Actually, most papers were written by engineers who have adequate knowledge of real conditions of farming because they are working for research institutions organized by farmers themselves or for local research organizations.

The conference site, Iguassu Falls City, well-known for its world famous large falls, is a beautiful place. In the Technical Visit, I could see the majestic Itaipu Dam and one of the world's greatest hydroelectric power plants constructed by a joint project of Paraguay and Brazil. It is indeed an environment-friendly energy source.

I also had the opportunity to visit farms and see the realities of farming in Brazil. Because the price of agricultural products is rising throughout the world, Brazilian farmers are enjoying a boom in production of soybeans, sugarcane and other crops. Brazil leads the world in ethanol production and sugarcane fields are rapidly expanding. Brazil is going to be the greatest country for the supply of ethanol to many other countries.

Reflecting increasing concern about energy problems, many research projects on utilization of bio-mass were presented at CIGR thematic conferences. In my view, it is important that more research be initiated on utilization of biomass in the non-food section, not in the food section.

For the past several years, the price of main agricultural products has risen by nearly three times. Although the market has calmed down and the price has gone down by about 30% from the peak, it still remains high. This is a critical issue for the countries with great dependence on imported agricultural products. Increasing population puts pressure on the food and energy shortage. Furthermore, food production is affected by environmental change such as global warming, which was brought about by our economic activities.

On a long-term basis, human beings must be in harmony with nature or other ecological systems on the globe. New science technologies will make it possible for human beings to live together with other ecological systems. Above all, agricultural engineering technologies will play a key role. We, in the profession of agricultural mechanization, must take initiative in this effort.

It can be said that agricultural machines have made progress along with the expansion of muscular power for a long time. In recent years, mechanization of human intelligence has been added and active research on agricultural robot and automation is being made. The development of intelligent machines will be the biggest challenge in the 21st century. At the CIGR conference, many research reports on precision farming and agricultural machine intelligence were presented. By introduction of intelligent agricultural machines, rapid increase in land productivity can be expected since it permits more precise and appropriate farm work. Intelligent systems will be also useful in pest control to reduce the amount of chemical used by applying only the necessary amount where it is really needed. This will also reduce the environmental burden.

In a country like Japan where small farm lands are scattered, it is expected that a high level of agricultural productivity will be ensured by using intelligent machines without large farm machines. It is essential that well-planned and precision farming be developed through the utilization of intelligent farm machines for the preservation of life for the large population on the limited surface of our planet. Again, the CIGR conference gave clear indication of the future task for us involved in agricultural mechanization.

AMA hopes that worldwide agricultural mechanization experts will join the efforts toward the solution of food, energy and environment problems with which we are confronted.

Yoshisuke Kishida
Chief Editor

September, 2008

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Designing a Fonio Mill; Screening an Operating Principle and Its Validation

by

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Abstract

Fonio milling is a long and laborious operation that needs to be mechanized to promote production and marketing of this cereal. The article presents an approach for the design of a fonio mill from definition of the equipment specifications to presentation of the knowledge required to develop the equipment. After investigating several principles, the authors selected the principle of the Engelberg mill used for other cereals such as rice. The choice of operating principle was based on understanding the milling principle. The design relies on the hypothesis that reducing the volume of the milling chamber will result in greater friction and shearing of the grains between the rotor and the stator, allowing them to be milled without excessive heating.

Introduction

Fonio is the oldest cereal in West Africa. Although marginalized for a long time, it is grown in more than eight countries, where it is greatly appreciated for its early maturity during the lean period and for its hardiness.

Mainly consumed as a couscous or porridge, it is currently experiencing a revival of interest in urban areas because of its nutritional and gustatory qualities. Fonio is a husked cereal and its caryopsis remains surrounded by glumes and paela after threshing (Cruz, Dramé et al., 2000). As with rice, processing paddy fonio into white fonio requires two successive operations: husking, to remove the husks from the paddy grain and obtain the caryopsis or brown grain, and whitening, to remove the bran (pericarp and germ) and obtain the white grain.

Fonio grains are much smaller than those of other cereals grown in the region, as is shown in **Table 1** by a comparison with rice.

The very small grain size makes the processing operations long and laborious for the women performing them. Fonio milling requires 4 to 5 successive poundings with a pestle and mortar, each separated by a winnowing. The productivity of this type of work is low as it takes nearly one hour to mill 1 to 2 kg of paddy fonio. It is therefore essential to mechanize milling so as to improve the processing operations and to reduce the laboriousness of the work.

To improve fonio post-harvest technologies, a regional project has been funded with the aim of mechanizing post-harvest operations and improving the market competitiveness of fonio in terms of quality and price. At the beginning, the project precised the required performances of the machines to be supplied to processors (Troude, Cruz et al., 2000). The milling specifications are presented in **Table 2**.

Four milling principles, those appearing most appropriate, were analyzed in terms of their suitability for milling fonio grains. The selected

Acknowledgment: The authors thank Garth Evans for the English translation. The project to improve post-harvest technologies for fonio has been funded by the Common Fund for Commodities (CFC). This regional project associates the CIRAD and the National Research Centres in Mali, Guinea and Burkina Faso (1999-2004).

principle was first evaluated using a functional mock-up, a modified existing equipment for rice milling. The results were then confirmed using a prototype specifically designed for fonio milling. The article concludes with a presentation of the knowledge required to develop a fonio mill.

Materials and Methods

Design Approach for a Fonio Mill

The approach consists of five stages:

- definition of the specifications of the future equipment;
- bibliographical study of the milling principles and choice of principle;
- detailed study of the selected milling principle using a functional mock-up;
- construction of a prototype and systematic experiments;
- definition of the knowledge required to develop a fonio mill.

Plant Material

The experiments were carried out in a Montpellier laboratory using paddy fonio purchased at a market in the Bobo-Dioulasso region of Burkina Faso. The fonio was first sieved with a laboratory cleaner equipped with two sieves, one of 1 mm, the other of 0.6 mm, placed one over the other to remove not only stones but also sand and small impurities.

Variables Measured in the Milling Experiments

The selected variables were those usually used for milling:

Determinant variables,

- Grain moisture content (% db),
- Rotor rotation speed (rpm),
- Position of inlet door, indication of the width of the outlet section (in millimetres),
- Position of outlet door (as for inlet door),
- Distance between rotor ribs and blade-brake (in millimetres).

Determined variables,

- Inlet thoughput during continuous operation (kg/hr),
- Outlet temperature of the grains (ºC),
- Milling yield (%): amount of dehusked or whitened and winnowed grains at the mill outlet relative to the amount of grain entering the machine,
- Power consumption (kW): the mill is driven by a speed change unit fitted with a device to measure the power really used,
- Milling rate (%): mass percent-

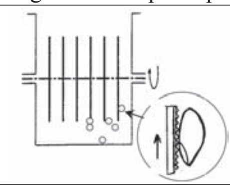
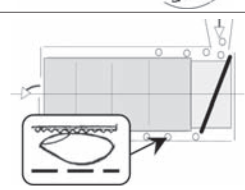
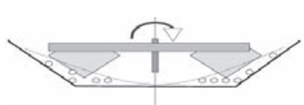
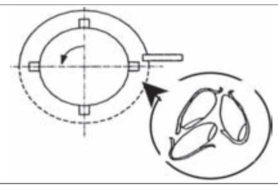
Table 1 Comparison of rice and fonio paddy grain size

Grain	Rice	Fonio	Ratio
Length, mm	6	1.5	4
Width, mm	3	0.9	3.3

Table 2 Simplified performance specifications of the fonio mill

Variable	Level
Throughput, kg/hr	60 to 100
Milling yield, %	65 to 68
Milling rate, %	≥ 99.5
Broken grains, %	≤ 10
Grains lost in the bran, %	≤ 2
Impurities in the grains, %	≤ 2

Table 3 Summary of the different milling principles investigated for fonio

Principle	Description	Diagram of the principle	Advantages/disadvantages
1. Abrasive disk dehulling	Outer envelopes of grains stripped off by a disk-type abrasive element Grains contained in a trough, rotor consists of a series of spaced ab-rasive disks immersed in the mass of grains		• Small size of fonio grains so large pericarp surface to abrade • Difficulty of ensuring that all faces of the grains come into contact with the abrasive • Risks of clogging of the abrasive by fatty bran
2. Abrasive stone dehulling	Outer envelopes of grains stripped off by a cylindrical rotor Grains held against the millstone by a perforated sheet Grains in helical movement around the rotor		• As above • Difficulty of controlling the helical movement of the grain - bran mixture
3. "Sanoussi" friction milling	Friction of grains between two rough surfaces, one inclined and fixed, the other consisting of 2 flexible rotating blades		• Existing equipment • Low capacity; many broken grains, inadequate milling particularly if grain not completely dry • Specifically for fonio
4. Engel-berg milling	Grains put under pressure by the helical ribs of the rotor Friction-shearing of grains against one another and on the sharp edges of the rotor and the stator		• Suitable for all husked grains • Processing in the mass of grains, therefore uniform for all grains • Milling pressure can be controlled to avoid damaging grains during milling

age of brown and white grains in a sample taken at the machine outlet relative to the mass of this sample (value determined after manual separation of the paddy grains),

- Broken grains (%): mass percentage of grains passing through a 500-micron sieve in a sample taken at the machine outlet relative to the mass of this sample.

Study of Milling Principles for Fonio

All milling principles likely to be applied to fonio milling are presented in the bibliographical summary (Marouzé, 2000). Only the four principles already used for fonio appear potentially interesting and are discussed in this article. **Table 3** presents the principles considered, with a diagram of each and their potential advantages/disadvantages. As fonio grain is very small, the surface of the pericarp is much larger than in the case of other cereals and this places strong constraints on milling.

Abrasive Dehulling With PRL Disks

PRL dehullers are designed for dehulling of millet, sorghum or maize grain as a continuous or batch operation (Bassey et Schmidt, 1990). The rotor consists of a series of spaced disks or millstones mounted on a horizontal axle. The rotation speed is around 2,000 rpm for a disk diameter of 230 mm. The stator consists of a metal trough concentric with the rotor and located below the axle. There is a door in the bottom part for emptying the grains.

The experiments conducted with several dehullers showed that paddy fonio could not be husked in a single pass (Cruz, Dramé et al., 2000). Two or three treatments were required to achieve a satisfactory milling rate, but this was at the expense of throughput and milling yield: very low yield (37 %) for a milling rate of 99 %. The whitening of brow grain was more satisfactory but not good enough to satisfy the performance specifications. The difficulty of fonio milling is probably linked to the difficulty of ensuring that the entire surface of the grain comes into contact with the abrasive element to strip off the outer envelopes.

Abrasive Dehulling With DMS 500 Millstones

The DMS 500 dehuller is designed for the dehulling of millet or sorghum as a continuous operation. Dehulling occurs by abrasion of the grains between a rotating series of contiguous millstones mounted on

Table 4 Dimensions (in mm) of the original and modified rotors used to evaluate the operating principal

	Original rotor	New rotor
Pitch diameter of rotor	54	68.5
External diameter of rotor	67.5	76.5
Length of rotor	300	300
Height of ribs	6	4
Width of ribs	6	10
Distance between ribs and cover or screen	7	2 to 3
Number of longitudinal ribs	3	3
Length of longitudinal ribs	200	210
Number of helical ribs	3	3
Length of helical section of the ribs	80	80
Angle of helical section of the ribs	220º	220º
Grain inlet section	ϕ 40	ϕ 40
Grain outlet section	25 × 25	25 × 25
Rotation speed for experiments, rpm	880-1100	650-1020
Clearance of brake-blade	1	0.4 to 1

Fig. 1 Fonio milling using the mock-up, influence of blade-brake clearance

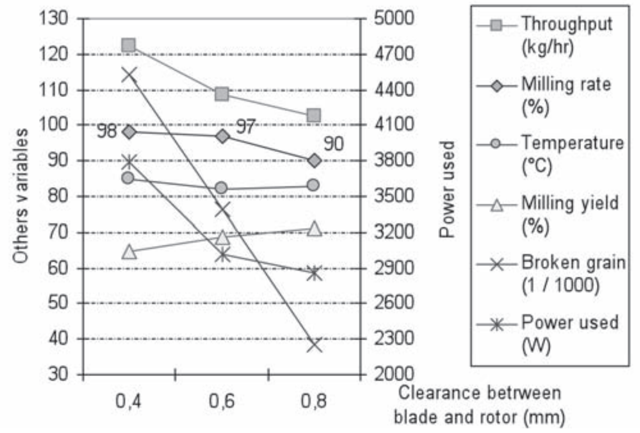
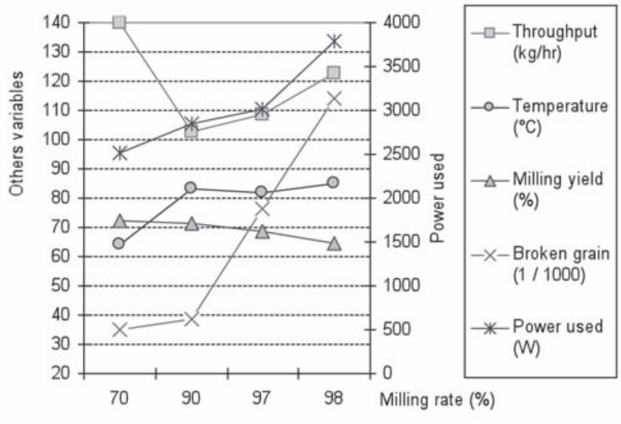


Fig. 2 Fonio milling using the mock-up, influence of milling yield on the other variables



a horizontal axle and a perforated sheet located 7 mm from the abrasive element (**Table 3**). The external diameter of the stones is 150 mm and the abrasive length is 300 mm. A feed screw forces the grains into the dehulling chamber, the space between the millstones and the perforated sheet. At the other end of the rotor, a door limits the outlet of the grains, thus regulating the dehulling intensity.

Tests for fonio milling were conducted by CIRAD (Marouzé, 1994), the perforated sheet having been covered with a fine mesh to prevent grains from escaping. The grains were properly milled but with a poor milling yield, limited throughput and excessive heating of the grains. Testing was therefore stopped.

"Sanoussi" Friction Mill

The "Sanoussi" mill is specifically designed for fonio milling and operates in batch mode. The grain is placed in a tapering chamber, the base of which is covered with a rough plastic coating. Two flexible blades covered with the same material are attached to a vertical rotor. Milling occurs through friction of the grains between the stationary and the moving parts. Husk and bran are removed from the top part by air flow. The chamber is inclined downwards allowing the grains to be emptied after milling. The machine works, but the experiments conducted during the project demonstrated the limitations of this principle: low thoughout (around 25 kg/hr), low milling yield (around 60 %), high percentage of broken grains and difficulty in milling if the grains are not completely dry.

Engelberg-type Friction-shearing Mill

The "Engelberg" type rice mill can carry out husking and whitening. The milling chamber is made up of a metal casing with a perforated screen in the bottom part, and an adjustable metal blade-brake at axle height and a movable cover in the top part. The latter includes a grain inlet and a grain outlet with a flow control door. The rotor is a ribbed longitudinal metal cylinder. There is a hand-operated door at the base of the hopper, allowing grain to be fed into the milling chamber through the cover.

In the "Engelberg" type mill, the grains are pushed in an axial direction by the first part of the rotor, equipped with helical ribs and put under pressure in the milling chamber. As the grains move along the cylinder, they are subjected to a shearing and friction action against one another and against the stator, particularly the blade-brake which impedes the rotary movement of the grains and the rotor ribs. The result of this action is milling, the stripping of husks and bran that pass through the perforated sheet and fall by gravity on the side of the machine. The inlet and outlet doors of the chamber regulate the throughput and the milling intensity. Closing the outlet door prevents the grains from exiting and thus augments the pressure inside the chamber, increasing the friction and hence the milling. The opposite effect is achieved by opening the door. The inlet door is either open, with gravity-driven grain flow, or partly closed, which regulates the feed rate.

Developing such a principle for fonio milling proved to be a delicate matter. Adequate pressure and shearing is required for milling without causing blockages or crushing the grains. In addition, the very small size of fonio grains (< 1 mm) prohibits the use of a perforated sheet to remove the husks and bran as they are stripped off. It has to be replaced with a solid sheet and the grains remain mixed with the husks and bran in the milling chamber (Marouzé, Thaunay et al., 2001).

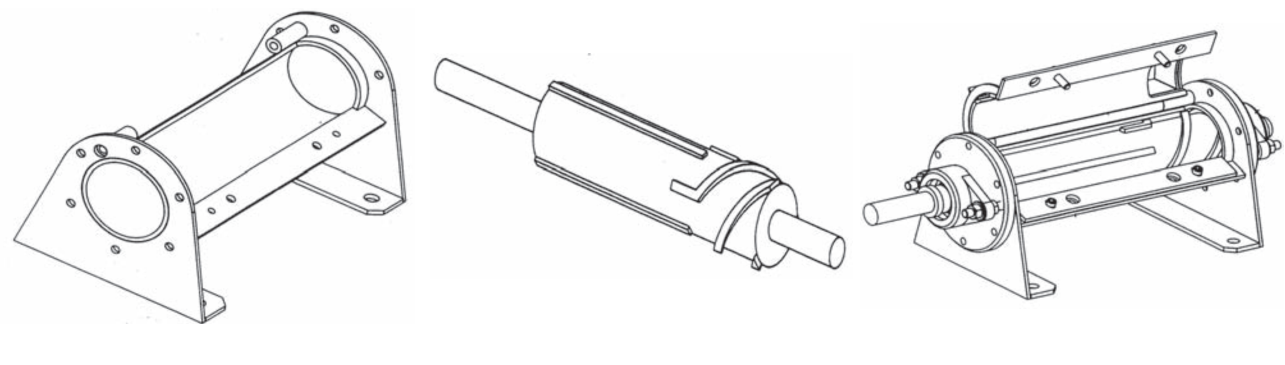
The principle is very suitable for husked grains like rice and fonio. When applied to the moving mass of grains, milling has better chances of being uniform for all grains. The experiments conducted with several models in Guinea in the late 1990s were promising, but the specifications presented above were not met in continuous operation (Cruz, Dramé et al., 2000).

Selecting the Operating Principle

The reasons for choosing the principle of the Engelberg mill are (**Table 3**):

- Principle very suitable for paddy grains like fonio and rice,
- Promising results obtained in

Fig. 3 Views of the fonio mill prototype, the body, the rotor and the assembled unit with the cover open



Guinea,
- Equipment already manufactured in West Africa and used for rice and other cereals,
- No use of special imported parts like millstones, disks, facilitating local manufacture and distribution of the equipment.

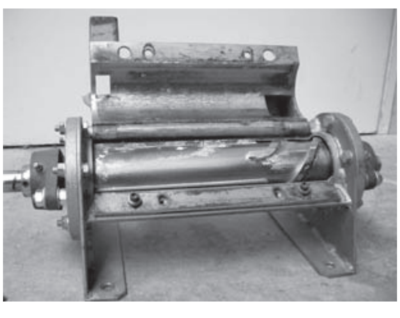
Study and Evaluation of the Operating Principle of the Fonio Mill

First Tests and Hypotheses

The aim of the first part of the study was to understand the functioning of the Engelberg mill principle when applied to fonio. It was conducted using Votex equipment (HULLER Model, serial number R.0831.14) (Marouzé, Jouve et al., 2000). The dimensions of the original rotor are shown in **Table 4**.

The first experiments gave very unsatisfactory results, with poor milling rate (from 40 to 95 %), high outlet product temperatures and low throughputs. A cake of wet bran settled inside the casing. The heat from the friction caused partial evaporation of the internal moisture. The steam then condensed on the cold walls. The moisture caused the bran to accumulate there, mainly on the cover but also to a lesser extent behind the rotor ribs. The cake of bran acted as a thermal insulator and impeded removal of the friction-generated heat. Its presence had a corresponding negative effect on the milling conditions.

Fig. 4 Photograph of the fonio mill prototype



To prevent this phenomenon, we hypothesized that reducing the size of the milling chamber and hence the distance between the rotor and the stator would provide a greater speed gradient in the chamber, resulting in:
- elimination of the dead zones, the spaces where the bran can accumulate,
- better removal of the thermal energy generated by the friction, as the grains are nearer the outer walls of the equipment,
- a smaller amount of grains inside the chamber so, with constant flow, a reduction in the time spent in the milling chamber.

Functional Mock-up for Evaluation the Operating Principle

The volume of the milling chamber was reduced by fitting a new rotor with a larger diameter. The external diameter of the new rotor was defined by making the distance between the rotor ribs and the screen or cover proportional to the ratio between the size of rice grains and that of fonio grains (**Table 4**). A ratio of 3:1 was chosen (**Table 1**). No change was made to the lengths of the rotor and the ribs.

Experiments to Evaluate the Operating Principle Using the Mock-up

The numerous experiments conducted showed that to obtain acceptable results, the throughput needed to be around 100 kg/hr; a low throughput led to excessive heating of the grains. The experiments showed (Marouzé, Jouve et al., 2000) that:
- A low moisture content made milling easier,
- A higher rotor rotation speed increased the throughput but also the outlet temperature of the grains,
- Opening the inlet door caused an increase in the milling rate but also in the percentage of broken grains,
- Closing the outlet door caused a major increase in the milling rate and the percentage of broken grains but reduced the throughput,
- Reducing the clearance between the blade-brake and the rotor caused a significant but varying increase in all variables except the milling yield, which decreases (**Fig. 1**).

More intensive one-pass milling to reduce the percentage of paddy grain in white grain led to poorer performances for the other variables: higher percentage of broken grains, higher product outlet temperature and higher power consumption, and furthermore a lower milling yield (**Fig. 2**). However if milling was done in two passes (husking and whitening), the performances were satisfactory, with a low grain temperature and reduced power consumption (**Table 5**). These results validated the principle, leading us to develop local equipment.

Table 5 Fonio milling using the mock-up with two successive passes

	Rotor speed, rpm	Operating of inlet door, mm	Operating of outlet door, mm	Clearance between blade and rotor, mm	Through put, kg/h	Milling rate, %	Milled grain temp., °C	Milled yield, %	Power used, W
Pass 1 (hulling)	890	14	40	0.6	154	75	50	72.9	2400
Pass 2 (whitening)	890	14	10	0.6	78	99	68	88.2	2400
Overall - for both passes					**63**	99		**64.3**	

Prototype Fonio Mill

Because of the smaller distance between the rotor and the stator and replacement of the perforated screen used for rice milling by a solid sheet, the mill will be unsuitable for rice. It will be used specifically for fonio.

Method of Prototype Manufacture

Designing a specific fonio mill allows the use of technical solutions other than those usually used with this type of equipment. Furthermore, the narrow width of the milling chamber requires a geometrical precision between the stator and the rotor that cannot be obtained with two mechanically welded half-shells, the customary method of manufacture. We, therefore, redefined the method of manufacture of the body to have a geometrical precision resulting from the geometry of the stele section and the tooling of parts instead of a mechanically welded construction (**Figs. 3** and **4**):

- use of a thick tube for the central section of the body (stator), with a longitudinal opening allowing the blade-brake to be adjusted and any blockages cleared,
- axial assembly/disassembly of the rotor, with the bearings mounted on flanges centred in relation to the tube, which has milled ends.

This assembly allows a geometrical precision of a few tenths of a millimetre between the rotor and the stator. The tube used for the body is 88.9 mm in diameter and 5.5 mm thick, i.e. its internal diameter is 77.9 mm. The rotor used is that of the mock-up.

Experiments With the Prototype

Milling Fonio in One Pass

The first series of experiments (Marouzé, Thaunay et al., 2001) showed that the variable with the greatest effect on the functioning of the mill was the position of the outlet door (Table 6). Performances were similar to those of the mock-up: throughput of 80-100 kg/hr, milling yield of 65 to 72 % and milling rate of 93 to 98 %. It was difficult to meet the targeted milling rate and milling yield in a single pass. However, the prototype achieved a milling rate of over 98 %.

Husking and Whitening Fonio in Two Passes

Milling fonio in two passes, the first to husk the grains and the second to whiten them, gave very satisfactory results, as indicated in **Table 7**. The less intensive milling at each pass reduces the stresses on the grain in comparison with one-pass milling.

It was possible to achieve a milling rate of over 99 % with a milling yield of slightly over 70 % for the two passes, better than with one-pass milling. Furthermore, the equivalent throughput for the two passes was between 60 and 65 kg/hr and power consumption was lower (2 kW, instead of the 3 kW for one-pass milling). It would be possible to optimize the two-pass combination to obtain better pairs of milling yield - milling rate values. It was decided not to do so until experiments in real conditions using equipment at a later stage of development.

The experiments also showed rapid wear of the blade-brake and the importance of a leakproof body

Table 6 Fonio milling with the prototype, influence of the position of the outlet door

Trials, No.	Opening of inlet door, mm	Opening of outlet door, mm	Through-put, kg/h	Milling yield, %	Huller rate, %	Broken grains, %
Clearance between blade and rotor = 0.6 mm, rotor speed = 815 rpm, grain moisture content = 10 %						
10	20	13	107	67.1	98.5	4.9
11	20	8	81	55.2	99.4	9.5
12	20	7	69	44.7	99.8	12.3
Clearance between blade and rotor = 0.6 mm, rotor speed = 815 rpm, grain moisture content = 12 %						
20	20	10	108	71.7	93.1	
21	20	7	86	65.2	98.2	
22	20	4	< 80		99.4	

Table 7 Fonio milling and whitening with the prototype, using two passes

Trials, No.	Opening of outlet door, mm	Through out, kg/h	Milled yield, %	Milling rate, %	Broken grains, %	Power used, W	Overall through-out, kg/h	Overall milling yield, %
Clearance between blade and rotor 0.6 mm, rotor speed 840 rpm, inlet door completely open								
Pass 1 (hulling)								
30	25	168	81.5	< 95		1,716		
Pass 2 (whitening)							equivalent for both passes	
31	7	112	89.1	95.8	4.6	1,633	75	72.7
32	6	96	88.8	97.7	4.3		69	72.4
33	5	90	89.4	98.8	3.9	1,881	67	72.0
34	4	83	87.0	99.1	4.3	1,992	64	70.9
35	3	78	86.7	99.6	3.9	2,074	61	70.7

to prevent bran from escaping. The grain outlet must be narrow so that the position of the outlet door can be easily adjusted, without causing blockages.

Conclusion

The result of this study is an innovative technical solution based on a known milling principle. It allows the mechanization of milling fonio in a single pass or, preferably, in two passes, the first to husk the grains and the second to whiten them. The two operations can be carried out successively or separately, with hulling being done in the production area and whitening done close to the consumption areas. The performances obtained were satisfactory and have led to the local manufacture of a pilot mill by an equipment manufacturer in Bamako. The equipment design, local manufacture and experiments in a real environment will be presented in a later article.

Designing this equipment is a matter of thinking about the principal technical function, milling, as this is the crucial factor. Other technical functions like feeding grain into the milling unit and motorization or support of all the parts do not require research effort and will be adapted from existing equipments. The research into the functioning of the principle when applied to fonio was conducted using existing equipment but slightly modified during experiment. To evaluate the selected operating principle, only a rotor in the first time and a body in second time had to be manufactured as all other components were salvaged items. The construction costs of the study were thus kept to a minimum. Such an approach is essential when designing equipment in developing countries, as resources for the development of new equipment are often very poor there.

The present design approach concentrates on understanding the operating principle of the equipment and the knowledge obtained allows the design choices to be made. In addition, this knowledge will serve to develop the first equipment manufactured in Mali and also be used for all future developments of these mills.

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A Model to Predict Anthropometric Dimensions of Farm Workers of South India

by

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Abstract

Use of anthropometric data can help in the design of farm equipment for better efficiency and more human comfort. So far, the anthropometric data of industrial workers were used. Available data on farm workers are inadequate for use in farm machinery design. When the requirements of hand tools, animal drawn implements, tractors, power tillers, power operated machines, self propelled machines and workplaces are considered, a total of 79 body dimensions have been identified. An anthropometric survey of farm workers was carried out in Tamil Nadu state with a sample size of 1,500 that was divided in proportion to agricultural workers population. The proportion of male and female subjects was 1,000 and 500 respectively. Using the Harpenden Anthropometric measurement kit, all the identified body dimensions were measured for 1,000 male and 587 female farm workers from the seven agro climatic zones of the state. From the recorded values of body dimensions, the mean value, standard deviation, 5th and 95th percentile values were computed for male and female subjects, respectively. The data bank created can be used in the design of various farm implements and equipment with respect to anthropometric suitability for enhanced comfort of human subjects and it will be highly useful to achieve enhanced performance and efficiency of man-equipment system along with better comfort and safety of operators. For prediction of anthropometric data of farm workers, mathematical modeling was performed through "Table Curve 1.0" package. All the 79 parameters measured were grouped based on the relationship among each other. In each group the base parameter was identified. The mathematical modeling was performed between the base parameters and the sub parameter in the same group. The mathematical equation for the best fit curve for the each combination was obtained. The procedure was repeated for the all the group. By measuring all the base parameters, 18 other sub parameters can be predicted using mathematical modeling.

Introduction

Comfort, physical welfare and performance of agricultural workers are influenced by farm equipment in terms of relevant features of the human body such as body dimensions and the range of body movements. More and more hand tools, implements and machines are being developed, manufactured and used for various farming operations. All of them are either operated or controlled by human workers. Hence, to achieve better efficiency of performance and more human comfort, it is necessary to design the equipment with consideration of the operator's capabilities and limitations. Use of anthropometric data in design of agricultural equipment is one step in this direction. Anthropometry deals with the measurement of physical features of the human body including linear dimensions, weight and volume. Agricultural mechanization has increased considerably over the last few years in India, but little anthropometric data is available for looking into the ergonomic problems of mechanization. Therefore this investigation was undertaken to generate and analyze anthropometric dimensions of male and female farm workers.

Review of Literature

Sen et al. (1977) reported that anthropometric dimensions of unorganized workers, including agricultural workers, were similar to those of industrial workers. Gupta and Sharma (1979) reported that the anthropometric data are used to determine the size and shape of the equipment which is operated by man and to determine the space in which a man has to work. Woodson (1981) described the anthropometry of human subjects by identifying 46 physical dimensions of the body for the design of equipment. Gupta et al. (1983) conducted an anthropometric survey of Indian farm workers and reported that linear relationships existed between the standing height and other body dimensions and hence other dimensions could be predicted from the standing height. They identified the standing height, seat height, seat depth, hip breadth, elbow rest height (vertical distance from the seat surface to the underside of the elbow) and shoulder seat (vertical distance from the seat surface to the acromion, i.e. the bony point of the shoulder) as the pertinent anthropometric parameters for matching with machine parameters. Gite (1993) reported that only very few studies are available on anthropometric data of Indian agricultural workers. Das and Bhattacharya (1984) investigated the optimum design and location of a hand operated rotary device and concluded that, though all the body dimensions are related to each other, shoulder height and forward arm reach had direct bearing on the design parameters of the rotary device.

Table 1 Sample size distributions in different agro-climatic zones

Agro-climatic zone and district	Sample size	
	Male	Female
North eastern zone (Tiruvannamalai district)	150	75
North western zone (Salem district)	150	75
Western zone (Coimbatore district)	150	137
Cauvery delta zone (Trichy district)	150	75
Southern zone (Pudukkottai district)	150	75
Heavy rainfall zone (Kanyakumari district)	150	75
Hill zone (Nilgiris district)	100	75
Total	1,000	587

Table 2 Nature and particulars of the agricultural workers surveyed in Tamil Nadu

Particulars	No. of males	No. of females
Right/left handed	933/67	532/55
Clothing won	Light clothing	
Job specification	Agricultural workers	
Smoker/non-smoker	766/214	7/581
Chewing tobacco	248	341
Chewing pan	648	465

Methods and Materials

Methodology for Data Collection

A major anthropometric concern in design and evaluation of engineering products is the statistical description of all those persons who may, throughout the life of the product's usefulness, be involved in its operation and maintenance. This group of persons is defined as the total user population. It is usually impossible or uneconomical to measure every individual in a population. Therefore, a smaller group called a sample is selected and measurements are carried out on the individuals in that sample.

Sampling Methodology

It is generally mentioned that a random sample should be taken from a population for the sample to be representative. However, in a large scale anthropometric survey, the ideal random sampling procedure is not feasible. To make the sample representative it was decided to take a sample from each district.

Table 3 Parameters and sub parameters that can be measured and predicted

Data to be measured	Data that can be predicted
Stature	Vertical reach
	Vertical grip reach
	Eye height
	Acromial height
	Elbow height
	Olecranon height
	Ileocrystale height
	Illiospinal height
	Trochanteric height
	Metacarpal- lll height
Bi-acromial breadth	Bi-deltoid breadth
	Chest breadth
Chest circumference	Wrist circumference
Sitting height	Vertical grip reach sitting
	Sitting eye height
	Sitting acromion height
Foot length	Instep length
Medial malleous height	Lateral malleous height
Suprailliac skin fold	Subscapular skin fold

The sampling technique followed for a representative sample is given below:

The proportion of male and female subjects was 1,000 and 500 respectively. The nature and particulars of the agricultural workers surveyed are furnished in **Table 2**.

From the measured values of the above mentioned body dimensions, the mean, standard deviation, 5th and 95th percentile values were computed. To develop a mathematical model with the greatest predictable value, the co-efficient of correlation 'r^2' was calculated between each Y and X; log Y and X, Y and log X and, log Y and log X. The highest 'r^2' valued relationship between the pertinent anthropometric dimensions was regressed linearly and finally reduced to the normal form. Among these, the one that furnished the maximum correlation was taken as the best fit. For prediction of anthropometric data of farm workers, mathematical modeling was performed through the "table Curve 1.0" package. All the 79 parameters measured were grouped based on the relation between each other. In the each group, a base parameter was identified. The mathematical modeling was performed between the base parameters and the sub parameter in the same group. The mathematical equation for the best fit curve for the each combination was obtained. The procedure was repeated for all the group.

Results and discussion

The highest 'r^2' value between the pertinent anthropometric dimensions was regressed linearly and finally reduced to the normal form. The best fit least square regression equations between selected base parameters and corresponding sub parameter were obtained for male and female workers and are furnished in **Table 1** and **2**, respectively.

Conclusions

The data bank created can be used in the design of various farm implements and equipment with respect to anthropometric suitability for enhanced comfort of human subjects and it will be highly useful to achieve enhanced performance and efficiency of man-equipment systems along with better comfort and safety of operators. The following combinations of the anthropometric data were found to be significant, for the both male and female workers.

Hence, by measuring seven base parameters, 19 other sub parameters can be predicted using mathematical modelling. Only sixty anthropometric parameters have to be measured manually including the eight base parameters. Hence, around 25 % of drudgery involved in measuring of anthropometric parameters is reduced by this mathematical prediction.

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Table 4a Mathematical modeling for male anthropometric data

Data to be measured	data can be calculated	Equation	R^2 value
Stature	Vertical reach	$Y = a+b/\ln x$, a = 1122.49, b = -4661.445	0.8078
	Vertical grip reach	$Y = a+b/\ln x$, a = 1123.9, b = -4708.064	0.7810
	Eye height	$Y = a+b/\ln x$, a = -41.86, b = 6.033	0.8477
	Acromial height	$Y = a+bx^2$, a = 69.07, b = 0.00257	0.8506
	Elbow height	$Y = a+bx^{1.5}$, a = 34.91, b = 0.03218	0.7308
	Olecranon height	$Y = a+bx^{1.5}$, a = 33.066, b = 0.0316	0.7013
	Ileocrystale height	$Y = a+bx^{0.5}\ln x$, a = -38.82, b = 2.059	0.6634
	Illiospinal height	$Y = a+bx^c$, a = 2.86, b = 0.554, c = 0.9977	0.6065
	Trochanteric height	$Y= a+bx$, a = 9.158, b = 0.487	0.6339
	Metacarpal - III height	$\ln Y = a+bx^3$, a = 3.396, b = 6.23e-08	0.6578
	Knee height	$Y = a+b\exp(-x/c)$, a = 25.13, b = 3.808, c = -91.0259	0.3187
Bi-acromial breadth	Bi-deltoid breadth	$Y = a+b/x^2$, a = 49.28, b = -7572.892	0.2758
	Chest breadth	$Y = a+bx+cx^{1.5}+dx^{2.5}+ee^x$, a = 26.19, b = -0.8159, c = 0.017, d = 0.0022, e = 6.423e-19	0.6476
	Chest depth	$Y = a+b\exp(-x/c)$, a = 18.74, b = 0.0515, c = -8.336	0.0932
	Inter seye breadth	$Y = a+b/x^2$, a = 32.80, b = -3070.0178	0.0384
	Waist breadth	$Y = a+b(\ln x)^2$, a = 9.68, b = 1.3336	0.0736
	Hip breadth	$Y = a+b/x^2$, a = 33.202, b = -3977.13	0.0940
	Wall to lumbosacral joint distance	$Y = a+bx\ln x$, a = 3.5807 , b = 0.0144	0.0644
	Abdominal extension to wall	$Y = a+bx^c$, a = 12.89, b = 0.3099, c = 1.035	0.0691
	Chest circumference	$Y = a+b/x^{1.5}$, a = 101.82, b = -2829.505	0.0944
	Wrist circumference	$Y = a+b/x^2$, a = 18.52, b = -2108.2641	0.1503
	Waist circumference	$Y = a+b/x^2$, a = 93.63, b = -13659.776	0.0621
	Thigh circumference	$Y = a+b/x^2$, a = 51.52, b = -8246.51	0.0940
	Calf circumference	$Y = a+b/x^2$, a = 36.1857, b = -4720.9639	0.0869
Chest circumference	Wrist circumference	$Y = a+b\ln x/x$, a = 23.579, b = -139.557	0.1894
	Waist circumference	$Y = a+bx^{1.5}$, a = 17.42, b = 0.0781	0.6511
	Thigh circumference	$Y = a+b/x^{1.5}$, a = 60.6469, b = -14050.698	0.2299
	Calf circumference	$Y = a+bx+c\ln x+d/x^{1.5}+e\ln x/x^2$, a = -762103.95, b = -1755.398, c = 189563.25, d = 1.223e+08, e = -1.52e+08	0.6441
Thigh circumference	Calf circumference	$Y = a+b/x^{0.5}$, a = 59.037, b = -181.99	0.3359
Sitting height	vertical grip reach sitting	$Y = a+b/x^2$, a = 111.95, b = -434199.58	0.7028
	Sitting eye height	$Y = a+b/xc$, a = 30.18, b = 0.9166, c = 0.882	0.2230
	Sitting acromion height	$Y = a+bx\ln x$, a = -8.65, b = 0.1862	0.9105
	Sitting popliteal height	$Y = a+bx\ln x$, a = -9.377, b = 0.1883	0.9262
	Knee height sitting	$Y = a+b/x^2$, a = 51.655, b = -5156.23	0.0142
	Thigh clearance height sitting	$Y = a+b/e^x$, a = 11.66, b = 2.0309e-41	0.0055
	Elbow rest height	$Y = a+b\exp(-x/c)$, a = 19.68, b = 3.33e-05, c = -8.377	0.0308
Arm reach from wall	Functional leg length	$Y = a+bx\ln x$, a = 67.509, b = 0.0885	0.1737
	Thumb tip reach	$Y = a+b/x^{0.5}$, a = 184.79, b = -965.47	0.1743
	Shoulder grip reach	$Y = a+b/x^2$, a = 101.046, b = -198174.57	0.1516
	Elbow grip reach	$Y = a+b\exp(-x/c)$, a = 32.05, b = 0.1085, c = -23.97	0.1002
Hand length	Fore arm hand length	$Y = a+b\exp(-x/c)$, a = 39.49, b = 0.20891, c = -25.597	0.2298
	Hand breadth across thumb	$Y = a+bx^3$, a = 7.81, b = 0.000344	0.2250
	Hand thickness at metacarpal III	$Y = a+bx^3$, a = 2.326, b = 3.99e-05	0.0209
	First phalynx digit lll length	$Y = a+bx^3$, a = 5.11, b = 0.0002004	0.2257
	Palm length	$Y = a+b/x^c$, a = 2.63, b = 0.493, c = 0.9444	0.3940
	Grip diameter (inside)	$Y = a+bx^{2.5}$, a = 3.865, b = 0.0007799	0.1396
	Grip diameter (outside)	$Y = a+bx^3$, a = 7.088, b = 0.000193	0.0743
	Middle finger palm grip diameter	$Y = a+bx^2\ln x$, a = 2.639, b = 0.000165	0.0078
	Grip span	$Y = a+bx^c$, a = 10.39 b = -31.31, c = -0.8817	0.0123
	Maximum grip length	$Y = a+bx$, a = 2.0547, b = 0.4418	0.0557
	Index finger diameter	$Y = a+bx^3$, a = 1.248, b = 9.922e-06	0.0116
Foot length	Instep length	$Y = a+bx+cx^{0.5}+d\ln x+e\ln x/x$, a = 6198371, b =-30138.72, c = 1044031.4, d = -2860735.6, e = -11313634	0.6360
	Foot breadth (ball of the foot)	$Y = a+b\ln x/x$, a = 16.12, b = -55.124	0.1762
	Heel breadth	$Y = a+bx^c$, a = 4.879, b = 5.21e-07, c = 4.33	0.0991
Medial malleous height	Lateral malleous height	$Y = a+bx^c$, a = 5.296, b = 0.0311, c = 1.8076	0.2141

Table 4b Mathematical modeling for male anthropometric data

Data to be measured	data can be calculated	Equation	R^2 value
Suprailliac skin fold	Bicep skin fold	$Y = a+bx^{0.5}lnx$, a = 0.563, b = 0.298	0.2896
	Subscapular skin fold	$Y = a+bx^c$, a = -2.32, b = 3.524, c = 0.375	0.6605
	Tricep skin fold	$Y = a+bx^c$, a = -0.595, b = 1.358, c = 0.3709	0.3921
Head length	Menton to top of the head	$Y = a+b/x^2$, a = 24.84, b = -1059.20	0.0591
Heal breadth	Foot breadth	$Y = a+bx^2lnx$, a = 7.69, b = 0.00188	0.0302
Hand breadth at metacarpal III length	Hand breadth across thumb	$Y = a+b/x^2$, a = 12.25, b = -157.53	0.2350
Stature	Waist back length	Y = a+blnx/x, a = 84.34, b = -1228.20	0.0985
	Scapula to waist back length	Y = a+bexp(-x/c), a = 26.84, b =0.2997, c = -54.66	0.0350
Waist back length	Scapula to waist back length	$Y = a+bx^{0.5}lnx$, a = 5.924, b = 1.034	0.2053
Wall to acromion	Chest depth	$Y = a+bx^2$, a = 18.11, b = 0.0322	0.0920
	Wall to lumbosacral joint distance	Y = a+bxlnx, a = 4.63, b = 0.0226	0.0223
	Abdominal extension to wall	$Y = a+bx^{1.5}$, a = 17.52, b = 0.2126	0.1181
Hip breadth sitting	Thigh circumference	$Y = a+b/x^{1.5}$, a = 56.71, b = -2252.127	0.1986
Thigh circumference	Thigh clearance height	$Y = a+bx^{2.5}$, a = 8.559, b = 0.000254	0.2328
Thigh clearance height	Elbow rest height	Y = a+bexp(-x/c), a = -22.83, b = 37.93, c = -94.085	0.0998
Arm reach from wall	Coronoid fossa to hand length	$Y = a+bx^3$, a = 32.799, b = 9.03e-06	0.1586
Bi acromian breadth	Elbow-Elbow breadth sitting	$Y = a+b(lnx)^2$, a = 5.21, b = 2.555	0.1061

Table 5a Mathematical modeling for female anthropometric data

Data to be measured	data can be calculated	Equation	R^2 value
Stature	Vertical reach	$Y^{0.5} = a+bx^3$, a = 11.66, b = 6.4e-07	0.8340
	Vertical grip reach	Y = a+bexp(-x/c), a = 46.83, b = 38.24, c = -117.7351	0.8200
	Eye height	$Y = a+bx^2$, a = 63.17, b = 0.0033	0.8540
	Acromial height	$Y = a+bx^2$, a = 61.63, b = 0.0028	0.8596
	Elbow height	$Y = a+bx^{0.5}lnx$, a = -27.967, b = 2.0226	0.6803
	Olecranon height	Y = a+bx/lnx, a = -8.615, b = 3.394	0.6374
	Ileocrystale height	Y = a+bx/lnx, a = 10.88, b = 3.361	0.6566
	Illiospinal height	$Y = a+bx^2lnx$, a = 49.834, b = 0.00033	0.6400
	Trochanteric height	$Y = a+bx+cxlnx+dx^{0.5}lnx+ex/lnx$, a = -1.63e+08, b = -10901992, c = 251941.1, d = -19435741, e = 93588660	0.6399
	Metacarpal - III height	$Y= a+bx^3$, a = 43.29, b = 6.103e-06	0.6915
	Knee height	$Y = a+bx^2$, a = 26.221, b = 0.00079	0.3831
Bi-acromial breadth	Bi-deltoid breadth	$Y = a+bx+cx^{0.5}lnx+dx/lnx+e/x^2$, a = -5.56e+08, b = -30549408, c = -76357192, d = 3.29e+08, e = -7.34e+08	0.8402
	Chest breadth	$Y = a+bx+cx^{0.5}+d/x^{0.5}+e/x$, a = -1.0623e+09, b = -6390714.7, c = 1.35e+08, d = 3.73e+09, e = -4.91e+09	0.8663
	Chest depth	$Y = a+b/x^2$, a = 32.61, b = -11287.65	0.2061
	Inter seye breadth	$Y = a+b/x^c$, a = 20.098, b = 4.6387	0.4306
	Waist breadth	Y = a+b/x, a = 49.49, b = -767.801	0.4796
	Hip breadth	$Y = a+b/x^2$, a = 36.53, b = -8048.042	0.0028
	Wall to lumbosacral joint distance	$Y = a+b/x^2lnx$, a = 4.920, b = 0.00017	0.1871
	Abdominal extension to wall	$Y = a+b/x^2lnx$, a = 25.3078, b = -4515.616	0.0344
	Chest circumference	$Y = a+b/x^2$, a = 103.48, b = -20262.219	0.2249
	Wrist circumference	$Y = a+b/x^2$, a = 398.178, b = -127872.04	0.3620
	Waist circumference	$Y = a+b/x^2$, a = 98.8798, b = -25373.323	0.2629
	Thigh circumference	Y = a+bexp(-x/c), a = 32.63, b = 0.053, c = -8.724	0.0529
	Calf circumference	$Y = a+b/x^3$, a = 21.689, b = 0.000016	0.1153
Chest circumference	Wrist circumference	Y = a+bexp(-x/c), a = 13.56, b = 0.002, c = -11.67	0.6657
	Waist circumference	Y = a+bexp(-x/c), a = 56.213, b = 0.019, c = -12.492	0.4288
	Thigh circumference	Y = a+bexp(-x/c), a = 21.82, b = 0.0458, c = -8.037	0.1760
	Calf circumference	Y = a+bex, a = 25.24, b = 3.670	0.1342
Thigh circumference	Calf circumference	Y = a+bxlnx, a = 28.511, b = 0.0180	0.0730

Table 5b Mathematical modeling for female anthropometric data

Data to be measured	data can be calculated	Equation	R^2 value
Sitting height	Vertical grip reach sitting	$Y = a+b(\ln x)$, a = -37.75, b = 7.889	0.8290
	Sitting eye height	$Y = a+b/x^c$, a = 13.77, b = 0.0479, c = 1.6001	0.9432
	Sitting acromion height	$Y = a+b/x^c$, a = 5.45, b = 0.0255, c = 1.738	0.9505
	Sitting popliteal height	$Y = a+b/x^2$, a = 42.45, b = -9901.48	0.0552
	Knee height sitting	$Y = a+b/x^2$, a = 50.63, b = -10964.512	0.0630
	Thigh clearance height sitting	$Y = a+bx^3$, a = 1.264, b = -1.2508e-06	0.0095
	Elbow rest height	$Y = a+b/x^2$, a = 22.32, b = -12201.317	0.1648
Arm reach from wall	Functional leg length	Y = a+bexp(-x/c), a = 90.88, b = 0.078, c = -17.35	0.2106
	Thumb tip reach	$Y = a+b/x^2$, a = 85.68, b = -94515.718	0.2133
	Shoulder grip reach	$Y = a+b/x^2$, a = 77.08, b = -94261.343	0.1772
	Elbow grip reach	Y = a+bexp(-x/c), a = 20.79, b = 3.752, c = -67.58	0.1731
	Fore arm hand length	Y = a+bexp(-x/c), a = 37.56, b = 0.0629, c = -18.843	0.2165
Hand length	Hand breadth at metacarpal III length	$Y = a+be^x$, a = 49.67, b = 2.938e-07	0.4076
	Hand breadth across thumb	$Y = a+be^x$, a = 8.47, b = 2.2126e-08	0.3462
	Hand thickness at metacarpal III	$Y = a+be^x$, a = 1.4145, b = 9.947	0.2407
	First phalynx digit III length	$Y = a+be^x$, a = 4.520, b = 6.153e-09	0.1321
	Palm length	$Y = a+b/x^3$, a = 6.26, b = 0.000659	0.2861
	Grip diameter (inside)	Y = a+be-x, a = 4.46, b = -733396.22	0.0841
	Grip diameter (outside)	$Y = a+be^{-x}$, a = 6.50, b = -458923.50	0.0251
	Middle finger palm grip diameter	$Y = a+be^x$, a = 2.4695, b = 2.349e-10	0.0014
	Grip span	$Y = a+b/x^2$, a = 5.822, b = 97.38	0.0783
	Maximum grip length	$Y = a+bx^3$, a = 6.88, b = -2.71e-05	0.0190
	Index finger diameter	$Y = a+be^{-x}$, a = 1.235, b = 63082.646	0.0073
Foot length	Instep length	Y = a+bexp(-x/c), a = 4.76, b = 2.47, c = -13.94	0.6861
	Foot breadth (ball of the foot)	$Y = a+bx^{2.5}$, a = 6.494, b = 0.000805	0.1829
	Heel breadth	Y = a+bexp(-x/c), a = 4.13 b = 0.0015 c = -3.662	0.2277
Medial malleous height	Lateral malleous height	$Y = a+bx+cx^{1.5}+dx^3+e\ln x/x$, a = -8307706.3, b = 1089071.8, c = -211514.4, d = 411.13, e =16045323	0.8556
Suprailliac skin fold	Bicep skin fold	Y = a+be-x, a = 0.903, b = -0.658	0.1250
	Subscapular skin fold	Y = a+bexp(-x/c), a = 0.0819, b = 0.5361, c = -1.91	0.6296
	Tricep skin fold	Y = a+bexp(-x/c), a = 0.59, b = 0.061, c = -0.867	0.3686
Head length	Menton to top of the head	$Y = a+b/x^2$, a = 21.94, b = -1157.9552	0.1108
Heal breadth	Foot breadth	$Y = a+bx^3$, a = 3.924, b = 0.0014389	0.1444
Hand breadth at metacarpal III length	Hand breadth across thumb	$Y = a+bx^3$, a = 7.506, b = 0.0033	0.2467
Stature	Waist back length	$Y = a+b/x^2$, a = 50.24, b = -315643.69	0.1876
	Scapula to waist back length	$Y = a+b/x^2$, a = 31.204, b = -208833.62	0.1240
Waist back length	Scapula to waist back length	$Y = a+b/x^3$, a = 16.63, b = 0.000109	0.3011
Wall to acromion	Chest depth	$Y = a+bx^c$, a = 17.98, b = 2.150e-06	0.0070
	Wall to lumbosacral joint distance	Y = a+bex, a = 5.37, b = 1.35e-07	0.0121
	Abdominal extension to wall	Y = a+be-x, a = 19.36, b = 4805.416	0.0137
Hip breadth sitting	Thigh circumference	$Y = a+bx^c$, a = 32.59, b = 0.000328, c = 2.59	0.0580
Thigh circumference	Thigh clearance height	Y = a+bexp(-x/c), a = 8.82, b = 0.0931, c = -11.096	0.0540
Thigh clearance height	Elbow rest height	$Y = a+bx^2$, a = 16.99, b = 0.0148	0.0380
Hip breadth sitting		Y = a+bexp(-x/c), a = 24.94, b = 0.00024, c = -3.9706	0.0296
Arm reach from wall	Coronoid fossa to hand length	Y = a+bexp(-x/c), a = 30.78, b = 0.41, c = -31.113	0.1806
Bi acromian breadth	Elbow-Elbow breadth sitting	Y = a+be-x, a = 36.41, b = -7.098e+11	0.0508

Development and Performance Evaluation of Manure Spreading Attachment to Two Wheel Trailer

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Abstract

Crops draw nutrients from the soil in order to grow and this withdrawal is compensated through fertilizers and manures to maintain the productivity of soil and to achieve higher yields. The manure can be distributed before plowing on the land surface as a thin or thick layer by means of manual forks or mechanically. The problem faced in the application of manure during the indigenous method is the rate to be applied per hectare and non-uniformity of the size of particles. So, a study was planned to evaluate the field performance of a tractor PTO operated manure spreading attachment to a two wheel trailer and compare it with the traditional method of spreading manure. The machine mainly consists of a manure tub to load the manure, an endless chain conveyor for conveying the manure towards the rear end of the trailer and a hydraulically operated spreader drum to shear off manure. The machine was tested at Research Farms of the Tamil Nadu Agricultural University and at the farmer's fields. It possesses the linear relationship for the forward speed and chain conveyor speed with the application rate. But, the speed of the spreader drum did not influence the application rate of the manure. The desired application rate of the manure (12.202 tonnes/ha) was observed for the forward speed of 2.31 km/hr and the chain conveyor speed of 1.51 m/min with the effective width of 1.20 m and a time saving of 50-60 % when compared to the conventional method. The spread pattern obtained was a flat top profile, which is acceptable for uniform spreading. It can also be used as a trailer by just shifting a door whenever the trailer is required for transportation.

Introduction

Crops need nutrients to grow and develop and they draw these nutrients from the soil. If this withdrawal is not compensated for, the crop yield goes down progressively. This withdrawal is completed through fertilizers and manures to maintain the productivity of the soil and to achieve higher yields. Soil fertilization is carried out by means of organic matter in the form of farmyard manure, liquid manure faces, plants or straw and mineral matters. The manure has to be handled in bulk. So, the problem faced during application of manure differs from that of other fertilizer not only with respect to the rate to be applied per hectare, but also with respect to non-uniformity of the size of the particles. The overall goal for any field receiving manure should be how many gallons or tons of manure should be applied to a known area and to apply the manure as uniformly as possible (Bruce A. Mackellar and Lee W. Jacob).

Organic manure is considered as the eco-friendly bio-fertilizer for the highly polluted modern era. Proper

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application of manure to the land is essential to prevent pollution of land, ground and surface water and to prevent loosing of ammonia and other nutrients from the manure. Timely application of manure in accordance with the nutrient requirements of the crops will result in improved crop production. The application rate for solid manure is shown in **Table 1**.

The effect of lack of uniformity can be reduced by adjusting the distance between adjacent spreader paths so that there is some overlap of the outside areas of the spreader swath. The additive effect in the overlap areas tends to even out the uniformity between spreader swath (Charles D. Fulage). The application of manure has become mechanized in advance countries like other field operations but in India, the indigenous methods are still followed, i.e. loaded trolley or bullock cart is moved in the field and stopped at regular interval where a man other than the driver unloads a small amount of manure and drops it in the form of a heap. These heaps are later spread around manually with spades. This type of spreading results in an uneven spread and uncontrolled rate per unit area. Keeping in view these problems, a study was carried out to evaluate the field performance of a tractor PTO operated manure spreading attachment to the two wheel trailer for spreading manure.

The measures to be taken into account while applying organic manure are as follows:

- Restrict manure spreading on the land to the growing season of the crop; do not apply manure on the land when there is no crop.
- Balance the quantity of manure with the nutrient requirements of the crop. The quantity of manure which can be applied per ha depends on the soil type and should be limited to not more than the equivalent of 150 kg N per hectare.
- Evaporation of ammonia and greenhouse gases will be reduced when manure is not (or only for a short time) exposed to fresh air. The manure should be covered with soil (e.g. by harrowing) immediately after spreading or should be injected into the soil directly.

Millions of tons of organic solid waste are produced every year in India and the land application of these solid wastes has become a popular method of disposing of them in the environmentally safe manner. In Taml Nadu the farmers use solid organic manure in the field as bio fertilizer. They spread the manure manually in the field, which is a laborious, tedious, uneconomical and time-consuming process. Unfortunately, there is no mechanical device commercially available to spread the solid organic manure uniformly in the field. In this situation the development of an implement to spread solid organic manure uniformly in the field is compatible to the tractor operated tipping trailer will be a milestone for the mechanization of Indian farms. The developed implement can reduce the cost of operation and can ensure the timeliness of operation with high spreading uniformity.

Review of Literature

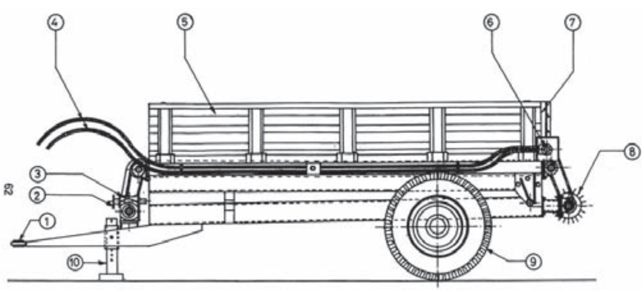
The organic manure spreading is a hot topic for the researchers in the modern world. Scientists have developed many manure-spreading techniques and the important ones are reviewed below to know the status of mechanization of organic manure spreading arena.

Crawford et al. (1976) developed a spreader for liquid or solid farmyard manure. The spreader comprised a manure container, an unloading rotor and a manure pusher. The rotor was spaced above the level of the bottom of the container and discharged over

Table 1 Application rate for solid manure

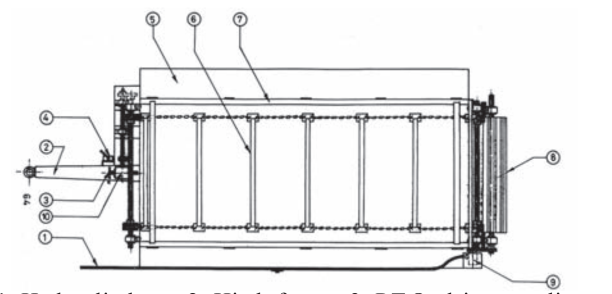
Spreader type	Manure density	Tons/acre
Large box	Light (30-35 lbs/ft^3)	7-25
Medium box	Heavy (60-65 lbs/ft^3)	10-30
Side slinger	Heavy	5-21

Fig. 1 Side view of the manure spreading attachment to two wheel trailer



1: Hitch frame, 2: P.T.O. drive coupling, 3: Reduction gear box, 4: Hydraulic hose, 5: Manure tub, 6: Hydraulic motor, 7: Adjustable door, 8: Spreader drum, 9: Pneumatic tyre, 10: Parking stand

Fig. 2 Top view of the manure spreading attachment to two wheel trailer



1: Hydraulic hose, 2: Hitch frame, 3: P.T.O. drive coupling, 4: Parking stand, 5: Tractor trailer, 6: Chain conveyor, 7: Manure tub, 8: Spreader, 9: Hydraulic motor, 10: Reduction gear box the rear wall of the container. Parish and Chaney (1986) studied the effect of forward speed on drop spreader performance and observed that the metering of two high quality drop spreaders was speed dependent but were neither fully gravimetric nor fully volumetric.

Vinyard (1994) suggested a rear pickup mechanism for a more even distribution of manure during spreading, the tank and attached rear pickup mechanism rotated fore and aft by means of a pintle attached to a frame. The tank was so placed relative to the pintle that, as the frame was raised relative to the wheels, the tank first tilted backward and then forward, preventing overspills. The tank was partially filled with water and then the tank and pickup mechanism rotated to keep the mechanism in contact with the area to be cleaned.

Parish (1995) estimated the effective swath width with a pendulum spreader and observed that the predicted swath widths were wider than the optimum swath widths determined from the pattern testing, but narrower than the normal swath widths determined from the pattern testing.

Dhaliwal and Vinay Madan (2003) developed and evaluated a tractor operated manure spreader and concluded that the unit required two persons and 8-10 min. to load a trailer and also the unloading time per trailer was a function of the conveyor speed and within four ranges of the speed of conveyor, the unloading time per trailer varied from about 2-6 min. while in the traditional method, it varied from 10-12 min. It showed that there was a saving of about 50 to 60 % of time with the use of this machine. The application rate increased with increase in conveyor speed at fixed forward speed and it varied from about 334 to 696 qt/ha.

Material and Methods

The tractor operated manure spreading attachment to two wheel trailer was used for the evaluation. This machine was tested at the research farms of the Tamil Nadu Agricultural University and the farmer's fields.

Description of the Manure Spreader

The main components of the developed implement were:

1. Main frame (Trailer)
2. Manure tub
3. Feeder (chain conveyor)
4. Spreader
5. Power transmission system
6. Adjustable rear door

i. Mainframe

The trailer was provided with two pneumatic tyres of size 7 × 5-16 PR to support the loaded trailer with minimum compaction. A front mounted adjustable parking stand was provided to support manure spreader for convenient hitching and attachment of PTO shaft. The manure tub, chain conveyor with feeder assembly and spreader assembly were mounted on the trailer (main frame).

ii. Manure Tub

The tub was rectangular shaped tub 3040 × 1340 × 450 mm. The spreader was on the rear end. The chain conveyor with feeder plate was mounted over the upper bottom of the manure tub. The chains moved the feeder plate from the front end to rear end of the tub. The chain drive shaft was at the front of the tub with a driven shaft at the rear. The side and top view of the manure spreader is shown in **Figs. 1** and **2**, respectively.

Fig. 3 View of the placement of collection tray for calibration

Fig. 6 Operational view of the manure spreader

Fig. 4 Acceptable spread patterns

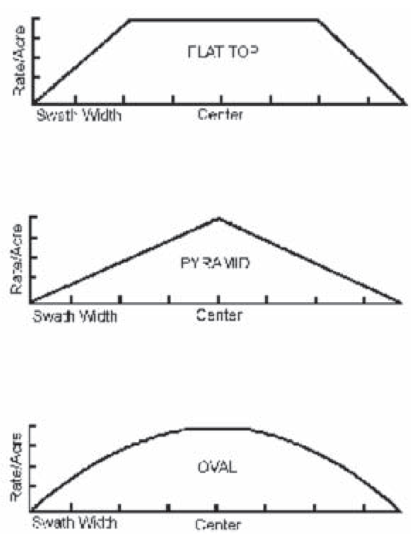
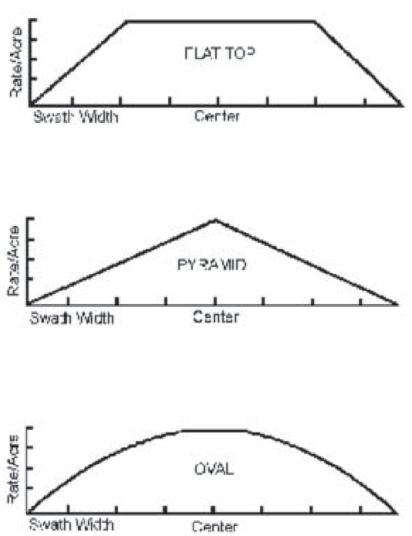


Fig. 5 Unacceptable spread patterns



iii. Feeder (Chain Conveyor)

A chain conveyor was used to carry the manure towards the spreader from the front end of the tub with help of feeder plate. The 16 feeder plates 1000 × 40 × 6 mm were welded to the endless chain with an interval distance of 450 mm. Also, two inverted "L" angles 1000 × 40 × 40 × 6 mm were provided between the feeder plate to remove the manure completely from the tub. The forward movement of the chain was achieved through the drive shaft, which was mounted at the front side of the manure tub. The driven shaft was mounted at the rear side of the manure tub. The chain was connected to the drive and driven shaft in such a way that it ran longitudinally over the manure tub.

iv. Spreader

The spreader assembly was mounted on the rear end of the manure spreader. It spread the manure fed by the feeder plate on the rear side of manure spreader. It consisted of 5 pair of disks with 40 mm diameter and twenty "L" angles of size 1050 × 40 × 40 × 6 mm that were welded longitudinally at the periphery of the pair of disks. The disk rotated at a speed of 200 rpm. All the disks were mounted on the drive shaft and the drives shaft received the drive from hydraulic motor through a chain and sprocket arrangement. The motor was connected to the tractor hydraulic lever through the cable.

v. Power Transmission System

The power for the manure spreader was transmitted from the tractor PTO to the reduction gearbox of the manure spreader where the power was reduced at the ratio of 30:1 and thence to the drive shaft of the chain conveyor assembly with chain and sprocket arrangement. The power for the spreader was transmitted from the tractor hydraulic motor with help of a cable.

vi. Adjustable Rear Door

An adjustable door made up of G.I. sheet of size 1340 × 450 × 10 mm was mounted in the rear end of the manure tub to control the amount of manure fed to the spreader. The door opening was adjusted from the 100 mm to 200 mm depending on the condition of the dry manure. The door opening distance needed to be calibrated for accurate application of manure with respect to moisture content since it is varying all the times.

Table 2 ANOVA for application rate

SV	DF	SS	MS	F
Treatment	26	1,631.5	62.75	293.02**
Spreader speed (S)	2	0.28	0.14	< 1
Conveyor speed (C)	2	90.03	45.02	171.47**
Forward speed (F)	2	1,523.2	761.6	2,901.0**
S × C	4	1.96	0.49	1.86 ns
S × F	4	1.15	0.29	1.10 ns
C × F	4	10.60	2.65	10.09**
S × C × F	8	4.30	0.54	2.05 ns
Error	54	14.18	0.26	
Total	80	1,645.7		

Calibration of Manure Spreader

Calibration of a manure spreader is a simple, easy management tool that can help the farmer use nutrients from animal waste more efficiently. By knowing the application rate of the manure spreader, correct amounts of manure can be applied to meet the crop needs. Over-application of manure wastes nutrients and increases the chance of ground water contamination. Using manure wisely is important for the farmers' crops and for their pocketbooks. The manure spreader is calibrated mainly for the application rate and determination of spread pattern of manure in the field.

Calibration Procedure

1. Load the spreader until the manure tub gets full.
2. The door opening distance needs to calibrated for the ac-

Fig. 7 Effect of forward of speed of tractor on application rate

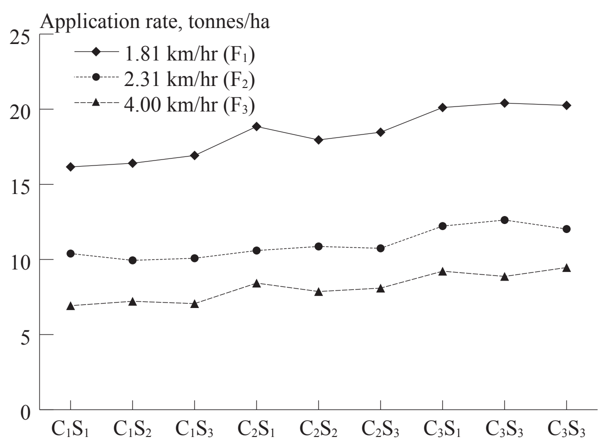
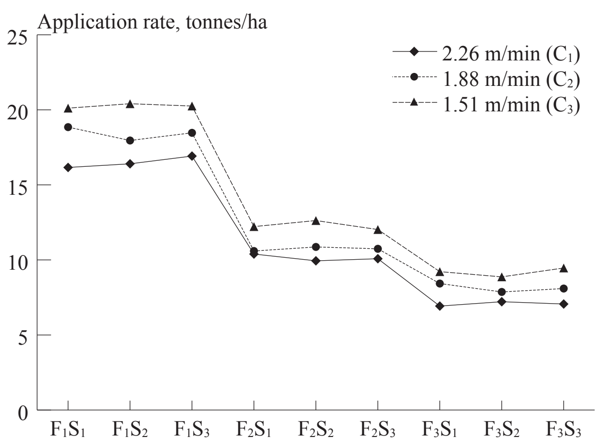


Fig. 8 Effect of chain conveyor speed of tractor on application rate



curate application of manure in the field for the every application of manure with respect to moisture content.

3. Keep the rear door in open position of 10 cm or 12.5 cm or 15 cm based on the manure condition.
4. Place collection trays on the ground so that they cover the entire width of the spreading (**Fig. 3**).
5. To get the results or done the calibration accurately, three batch of the trays were places as shown in the Fig.
6. Start the tractor and engage the PTO and move forward at selected gear. Then the manure starts spreading over the field and at a particular instant on the collection trays also.
7. The amount of manure collected on each tray were collected separately, labeled and weighed.
8. The graphical representation of relationship was made between the position of try (spreading width) and the amount of manure collected.
9. Using these results, the uniformity of distribution and application rate of the manure can be optimized.
10. The test procedure was repeated for all combinations of three forward speeds of tractor, three chain conveyor speeds, and three spreader drum speeds.
11. The procedure was repeated for getting concordant values for each combination of parameters.

Spread Patterns

Acceptable spread patterns include the flat top, the pyramid and oval as shown in **Fig. 4**. If the spreader does not spread any of the above acceptable patterns or something very close, make adjustments should be made using the operators manual until an acceptable pattern is realized.

It should be noted that the application rate is the amount at the center of the pattern (if acceptable pattern). The application should be uniform if the pattern is acceptable and proper swath width is observed. Unacceptable patterns are shown in **Fig. 5**. If the pattern is unacceptable, adjustments must be made until an acceptable pattern is found before swath width and application rate can be determined.

Evaluation of Manure Spreader

The evaluation of the manure spreader was conducted with the following treatments by measuring rate of application and pattern of spreading. The operational view of the manure spreader is shown in **Fig. 6**. The levels of the variables selected for the evaluation are furnished below.

Forward speed of operation, km/hr - 3 levels
1.88 km/hr - F_1
2.31 km/hr - F_2
4.00 km/hr - F_3

Linear speed of chain conveyor, m/min - 3 levels
2.26 m/min - C_1
1.88 m/min - C_2
1.51 m/min - C_3

Spreader drum speeds, m/min - 3 levels
25.12 m/min - S_1
37.68 m/min - S_2
47.10 m/min - S_3

Results and Discussions

The amount of manure collected on each tray were collected separately and weighed in the laboratory.

Table 3 C × F table of means for application rate (tonnes/ha)

Forward speed (F)	Chain conveyor speed (C)			F-Mean
	2.26 m/min	1.88 m/min	1.51 m/min	
1.81 m/min	16.482 a	18.447 a	20.281 a	18.403
2.31 m/min	10.100 b	10.733 b	11.928 b	10.920
4.00 m/min	7.076 c	8.131 c	9.192 c	8.133
C-Mean	11.219	12.437	13.800	12.486

Fig. 9 Effect of spreader speed of tractor on application rate

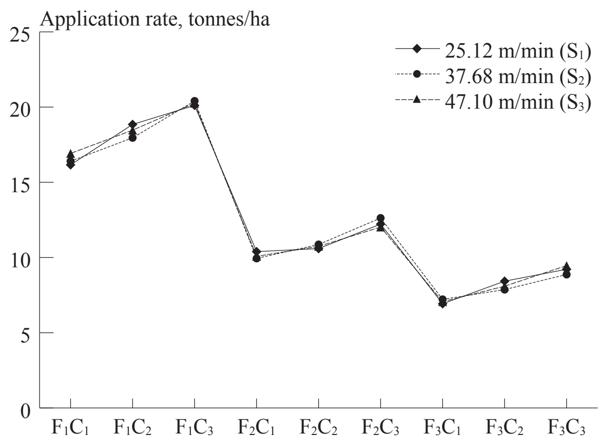
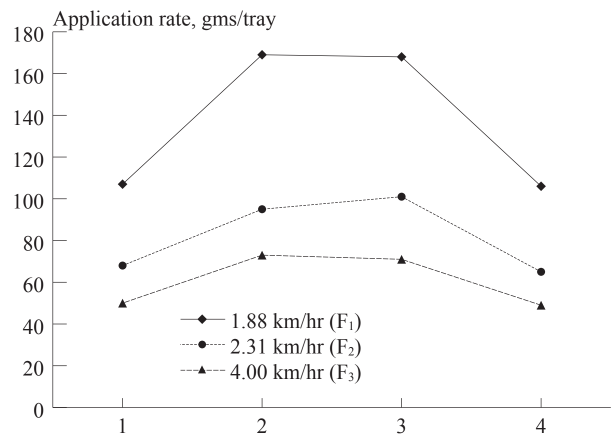


Fig. 10 Effect of forward of speed of tractor on spread pattern



The graphical representation of the relationship was made between the position of try (spreading width) and the amount of manure collected. The results were statistically analyzed using analysis of variance technique (ANOVA) with IRRISTAT package by following Completely Randomized Design (CRD) to assess the effect of levels of variables, namely, forward speed (F), chain conveyor speed (C) and spreader speed (S) on application rate of the manure.

From **Table 2** it was observed that the main effect of chain conveyor speed (C) and forward speed (F) were significant at the one percent level of probability, which indicated that the speed of the chain conveyor and forward speed of operation influenced the application rate. The main effect of spreader speed (S) was not significant, which revealed that it had no influence on application rate.

Effect of Forward Speed of Tractor on Application Rate

The effect of forward speed on application rate of the manure is presented in **Fig. 7**. It was observed that the application rate of the manure was significantly decreased when increasing the forward speed. Forward speed, F_3, respective of other variables, registered the minimum value (8.13 tonnes/ha) of application rate followed by F_2 (10.9 tonnes/ha) and F_1 (18.4 tonnes/ha). The reason was that when the forward speed was increased, application of manure over the field must be reduced. The interaction table for application rate is furnished in **Table 3**.

Effect of Chain Conveyor Speed on Application Rate

The effect of chain conveyor speed on application rate of the manure is represented in **Fig. 8**. The application rate of the manure linearly decreased with increased chain conveyor speed. The maximum application rate (13.80 tonnes/ha) was with a chain conveyor speed of 1.51 m/min followed by 1.88 m/min (12.437 tonnes/ha) and 11.219 tonnes/ha), respectively. The interaction table for application rate is furnished in **Table 3**.

Means followed by a common letter in a column are not significantly different at the 5 % level by DMRT.

Comparison	S.E.D.	LSD (5 %)	LSD (1 %)
2-C*F means	0.242	0.484	0.645

The interaction effects of forward speed and chain conveyor speed on application rate of the manure is given in **Table 3**. The results observed from the interaction table substantiated the results obtained from the graph.

Effect of Spreader Drum Speed on Application Rate

The effect of the spreader drum speed on application rate shown in **Fig. 9**. The quantity of manure spread over the field was not dependent on the speed of spreader drum. This may be because the spreader drum only spreads manure that was fed by the chain conveyor. Hence, the quantity of manure applied over the field depended on chain conveyor speed or forward speed of operation rather than the spreader drum speed. The interaction table for the application rate is shown in **Table 4**.

The interaction effects of forward speed and spreader drum speed on application rate of the manure is given in **Table 4**. The amount manure applied over the filed for the spreader speed of 25.12 m/min is 12.441 tonnes/ha followed by the spreader speed of 37.68 m/min and

Table 4 C × F table of means for application rate (tonnes/ha)

Spreader speed (F)	Forward speed (F)			S-Mean
	1.81 km/min	2.31 km/min	4.00k m/min	
25.12 m/min	18.423 a	10.702 a	8.199 a	12.441
37.68 m/min	18.248 a	11.107 a	7.986 a	12.447
47.10 m/min	18.539 a	10.952 a	8.214 a	12.569
F-Mean	18.403	10.920	8.133	12.486

Fig. 11 Effect of chain conveyor speed of tractor on spread pattern

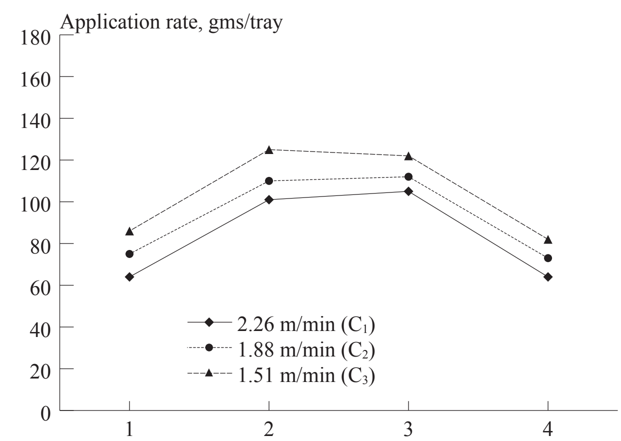
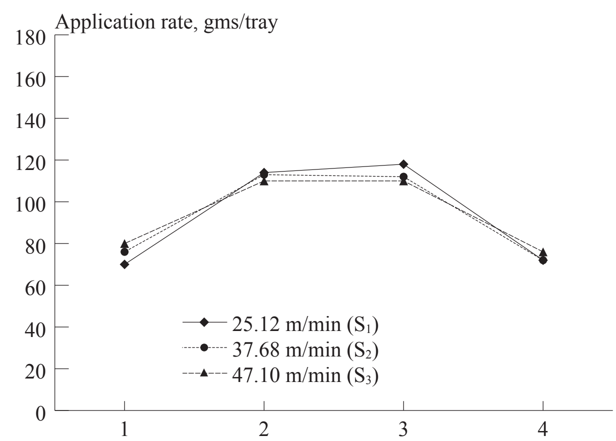


Fig. 12 Effect of speeder drum speed of tractor on spread pattern



47.10 m/min with 12.447 tonnes/ha and 12.569 tonnes/ha, respectively. The results observed from the interaction table substantiated the results obtained from the graph.

Effect of Forward Speed, Chain Conveyor Speed and the Spreader Speed on Spread Pattern

The spread pattern for the all the treatments were plotted using values averaged over three replications with tray position in X-axis and amount of manure collected in tray is in Y-axis. The spread patterns are shown in **Figs. 10** to **12**. The application in tones per hectare decreased with increase in speed of the tractor and increase with decrease in the linear speed of the chain conveyor.

In all the treatments spread pattern obtained was a flat top profile, which was acceptable form from the point of achieving uniform spreading.

Summary and Conclusions

The desired application rate of the manure can be obtained by selecting the suitable combination of the forward speed of operation, chain conveyor speed and the spreader speed. The application rate for the selected combination levels of the variables should meet optimum requirement of manure to be applied over field, which should be around 12 tonnes/ha. The results of the investigation are summarized and the values are furnished in the **Table 5**.

It may be seen from the table that the combination of the forward speed of 2.31 km/hr, chain conveyor speed of 1.51 m/min and the any of the speed of spreader drum equals the (12.202 tonnes/ha) optimum requirement of the manure to be applied over the filed. Based on analysis of results the following conclusions were made.

- The application rate decreased with increase in forward speed of tractor. Minimum (8.13 tonnes/ha) and maximum (18.40 tonnes/ha) application rate were observed for the forward speed of 4.00 km/hr and 1.88 km/hr, respectively.
- The application rate increased with decease in chain conveyor speed. The maximum application rate (13.80 tonnes/ha) was observed for the chain conveyor speed of 1.51 m/min followed by 1.88 m/min (12.437 tonnes/ha) and 11.219 tonnes/ha), respectively.
- There was a linear relationship for the forward speed and chain conveyor speed with the application rate manure.
- The speed of the spreader drum did not influence the application rate of the manure over the field.
- The spread pattern obtained was a flat top profile, which is acceptable form from the point of achieving uniform spreading.
- The desired application rate of manure (12.202 tonnes/ha) was observed for the forward speed of 2.31 km/hr and the chain conveyor speed of 1.51 m/min.
- The effective width of the manure for the all the treatments was 1.20 m.
- There was a 50-60 % of time saving with the manure spreading attachment two-wheel trailer when compared to conventional method of manure application.
- The manure spreading attachment to two-wheel trailer can also be used as a trailer by just shifting a door whenever the trailer is required for transportation.

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Table 5 Application rate of the manure for the different combination of variables

Chain conveyor speed, m/min	Spreader speed, m/min	Application rate of manure (tones/ha) at selected levels of forward speed		
		1.88 km/min	2.31 km/min	4.00 km/min
2.26 m/min	25.12 m/min	16.16	10.39	6.93
	37.68 m/min	16.40	9.94	7.22
	47.10 m/min	16.92	10.08	7.06
1.88 m/min	25.12 m/min	18.85	10.59	8.43
	37.68 m/min	17.96	10.86	7.87
	47.10 m/min	18.47	10.74	8.09
1.51 m/min	25.12 m/min	20.11	12.22	9.22
	37.68 m/min	20.41	12.62	8.87
	47.10 m/min	20.25	12.02	9.46

Development of Power Tiller Operated Groundnut Harvester

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Abstract

The power tiller drawn groundnut harvester was designed, developed and its performance was evaluated. The major parts of the groundnut harvester were main frame, side flange, tool mounting frame, tool, picker conveyor and depth wheel. Power for the picker conveyor was provided from the rotary gear box of power tiller through the belt pulley transmission system. The maximum harvesting efficiency obtained was 99.99 % with the draft requirement of 158.33 kg. The conveying efficiency, soil separation efficiency and conveyor loss were 99.99, 98.87 and 0.01 %, respectively. The field capacity of the groundnut harvester was 0.1 ha h^{-1}. The cost of harvesting with the prototype unit was Rs. 700/- ha^{-1}. The saving in cost and time were 30 and 93.75 %, respectively, as compared to conventional method of manual harvesting. Cost of the groundnut harvester was Rs. 5600/-.

Introduction

India earns commendable foreign exchange through the production of edible oils. Among the edible oilseeds, groundnut (*Arachis hypogea L*) is an important source of edible oilseed with 30 % of the total area under groundnut cultivation in the world. The groundnut production in India is 18 % of the total production with a productivity of 924 kg per ha as against the worlds average productivity of 1,449 kg per ha. (Annon, 2000). The productivity of oilseed crops in India can be improved by the introduction of improved varieties and the adoption of viable technologies in the mechanization of groundnut cultivation suitable to the Indian conditions. Mechanization of groundnut harvesting is very essential to increase pod recovery from the soil. The prevalent methods of harvesting operations are manual uprooting, using hand tools, using animal drawn groundnut diggers and using tractor mounted groundnut diggers. However, manual digging of pods from depth ranging from 6.5 to 10 cm is laborious, time consuming and less economical. Though the bullock drawn diggers have economic and timeliness performance compared to the conventional methods, it still consumes a major share of cultivation cost, which can be reduced only by the introduction of mechanical source of power. To materialize this objective, the groundnut harvester was developed as an attachment to a tractor at PAU, Ludhiana (Annon, 1974) and AEC&RI, TNAU, Coimbatore (Duraisamy, 1997), which caters the tractor owning big farmers. The large group of farmers with small and medium size holdings requires a suitable intermediate power source like power tillers to achieve the desired level of mechanization.

The productivity of the land is increased by 10 to 20 % with the use of power tillers (Narang and Varshney, 1989). According to the information furnished by the power tiller manufacturers and supplied by the Joint Commissioner, Department of Agriculture, Government of India (1996), Tamil Nadu accounts for 17.41 % of the total power tillers available in India. At present, implement attachments for power tillers have been developed only for performing tillage and sowing operations in groundnut cultivation. Keeping all these facts in mind, a power tiller operated groundnut harvester was designed, developed and its performance was evaluated to provide economical and efficient harvesting equipment suitable for farming systems of small and marginal farmers of developing countries.

Materials and Methods

The groundnut harvester was developed as an attachment to a power tiller as shown in **Fig. 1**. The power tiller used was of 9-12 hp. However, it was kept in mind that the drawbar horsepower available with the power tiller was only 10 to 20 % of the brake horse power (Tomar, 1985) and hence the power available would be 1.2 to 2.4 hp only. The groundnut harvester includes a main frame, side flanges, tool mounting frame, tool, gearbox and transmission system, picker conveyor and depth wheel as shown in **Figs. 2** and **3**. The function of each part and the materials of construction, along with specifications, are as follows.

Fig. 1 Prototype groundnut harvester as an attachment to power tiller

Main Frame

The main frame of the groundnut harvester was made from M.S. channel 40 × 40 × 6 mm. The main frame was 820 × 550 × 50 mm and was attached at the center to the rotary gear box of the power tiller. Two holes at a distance of 100 mm were provided on the main frame to adjust the distance between digging tool and pickup conveying mechanism.

Side Flange

Two side flanges 300 × 210 × 12 mm were made of M.S. flat as shown in **Fig. 4**. These were bolted to the main frame. Each side flange was provided with the semi-circular slot, which enabled the adjustment of the rake angle at different levels.

Tool Mounting Frame

Tool mounting frame (as shown in **Fig. 5**) of size 525 × 285 × 110 mm was made of flat M.S. 40 × 10 mm to enable the mounting of the tools with different geometry. It was bolted to the side flanges. Provision was also made to adjust the rake angle at different levels by rotating the tool mounting frame through a semi-circular slot on the side flanges. The frame had five holes 10 mm diameter on which to fasten the tool.

Tool

The tool with three types of geometry, namely, straight shaped, inverted V shaped and crescent shaped was developed for the experiment. The approach angle of zero deg was selected for straight tools and 15 deg for inverted V shaped and crescent shaped tool for the study, considering the soil tool interface interaction and penetration depth parameters. The tool was fabricated with 6 mm thick mild steel. The length, width and thickness of the tool were 500 mm, 65 mm and 6 mm, respectively. The front 25 mm of the tool was sharpened to have 15 deg taper. The tool was mounted on the tool mounting frame with screws for easy replacement.

Picker Conveyor Mechanism

The picker conveyor mounting frames were fabricated with 40 × 40 × 6 mm mild steel angles and the entire conveyor unit was hinged to the main frame. The picker conveyor consisted of two shafts mounted on self-aligned bearings fixed apart

Fig. 2 Front view of groundnut harvester

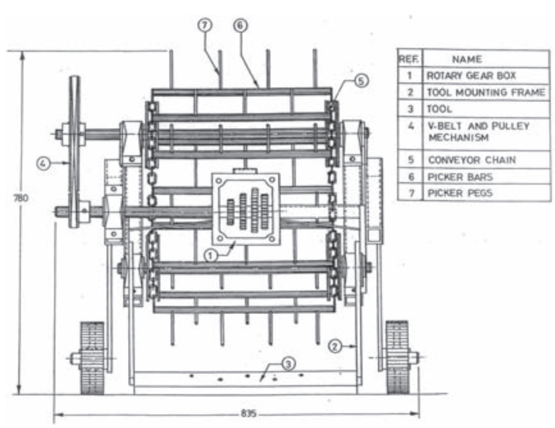
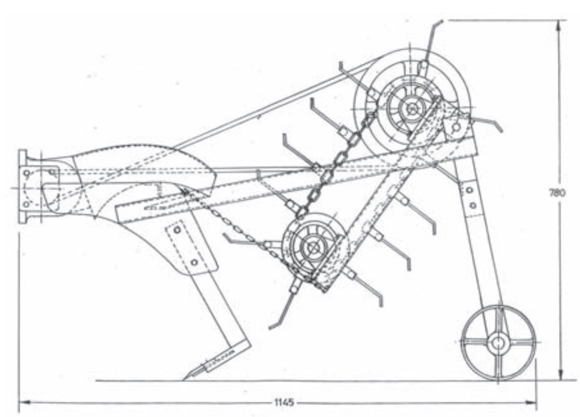


Fig. 3 Side view of groundnut harvester



at a center distance of 500 mm. Four chain pulleys of 16 cm diameter were mounted on the picker conveyor shafts. Picker bars spaced at 90 mm were fixed on the chains of 30 × 15 × 5 mm size connected end to end on both sides. Picker pegs 6 mm thick and 100 mm long were welded at 10 mm spacing on each cross bar. All the pegs were provided with the peg angle of 135 deg at their end along the travel direction for easy pick up. The lower end of the conveyor could be adjusted for making the pegs to comb the soil for easy pick up of the harvested plants.

The drive for the picker conveyor was provided from the rotary gearbox of the power tiller. From the rotary gearbox, the power was transmitted to the shaft of the groundnut harvester unit through V-belt and pulley mechanism. The driver pulley of 8 cm diameter was fixed on the splined end of the shaft of the rotary gearbox of power tiller, which has a facility of adjusting two variable speeds whereas the driven pulley of 25 cm diameter was fixed on the shaft of conveying mechanism.

Experimental Procedure

The ground nut digger shaker was tested in red sandy loam soil at different levels of tool geometry, rake angle, operating speed and soil moisture as shown below:

Tool geometry: straight, inverted V, crescent shaped

Rake angle (deg): 10, 15, 20.

Operating speed (kph): 1.5, 2.0, 2.5.

Soil moisture (percent): 10.5, 12.5, 15.5

The straight shaped tool was fixed to the tool mounting frame and the unit was attached to the hitch system of the power tiller. The power tiller was run at 10 cm penetration depth and 10 deg rake angle with 1.5 kph forward speed for 10m distance. The weight of pods collected from the harvested plants was noted. The pods left in the soil were manually collected and weighed. The harvesting efficiency was calculated as follows:

$\eta_h = W_p / (W_p + W_s) \times 100$

where,

η_h: Harvesting efficiency, percent

W_p: Weight of pods collected, kg

W_s: Weight of left out podsin the soil, kg

The experiment was repeated for all the levels of variables mentioned above. The pickup conveying mechanism was also evaluated in terms of conveying efficiency, soil separation efficiency and conveyor loss and were calculated as follows:

Conveying Efficiency

$\eta_{pc} = (W_1 + W_2) / (W_1 + W_2 + W_3) \times 100$

where,

η_{pc}: Conveying efficiency, percent

W_1: Weight of plants delivered by the conveyor, kg

W_2: Weight of plants remaining on the conveyor, kg

W_3: Weight of unpicked and dropped plants, kg

Soil Separation Efficiency

$\eta_{ss} = (W_1 - W_2) / (W_1 - W_2 + W_3) \times 100$

where,

η_{ss}: Soil separation efficiency, percent

W_1: Weight of plants fed at the picking end, kg

W_2: Weight of plants collected at the delivery end, kg

W_3: Weight of soil collected at the delivery end, kg

Conveyor Loss

$C_1 = W_2 / (W_1 + W_2) \times 100$

where,

C_1: Conveyor loss, percent

W_1: Weight of the pods collected at the delivery end, kg

W_2: Weight of pods lost in the conveyor from the plants, kg

Results and Discussion

The prototype groundnut harvester was developed and its detailed specifications are given in **Table 1**. The performance of the unit was evaluated in terms of draft requirement, harvesting efficiency, conveying efficiency, soil separation efficiency and conveyor loss.

It has been observed that the draft requirement was steadily increased

Fig. 4 Side frange

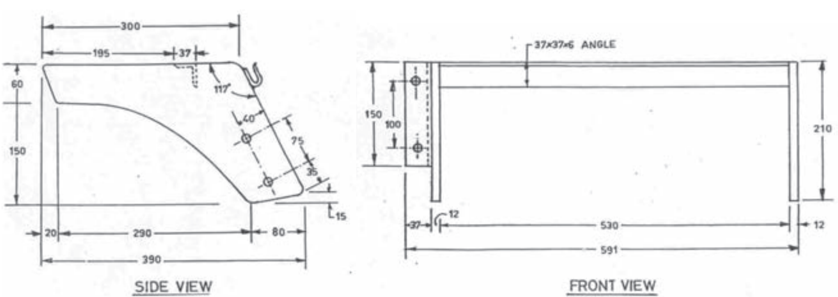
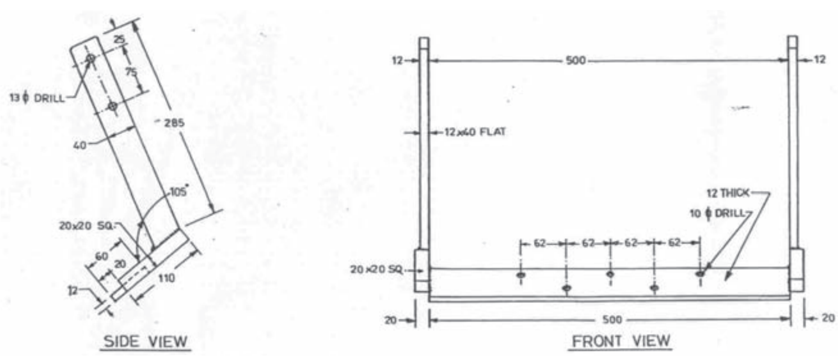


Fig. 5 Tool mounting frame



with the decrease in soil moisture level for all the three types of tool geometry. This might be due to more soil resistance due to decrease in soil moisture from 15.5 to 10.5 %. The increase in rake angle in all the three tool geometry increased the draft of the tool because of increase in soil resistance as the increase in rake angle increased the soil contact area (Harrison, 1982). The draft required was minimum for the straight tool while it was maximum for crescent tool at all the levels of rake angle and soil moisture under the study. The draft of 160.56 kg for straight tool, 174.11 kg for inverted V tool and 184.89 kg for crescent tool was required at 15 deg rake angle and 15.5 % soil moisture.

The harvesting efficiency also was significantly affected by the soil moisture, tool geometry and rake angle. The harvesting efficiency was maximum at 15.5 percent soil moisture while it was minimum at 10.5 percent soil moisture. The harvesting efficiency increased from 96.57 to 98.33 % for straight, 95.41 to 97.15 % for inverted-V and 95.14 to 96.80 % for crescent tool when the soil moisture level was increased from 10.5 to 15.5 %. The maximum harvesting efficiency was 98.93 % for straight tool, 97.64 % for inverted V tool and 97.38 % for crescent tool at 15 deg rake angle.

Comparing the best combinations of parameters, the maximum harvesting efficiency was achieved at a combination of 15 deg rake angle, 15.5 % soil moisture and 2.0 kph forward speed for the straight tool. The harvesting efficiency at this combination was 99.9 % with the draft requirement of 158.33 kg. The maximum conveying and soil separation efficiency was obtained as 99.9 and 98.87 % respectively with a minimum conveyor loss of 0.01 %. The capacity of the groundnut harvester was found to be 0.1 ha/h. The cost of harvesting with the prototype unit was worked out as Rs. 700/- ha^{-1}. The saving in cost and time were 30 and 93.75 %, respectively, as compared to conventional method of manual harvesting. The break even point of the prototype groundnut harvester costing Rs. 5600/- was 40.43 hr of operation per year.

Conclusion

The developed groundnut harvester was economical and efficient for harvesting of the groundnut crop with 30 and 93.75 % saving in cost and time respectively. The maximum harvesting efficiency at the best combination obtained was 99.99 % with the draft requirement of 158.33 kg. The conveying efficiency, soil separation efficiency and conveyor loss obtained were 99.99, 98.87 and 0.01 % respectively. The cost of the groundnut harvester was worked out as Rs. 5600/-.

Table 1 Specifications of the groundnut harvester

Name	Goundnut harvester
Source of power	Power tiller
Overall dimensions (L × B × H), mm	1145 × 835 × 780
Width of operation, mm	500
Depth of operation, mm	100
Digging tool dimensions (L × B × H), mm	500 × 65 × 6
Length of picker conveyor, mm	550
Width of picker conveyor, mm	450
Diameter of picker bars, mm	10
Spacing of picker bars, mm	90
Number of picker bars	12
Diameter of picker pegs, mm	6
Spacing of picker pegs, mm	100
Number of picker pegs	42
Weight of groundnut harvester, kg	87
Conveyor speed, ms^{-1}	1.05
Cost of the unit, Rs.	5600/-

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Development of High Capacity Fodder Densification Machine

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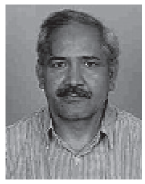

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Abstract

A commercially-viable fodder densification machine of one ton per hour capacity, capable of compressing all kinds of crop residues into feed blocks was developed. The machine could produce blocks of 37 × 37 cm cross section with variable thickness. A maximum volume reduction of 8.64 times could be achieved in a tough feed like wheat straw by this machine. The cost of the feed block formation using the machine was Rs. 265 (US $ 5.76) per ton.

Introduction

Crop production in the country has achieved new feats. This has simultaneously led to increased production of crop residue, which are usually considered as waste despite their huge potential for utilization as fuel, feed and chemicals. India produces 540 million tonnes (Baruah and Jain, 1998) of crop residues at present. The major problem associated with the residues is their low bulk density, which causes a serious problem in their transportation and handling. This leads to the problem of residue disposal during the harvest season. Consequently, most farmers prefer to burn them in the field, which leads to environmental pollution and loss of income that could otherwise be realized through their potential use. It is, therefore, felt that densification of these residues to an economical level is very important for their further use.

There are several densification processes like baling, briquetting and palletting which are in use in the country and elsewhere. However, these processes have been found to be useful for crop residues only to a limited extent. In a hunt for a better process, animal nutrition experts, through much research have suggested that the crop residue could profitably be used as animal feed by mixing with diet supplements like concentrates, molasses and mineral mixtures and densifying the mixture. It is an eco-friendly process as harmful gases are prevented from entering the environment as in the case of burning and soil friendly dung and urine are returned to the environment through the animal system. However, lack of a suitable machine for densification remained a deterrent for popularisation of this technology in the country. So, research efforts were undertaken towards development of a suitable machine at the Indian Agricultural Research Institute, New Delhi. Development of 60-70 kg/h capacity machine for feed block formation was reported by Verma et al. (1996) but it was not found suitable for commercial production. After development of the 200-250 kg/h capacity machine on a commercial scale by Singh et al. (2002), the technology of feed block formation received a major boost in the country. There was further demand for a commercial scale higher capacity machine from the feed industry. Therefore, the present work was undertaken to develop a one ton per hour (TPH) capacity machine for densification of crop residue based complete feed.

Materials and Methods

A fodder densification machine of one ton/h capacity was developed for commercial production of compressed complete fodder blocks, which could be used as a balanced diet for animals. The machine consisted of frame, hydraulic cylinders, power pack and electric control panel.

The machine was tested on a wheat straw based feed as it is considered to be the toughest feed from densification point of view. Since the wheat straw feed blocks were not found stable after compaction, it was mixed with varying molasses content (2 to 8 %). Four levels of compaction pressure (P) were applied to the samples of wheat straw with molasses for preparation of fodder blocks. The blocks were tested for their bulk density and stability. The bulk density of the compacted blocks was calculated with the sample weight and the measured volume. The volume was determined by the fixed cross section area and variable thickness of the blocks obtained after 24 h of compaction as the sample expanded and attained stability in their dimensions. The thickness of the blocks was measured initially and then after 24 h. The volume ratio of the two samples was defined as the resiliency of the compacted samples. Resiliency indicated the stability of the blocks after compaction. Higher resiliency indicated lower stability of the block. The compression ratio, an indicator of volume reduction, was obtained as the ratio of bulk density of compacted blocks to the initial density of the material compressed.

Results and Discussions

Development of High Capacity Fodder Densification Machine

A fodder densification machine of one ton per hour (TPH) capacity (**Figs. 1** and **2**) was developed. The machine was powered by a 45 hp electric motor. It consisted of the following components:

Frame: The frame consisted of a feed hopper, feeding chamber, compression chamber and feed block retention chamber. In addition to this, it supported the hydraulic cylinders. The overall dimensions of the machine were 5715 mm length, 1975 mm height and 1517 mm width.

Hydraulic Cylinders: The machine had four hydraulic cylinders; namely, main cylinder, feed hopper cylinder, exit door cylinder and top door cylinder. The main cylinder was used for compression of feed and to pushed the compressed block through the outlet of the machine. The feed hopper cylinder was used for automatic feeding of the feed material into the compression chamber. The exit door cylinder was used to close the door during compression of the feed material and to open the door for exit of compressed block. The top door cylinder was used for closing of the feed chamber from top during compression. The specifications of the cylinders are given in **Table 1**.

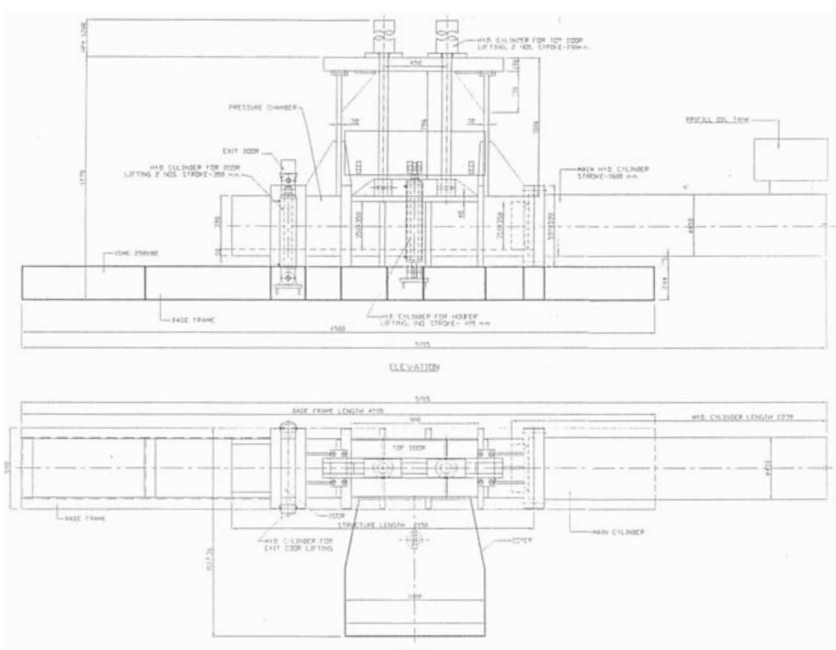
Power Pack: This consisted of high and low pressure pumps, pressure switch, pressure gauge, solenoid valve, oil reservoir, etc. The operation of hydraulic cylinder was conducted through high and low-pressure pumps. The direction of movement of cylinders was governed by a solenoid valve.

Electric Control Panel: This controlled the sequence of movement of the cylinders. Provisions were made for these controls in both automatic and manual modes. In automatic mode, the movement of cylinders was synchronized to complete a cycle of feed block formation.

Working of the Machine

A pre-weighed quantity of the formulated ration was fed to the hopper. The hydraulically operated feed hopper dumped the ration into the compaction chamber and returned to its initial position. Then, the top door cylinder moved downward and closed the compaction chamber from top. The ram of main cylinder then started moving forward and the plate fitted with the ram compressed the feed to a pre-set pressure. When the pre-set

Fig. 1 One ton per hour capacity fodder densification machine

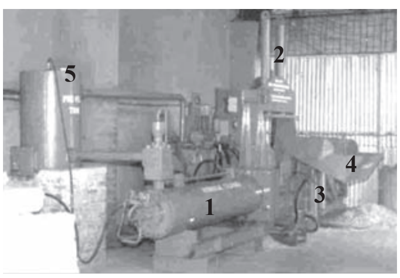


pressure was achieved, the forward movement of the cylinder stoped. Then, the cylinder moved backward a bit to release the pressure. The exit gate opened and the main cylinder, again, moved forward and pushed the compressed block through the outlet of the machine. The ram of main cylinder moved backward and returned to its original position, the exit gate closed and the cycle of feed block formation was completed. Time required to complete one cycle was about one minute. The machine had the provision to control the movement of the cylinders either in automatic mode or in manual mode. In automatic mode, the full cycle of feed block formation was completed by just pushing an electric button.

Features of the Machine

i. Three persons (unskilled/semi-skilled) are required to regulate the entire operations of the machine.
ii. The working pressure of the machine can be varied up to 420 kg/cm^2.
iii. It can compact all kinds of feed materials to square shape (37 cm × 37 cm) and of varying thickness and weight.
iv. The output capacity of the machine is one ton/h.
v. Fodder blocks prepared from the machine do not require tying, which is a significant incentive over the traditional baling machine in which tying is an integral part.

Fig. 2 High capacity fodder densification machine



1: Main cylinder, 2: Top door cylinder, 3: Hopper cylinder, 4: Hopper. 5: Prefill tank

Testing of the Machine

Bulk Density of Fodder Blocks

The fodder blocks were prepared using the wheat straw and molasses at different levels of compaction pressure. Bulk density (ρ) of the blocks as a function of compaction pressure (P, kg/cm^2) and molasses content (M, %) is shown in **Fig. 3**. Regression Eq. 1 was obtained for bulk density using statistical package SPSS. It varied from 334.8 to 468.7 kg/m^3. The bulk density at a given level of applied pressure increased with increased molasses content. Similarly, the bulk density of fodder blocks increased linearly with the increase in compaction pressure. A similar relationship of bulk density with compaction pressure was reported for wheat, barley and rice straw up to a compaction pressure of six MPa by Ferrero et al. (1990). Analysis of variance showed that both moisture content and compaction pressure had significant effect on bulk density.

$$\rho = 239.09 + 0.29 \times P + 11.96 \times M \quad (R^2 = 0.892) \qquad (1)$$

Resiliency of Fodder Blocks

The stability of the fodder blocks was a very important parameter to determine their quality. Resiliency (R, %) gives a relative measure of block stability. The higher the resiliency, the less stable was a compacted block. Resiliency as a function of compaction pressure (P, kg/cm^2) and molasses content (M, %) of samples of wheat straw blocks is shown in **Fig. 4**. It varied from 25.49 to 30.28 %. O'Dogherty and Wheeler (1984) reported a total resiliency of 56-

Table 1 Specifications of hydraulic cylinders fitted in feed block formation machne

Specification	Components			
	Main cylinder	Feed hopper cylinder	Exit door cylinder	Top door cylinder
Bore diameter, mm	350	100	100	100
Ram diameter, mm	280	56	56	56
Stroke, mm	1600	350	400	800
Mounting	Front flange	Clevis mounted	Clevis mounted	Clevis mounted
Prefill cylinder ram diameter, mm	135	-	-	-
Maximum working pressure, MPa	24.52	24.52	24.52	24.52

Table 2 Cost calculation of fodder block formation

Fixed cost (Rs.)	
Depreciation @ 20 % per year	48,000.00
Interest @ 10 % per year	72,000.00
Housing @ 20 % per year	120,000.00
Insurance @ 1 %	12,000.00
Total fixed cost per year	252,000.00
Variable cost (Rs.)	
Maintenance and repair @ 10 % per year	120,000.00
Hydraulic oil per year	120,000.00
Labour (10 per day) @ Rs. 100 per labour per day	300,000.00
Electricity @ Rs. 5 per unit	840,000.00
Total Variable cost per year	1,020,000.00
Total cost per year = Fixed cost + Variable cost = 252,000 + 1,020,000 = 1,272,000.00	
Cost per ton = 1,272,000.000 / 4800 = 265.00	

60 % in one h in wheat and oil seed rape straw. A correlation (Eq. 2) of feed block resiliency with pressure and molasses content was obtained by linear regression using SPSS package. Resiliency decreased with increase in compaction pressure and molasses content. Analysis of variance showed significant effects of moisture content and compaction pressure on resiliency.

$$R = 34.08 - 0.01 \times P - 0.46 \times M \quad (R^2 = 0.882) \text{ ....(2)}$$

Compression Ratio

Compression ratio (CR) indicated the reduction in volume as a result of compaction, which indicated the savings in transportation and storage by the same factor of volume reduction. Compression ratio varied from 6.35 to 8.84 for wheat blocks, indicating that densification into blocks saved up to 8.84 times of the storage, transportation space and costs. The compression ratio increased with increase in molasses content and compression pressure. Eq. 3 shows the correlation between compression ratio, molasses content and compaction pressure.

$$CR = 4.59 + 0.005 \times P + 0.23 \times M \quad (R^2 = 0.892) \text{ ....(3)}$$

Economics of Feed Block Formation

Economics of fodder block formation is an important aspect for utility of the machine. It was calculated as per the details given in **Table 2**. The following assumptions were made for the calculation:

Assumptions

Capacity: 1 ton/h
Machine price: Rs. 1,200,000.00
Useful life: 20 years
Working days per year: 300
Working hours per day: 16 (two shift of eight hours)
Depreciation: 20 %
Interest on capital: 10 %

Conclusions

A one ton/h capacity fodder block formation machine was developed for commercial production of fodder blocks of 37 × 37 cm size with variable thickness. Volume of wheat straw could be reduced up to 8.84 times by compaction into blocks using the machine. Cost of feed block formation was found to be Rs. 265 per ton.

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Fig. 3 Bulk density of fodder blocks as a function of molasses content and compaction pressure

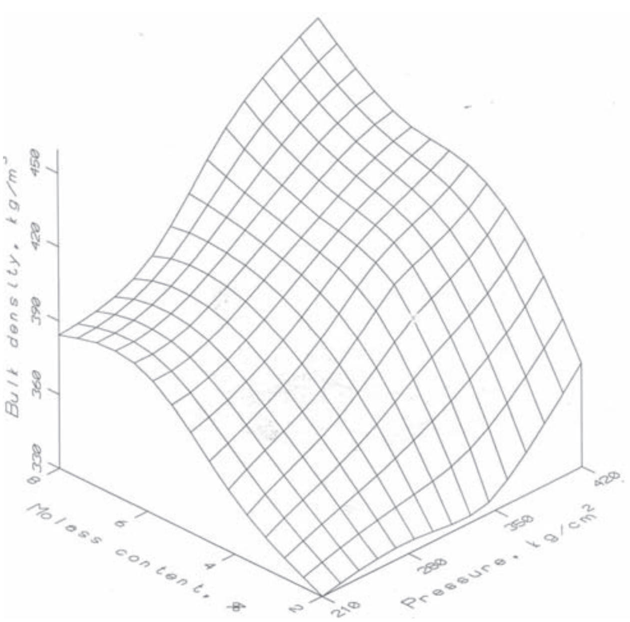
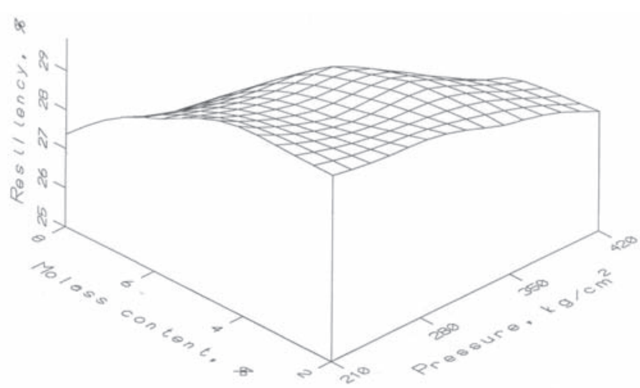
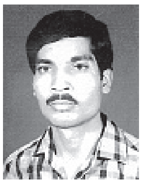


Fig. 4 Resiliency of fodder blocks as a function of molasses content and compaction pressure



A Review of Draught Animal Power as a Prime Mower for Site Specific Operations

by



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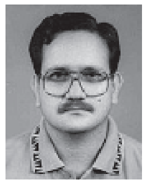

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Abstract

Use of mechanical power is increasing in Indian agriculture, still draught animal power continues to be used by a majority of small farmers. About 77 million draught animals supply 14.5 % of total farm power. The average annual use of draught animal has decreased from 655 to 567 hours per year during the period 1972-91. This power needs to be effectively utilised. Animal power can be harnessed by six different systems for operating agro-processing machines. The rotary gear system seems to be the most suitable of the all. Different systems of harnessing the animal power, and development work on rotary gear system at different places has been described in the paper.

Introduction

Draught animals are the major source of motive power (tractive and rotary) for a majority of farmers (mostly small) in India. Bullocks, buffaloes, camels, horses, mules and donkeys are common draught animals with a total population of 77.13 million in 1996-97. This represents 14.5 % of total farm power available in India (Singh, G., 1999). These animals perform different field operations and are also used for rural transportation. There are many advantages of using draught animals. They depend on locally available vegetation and grasses, thus, avoiding the risks inherent in the cost of commercial fuels like diesel and petrol. They have zero replacement cost as they multiply by reproducing. By-products like dung, milk, meat and leather also have commercial value. They can provide peak power at several times the average power over short periods. Even small farmers can afford to own them. It was observed that bullocks, camels and buffaloes are respectively utilized for 281 to 828, 499 to 1220 and 480 hours per year on an average in different agricultural operations. For the rest of the time they remain idle (Singh, G., 1999). Farmers have to maintain the animal throughout the year whether or not it is employed in gainful activity. Increased use of draught animal can add to the income of the farmer and also reduce the dependence on commercial fuels, which are getting costlier.

Animals in rotary mode can be used for different applications; such as water lifting, threshing, grinding, oil expelling, cane crushing and chaff cutting work. Thus, they can be used as a prime mower for most of the machines in villages and run between speed ranges of 200-1500 rpm. In this paper, an attempt has been made to present the review of different systems of harnessing of draught animals and development work being done on rotary gear systems at different places.

Systems for Harnessing Draught Animal Power

A study by Ajit Kumar (1991) described the different systems by which animal power can be harnessed to develop a prime mower that can be used to operate different agro processing machines. These systems are described here.

Hydraulic System

The system consists of a number of rubber or leather bags filled with water. These bags are placed one after another making a circular track. Animals walk continuously on the above track. The bags are connected to a cylinder-piston system (**Fig. 1**). The weight of the moving animal creates the pressure difference that drives the piston. The piston imparts this motion to a crank, converting this motion to rotary motion. As the body weight of the animal creates the pressure difference in the water tubs so an animal without a hump can also be gainfully employed. Animals can work for a longer period of time but very high precision is required to manufacture such a leak proof system. Thus, it will be very costly. The output from the system for bullock has been estimated as 0.245 hp, which is very low compared to the average output of a bullock of 0.5 hp.

Plank and Ratchet System

The animals walk over wide plank whose lower end rests on ground with the upper end attached to a ratchet and pulley (**Fig. 2**). The weight of the animal forces the plank downwards, the rope and pulley transmits this motion to the ratchet. The ratchet is connected to a shaft. A number of such planks are arranged to make a circular path, on which the animal walks and, thus, imparts continuous movement into the ratchet. The ratchet imparts this motion to the cylinder from where it can be used as prime mower. After the animal gets down a particular plank a spring winds the rope over the ratchet again. Body weight of animal is used to push the plank downward. Animals can work for longer periods of time. The output from the system has been estimated as 0.9 hp from one pair of bullocks, and that is good. Initial cost in manufacturing is high. It may require some training for the animal to walk over such inclined plank.

Drum Rope System

This device has cylindrical drums rotated by unwinding of a previously wound rope (**Fig. 3**). The animal walks in a straight path unwinding the rope tied to yoke on its neck, thereby rotating the drum. It is simple to operate, easy to manufacture and efficient. The cost is low but it has two major drawbacks; first, when the rope is unwound, how will it be rewound and, second, the returning animal doesn't contribute to productive output. The problem of unwound rope may be solved by using two cylinders or some other mechanical means. The output of the system has been reported satisfactory.

Hexagonal Pulley System

This device consists of chain and pulleys. The pulleys are mounted on pillars making a hexagon. The pulleys rotate in a horizontal plane by a chain passing over the six pulleys. A long beam connected to the chain through a link. The animals are hitched to along beam and move in a circular track outside the hexagon. One of the pulleys acting as main pulley transmits the power for productive use in the machines. Sagging of the chain is a major drawback of this system. A gear box is needed for stepping up the speed of the output shaft to suit the agro processing machines to be operated.

Two Plank System

The device consists of two planks, made to swing about a transverse axis. The planks are connected to the pulleys as well as to each other so that both of them do not come down or go up simultaneously (**Fig. 5**). Diagonal ends of the planks go down or come up simultaneously, like natural situation of walking of a four footed animal, in which the total weight of animal at any time is supported by the diagonally opposite legs and their centre

Fig. 1 Hydraulic system

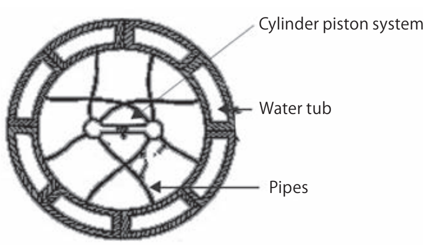


Fig. 2 Plank and ratchet system

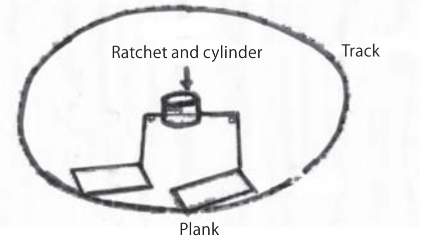


Fig. 3 Drum rope system

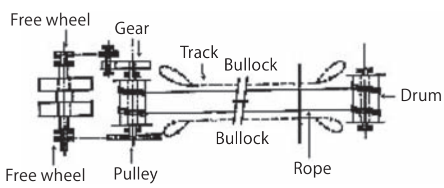


Fig. 4 Hexagonal pulley system

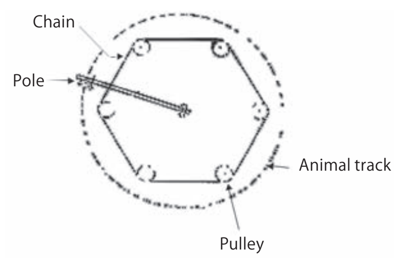


Fig. 5 Two Plank system

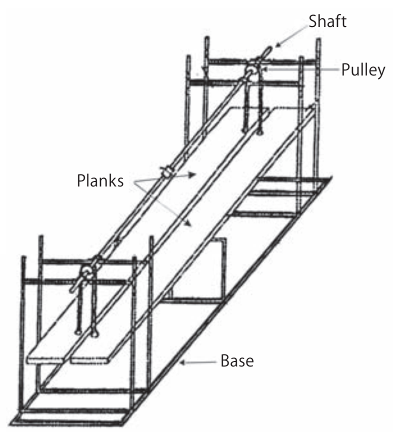
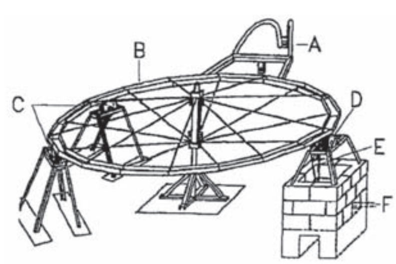


Fig. 6 Multipurpose gear system



of gravity remains at the centre of the diagonal, thus, maintaining equilibrium while walking quickly. Animals are allowed to stand in such a way that the two right legs rest on one plank and the two left legs rest on another plank. The animal is required to train, as initially it may fall from the planks. The power developed from one pair of bullocks is 0.9 hp.

Rotary Gear System

In the animal powered gear system, the animal moves on a circular path, the traction force developed through the neck is utilized to drive a gear system, which changes the horizontal rotary motion of the walking animals in to vertical rotary motion. This method is traditionally used in cane crushing, Persian wheel and oil expellers, which require low speed and very high torque. This low speed if stepped up with the help of gears can be utilized to operate agro-processing machines.

On comparing the above-discussed systems one can see that in the hydraulic system and inclined plank system, the body weight of the animal is used so animals can work for longer periods of time. But very high precision requirement in manufacturing as well as higher initial cost makes them unsuitable. The drum rope method is simple to operate, easy to manufacture, efficient and the cost is a low. But the returning animal does not contribute to productive output. The hexagonal pulley system is quite simple, but has practical difficulties like sagging of the chain. The two-plank system also uses body weight of the animal and requires training of the animal but chances of animals falling from planks are there. The animal powered transmission unit, which uses the animal walking on a circular track of 3.0 to 4.5 meter radius at 2-3 rpm can be stepped up to 400-500 rpm for operating many agro processing machines. It is certainly the most suitable of the above discussed methods for harnessing the animal power.

Developments in Rotary Gear System

A number of rotary gear systems have been developed in India and the world. The system consisted of gears to convert the rotary motion of bullock moving at 2-3 rpm in a circular track of 4-4.5 meter radius. The speed may be enhanced to suit the agro-processing machine to be driven. Until now, not a single system is available that can be used universally to act as prime mower to operate different agro-processing machines. There have been several different initiatives and various designs of equipment and techniques developed. Several efforts have been made to develop animal powered gear systems, which are discussed here.

Animal power was used to drive commercially available pumps using multipurpose gears. Eight donkeys pumped 5.3 cubic meters of water per hour with a head of 38 meters (Masang and Jacobi, 1988).

A multipurpose gear system for lifting water and grinding cereals that was developed by GATE (project-consult, 1986) is shown in Fig. 6. The system consisted of a large wheel (A) (4 m dia.) and three small wheels (B, C, D). Two of the small wheels supported the large wheel. When the large wheel rotated, its weight compelled a third wheel to rotate. This third wheel was connected to an output shaft through chain (E) and (F). The output shaft was situated below ground level so that the animals could walk easily in a circular path to drive the large wheel.

An animal drawn drilling rig for shallow tube wells was developed at IIT, Kharagpur is shown in **Fig. 7**. Horizontal rotary motion of the animals was converted to a vertical reciprocating motion to operate a mud pump used in drilling of a shallow tube well. The average speed of the bullock was 5 kmph and the power developed was 0.5 to 0.7 hp. The bullocks were allowed to move in a circular path of 2 m radius at 7

Fig. 7 Animal powered drilling rig

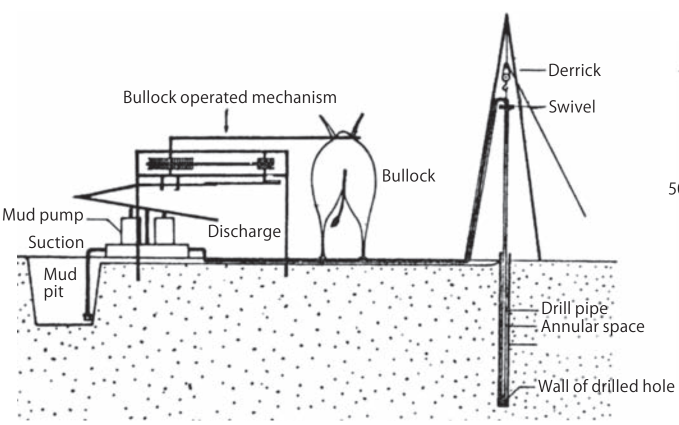
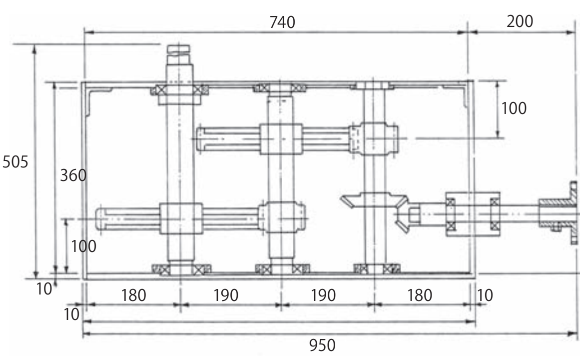


Fig. 8 Rotary gear system



rpm (Tiwari, 1984).

A bull gear was operated by a wooden beam (4.5 m) at CIAE, Bhopal. It had a speed ratio of 1:28 with an overall power transmission efficiency of 37-50 %. Frequent failure of first stage bevel gear was reported (Anon, 1988). To overcome this problem a rotary gear system was developed, using bevel and spur gears with a speed ratio of 1: 34.3 (**Fig. 8**). A shaft was used to transmit the power outside the animal track. A duplex water pump, flour grinder, and grain cleaner were operated. The system was technically suitable for chaff cutting operation (Anon, 1997).

A bullock powered gear (bull gear) with speed ratio of 1:33, developed at Rewari, (Haryana) shown in **Fig. 9**, was used to run a paddy thresher (hold on type) at 260-430 rpm (Anon. 2000). The draught requirement to run the thresher was low. Further, they suggested matching machines for development that would utilize the power developed by the system.

A bull gear already available in the market with speed ratio of 1: 57.5 was used at Pantnagar. There was a problem of frequent wearing of the bevel gears (Anon, 1988). A new system was designed and developed that is shown in **Fig. 10**. It consisted of two split flanged housing, vertical shaft with crown gear, horizontal shaft with spiral, pinion and spur gear. Two taper roller bearings, one near the top and other at the bottom end of the vertical shaft, were provided to minimize the friction and side thrust. It had a speed ratio of 1: 117.29 (Anon, 2000). A rotary Gear System was fixed to the concrete foundation by bolts and nuts. A wheat thresher and seed cleaner cum grader were operated as the matching machines for the developed system.

A Rotary Gear System developed at University of Agricultural Sciences, Dharwar (Karnataka), consisted of a set of bevel and spur gears, shafts and sprocket (Anon, 1988). Ball bearings were provided for the four shafts. An oil bath was provided in the bottom of gearbox to reduce friction (**Fig. 11**). Power from the gearbox was transmitted to the reciprocating pump and chaff cutter through pulleys, chain and sprocket. The system was used to drive a chaff cutter at 102 rpm. The output was low due to high losses in system. Slippage of the belt was observed while operating the chaff cutter by a single bullock (Anon, 1988).

A bullock powered Rotary Gear System was developed with speed ratio of 1:33 developed at PAU, Ludhiana, (Punjab). It was used to run a paddy thresher at 195-430 rpm with output of 80 kg per hour. It was suggested that, since the electric motors and engines are more popular, equipment needed to be developed to make the bullock-powered gear feasible (Anon, 1988).

The Rotary Gear System developed at Allahabad Agriculture Institute is shown in **Fig. 12** (Anon. 1988). It had four shafts comprised of one input, two intermediate and one output shaft arranged in such a way that three shafts horizontal and vertical and one shaft was horizontal. One of the shafts was used as input and the horizontal shaft was used as output. The upper end of the input shaft had splines to mount two rectangular plates with a splined hub on one plate and, in order to fix the beam for hitching the animals, the total stepping up was 117.29. The system was used to operate a loop type paddy thresher, disk type maize sheller, chaff cutter, flour mill and seed cleaner cum grader. They further stated that a pair of bullocks can develop only one hp. To operate a machine of 1-1.5 hp, three or more animals may be hitched.

Donkey powered equipment developed by GATE is a single purpose grinding mill mounted on a rotating beam (Boi, 1989). The power is supplied by a short chain driven from a ground wheel running on a low circular wall of 5-6 meter diameter. The speed ratio is about 1:10. The mill fitted with grinding stone can grind 515 kilograms of millet per hour into relatively fine food quality flour. The grain needed to be over dried.

Conclusion

Draught animals are not fully utilised in field operations. The idle period should be utilised in some gainful activity. There can be six different systems to harness this power using either traction force of walking animals or by body weight of the animal. A rotary gear system uses traction force developed by animals walking on a circular track. This system is similar to one that is traditionally used in water lifting, cane crushing and oil expelling. This system is suitable for harnessing the draught animal power. It is convenient, simple and easy to

Fig. 9 Rewari bull gear

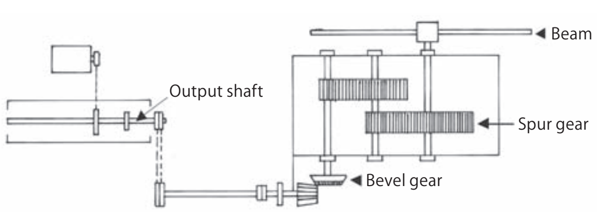
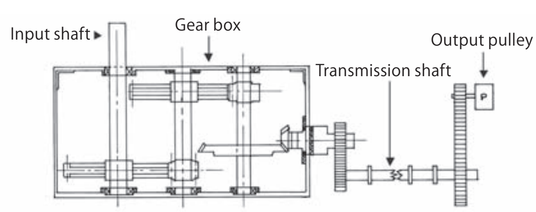


Fig. 10 Pantnagar-rotary gear system



operate. Many systems have been designed and developed at different places and tried for operating agro-processing machines. However a system acceptable to farmers is not yet available that can be used for such operations as chaff-cutting, flour grinding and threshing.

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Fig. 11 Dharwar rotary gear system

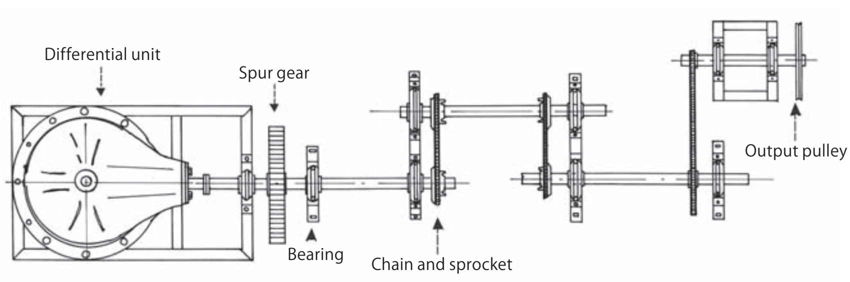
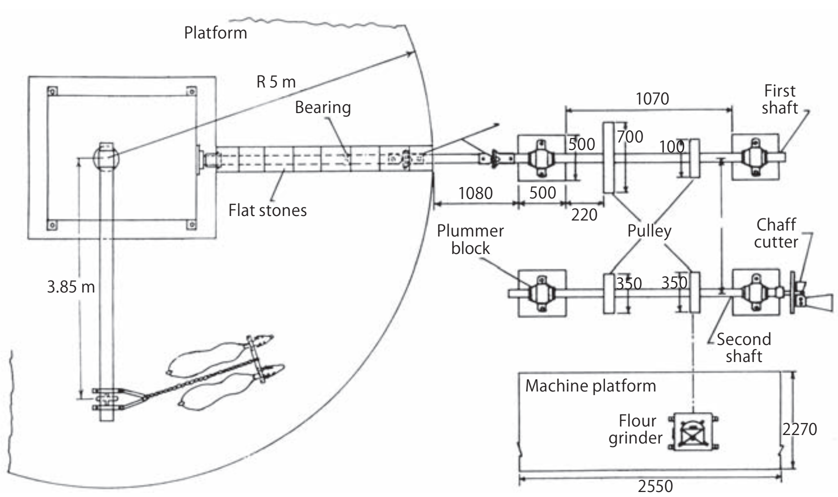


Fig. 12 Allahabad rotary gear system



Studies on Storage Characteristics of Betel Leaves

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Abstract

Betelvine, commonly known as Pan (*Piper betle L.*) is cultivated in India in about 55,000 hectares with annual turn over of Rs. 900 crores providing livelihood to about 15 million people. It is not only a local consumable commodity but also is exported to other countries. In addition to the medicinal value the betel leaves also have a good nutritional value. The essential oil of the betel leaves has high market value, which is used in the production of perfume, medicine, talc, beverages, food additives and mouthwash. Moreover, the betel vine cultivation, being labour intensive, provides employment throughout the year for cultivation, harvesting, grading, packing and marketing operations. The movement of the betel leaves starts from the growers' field to the consumer point through different ways. The green leaves are directly sold to the local pan vendors in local markets or to retailers that takes about 2 to 5 days to reach to the consumers. Betel leaves being high in moisture content is highly perishable in nature. So many a times the farmers have to bear the loss as they have to sell the products at throwaway price. Maintenance of the freshness of the green leaves for a few more days at the farmers' level would be a great help to them. The present study is an effort to increase the shelf life of the fresh betel leaves using low cost methods, which a producer can afford. Storage experiments for betel leaves were carried out using wet cloth wrapping, polyethylene pouches and ventilated polyethylene packaging. All these types of packages were stored in room temperature as well as in zero energy cool chamber. The stored leaves were subjected to physical examination (rotten leaves), sensory evaluation (freshness and taste) and biochemical estimation (moisture content, chlorophyll content, total soluble solids, ascorbic acid and pH) at an interval of three days. The environmental conditions that prevailed in the zero cool chamber was measured and compared to those of ambient conditions. The temperature remained less by 3 to 5 ºC and the relative humidity was higher by 8 to 10 % than the ambient conditions during the storage period. The overall analysis of the quality characteristics of the stored betel leaves showed that the zero energy cool chamber performed better than ambient conditions in respect of storage of fresh betel leaves. The betel leaves could be stored in zero energy cool chamber with acceptable qualities 2 to 5 days more than the leaves stored under ambient conditions, depending on packaging system. Among various packaging systems, the traditional package gave best results under ambient conditions, where as much difference could not be noticed among packages stored in the zero energy cool chamber.

Introduction

Betel leaves (*Piper betle L.*) is an important crop cultivated in the state of Orissa, India. The estimated acreage under betel leaves cultiva-

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tion in Orissa is around 4,000 ha. Limited shelf life and losses in quality have been identified as the major problems faced in the marketing of fresh green leaves. From an extensive survey in the betel leaves growing area it is observed that farmers incur great loss in the local market if the leaves are not sold on the same day. They are compelled to sell at a throwaway price. Refrigeration and cold storage systems often used for fresh produce storage are not always suitable due to their high cost and energy requirement. It is also reported that betel leaves are subjected to chilling injury when stored at refrigeration temperature. Since betel leaves consumption is mainly in the fresh form, it is essential that they are stored in a system that can maintain their freshness until consumption without any noticeable physiological disorder. The objective of this study was to asses the effects of evaporative cooling environment and various packaging systems on the storage life and their visual as well as biochemical qualities.

Fig. 1 Zero energy cool chamber

Fig. 2 Betel leaves under storage

Materials and Methods

A zero energy cool chamber (Indian Agricultural Research Institute, model) was constructed. The design was based on the evaporative cooling of a porous body. The structure consisted of a rectangular, double walled chamber carrying a heat insulating detachable roof. Each of the four composite sides consisted of two inter spaced walls. This jacketed type room in fresh leaves storage had the advantage of preventing heat leakage into the storage cabin. Each wall was 125 mm thick. The dimensions of the outer walls were 1650 mm × 1150 mm × 675 mm. The inner-spaced capacity (75 mm thick) was filled with river sand to the top of the cabinet. This absorbed water during wetting so as to keep the entire structure wet thereby preventing evaporation of internal moisture from the stored fresh leaves. The floor was plastered to a smooth finish. The top cover was prepared using gunny cloth and straw with a bamboo frame. The structure was constructed in a laboratory corridor where sufficient ventilation was available. A drip pipe system was laid on the sand bed of the inner space for uniform wetting of the sand. This pipeline was connected to a bucket filled with water which was placed on an elevation higher than the top level of the chamber (**Fig. 1**).

Experimental Procedure

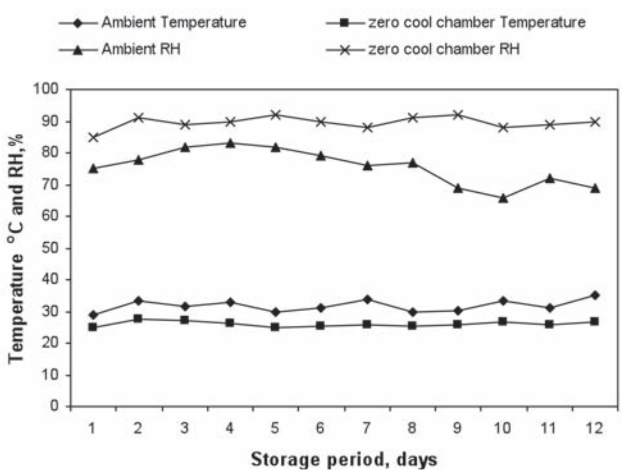
To study the effectiveness of the chamber, the environmental condition of the chamber was observed. Temperature and RH profile of the chamber were noted using temperature and RH indicator for comparative evaluation with ambient conditions. Fresh matured betel leaves of 'GodiBangla' variety were obtained from the growers' betel leaves garden. The leaves free of any visible defects were washed carefully under tap water and petioles were removed. The leaves were bundled into 50 each and packed in various packages. The polyethylene bags (film thickness 0.050 mm) of 20 cm × 20 cm size to simulate consumer packs were selected. The experiment had treatments in three sets in duplicates that were perforated, not

Table 1 Percentage rotten leaves in the storage experiment

No. of days		3	6	9	12	Shelf life of green betel leaves, days*
Ambient	SPA	20 %	40 %	-	-	3
	VPA	10 %	-	-	-	3**
	TA	2 %	16 %	35 %	-	7
Zero energy cool chamber	SPC	10 %	32 %	-	-	5
	VPC	4 %	22 %	-	-	4**
	TC	0	2 %	12 %	21 %	12

* < 20 % rotten leaves considered to be the limiting no. of days for accepted lot
** lost freshness through rotting was less

Fig. 3 Temperature and RH profile of storage environment



perforated and traditional packages (**Fig. 2**). A set of bags were perforated at four different points each side with each perforation creating 0.8 cm^2 space for aeration of packed leaves. After loading the produce, the chamber was closed with the insulated a cover. Another same set was stored under ambient conditions. Samples were drawn at intervals of 3 days to study the changes in the quality.

Quality Evaluation

Percentage rotten leaves were used as indices of decay upon daily inspection. The leaves showing decay signs were recorded and removed from the stored samples. Rotten percent was calculated using the number of rotten leaves divided by the total number of leaves per treatment. Generally black spots, over softening and mold growth were used as indices of rotting. Performance of all the packaging and storage conditions was evaluated through quality analysis of leaves. The analysis included the test for moisture content, pH, TSS, ascorbic acid & chlorophyll content. All these tests were conducted following the standard procedure (AOAC).

Results and Discussion

The performance of different packaging systems was different under different environmental conditions as expected. Analysis of the results and optimization of the storage parameters have been made. The climatic conditions (temperature and RH profile) during the storage period have been plotted as compared to that of zero energy cool chamber and presented in **Fig. 3**. The temperature remained less by 3 to 5 ºC and the relative humidity was higher by 8 to 10 % than the ambient conditions during the storage period. The results of the study indicated that the shelf life of the leaves stored by various methods ranged between 3 to 12 days (**Table 1**). Though there is a change in all the biochemical qualities, the changes are not noticeable to an extent that could affect the nutritional quality. Therefore, the storability of the green leaves may be assessed based on percentage rotten/rejected leaves. However, the overall analysis of the bio-chemical changes with time (**Table 2**) showed that the zero energy cool chamber gave better performance in comparison to ambient conditions in storing green

Table 2 Quality characteristics of betel leaves as influenced by storage conditions

Moisture content % (wet basis)

No. of days	Ambient			Zero energy cool chamber		
	TA	SPA	VPA	TA	SPA	VPA
0	87.25	87.25	87.25	87.25	87.25	87.25
3	86.92	87.03	85.26	87.10	87.22	86.80
6	86.65	86.96	80.15	86.92	87.10	84.28
9	85.92	85.26	74.32	86.55	86.88	78.35
12	85.02	84.44	*	86.10	85.36	*

TSSºB

No. of days	Ambient			Zero energy cool chamber		
	TA	SPA	VPA	TA	SPA	VPA
0	5.2	5.2	5.2	5.2	5.2	5.2
3	5.2	5.2	5.2	5.2	5.2	5.2
6	5.2	5.1	5.1	5.2	5.2	5.2
9	5.1	5.1	5.0	5.1	5.2	5.1
12	5.1	5.0	*	5.1	5.0	*

pH

No. of days	Ambient			Zero energy cool chamber		
	TA	SPA	VPA	TA	SPA	VPA
0	5.43	5.43	5.43	5.43	5.43	5.43
3	5.40	5.42	5.40	5.44	5.40	5.40
6	5.35	5.22	5.00	5.30	5.36	5.20
9	5.25	4.80	4.62	5.30	5.10	4.90
12	5.02	4.76	*	5.22	5.05	*

Ascorbic acid, mg/100g

No. of days	Ambient			Zero energy cool chamber		
	TA	SPA	VPA	TA	SPA	VPA
0	82.82	82.82	82.82	82.82	82.82	82.82
3	82.66	82.52	80.21	82.60	82.55	82.02
6	76.32	74.21	72.66	80.45	75.33	78.65
9	68.86	72.52	65.45	75.23	73.21	72.12
12	58.22	60.54	*	64.78	66.66	*

Chlorophyll content, mg/g

No. of days	Ambient			Zero energy cool chamber		
	TA	SPA	VPA	TA	SPA	VPA
0	0.748	0.748	0.748	0.748	0.748	0.748
3	0.746	0.740	0.701	0.745	0.745	0.722
6	0.735	0.735	0.652	0.740	0.730	0.688
9	0.712	0.702	0.565	0.741	0.730	0.602
12	0.652	0.651	*	0.705	0.680	*

* lost freshness so observations have not been taken
TA: Traditional packaging, Ambient condition
SPA: Sealed Polyethylene packaging, Ambient condition
VPA: Ventilated Polyethylene packaging, Ambient condition
TC: Traditional packaging, zero energy Cool chamber
SPC: Sealed Polyethylene packaging, zero energy Cool chamber
VPC: Ventilated Polyethylene packaging, zero energy Cool chamber

betel leaves. This may have been due to the favourable environmental conditions that prevailed inside the zero energy cool chamber as shown in **Fig. 1**. Although there was no appreciable difference in range of temperature as well as RH of the ambient conditions with respect to optimum storage conditions of betel leaves, the zero energy chamber maintained a relatively constant environment, which probably prevented the spoilage of the biochemical qualities of the leaves. Leaves stored in ventilated packs maintained nutritional qualities almost at par with those in other packages but the freshness of the leaves were lost because they did not obtain sensory acceptability.

Conclusion

The study exclusively concludes that though there was a change in all the biochemical qualities, The changes were not noticeable to an extent that could affect the nutritional quality. The zero energy cool chamber gave better performance in comparison to ambient conditions in storing green betel leaves for a short period. Among the different packaging system used in the experiment, the leaves store.d in traditional package fetched highest sensory acceptability. Ventilated polyethylene packs are not to be recommended at all as it losses the moisture rapidly. Polyethylene packs are to be used if the leaves are to be stored for a limited period only.

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Prospects of Paddy Cultivation Mechanization in Hills of Himachal Pradesh

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Abstract

Paddy is an important cereal crop of the state, next only to maize, during wet season as it is grown in 22.2 % of the net cultivated area with average yield of 1.7 t/ha. Research work in the development and dissemination of engineering cost effective technologies carried out to mechanize the paddy cultivation for the state can play a dominant role in augmenting and sustaining the paddy production. Seedbed preparation and puddling with power tiller rotary has enhanced the yield by 25-30 % and capacity and quality of work 3-4 times with 50 % reduction in cost of operation in comparison to bullock ploughing and puddling. The practice of rota-tilling and puddling for paddy cultivation is becoming popular among the farmers of this region. Mechanical paddy transplanting by manual paddy transplanter has ensured proper crop stand and has given 25-30 % increased yield compared to traditional sowing. Serrated sickle for harvesting paddy has given 25-35 % higher capacity as compared to plain sickle. Similarly, weeding and threshing operations by cono weeder and different types of paddy threshers has produced better results and has save labour and time. This means that the various operations needed for paddy cultivation have to be mechanized, not necessarily with the costly automatic equipment, but with suitable improved implements suited to local hilly conditions.

Introduction

Paddy (*Oryza sativa*) is one of the important cereal crops of the Himachal Pradesh. It accounts for 10.8 % of area and 10.2 % of production on a total food grain basis and 22.2 % of area and 18.6 % of production on wet season crops basis. During 2000-01, it was cultivated on an area of 806,000 ha with a production of 1,374,000 tonnes and productivity of 1,705 kg/ha (Anon, 2002). Paddy-wheat is the major cropping system in the paddy growing areas of the state. In paddy crop cultivation, conventional practices are followed for most of the farm operations that consume maximum time, energy, cost as well as increase drudgery to the farmers and farm laborers. Not only this, but rearing of draft animal power is becoming very costly resulting in enhanced cost of farm operation (Varshney and Bohra, 1989). The unique undulating topography of the state and small field size restrict the introduction of bigger power sources and equipment. A few countries like China, Thailand and Japan have replaced the draft animal power significantly with the introduction of the power tiller (Chancellor, 1971 and Depeng et al., 1983). Such a power source may lead to farm mechanization, thus reducing human physical strain for all the farm operations in hilly region also. It is well known that better cultivation practices, plant protection measures and a balanced dose of fertilizer play a significant role in augmenting paddy yields. Nevertheless, the adoption of improved implements is equally important for better germination, proper plant stand and interculturing. These are the pre-requisites for good crop yields and mechanical harvesting and threshing that result in less losses, reduction in drudgery and labour saving. It is the need of the hour and a challenge to change agricultural strategy for increasing crop yields through appropriate mechanization to meet the food grain requirement of increasing population.

Research conducted by scientists on different aspects reveals that decisively higher yield can be obtained by the vigorous introduction of improved power source, tools, implements and machines. This means that the various operations needed for paddy crop cultivation have to be mechanized, not necessarily with the costly automatic equipment, but with improved implements better suited to local hilly conditions. To explore the possibility of mechanizing paddy cultivation, different farm operations have been reviewed and available information has been analyzed for the benefit of hill farmers.

Mechanization Prospects in Paddy Cultivation

Seed Bed Preparation and Puddling

Land preparation is one of the critical farm operations for paddy farmers of Himachal Pradesh and it plays a significant role in crop establishment. The seedbed preparation including ploughing and puddling take up nearly 45 % of the total power required for cultivating paddy (Anon, 2002) and hence the choice of type of power source and implement for seedbed preparation and puddling will determine the cost economics of paddy production.

Bullock power is still dominating in the hill farming of Himachal Pradesh and traditionally, bullock drawn indigenous plough/soil stirring plough is used in all stages of land preparation, starting from primary tillage to puddling (**Fig. 1**), requiring a fair chunk of operational energy (Singh, Sukhbir, 2005). Introduction of improved bullock drawn puddler has not been possible due to inadequacy of power obtained from local bullocks. In most of the region, there is a problem of clod formation after ploughing in clay loam soil, especially after paddy harvesting. Then, farmers have to apply extra labour and time for clod breaking, which ultimately increases cost of operation with higher drudgery. Field experiments conducted by Vatsa and Singh (1997) to study the effect of modern and traditional tillage treatment on paddy (**Table 1**) reveals that there is a significant saving in cost, time and energy with power tiller system. **Table 1** also indicates that the field capacity of the power tiller rotavator was 3.0 times more than the field capacity of bullock ploughing with soil stirring plough. However, field capacity and cost of operation of planker was almost same in both the power tiller and bullock systems.

Statistical analysis showed that yield under rota-puddling twice was significantly higher than puddling twice with bullock plough. Seedbed preparation and puddling should be done with power tiller rotavator to achieve better puddling index (**Fig. 2**). Rota-puddling with power tiller can successfully enhanced crop yields by 25-30 %.

Sowing and Transplanting

Establishing proper plant stand is the most crucial requirement in any crop cultivation. On the other hand, farmers are still using traditional methods, i.e. broadcasting of sprouted/dry seed in puddle/dry soil and haloding (thinning) after 20-25 days with bullock drawn plough (**Fig. 3**).

Manual transplanting is done by

Table 1 Comparison of power tiller and bullock farming systems

Parameter	Power tiller system		Bullock system	
	Rota-puddling × 2	Planker × 1	Puddling with S.S. Plough × 2	Planker × 1
Effective field capacity, ha/h	0.069	0.22	0.023	0.24
Field efficiency, %	64.2	75.1	57.4	71.6
Labour requirement, man-h/ha	14.49	4.54	43.47	4.76
Cost of operation, Rs/ha	704.49	214.77	1,994.34	191.12
Yield, q/ha	24.8		18.4	

Source: Vasta and Singh (1997)

Fig. 1 Puddling with bullocks

Fig. 2 Puddling with power tiller

Fig. 3 Broadcasting of sprouted seeds

few farmers. These methods results in higher labour and cost involvement with poor germination resulting in less yield. To mechanize the transplanting of paddy in hills, field experiments conducted under AICRP on FIM on use of manual paddy transplanter (**Fig. 4**) indicate that transplanter can save 2-4 times labour and 54-73 % cost of operation over traditional sowing (**Table 2**). Additionally, there was a 25-30 % increase in yield also due to better plant stand and tillering.

Weeding and Irrigation

Sub-optimal plant stand, low and imbalanced use of plant nutrients, poor weed and water management are key production constraints to higher rice productivity in the state. Weeds compete with the crop plants for soil nutrients, moisture, light and space. Generally, weeding in paddy is done manually by hand resulting in very low output and involves great drudgery. By the use of improved weeding tools and implements, weeds can be controlled effectively and timely resulting in higher production and productivity. Various weeders like cono weeder are now available which could be used between crop rows in paddy crop for higher efficiency. Line sown/planted crop can only be weeded with improved available weeders.

A fertilizer dose of 90:40:40 kg N, P_2O_5 and K_2O/ha has been recommended for transplanted rice. In zinc deficient soils 25 kg zinc sulphate/ha should be used. Use of Butachlor at 1.5 kg a.i./ha for upland rice, Butachlor + Safener at 1.0 kg a.i./ha for sprouted rice and Butachlor granules at 1.5 kg a.i./ha for transplanted rice gives efficient weed control.

For efficient water management in upland rice, raising of field bunds by 25 to 30 cm is a must to harvest adequate rainwater in field. In areas of low temperature, water level of 4 to 5 cm depth should be maintained and continuous flow of water from field to field should be avoided.

Crop Protection

Plant protection measures are imperative in saving the paddy crop from disease, insects and pests. Many different kinds of spraying and dusting machines are available to meet the requirements of agriculturists in controlling insects, disease and weeds. The common type of sprayer is knapsack sprayer, which can be used in hilly areas. It is provided with a pump and large air

Table 2 Comparative performance of paddy sowing/transplanting techniques

Particulars	Mannual paddy transplanter	Hand transplanter	Traditional
Type of nursery used	Mat type	Root wash	-
Row spacing, cm	20	8-10	-
Plant to plant spacing, cm	15-16	10-14	-
No. of plant or seed/hill	3	2-3	2-3
No. of plant or seed/m^2	42-48	47-56	82-90
Field capacity, ha/h	0.03	0.004	0.16
Field capacity for halod, ha/h	-	-	0.025
Labour requirement, man-h/ha	66	250	144.75
Cost of operation, Rs/ha	528	2,000	1158
Yield, q/ha	27.84	26.20	21.52

Source: Annual report, AICRP on FIM (2004)

Table 3 Performance of hand and power operated paddy threshers

Parameters	Paddy thresher			Bullock treading
	Hand operated	Power tiller operated	Tractor operated	
Threshing capacity, qtls/h	0.3	1.5	8-10	0.30
Cost of operation, Rs/qtls	70	35	35-38	153
Cost of machine	2,500	6,750	60,000	6,000*

Source: Annual report, NATP (2004) * Pair of bullocks

Fig. 4 Manual paddy transplanter in operation

Fig. 5 Traditional system of paddy threshing

Fig. 6 Improved system of paddy threshing

chamber permanently mounted in a 9 to 22.5 liter tank. One man can spray about 0.4 hectare in a day thus spraying about 90 liters of liquid. Engine operated, shoulder mounted sprayers are available which are ideal for spraying operations. Since they are very precise in their operation, good care is required in their operation. Where dusting is to be done for the control of pests, manually operated crop dusters are quite effective.

A single spray of Chlorpyriphos 20 EC at 1,250 ml/ha saves the crop from insects and pests along with economic loss. For management of disease like rice blast, brown spot and grain discoloration, the standing crop can be sprayed with Bavistin (0.1 %) at tillering, PI & booting or Beam 75 WP (0.06 %) at PI and booting stage.

Harvesting

Timely harvesting of cereal crops reduces the risk of weather hazards and clears the fields for the next operations. The most common harvesting tool in Himachal Pradesh is the plain sickle, which has lower capacity and higher drudgery. Serrated sickle used for harvesting paddy gives better performance (25-35 % higher) as compared to plain sickle. However, a mechanical harvesting device like the vertical conveyer reaper with width around 1.0 meter is the need of hour to easily harvest the paddy crop in time with reduced drudgery.

Threshing/Shelling

The treading bullock is the most commonly used practice for paddy threshing (**Fig. 5**) by the majority of the farmers in the state (Singh, Sukhbir, 2005). Threshing of paddy can be done easily and quickly by the use of various paddy threshers. However, some farmers use beating practice. Various types of hand and power operated paddy threshers have been evaluated here and results are presented in **Table 3** (**Fig. 6**). It is clear from the table that the cost of operation of the traditional system is very high (2-4 times) as compared to different types of paddy threshers.

Conclusion

There is a good scope for mechanizing paddy crop in the hills of Himachal Pradesh by adopting the suitable improved implements for different operations which reduce time, cost of operation and drudgery over traditional methods. Of course, small and marginal paddy growers cannot afford costly machines and implements but there is a way to solve this problem through custom hiring services.

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Design, Development and Evaluation of Manual-Cum-Bullock Operated Zero-Till Seed-Cum Fertilizer Drill for Hills

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Abstract

A double row manual-cum-bullock drawn seed-cum-fertilizer drill (Vivek seed-cum-fertilizer drill; cost INR 2000/=) suitable for sowing rice, wheat and lentil has been developed at Vivekananda Institute of Hill Agriculture, Almora, India. The machine was fabricated using locally available materials. It consists of an MS body, inverted T-type furrow opener with 25º rake angle, adjustable MS beams for man and bullock power, seed box with fluted feed metering device, fertilizer box with agitator, plastic delivery tube, and MS transportation-cum-power wheel. The weight of the seed-cum-fertilizer drill is 23 kg. It can be operated by two persons for sowing in a prepared seedbed and by a pair of bullocks in case of no-till sowing. The machine has the capacity to sow 0.025 to 0.04 ha/hr. Line sowing of wheat and lentil with zero-till seed-cum-fertilizer drill (power source: 2 men) resulted in saving of INR 5059 and INR 4206 respectively as compared to traditional practice (two passes of ploughing with indigenous plough + Manual clod crushing + Two pass of wooden plank + Manual broadcasting; Power source: 1 Man and 1 bullock pair). Energy savings in wheat and lentil sown with zero-till seed drill were 1,305.3 MJ/ha and 1,106.6 MJ/ha, respectively, as compared to the traditional method of broadcast sowing. Study of soil physical properties showed that soil water content at all the studied soil depths were higher in plots under line sowing without seedbed preparation (T_2) than those in plots under line sowing with seed bed preparation (T_1). The values of soil bulk density at harvest under T_2 were higher in 0-15 cm soil depth. Initial infiltration rates were greater in the plots under T_1 than those in T_2. However, the steady state infiltration rate and mean weight diameter (MWD) were higher in the plots under T_2 than those under T_1. The advantage of zero-tillage with animate (man + animal) power source could be realized by using zero-till seed cum fertilizer drill.

Introduction

Unlike in plains, the green revolution has little impact in hilly areas. The reasons could be difficult terrain with undulating topography with small and scattered land holdings on steep slopes and lack of mechanization. Mechanization of agricultural operations in plains has played a vital role in efficient field operations thereby reducing the production cost. Whereas, Indian hill farming is almost untouched as far as mechanization is concerned.

The productivity of major cereals in hills is much lower than the productivity of those crops observed in plains of Uttaranchal. This may be due to poor germination and population because of traditionally popular broadcast sowing in hills. Broadcast sowing not only requires more seed rate but also makes the intercultural operations cumbersome and labour intensive. Line sowing, where seeding is done at appropriate depth, gives 10-15 % more grain yields than broadcast sowing across the crops.

It has been estimated that about 15 % of the total energy available for the rural sector is used for agricultural production (Singh, 1997) of which about 20 % is consumed only in seedbed preparation (Anonymous, 1984). Studies in India have shown that a yield increase of 10 to 12 % obtained in wheat and maize can be achieved with the use of seed-cum-fertilizer drill and planters. Due to lack of a proper sowing device, the adoption of line sowing is almost negligible in hill farming. In hills, agriculture is performed on small zig zag terraces and farmers are resource poor. The bullocks available with the farmers are smaller in size and less in power than plain areas. Considering these points, efforts were made to develop a small compact and lightweight seed drill matching existing farming resources and situations. Farmers in hills are generally poor and the higher production cost (almost all the agricultural operations are done manually) is a matter of concern. Therefore, during the seed drill development, the priority was whether the machine should be dual purpose, i.e. suitable for both ploughed (power source: 2 men) and un-ploughed (power source: 1 man and two bullocks) conditions and also had the provision to place the fertilizers at the proper place.

Further, hills generally receive very high rainfall and soil is prone to different kind of degradation. Under such situation, sowing under zero-till condition can be a suitable answer to reduce the degradation process. The improvement of soils structure is important for controlling water erosion processes. Effect of cultivation of soils in structural degradation and decrease in soil organic matter (SOM) has been well documented. Oades (1993) stated that the repeated cultivation of soils, combined with limited SOM inputs, would eventually result in breakdown of aggregates leaving the soil vulnerable to erosion. Tillage incorporates organic matter in soil surface layers, which alters the distribution and may increase decomposition. In soils with low to medium clay content (sandy clay loam soil), loss of SOM can be minimized with the use of conservation tillage, which retains crop residues on the soil surface and minimizes soil disturbance. Zero-tillage practices modify soil physical properties including soil structure (Kay, 1990), dry bulk density (Wu et al., 1992), water distribution (Azooz et al., 1996), pore size distribution (Kay, 1990) and root distribution (Lal et al., 1989). Thus, conservation tillage results in improvement of storage and transmission of air along with water and solutes, which in turn may lead to improved crop performances.

Considering these facts, a lightweight, two-row seed-cum-fertilizer drill was designed and developed at this Institute, which not only enables the placement of seeds and fertilizer at proper soil depths but also considerably reduces the cost of cultivation.

Materials and Methods

Design of Various Components

In hills of Uttaranchal, the soils range from light textured sandy, sandy loam, loamy sand and loam in upland to medium textured silty clay loam in valley areas. Before the development of the present seed-cum-fertilizer drill (**Fig. 1**), a survey was conducted to find out the suitability of machine considering the local situations. Following points emerged during the process.

- The weight of seed drill should be limited to 25 kg, so that it can be easily carried by a single person,
- Preferably it could be operated, both manually and by bullocks, and
- It should be easy in operation and maintenance.

A zero-till seed-cum-fertilizer drill of 500 mm width and 1,640 mm length was developed at VPKAS (ICAR) Research Farm, Hawalbagh, Almora. The technical details of the drill are given in **Table 1**. There are four assemblies in the machine, i.e. furrow opener, frame, seed-cum-fertilizer box and transportation-cum-power wheel. Physical attributes of the grains have major consideration on designing parameters. The theoretical basis of the design of different components is given in subsequent sections.

Frame

The Frame of the machine is made

Table 1 Technical details of the seed-cum-fertilizer-drill

Component	Description
Body	Mild steel body, 640 mm length and 500 mm width
Transportation cum power wheel	Mild steel, 490 mm diameter, 6 no of spokes and 25 mm lug height
Number of furrow opener	Two
Furrow to furrow spacing	Adjustable, 15 to 25 cm
Furrow opener	Inverted T type
Shank	Mild steel flat, 30 × 6 mm size and 300 mm length
Share	Mild steel, hardened by arc welding/griding
Fertilizer and seed box	Mild steel shaft of 1 mm thickness
Volume of seed box	0.0056 cu.m
Volume of fertilizer box	0.0056 cu.m
Weight of the seed drill	23 kg
Seed and fertilizer tube	Plastic tube of 30 mm diameter
Handle	Mild steel pipe of 25 mm diameter
Beam	Mild steel pipe of 45 mm diameter

of mild steel square box and MS angle having length and width of 210 and 180 mm, respectively. The front arm, on which the furrow openers are mounted, is made of MS square box (30 × 30 × 5 mm) to provide more strength whereas, other arms are made of MS angles (30 × 30 × 6 mm) to reduce the weight of the machine. In the front arm, circular holes (10 mm) at a regular intervals (2 cm) have been made for adjusting the spacing between furrow openers to suit the spacing requirement of different crops. In the same frame, seed box, fertilizer box, adjusting beam and adjustable guide arms are fitted. The size and type of the material of the frame has been selected on the basis of several test runs.

Furrow Opener Assembly

In the furrow opener assembly, the main components are shank, share, and seed and fertilizer pipes.

Design of Shank

An inverted T-type furrow opener is fitted at one end of the Shank and the other end of the shank is attached with frame by nuts and bolts. The thickness, width and length of the shank were decided on the basis of design given below:

The section modulus of the shank can be computed from the classical flexure formula (Seely et al., 1952 and Timoshenko et al., 1964) as given below

$f_b = M_b Y/I$ ....(1)

where,

f_b = Bending stress, kgf /cm^2

M_b = Bending moment, kgf-cm

Y = Distance from the neutral surface to the fiber where the stress is fb in cm

I = Moment of inertia for rectangular cross-section about the neutral axis in cm

From equation number (1)

Section modulus = $I/Y = M_b/f_b = b_b^2/6$ ....(2)

Mb = Dd L

where,

D_d = Design draft in kgf which should be kept 3 to 5 times of actual draft for safety point of view.

Actual draft = k_0 A

where,

k_0 = Soil resistance, kgf/cm^2

A = Cross-section area of furrow, cm^2

Therefore $M_b = 5\ k_0\ A\ L$ ....(3)

From equation (2)

Here the length of shank (L) = 30 cm

Area of cross-section of furrow = 9.1 cm^2

f_b for mild steel rectangular cross-section = 1000 kgf/cm^2

It is assumed that b: d = 1:4 or d = 4b

$b^3 = 0.36$

b = 0.71 cm say 7 cm

Therefore d = 2.84 cm say 3 cm

Standard MS flat of size 30 × 6 mm was used for fabricating the shank of furrow opener

Design of Inverted T-type Furrow Opener

The furrow opener is fitted with multi hole shank with nuts and bolts.

The depth of cut can be adjusted by changing the hole order of the shank and rake angle of the furrow opener (**Fig. 2**). Generally the draft increases with increase in rake angle and the rate of increase in draft becomes greater with tynes of more than 500 rake angle. This phenomenon is extremely important for reducing the draft (Osman, 1964).

Siemens et al. (1965) analyzed and concluded experimentally that a furrow opener with 25º rake angle gave minimum draft. In this machine, provision has been made to change the rake angle ranging from 15 to 25º to suit different soil conditions. However, after several test runs under different soil conditions, it was found that the furrow opener with 25º rake angle provided optimal upward force, soil disturbance and draft. The furrow opener is made up of 5 mm thick mild steel plate. For hardening the soil cutting edge of furrow opener, arc welding and grinding was done.

Fig. 1 VL seed-cum-fertilizer drill

Fig. 2 Furrow opener

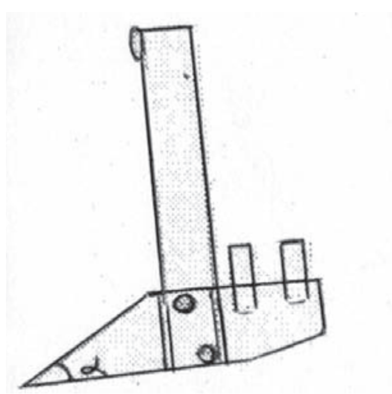

Table 2 Sowing method-wise time requirement, energy consumption and cost of sowing for Lentil crop

Treat.	Time, hr/ha	Man-hr/ha	Bullock pair-hr/ha	Energy consumption, Mj/ha	Sowing cost, INR/ha	Yield, q/ha
Wheat						
T_1	287.2	287.2	187.2	2,073.6	6,975	38.6
T_2	38.3	38.3	76.6	768.3	1,916	39.1
Lentil						
T_1	259.9	259.9	159.9	1,799.8	6,122	7.2
T_2	38.3	38.3	76.6	693.2	1,916	8.5

Labour charge = INR 80/day (8 working hour in a day)
Bullock pair charge = INR 144/day (8 working hour in a day)
1 Bullock hour = 8.07 MJ (Body weight less than 350 kg)
1 Man hour = 1.96 MJ

The inverted T-type furrow opener was selected because it caused less soil disturbance with less draft and firm furrow for better placement of seed and fertilizer.

Seed and Fertilizer Box

The size of seed box was decided on the basis of field size and seed rate of wheat crop. In general, the available working field size in hills is approximately 2 Nalies (0.04 ha), which requires 4 kg seed at 100 kg/ha. The seed box was made of mild steel sheet of 1.0 mm thickness. The top length and width of the seed-cum-fertilizer box is 320 mm and 260 mm, respectively, and partitioned with 1.0 mm MS sheet to have separate seed and fertilizer boxes. The bottom length and width of the box was 160 and 130 mm, respectively. According to RNAM recommendation, the orifice diameter for particle size of 5 mm should be 25.1 mm and bottom width of 25 mm on each side of the opening. The volumetric capacity of each of the seed and fertilizer box was 0.005 cu. m. The height and inclination of seed box was calculated as follows:

Average field size of Uttaranchal hill's field = 0.04 ha

Seed required for this area at 100 kg/ha = 0.04 × 100 = 4 kg

Bulk density of wheat grain (measured) = 0.79 g/cm^3

Volume of 4 kg seed = 5050 cm^3

Required volume of seed box with 10 % free board = 5555 cm^3 = 0.0056 m^3

Calculation of Height of Seed Box

$$\text{Volume} = \tfrac{1}{2}[(L_t - L_b) \times B_t \times h + (B_t - B_b) \times L_b \times h + L_b \times B_b \times h] = 5555$$

Or h = 21.36 cm, say 22 cm

Side slope angle of the seed box =

$$\cot^{-1} \frac{\text{Top width} - \text{Bottom width}}{\text{Height of the box}}$$

$= \cot^{-1} 0.25$

$= 75.96^{\circ}$, say 76°

The side wall of fertilizer box and seed box were kept 76º inclined, which was greater than the angle of repose of seed and fertilizer. The angle of repose in case of wheat ranges from 31.3 to 33.1º (IS: 6663-1972) and is approximately 28º for lentil.

Seed metering and fertilizer agitating device: For controlling the seed rate, fluted feed roller type metering device (**Fig. 3**) with adjustable opening is fitted in the seed box. This type of metering device is generally used for seed such as wheat, barley, paddy, oats, maize, sorghum. The exposed length of the fluted feed can be calculated as follows:

Volume of seed grain required in 1.0 m running length,

$$V = 1/8\,[N_f \times \pi \times (D_f)^2 \times L_e]$$

$$L_e = 8V / (\pi N_f D_f^2)$$

where,

L_e = Exposed length of fluted feed roller, cm

N_f = Number of flutes in fluted feed roller

V = Volume of seed grain required in 1 m running length, cm^3

D_f^2 = Diameter of semi circular flute, cm

The fertilizer box is equipped with agitator and orifice with adjustable opening. In this device, four flats of 25 × 25 mm size have been welded on an agitator shaft vertically just above the orifices of fertilizer box. Power for the agitator shaft is from the feed shaft with the help of chain and sprocket, which receives power from ground wheel. For controlling the fertilizer rate, a sliding shutter is fitted below each orifice of the fertilizer box. Plastic tubes of 30 mm diameter have been used for providing smooth seed and fertilizer flow from seed and fertilizer box to furrows.

Power-cum-transportation Wheel

In this seed-cum-fertilizer drill, the transportation wheels acts for power as well as depth control. Ground wheels or power wheels were made of mild steel MS flat of size 30 × 5 mm and round bar of size 10 mm diameter. Lands are stony in the hills, therefore, peg type ground wheels were provided for uniform power transmission to the central shaft, which, in turn, transmit power to seed metering device and fertilizer agitating device. For removing the requirement of an extra chain sprocket and central shaft for the ground wheel, the wheel size was increased to 490 mm (diameter) with 25 mm pegs. It also provided space for a furrow opener, seed tube and primary hopper as well as higher ground clearance.

During development of this seed-cum-fertilizer drill, main emphasis was given to make it lightweight so that it can easily be carried in hilly terrains. The total weight of this seed-cum-fertilizer drill was 23 kg. It could be operated by animate (man and animal both) power source. It was named the Vivek zero-till seed-cum-fertilizer drill.

The speed of power wheel, centre shaft and fluted roller was worked out as follows

Normal man speed = 2 km/h

Wheel diameter = 490 mm

$$N = [V / \pi D] \times [(2 \times 1000) / 60] \times [1 / (3.14 \times 0.49)] = 22 \text{ rpm}$$

If we assume slippage = 6 %

Then N for fluted feed roller = 21 rpm

In hills, row to row spacing for lentil = 16 cm

Total running length of the furrow in one ha field = 62500 m

Distance covered by ground wheel in one rotation = πd = 3.14 × 49 = 1.54 m

No. of rotations in 1 ha = 40584

Seed rate for wheat crop = 100 kg/ha

Seed of wheat required in one rotation = 2.46 g

Adjustable Beam

Adjustable beams have been provided to make it manual as well as bullock operated. For manual operation, the beam was made of 25 mm OD/22 mm ID MS pipe having total length of 1200 mm and a grip of same MS pipe having 370 mm length was welded on the beam perpendicularly. The beam is fitted with the frame with the help of two nuts and bolts. While designing the beam, the ergonomic aspect was taken into consideration. The position of the beam could be adjusted according to the height of the operator using two-point linkage system. For bullocks, beams could be replaced by 45 mm OD/42 mm ID MS pipe. The total length (3000 mm) of the beam was made using three MS pipes (length of each pipe = 1000 mm), which were joined with each other using nuts and bolts during operation.

Characterization of Physical Properties of Soil

Soil bulk density was measured by core sampler. Soil moisture content at different soil layers was determined by gravimetric method. Infiltration rate was determined by a double ring infiltrometer. Aggregate size distribution was determined by wet sieving method as described by Yoder (1936). Approximately a 50 g soil sample (2-4.75 mm) was immersed in water on a nest of sieves (2, 1, 0.5, 0.25 and 0.1mm) for 10 minutes before the start of wet-sieving action. The sieve nest was then clamped and transferred to the drum securely. The sieve assembly was oscillated up and down by a pulley arrangement for 20 min at a frequency of 30-35 cycles min-1 with a stroke length of 4 cm in salt free water inside the drum. The water stable aggregates retained on sieves were then backwashed into pre-weighed containers, oven dried at 50 0 C for 2 to 3 d, and weighed. The MWD was calculated taking into account the sand content in each aggregate size fraction, using the following relationship:

MWD (VanBavel, 1949) = Σxiyi

Where, xi is the mean diameter of the soil aggregate size (mm) fractions and yi is the proportion of each aggregate size with respect to the total sample weight.

Field Evaluation

Seeding performance of this seed-cum-fertilizer drill was studied, on a sandy clay loam soil at the Experimental Farm (Hawalbagh) of VPKAS (ICAR), Almora. Both wheat and lentil was grown under rainfed condition. Soil characteristics in the plots where wheat was sown were 57.2 % sand, 20.1 % silt, 22.7 % clay, 0.95 % organic carbon, moisture content 16.12 % (d.b.) and 1.33 Mg/m3 bulk density and in the plots where lentil was sown had 58.5 % sand, 19.7 % silt, 21.8 % clay, 0.92 % organic carbon, moisture content 16 % (d.b.) and 1.34 Mg/m^3 bulk density. Time required for sowing, energy consumption and cost of sowing were calculated for each of the following treatments.

T_1 = Two passes of ploughing with indigenous plough + Manual broadcasting + One pass Manual clod crushing + Two passes of wooden plank + Line sowing by Vivek seed-cum-fertilizer drill (Power source: 1 man and 1 pair of bullocks).

T_2 = Line sowing with Vivek seed-cum-fertilizer drill with out seedbed preparation + One pass planking (power source: 2 men).

Result and Discussion

Time Requirement for Sowing Operation

The sowing of lentil crop, using newly developed seed-cum-fertilizer drill, was successfully carried out under zero-tillage condition. Time requirement (**Table 2**) for sowing operation was less by 650 % in zero-till condition sowing of wheat crop compared against the sowing in prepared seed bed. A similar trend was observed in lentil crop sowing.

Energy Requirement

Use of the above mentioned seed-cum-fertilizer drill resulted in considerable reduction in energy consumption for sowing of both crops. The consumption of energy for wheat sowing was 768.3 MJ/ha in the plots under T_2 treatment. This increased to 2,073.6 MJ/ha in the plots under T_1. A similar trend was observed in lentil crop sowing. In prepared seed bed sowing, energy requirement increased due to the involvement of extra energy in seed bed preparation (**Table 2**).

Cost of Sowing

The sowing cost of wheat and lentil crops by the traditional method comes to INR 6,975/ha and INR 6,122/ha. However, it was only INR 1,916/ha for zero-tillage (T_2) with the newly developed seed-cum-fertilizer drill for the both crops. Thus, line sowing with Vivek seed-cum-fertilizer drill not only saved time and energy but also considerably reduced the cost of sowing.

Crop Performance

The plant stand was up to the mark both under prepared seed bed and zero-tillage conditions. It was 38/m and 49/m row in ploughed plots and 42/m and 46/m in unploughed plots for wheat and lentil, respectively. Only 59.0 mm rainfall

Table 3 Soil bulk density and mean weight diameter (MWD) at harvest of wheat crop

Treat.	Soil bulk density, $Mg\ m^{-3}$					MWD, mm				
	0-15	15-30	30-45	Mean	S.D.	0-15	15-30	30-45	Mean	S.D.
Initial	1.33	1.35	1.39	1.36	0.02	1.12	1.01	0.94	1.02	0.07
T_1	1.33	1.36	1.39	1.36	0.03	1.09	0.99	0.94	1.01	0.09
T_2	1.35	1.36	1.40	1.37	0.02	1.13	1.03	0.95	1.04	0.09

Table 4 Soil bulk density and mean weight diameter (MWD) at harvest of lentil crop

Treat.	Soil bulk density, $Mg\ m^{-3}$					MWD, mm				
	0-15	15-30	30-45	Mean	S.D.	0-15	15-30	30-45	Mean	S.D.
Initial	1.34	1.36	1.40	1.37	0.03	1.10	1.02	0.92	1.01	0.09
T_1	1.33	1.36	1.39	1.36	0.03	1.08	1.02	0.91	1.01	0.08
T_2	1.37	1.37	1.40	1.38	0.02	1.12	1.03	0.91	1.01	0.097

was received during the entire crop season and, as a result, the grain yield was low. The grain yield of wheat and lentil crops under two situations did not differ significantly being 3860 kg/ha and 394 kg/ha in ploughed plots and 39.1 kg/ha and 383 kg/ha, respectively, in un-ploughed plots.

Soil Bulk Density

Treatments were imposed for 2 years. Results showed that, with increase in soil depths, bulk density values increased and the highest bulk density value (1.40 Mg m^{-3}) was observed at 30-45 cm soil depth (**Tables 3** and **4**). At harvest of wheat and lentil crops soil bulk density was higher in plots under T_2 at the soil surface (0-15 cm) compared with tilled T_1. There were no variation in soil bulk density values due to tillage management at the other two studied soil depths (15-30 and 30-45 cm soil layer). The higher value of soil bulk density under ZT at the surface soil layer might be due to non disturbance of soil matrix that resulted in less total porosity compared to tilled plots.

Mean Weight Diameter (MWD)

Aggregate stability is a soil quality indicator directly related to soil organic matter (SOM). The stability of soil surface aggregates relies on SOM, enabling them to withstand mechanical forces due to tillage implements. The results indicated a decline in MWD after plowing for both the crops in plots under T_1 treatment (**Tables 3** and **4**). After harvest of both wheat and lentil crops it was observed that plots under T_2 had higher MWD than that in the plots under T_1 in all the studied soil layers.

Soil Infiltration Rate

The initial rate of infiltration through the soil profile at harvest of both the crops were higher in the plots under T_1 than that observed in the plots under T_2. In comparison, the steady state infiltration rate in the ZT system (T_2) was slightly higher at harvest of the crop than that in the plots under T_1 (**Table 5**).

Soil Moisture Content

In plots under T_2, seedbed was not prepared before sowing and hence the sowing time moisture contents (average of 4 samples) for both the plots were considered the same. As we imposed two passes of plowing in the plots under T_1 before sowing of lentil on the same date in all the plots, soils under T_1 for both the crops contained different moisture content (**Tables 6** and **7**). Soils under T_2 contained more soil moisture than soils under T_1 at harvest of both the crops, irrespective of the date of sampling at 0-15 and 15-30 cm soil depths, suggesting significant re-arrangement of pores near the soil surface (**Table 5**). In contrast, the differences in soil water contents were small at the 30-45 cm soil layer. The average soil moisture content of 11.57 % in plots under T_2 was greater than in the plots under T_1 (10.86 %) up to 45 cm depth of soil profile at 60 days after sowing of lentil. A similar trend was observed in the wheat growing season also. Greater water retention in the 0-15 cm soil depth under ZT than under conventional tillage (CT) was also observed in a silt loam and sandy loam soil by Azooz et al. (1996) in Canada.

Discussion

The developed seed-cum-fertilizer drill was compared with the performance of traditional method of sowing (in prepared seed bed) of wheat and lentil crops. For wheat sowing, the traditional method (T_1) covered only 0.028 ha area in a day (8 h duration) with a pair of bullocks and one labourer. But Vivek zero-till-ferti- seed drill with zero-tillage sowing (T_2) covered 0.21 ha in the same period of 8 hours with the same number of bullock and one additional labourer i.e., with 2 labourers (**Table 2**).

The developed seed-cum-fertilizer drill saved 1205.3 MJ/ha and INR 5059/ha in sowing wheat and fertilizer application over the traditional methods. A similar trend was found for lentil sowing. The use of the developed seed drill was really advantageous for the resource poor hill; farmers as it save time, energy and money and also more area covered under favorable climatic conditions to get higher yields and returns.

Trends in soil bulk density are gen-

Fig. 3 Fluted feed roller type metering device

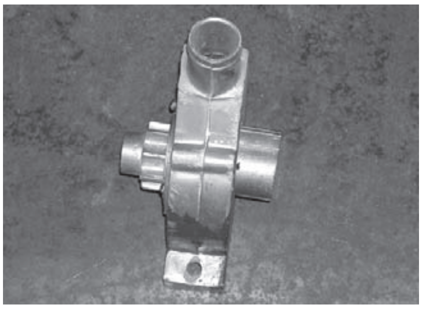

Fig. 4 Lentil crop sown by VL seed-cum-ferti drill

Table 5 Infiltration rate (cm min^{-1}) of soil at harvest of wheat and lentil crops

Time*, min	Wheat		Lentil	
	T_1	T_2	T_1	T_2
5	0.19	0.16	0.18	0.14
10	0.17	0.15	0.17	0.14
20	0.14	0.12	0.12	0.10
30	0.11	0.09	0.107	0.08
45	0.085	0.076	0.081	0.07
60	0.07	0.068	0.068	0.065
90	0.064	0.061	0.053	0.053
120	0.051	0.053	0.045	0.046
180	0.031	0.042	0.032	0.037

*Cumulative time

erally considered a rough approximation of soil structural changes (Liebig et al., 2004). Several studies have reported higher bulk density under zero-tillage (ZT) at the soil surface compared with tilled soil (Wu et al., 1992, Hill, 1990). Tillage loosens the soil and decreases soil macro porosity (Vazquez et al., 1991). Significantly lower core (0-15 cm) soil bulk density with conventional tillage (CT) system could be due to the incorporation of crop residues by tillage to the surface soil depth.

The effect of tillage methods on soil structural properties needs to be discussed in terms of tillage-induced differences in: (i) soil organic carbon (SOC) content, and (ii) activity of soil fauna. Higher SOC content in the surface layer of ZT system (measured by us) may lead to more and stable aggregation. Tisdall and Oades (1982) indicated marked reductions in water stable aggregates following cultivation. The decline in the size of aggregates with tillage could be credited to mechanical disruption of macroaggregates, which might have exposed SOM previously protected against oxidation. Although we did not measure root density of soil, from the results we can speculate that T_2 would have resulted in greater root density at the surface soil layer due to greater aggregate stability.

The high initial infiltration rate in the plots under CT system might be due to high soil porosity at the surface soil layer. The effect of ZT management might be to reduce the volume fraction of large pores and increase the volume fraction of small pores with better pore continuity relative to CT management, which ultimately resulted in higher steady state infiltration rate under ZT systems. Final infiltration rate is highly dependent upon the size, continuity and arrangement of pores. Greater final infiltration rate in tilled soils was an indication of better pore continuity, as the proportion of larger pores was comparatively less. Greater content of water stable aggregates in the reduced tillage system T_2 probably also contributed to its higher final infiltration rate (Singh et al., 1994). Although infiltration rate can be extremely variable, it is possible that the higher steady flow rates for the plots under ZT might have been partially due to the burrows of the endogenic earthworms (Joschko et al., 1992).

Considering the performance of the present seed-cum-fertilizer drill and its operational feasibility in hill farming, it can be concluded that Vivek seed-cum-fertilizer drill is an effective mean for reducing the cost of cultivation and offers good scope for mechanization in hill farming, having small and scattered land holdings.

Table 6 Soil moisture during wheat growing season

Soil depth, cm	Sowing time		60 days after sowing		Harvest	
	T_1	T_2	T_1	T_2	T_1	T_2
0-15	16.12	16.15	11.86	12.01	9.86	10.05
15-30	15.22	15.59	10.95	11.06	8.68	8.91
30-45	13.09	13.99	8.22	8.17	7.09	7.23
Mean	14.81	15.24	10.34	10.41	8.54	8.73
S.D.	1.1	1.09	1.34	1.62	1.49	1.71

Table 7 Soil moisture during lentil growing season

Soil depth, cm	Sowing time		60 days after sowing		Harvest	
	T_1	T_2	T_1	T_2	T_1	T_2
0-15	15.47	15.99	12.22	13.15	10.21	11.13
15-30	15.01	15.44	11.10	12.12	8.78	9.58
30-45	13.22	13.85	9.25	9.44	7.05	7.33
Mean	14.56	15.09	10.86	11.57	8.68	9.35
S.D.	1.15	1.07	1.44	1.82	1.70	1.80

Conclusion

The following conclusions are drawn: The machine is suitable for zero-tillage sowing as well as sowing in prepared seedbed for wheat and lentil crops. The saving of 157 % energy, 650 % time and 264 % money as compared to prepared seedbed sowing (T_1) can be achieved with help of developed zero-till seed-cum-fertilizer drill in zero-till sowing of wheat crop (T_2). Similar trends can also be achieved in lentil sowing. Yields were comparable under tilled and un-tilled conditions. In this sub-temperate climate of the Indian Himalayas, a sandy clay loam soil can effectively be managed with conservation tillage to increase water storage and transmission properties.

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(continued on page45)

Performance Evaluation of Two On-farm Feed Mixers

by

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Abstract

Performance evaluation of vertical and horizontal feed mixers was carried out using an international test code (ASAE S380). The tests were performed using sodium chloride (NaCl) as tracer for a compound feed. Sampling times of 4, 8, 12, 16 and 20 min were used during mixing in a horizontal mixer, and during discharge from the vertical mixer. The coefficient of variation (CV) for the horizontal mixer was 9.50 % at 12 min and that for the vertical mixer was 18.33 % at 20 min. The results show that the horizontal mixer performed better than the vertical mixer. The higher CV obtained for the vertical mixer was due to worn out parts. Routine evaluation of mixer would provide adequate information on its performance.

Introduction

Mixing is one of the most essential and critical operations in the process of poultry feed manufacturing, yet it is frequently given little consideration. The objective in mixing is to obtain a completely homogeneous blend. In other words, every sample taken should be identical in nutrient content (Fei, 1997). Uneven ingredient dispersion of feeds may lead to reduced bird performance. In order for birds to reach their genetic potential for growth and meat yield, levels of protein, energy vitamins and minerals must be provided in their proper ratio (Fei, 1997). Duncan (1989) reported that as protein variation increased in feeds, growth rate and feed conversion were depressed. A 10 % variation in the feed quality significantly reduced both weight gain and increased feed conversion. When the coefficient of variation (CV) of the feed was increased to 20 %, another significant increase was observed in feed/gain. A satisfactory mixing process produces a uniform feed in a minimum time with a minimum cost of overhead, power, and labour. Some variations between samples should be expected, but an ideal mixture would be one with minimal variation in composition (Lindley, 1991).

In recent times, on-farm poultry feed production has been popular in Ghana. But farmers do not test the mixers as a quality control measure. Most of the mixers used are locally manufactured, but some imported models are also available. Therefore, this study has attempted to understand if on-farm prepared poultry feeds are uniformly mixed.

Materials and Methods

A locally manufactured vertical batch mixer and an imported horizontal batch mixer were used for this study. To objectively evaluate the performance of the mixer, a standard test procedure (ASAE S380-2001) was used. The standard defined a uniform test procedure and measurement for evaluating the mixing ability of an on-farm portable batch mixer.

In order to obtain data on average particle size of ground maize, 1 kg samples for each mixer were obtained. A 200 g sub-sample of ground maize from each plant was dried at 40 ºC for 6 h to attain equal moisture content, and 100 g was screened through five sieves with a sieve shaker (Retsch GmbH & Co. KG, Germany) and the weight of the ground maize particles not filtering through each screen was determined and recorded (ASAE, 2003). The fine particles that filtered through all screens were collected in the pan and weighed. The size of screen openings (µm) used were 2360, 1600, 1180, 710, 425, 250 and 100. The weight of particles collected on each screen were entered onto a spreadsheet to determine the diameter of ith sieve in the stack, average particle size GMD and GSD using equations (1), (2) and (3).

$d_i = (d_u \times d_o)^{0.5}$..............................(1)

where,

d_i = diameter of ith sieve in the stack

d_u = diameter opening through which particle will pass (sieve proceeding ith)

d_o = diameter opening through which particle will not pass (sieve proceeding ith)

Because it was not practical to count each particle individually and calculate an average, the average particle size was calculated on a weight basis with the following equation:

$$d_{gw} = \log^{-1}\left[\frac{\Sigma W_i(\log d_i)}{\Sigma W_i}\right] \text{..............(2)}$$

where,

d_{gw} = geometric mean diameter (µm)

W_i = mass on ith sieve, g

The standard deviation was calculated from equation (3):

$$S_{gw} = \log^{-1}\left[\frac{\Sigma W_i(\log d_i - \log d_{gw})^2}{\Sigma W_i}\right]^{0.5} \text{............................(3)}$$

The mixer was loaded with all the field ingredients. The tracer material, NaCl, was loaded last and the mixing was started. For each test time, 500 g each were taken from different locations in the horizontal mixer and during discharge for the vertical mixer. For the vertical mixer, sampling was only possible during discharge.

The sodium chloride concentration was determined according to the method of the FAO (1981). A 2 g feed sample for a particular time was weighed and 250 ml of distilled water was added to it. This was heated below 60 ºC for 15 min and filtered with a filter paper into a conical flask. Twenty millilitres of the filtrate was measured into a different conical flask and mixed with 10 ml KCr. After that, $AgNO_3$ was titrated against the feed sample until there was a change in colour at the endpoint. The concentration of the salt in the sample was calculated according to the following equation:

Sodium chloride concentration [%] = (Titre × factor × 0.1) / (weight of sample) × 100 ....(4)

where,

Titre value = volume of titre used

factor = 0. 0058

0.1 = concentration of $AgNO_3$

Results and Discussion

The distributions of particle size fractions collected over the sieves are shown in **Figs. 1** and **2**. There were different distributions of particle size used in the mixers. For the vertical mixer (**Fig. 1**), about 46 % ground coarser than 710 µm composition and for the horizontal (**Fig. 2**), about 54 % material was coarser than 710 µm. The GMD of ground maize used for the horizontal and vertical mixers were 993 and 1122 µm, respectively, and the corresponding GSD were 2.1 and 2.0, respectively.

Fig. 3 shows the data of coefficient of variation (CV) with sampling time. During mixing in the vertical mixer, sampling on discharge decreased from 19.98 % at 4 min to 19.37 at 12 min. This value increased to 18.14 % at 16 min before decreasing to 12.16 % at 20 min, which was higher than the recommended CV. A vertical mixer requires about 15 min after the last ingredient has been added to adequately mix a batch of feed (Crenshaw, 2000). Although samples were taken during discharge, mixing was not thorough as expected. On the other hand, for the horizontal mixer the CV tended to increase from 12.29 % at 4 min to 12.60 % at 8 min but decreased to a CV of 9.50 % at 12 min before increasing to 7.94 % at 20 min.

For proper mixing, a horizontal mixer requires 5 to 10 min after the last ingredient has been added (Crenshaw, 2000). The CV value obtained at 12 min was below the

Fig. 1 Ground maize particle size in vertical mixer

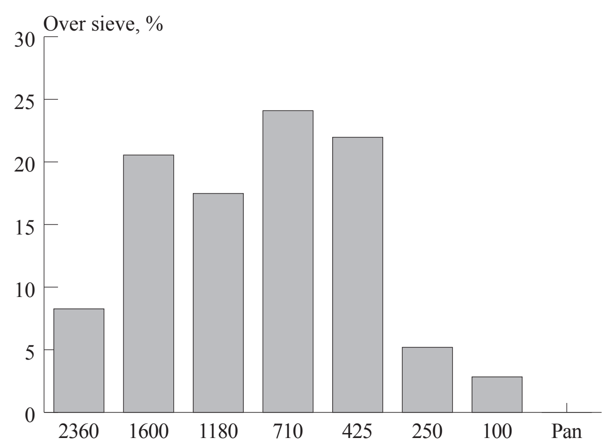
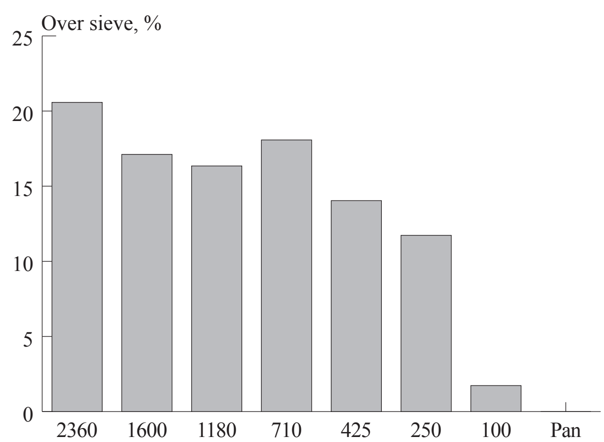


Fig. 2 Ground maize particle size in horizontal mixer



recommended industry value of 10 %. The results show that there are variations in uniformity of on-farm feed mixing. For a lower GMD of 993 µm of ground maize used in the vertical mixer, the expectation was that mixing would have been more uniform than for the horizontal one with particles of a higher GMD. The disparity in the results confirmed that worn out parts of the vertical mixers, upon inspection, was responsible for the non-uniform mixing of the ingredients. The increased operating times beyond the recommended mixing times for both mixers meant that the poultry farmers are spending more on electrical and labour costs during feed mixing. Adequate knowledge of evaluating mixer performance could help in reducing the cost of feed production on farms.

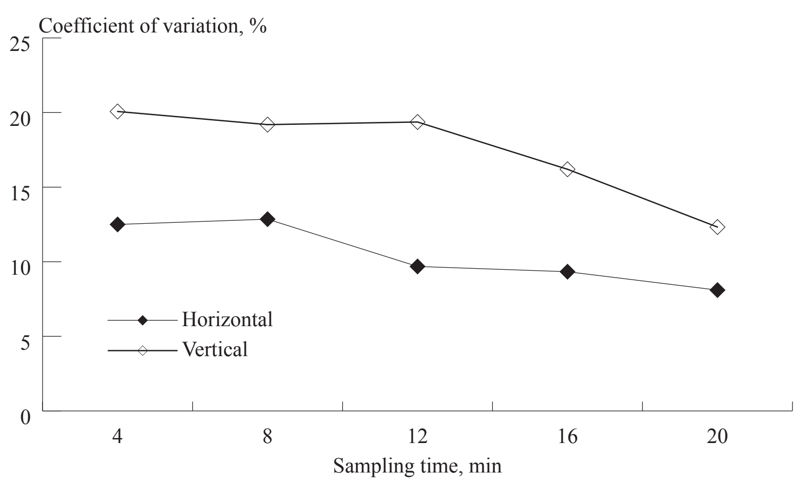
The size uniformity of the various ingredients that comprise the finished feed can directly impact final ingredient dispersion (Herrman and Behnke, 1994). If all the physical properties are relatively the same, then mixing becomes fairly simple. As the physical characteristics of ingredients begin to vary widely, blending and segregation problems are compounded. Large and small particles do not mix well and are subject to directional influence in nearly any type of mechanical mixer. For example, ground grain with a particle size of 1200-1500 microns reduced the likelihood of uniform incorporation of micro-ingredients compared to grain ground to an average particle size of 700 microns (Herrman and Behnke, 1994). The size uniformity of the various ingredients that comprise the finished feed can directly impact final ingredient dispersion (Herrman and Behnke, 1994). If all the physical properties are relatively the same, then mixing becomes fairly simple. As the physical characteristics of ingredients begin to vary widely, blending and segregation problems are compounded. The average GMD particle sizes were 933 µm and 1291 µm in the vertical and horizontal mixers respectively. Thus, there were considerable variations in the average GMD particle size of ground maize for blending in both mixers. As a point of reference, the target mean particle size for mash diets for poultry is 600-900 µm (Nir et al., 1994; Dritz and Hancock, 1999).

The sequence of ingredient addition also determines ingredient dispersion in the mixing process (Herrman and Behnke, 1994). Mixers may have dead spots, where small amounts of ingredients may not be readily incorporated into the feed. This situation is exasperated when mixing ribbons, augers, or paddles become worn. It has been determined that for the quickest distribution of the micro ingredients within the mass of major ingredients, the micro ingredients should enter the horizontal mixer early in the dumping order, no later than 10 seconds after the first of the major ingredients begins its entry (Lanz, 1992).

Insufficient mixing time and filling the mixer beyond rated capacity are often implicated as common source of variation in finished feed. Other factors such as particle size and shape of the ingredients, ingredient density, and sequence of ingredient addition, worn, altered, or broken equipment, improper mixer adjustment, poor mixer design, and cleanliness can affect the mixer performance (Wilcox and Balding, 1986; Wicker and Poole, 1991).

For optimum transport of particles within the horizontal mixer, it is essential that the rotor be kept as clean and free of build-up as possible (Wilcox and Unruh, 1986). Residual ingredient build-up on ribbons, paddles, or augers can reduce mixer performance and eventually lead to feed contamination (cross contamination). Wilcox and Unruh (1986) reported that mixing non-uniformity can also be dramatically affected by broken equipment. Feed mill personnel should routinely inspect the inside of the mixer to maintain optimum conditions for feed preparation. Relative to its importance, this action takes little time, but can be the single most effective way to ensure that the final feeds are prepared in accordance with nutritionist's specifications.

Fig. 3 Effect on sampling time on the coefficient of variation for the mixers using NaCl as the tracer



Conclusions

The performances of vertical and horizontal on-farm mixers were studied. The horizontal mixer attained CV of 9.50 % below the recommended value at 12 min during mixing, whereas the corresponding value for vertical mixer was 18.33 % at 20 min during discharge. This value for the vertical mixer was higher than the recommended value of 10 %. The increased time beyond the recommended time means that the farmers are spending extra money on electrical and labour costs during feed mixing. Mixer testing could form an integral quality control aspect of feed preparation to ensure adequate uniformity of nutrients in a batch of feed for each bird.

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Design and Evaluation of Aquifer Water Thermal Control System for Greenhouses

by

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Abstract

An Aquifer Water Thermal Control System (AWTCS) was designed and its performance was experimentally evaluated for heating as well as cooling of agricultural greenhouses during extreme winter and summer conditions. The designed system utilized almost constant temperature aquifer water available on the ground surface at around 24 ºC (year round) in all the agricultural fields through a deep tubewell (used for irrigation purposes). This water was passed through a shallow cavity or trench dug around the perimeter of the greenhouse (before being used for irrigation purposes) in which a pipe was horizontally placed and fully immersed in water for moving the greenhouse air. Greenhouse air received or delivered heat from or to the aquifer water flowing in the cavity through indirect contact by means of a counter flow heat exchanger configuration between air and water. Area and power requirement of the AWTCS for different greenhouse areas for complete range of sol-air temperature is computed and presented. Experimental performance was tested during full winter as well as for summer months of the year 2004-05. The greenhouse room air temperature was maintained about 7-9 ºC above ambient in winter nights and 6-7 ºC below ambient during summer days besides decreasing the daily temperature fluctuations inside the greenhouse. A significant improvement in the inside relative humidity was, also, observed during extreme summer conditions.

Nomenclature

- a: Cross sectional area of pipe, m^2
- A_g: Area of greenhouse floor, m^2
- A_h: Total area of ACCFHES, m^2
- c_a: Specific heat of air, J kg^{-1} $ºC^{-1}$
- C_c: Heat capacity of cold fluid, J $ºC^{-1}$
- C_h: Heat capacity of hot fluid, J $ºC^{-1}$
- c_w: Specific heat of water, J kg^{-1} $ºC^{-1}$
- d: Diameter of pipe, m
- d_i: Diameter of orifice, m
- E: Effectiveness of ACCFHES, dimensionless
- f: Coefficient of friction, dimensionless
- h_a: Heat transfer coefficient from air to water, W m^{-2} $ºC^{-1}$
- h_w: Heat transfer coefficient from water to air, W m^{-2} $ºC^{-1}$
- I_t: Incident solar radiation on greenhouse floor, Wm^{-2}
- k_a: Conductivity of air, W m^{-1} $ºC^{-1}$
- L: Length of pipe, m
- LMTD: Logarithmic mean temperature difference, ºC
- m_a: Mass flow rate of air, kg s^{-1}
- m_w: Mass flow rate of water, kg s^{-1}
- NTU: Number of transfer units, (= $U_h A_h / C_{min}$), dimensionless
- Nu_a: Nussalt number, dimensionless
- P: Pumping power, W
- Pr_a: Prandtl number at mean air temperature (= $\mu C_a / k_a$), dimensionless
- Q_p: Quantity of heat required to be removed from the greenhouse air, W
- Re_a: Reynolds number for air (= $V_a d / \nu_a$), dimensionless
- T_a: Ambient air temperature, ºC
- T_{ci}: Inlet temperature of cold fluid, ºC
- T_{co}: Outlet temperature of cold fluid, ºC
- T_d: Delivery air temperature of the circulating air at the pipe outlet, ºC
- T_{hi}: Inlet temperature of hot fluid, ºC
- T_{ho}: Outlet temperature of hot fluid, ºC
- T_i: Inlet temperature of greenhouse air to the pipe, ºC
- T_o: Outlet temperature of greenhouse air from the pipe, ºC
- T_R: Greenhouse room air temperature, ºC
- T_{sa}: Sol-air temperature, ºC
- U_h: Overall heat transfer coefficient of ACCFHES, W m^{-2} $ºC^{-1}$
- U_t: Overall heat transfer coefficient of the greenhouse, Wm^{-2} $ºC^{-1}$
- V_a: Velocity of air through pipe, m s^{-1}
- V_{fa}: Volume flow rate of air, m^3 s^{-1}

Greek Symbols

- α: Absorptivity of ground, dimensionless

μ_a: Dynamic viscosity of air, N-s m^{-2}

ν_a: Kinematic viscosity of air at mean air temperature, $m^2\ s^{-1}$

ρ_a: Density of air, kg m^{-3}

τ: Transmissivity of the covering material, dimensionless

ΔP: Pressure drop through the pipe, cm.

Introduction

In the hotter climatic areas of the world where summers are harsh, higher solar radiation intensity increases the greenhouse air temperature to excessively high levels (> 50 ºC) due to which it becomes almost impossible to grow any crop inside the greenhouse. Similarly, in the colder climatic zones very low night temperature (< 4 ºC) adversely affects the plant growth. A greenhouse cooling or heating system is, thus, required for controlling the inside air temperature. There are many technologies used for cooling as well as heating of greenhouses around the world depending upon the climatic conditions of the area. In the cooling technologies, such systems as natural and forced ventilation, shading screens and nets, evaporative cooling and misting are being used. In the heating technologies such systems as water storage, rock bed storage, phase change material storage and thermal curtains are currently being used.

In combined heating and cooling technologies, use of ground potential for thermal control of greenhouses has gained an increasing acceptance during the last few years. Earth-to-Air Heat Exchanger Systems (EAHES) are currently being used for greenhouse heating as well as cooling purposes. Earth temperature below its surface at a depth of about 3-4 m remains almost stagnant at about 26-28 ºC throughout the year as studied by Jaffrin et al. (1982) and Santamouris et al. (1995). Underground pipes are buried at depths varying between 50 and 400 cm and spacing between them are 40 cm depending upon the size of the greenhouse as studied by Santamouris et al. (1995). The heat exchangers are constructed using plastic, aluminum or concrete pipes, having 10-20 cm diameter. Many studies conducted by researchers like Jaffrin et al. (1982), Kozai (1985), Imamkulov (1986), Bascetincelik (1987), Bernier (1987), Yoshioka (1989), Boulard (1989), Herve (1990), Sawhney and Mahajan (1994), Sodha et al. (1994), Mihalakakou et al. (1995), Gauthier et al. (1997) have presented the heating and cooling potential of EAHES.

In a composite climate where heating a greenhouse is required in winter and cooling in summer, no single system except EAHES can do the same. However, the limitation of using EAHES is the cost of digging the soil and laying the pipes up to 3-4 meters depth. Horizontal layout of pipe network at this depth is not easy. For the short-term use, temperature around the soil mass gradually increases due to dissipation of heat from the outside pipe surface thereby decreasing the efficiency of the system. The advantages of the proposed system over the existing EAHES are that the cost of deep digging of soil is not required at all, which saves a lot of labour cost. Aquifer water is available at a lower temperature (around 24 ºC) through out the whole year as compared to the ground temperature which improves the cooling performance of the system. For the same pipe length, higher heat transfer takes place due to counter flow arrangement of air and water flow. The temperature of soil mass increases around the pipe in a EAHES after some time which lowers the rate of heat flow from pipe surface to soil whereas in the proposed system the continuous flow of water outside the pipe surface in the counter flow direction instantly carries away or delivers the heat.

This study presents the design and experimental evaluation of an Aquifer Water Thermal Control System (AWTCS). The temperature of the underground aquifer water at the outlet of three tubewells in agricultural fields were measured and found to be between 23.5 ºC (in January) and 24.5 ºC (in June) at Ludhiana (30.56 ºN latitude and 77.28 ºE longitude) Punjab, India. The system is a low cost single unit, which can be effectively used for creating favorable climate inside the greenhouse for the whole year. The cost of lifting the aquifer water and digging of ashallow trench is almost zero as existing deep tubewell and trenches in the field for irrigation purposes can be used for the purpose.

Materials and Methods

An even span, east-west (E-W) oriented greenhouse of 6 m × 4 m floor area having central and side height of 3 m and 2 m respectively situated at 31 ºN latitude, near Chandigarh, Punjab, India was used for the study. The greenhouse was integrated with the designed AWTCS as shown in **Figs. 1** and **2** (pictorial view). Aquifer water already available on the ground

Fig. 2 Pictorial view of greenhouse integrated to aquifer water thermal control system

surface at the tubewell outlet near the greenhouse sight was allowed to pass through a shallow cavity (trench) dug around the perimeter of the greenhouse in which a 20 m long and 0.10 m diameter plastic pipe was horizontally placed. Dimensions of the trench (0.30 m × 0.30 m) were kept in such a way that the pipe remained fully immersed in water and could carry the minimum quantity of water required for removing or delivering the heat. In the heating mode, cool air from the greenhouse was heated during night time in winter by means of receiving heat from the aquifer water. In the cooling mode, hot air from the greenhouse was cooled during day time in summer by means of delivering heat to the aquifer water in the trench. To keep the pipe fully immersed in water, iron bar supports on the top of the pipe were provided after every 2.5 m length. The system used a motor & blower assembly of 1,100 W to draw greenhouse air into the pipe and provided an air flow rate of about 1,700 m^3/hr. Direction of water and air was kept as counter flow in order to maximize the effectiveness of the heat exchanger system. Cool or hot air from the greenhouse was sucked near the roof and pushed through the pipe horizontally placed in the trench.

Maximum greenhouse air temperature in extreme summer was recorded about 50 ºC (7.5 ºC above ambient) along with solar radiation of 857 W/m^2 on the horizontal surface outside the greenhouse as shown in **Fig. 3**. Ambient air temperature range of 30-45 ºC (during summer) along with the solar radiation range of 350-900 W/m^2 has been used for computing the sol-air temperature range for generalizing the design of the proposed system as the sol-air temperature combines the effect of solar radiation and ambient air temperature. Physically sol-air temperature can be interpreted as the temperature of the surroundings that will produce the same heating effect as the incident radiation in conjunction with the actual external temperature (Tiwari, 1998). In order to improve the relative humidity inside the greenhouse during summer months a small quantity of water was mixed (state point 5, **Fig. 1**) along with the circulating air to increase the moisture content of the air. An 8 mm (inner diameter) flexible rubber pipe was inserted inside a drilled hole in the pipe for mixing water with air. Mixing of water with air served two purposes as it improved the relative humidity inside the greenhouse and also took away significant quantity of latent heat from the circulating air thereby further lowering the temperature of the circulating air. The high velocity air broke these water droplets into smaller particles and took away the latent heat of vaporization from the air. Most of the sprayed water was evaporated and the small left over water that came out of the delivery pipe along with the cool air was allowed to flow in the central path inside the greenhouse. Due to continuous addition of water vapors, relative humidity inside the greenhouse continued to increase, which reduced the efficiency of the evaporative cooling process. Thus, an optimum percentage of the outside ambient air (20 % by volume) was mixed with the re-circulating greenhouse air (state point 2, **Fig. 1**) to prevent too much increase in the inside relative humidity. This optimum value was selected on the basis of maintaining the minimum number of air changes of the greenhouse air without affecting the cooling effect.

Measurement of air temperature was made at all the state points (1-6) by inserting calibrated mercury thermometers up to the centre of the pipe. Greenhouse room air temperature was also recorded by hanging three mercury thermometers at 1 m height from the ground at different places inside the greenhouse (protecting their bulbs from direct sunlight) and then an average taken. Air temperature was recorded after every two hours from 6 am to 6 pm

Fig. 1 Top view of the greenhouse integrated to aquifer water thermal control system

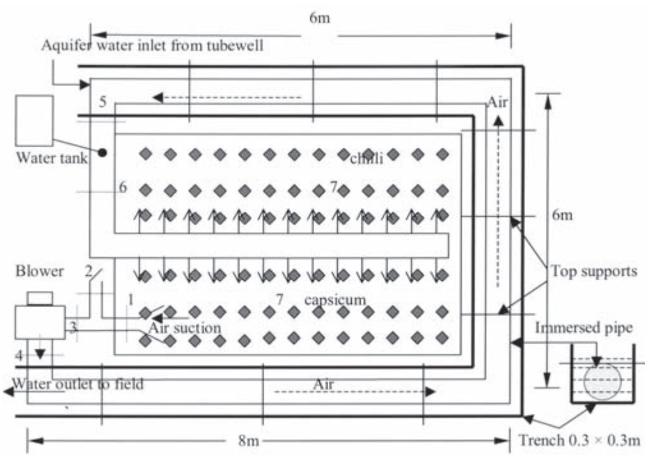
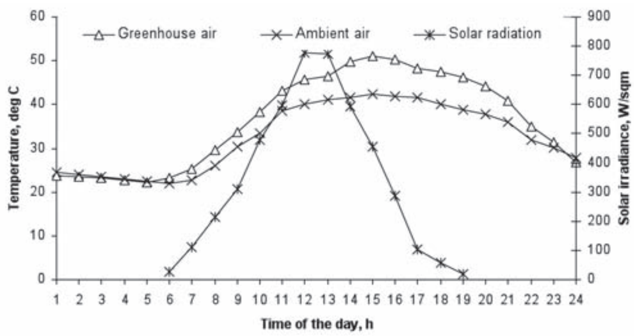


Fig. 3 Variations of climatological parameters during an extreme summer day at 31 ºN latitude (01-06-05)



in summer and 8 pm to 8 am in winter once in a week. Airflow rate was computed by using a water manometer across an orifice meter (d_i / d = 0.5) fitted in the flow path just after the state point 6 in **Fig. 1**. Water temperature was also measured at different locations (suction, delivery and in the centre) along the length of the pipe using mercury thermometers at a depth of 10 cm from the water surface. Relative humidity was measured using two thermo hygrometers hung at 1 m from the ground at different locations inside of the greenhouse.

Design Methodology

Design of AWTCS was carried out for the extreme summer conditions which required a quantity of hot air from the greenhouse to be removed in order to maintain the desired inside room air temperature. The same designed system was used for heating purposes during the winter conditions.

The quantity of heat required to be removed from the greenhouse in order to maintain the design room air temperature (T_R) of greenhouse at steady state is governed by Eqn. 1 as suggested by Tiwari (1998):

$Q_p = A_g [\tau I_t - U_t (T_R - T_a)]$ ....(1)

The first term of the right side in the above equation (1) is the quantity of heat available from sun inside the greenhouse and second term is the heat addition from the surrounding to the greenhouse due to lower design temperature as compared to the ambient temperature (T_a). This may be positive or negative depending upon the ambient temperature.

Volume flow rate (V_{fa}) in m^3/s required to remove the instant solar heat gain during a summer day is given by:

$V_{fa} = Q_p / [\rho_a C_a (T_R - T_d)]$ ....(2)

Minimum velocity of air (V_a) in m/s through the pipe is:

$V_a = V_{fa} / a_a$, ...(3)

where a_a is the X-sectional area of the pipe with selected diameter d of the pipe.

Reynolds number for air (Re_a) through the pipe is given by Domkundwar (1996):

$Re_a = V_a \times d / \nu_a$ ....(4)

Prandtl number for air (Pr_a) can also be calculated from the given properties of air at mean air temperature. Nussalt number (Nu_a) is known from the following equation which leads to the computation of air side heat transfer coefficient (ha) as suggested by Domkundwar (1996):

$Nu_a = 0.023(Re_a)^{0.8} (Pr_a)^{0.33}$ (for cooling) ....(5a)

$Nu_a = 0.023(Re_a)^{0.8} (Pr_a)^{0.40}$ (for heating ....(5b)

$h_a = Nu_a \times k_a / d$ ....(6)

Similarly, using the same criteria, heat transfer coefficient from water to air (h_w) can be calculated.

Neglecting the thermal resistance of the material, overall heat transfer coefficient (U_h) of the heat exchanger system of AWTCS is given by:

$U_h = h_a \times h_w / (h_a + h_w)$ ....(7)

Total area of AWTCS required in order to remove the required quantity of heat Qp gained by the greenhouse is:

$A_h = Q_p / U_h \times LMTD$ ....(8)

Considering the arrangement as counter flow, optimum Logarithmic Mean Temperature Difference (LMTD) of the heat exchanger was theoretically computed using Eqn. 9. Variation of area of AWTCS, power required and effectiveness of the system with LMTD is shown in **Fig. 4**. It is observed from the figure that area and power requirements decrease with the increase in LMTD and so does the effectiveness. However, above an LMTD value of 12 the decrease in effectiveness is very small with the further decrease in area and power requirements. So, an economically suitable LMTD value of 13 ºC was taken by making a compromise between effectiveness and area of heat exchanger and effectiveness and power consumption.

$LMTD = (\theta_i - \theta_o) / \ln \theta_i / \theta_o$ ....(9)

where

$\theta_i = T_{hi} - T_{co}$ and $\theta_o = T_{ho} - T_{ci}$

Coefficient of friction (f) which is a function of Reynolds number was calculated using the equation (Domkundwar, 1996):

$f = 0.005 + 0.396(Re_a)^{-0.3}$...........(10)

Pressure drop (ΔP) through the pipe was then calculated using the well known Darcy equation as given below:

$\Delta P = (4f \times L \times V_a^2 \times \rho_a) / 2d$ ....(11)

Finally the pumping power (P)

Fig. 4 Relationship of area, effectiveness and power for aquifer water thermal control system at different LMTD values

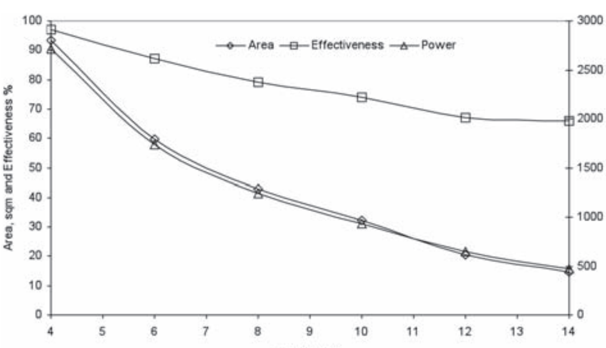
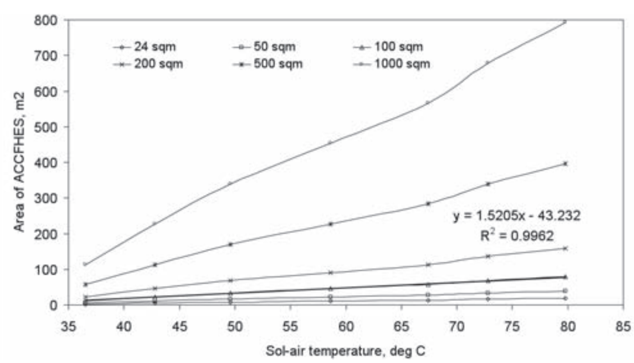


Fig. 5 Area requirement of aquifer water thermal control system at different sol-air temperatures for different greenhouse areas



requirements are:

$P = \Delta P - V_{fa}$ ....(12)

Effectiveness E of the AWTCS was also calculated using the relations for counter flow heat exchanger system (Domkundwar, 1996) as:

$E = 1 - \{e^{-NTU(1-R)}\} / 1 - R\ \{e^{-NTU(1-R)}\}$ ....(13)

where

$R = C_{min} / C_{max}$

$C_{min} = C_h$ if $C_h < C_c$

$C_{min} = C_c$ if $C_c < C_h$

$C_h = m_a \times Cp_a$

$C_c = m_w \times Cp_w$

$NTU = U_a \times A / C_{min}$ ....(14)

Thermal Energy Gain Inside the Greenhouse

The rate of cool air required per sq meter for the greenhouse area depends upon the instant solar radiation, the overall heat transfer coefficient, greenhouse room air temperature and ambient temperature conditions at a particular time and place along with the type of the covering material used. Sol-air temperature was calculated for generalizing the design of the system for any time of the year and location of the place. The instant heat gain per unit area of the greenhouse is equal to the heat available at the greenhouse floor through the canopy cover minus the heat loss from the greenhouse by convection, radiation, evaporation and conduction through bottom as given by Tiwari (1998):

$q = U_t\ [\alpha\ \tau\ I_t / U_t + T_a - T_R$ ....(15)

or

$q = U_t\ (T_{sa} - T_R)$ ....(16)

This heat q per sq m of greenhouse area is, thus, required to be removed for maintaining the desired room air temperature inside the greenhouse.

where

$T_{sa} = \alpha\tau\ I_t / U_t + T_a$ ....(17)

For winter heating during the night, It term is zero and the heat required to be added is equal to the instant heat lost by the greenhouse in order to achieve the desired inside room air temperature.

$q = U_t\ (T_a - T_R)$ ....(18)

where U_t is the overall heat transfer coefficient of the greenhouse whose value is obtained as 10.57 W m^{-2} $°C^{-1}$ for day cooling after considering the effects of convection (at 1 m s^{-1} wind velocity), radiation and evaporation from the greenhouse plants (at relative humidity of 0.7) using the standard empirical relations for greenhouse as suggested by Tiwari (1998). For night heating the value of U_t is taken as 5.7 W m^{-2} $°C^{-1}$.

Also, the quantity of solar heat required to be removed from the greenhouse air in order to achieve the desired room air temperature is given by:

$Q_p = q \times A_g = m_a\ c_a\ (T_i - T_o)$ ....(19)

which is also equal to the quantity of heat lost to the AWTCS and is given as:

$Q_p = U_h\ A_h$ LMTD ....(20)

Results and Discussion

Area Requirement

Effect of sol-air temperature on the area of heat exchanger requirement for different greenhouse areas is shown in **Fig. 5** at selected velocity and pipe diameter (15 m/s, 0.10 m). It was observed that the area of heat exchanger requirement for 24m^2 greenhouse floor area varied between 2.72 to 13.58 m^2, from the lowest to the highest sol-air temperature value. Similarly, the area of heat exchanger requirement for 50 m^2, 100 m^2, 200 m^2, 500 m^2 and 1000 m^2 greenhouse area varied between 5.66 to 39.62 m^2, 11.32 to 79.25 m^2, 22.64 to 158.5 m^2, 56.6 to 396.23m^2 and 113.21 to 792.48 m^2 from the lowest to the highest sol-air temperature. It was observed that the area of AWTCS requirement increased with the increase in the sol-air temperature for the same greenhouse. It was due to the increased effect of ambient air temperature and solar radiation that increased the heat input to the greenhouse. Hence, in order to lower the greenhouse room air temperature greater area of AWTCS was required. Area of AWTCS requirement also increased with the size of the greenhouse. This variation was almost linear as shown by the linear equation generated by the best line of curve fit for 100 m^2 greenhouse area which shows an R^2 value of 0.9547. In general, for the peak sol-air temperature of around 100 °C,

Fig. 6a Power requirement of aquifer water thermal contorol system at different sol-air temperatures for different greenhouse area (upto 100 m^2)

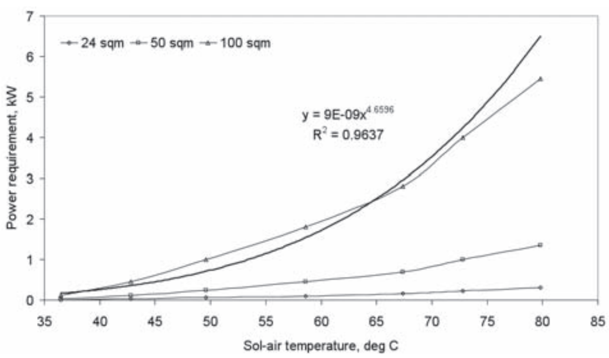
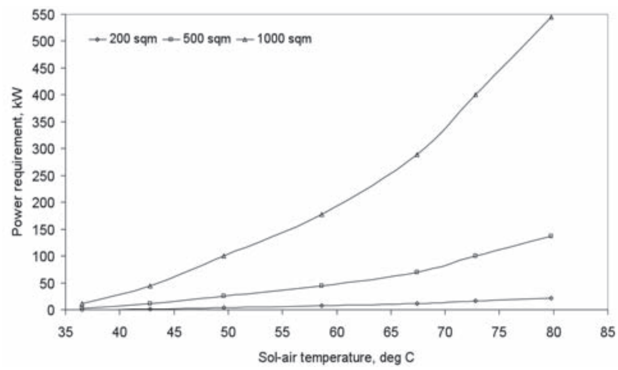


Fig. 6b Power requirement of aquifer water thermal contorol system at different sol-air temperatures for different greenhouse area (200 to 100 m^2)



area of heat exchanger required was 0.8 m^2/m^2 of greenhouse area. **Fig. 5** can be used for finding the area of heat exchanger required for AWTCS at any location depending upon the peak ambient temperature and solar radiation availability, i.e. sol-air temperature.

Power Requirement

Power requirement for 24 m^2 to 1,000 m^2 greenhouse area from the lowest to the highest sol-air temperature is shown in **Figs. 6a** and **6b**. It varied from 0.006 to 0.313 kW for 24 m^2 greenhouse area, 0.028 to 1.36 kW for 50 m^2 greenhouse area, 0.111 to 5.45 kW for 100 m^2 greenhouse area, 0.445 to 21.8 kW for 200 m^2 greenhouse area, 2.78 to 136.9 kW for 500 m^2 greenhouse area and 11.12 to 545.4 kW for 1,000 m^2 greenhouse area, respectively, from the lowest to the highest sol-air temperature. It was observed that the power requirement of AWTCS increased with the increase in the sol-air temperature at same greenhouse area. It was because of the higher heat gain by the greenhouse at higher ambient air temperature coupled with the higher solar radiation which needed greater air flow rate to lower the inside air temperature through the same diameter pipe. It was also observed that the increase in the power requirement was not linear with the increase in the sol-air temperature. It is clear from the best line of exponential curve fit for 100 m^2 greenhouse area which showed an R^2 value of 0.9955 as shown in **Fig. 6a**. Hence, at higher sol-air temperatures, the power requirement suddenly increased. It was due to the fact that the pressure drop in the pipe varied as a square of the air velocity through the pipe which was responsible for higher power requirements at higher sol-air temperatures.

Experimental Evaluation

The designed system was tested for its heating and cooling potential during the winter and summer months of year 2004-05 (November to February and March to June). The winter heating (8 pm to 6 am) performance of the system from the first week of November (N1) up to second week of February (F2) is shown in **Fig. 7**. The summer cooling (8 am to 6 pm) performance of the system from March to June is presented in Fig. 8 starting from the first week of March (M1) upto fourth week of June (J4). These figures show the hourly average of greenhouse inside air temperature, outside air temperature, delivery air temperature from pipe outlet, inside relative humidity and outside relative humidity for different weeks of each month.

Heating Mode

Heating performance of AWTCS is shown in **Fig. 7**. It is clear from the figure that the average inside air temperature of the greenhouse remained higher by about 7-9 ºC for different weeks of each month as compared to the outside air conditions. In the month of November, average night outside air temperature decreased from 18.6 to 11.8 ºC. The inside greenhouse air temperature also dropped from 23.5 to 19.8 ºC showing an increase of about 8 ºC above ambient air conditions. In the month of December, average night outside air temperature decreased from 11.2 to 6.5 ºC. Simultaneously, inside greenhouse air temperature also dropped from 19.3 to 13.4 ºC showing an increase of about 7-8 ºC above ambient air conditions. In the month of January average night outside air temperature decreased from 6.0 to 4.4 ºC up to mid January and then increased to 8.5 ºC in the last week. The inside greenhouse air temperature also dropped from 13.3 to 10.8 ºC up to mid January and then increased to 16.1 ºC showing an increase of about 8 ºC above ambient air conditions. In the month of February ambient air temperature further increased up to 11.4 ºC in the second week and greenhouse air temperature also increased up to 20.3 ºC, again, showing an increase of about 9 ºC above ambient. The decrease in the difference between greenhouse and ambient air temperature from mid December to mid January may be due to the gradual decrease in the delivery air temperature and increase in greenhouse losses because of outside foggy conditions. It may also be due to slight

Fig. 7 Heating performance of aquifer water thermal control system in winter months

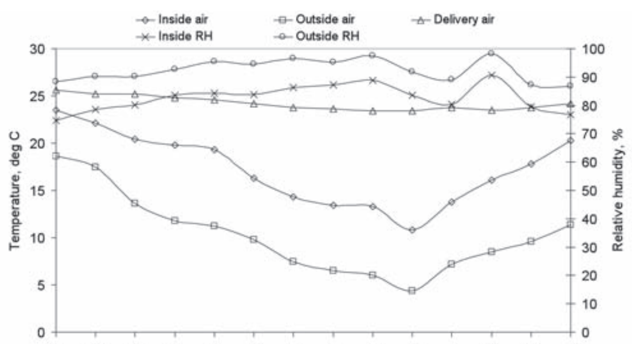
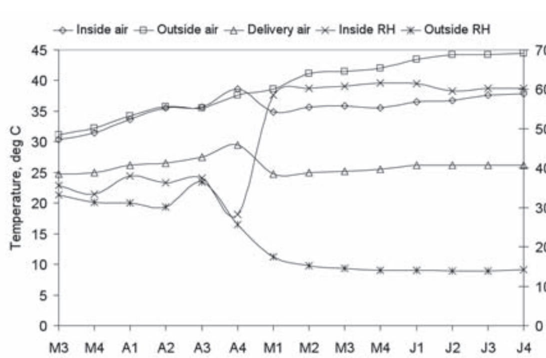


Fig. 8 Cooling performance of aquifer water thermal control system in summer months



cooling of the moving water in the trench due to convective heat transfer to air from the moving water surface. The delivery air temperature of heated air gradually decreased from 25.5 to 23.4 ºC from November to mid January and again gradually increased to 25.2 ºC in the mid February. This slight variation in delivery air temperature did not affect the performance of the system much and the system was able to maintain the greenhouse air temperature by about 9-7 ºC during winter months.

Cooling mode

Performance of the designed system was tested in the cooling mode during the months from mid March to April (without mixing of water) when the maximum ambient air temperature remained between 33-38 ºC. It is clear from the Fig. 8 that the average greenhouse air temperature dropped by about 7-8 ºC which was about 1-2 ºC below ambient for different weeks of each month as compared to the outside air conditions. During the first and second week of March, average ambient air temperature increased from 31.1 to 32.2 ºC. The inside greenhouse air temperature remained from 30.4 to 31.5 ºC which was 1-2 ºC below ambient air conditions and was well with in desirable range. In the month of April also when the average ambient air temperature increased from 34.2 to 37.8 ºC, the inside greenhouse air temperature was between 33.7 to 38.6 ºC which was almost closer to ambient air conditions, i.e. 6-7 ºC lower, as compared to no cooling condition. Relative humidity inside the greenhouse also dropped very low (around 28 %) in the fourth week of April. Thus, mixing of water (evaporative cooling process) was started after the completion of the sensible cooling process (state points 5 and 6) as shown in **Fig. 1** before the delivery of cool circulating air (state point 7). The greenhouse room air temperature dropped from 38.6 to 34.9 ºC, i.e. 7 ºC below ambient. This difference was maintained throughout the months of May and June as evident from points M1 to J4. Relative humidity also appreciably increased from 28.3 % to 58.5 %. The relative humidity inside the greenhouse did not increase beyond 65 % even after the mixing of water. It was due to the addition of the outside dry air (20 % by volume, state point 2) with the circulating air before feeding to the blower.

Conclusions

It can be concluded that the designed system is capable of maintaining the greenhouse room air temperature 7-9 ºC above ambient in winter months and 6-7 ºC below ambient in summer months. Relative humidity of the greenhouse is also maintained around 60 % during the extreme summer months of May and June.

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Drying of Fruits With Solar Tunnel Dryer

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Abstract

Drying vegetables and fruits means the decreasing of natural water content down to a level that the activity of micro organisms is stopped without destroying any tissue or affecting the edibility of the produce. Used initially in domestic farms for personal needs, this method (known as the oldest conservation method for vegetables and fruits) has extended itself to an industrial level, the purpose being an increasing demand of such produce on the market. The phenomena that takes place during drying process leads to a higher concentration of the dried matter, a reduction of the initial volume, an increase of alimentary value per weight unit and more or less profound physical and chemical changes in cell components and membrane. The loss of water content from vegetables and fruits might go through natural drying or artificial drying. The difference is the nature of thermal energy used:

a. solar energy and
b. burning fossil fuels.

A tunnel solar dryer has been tested in Romania and also some varieties of plums have been dried.

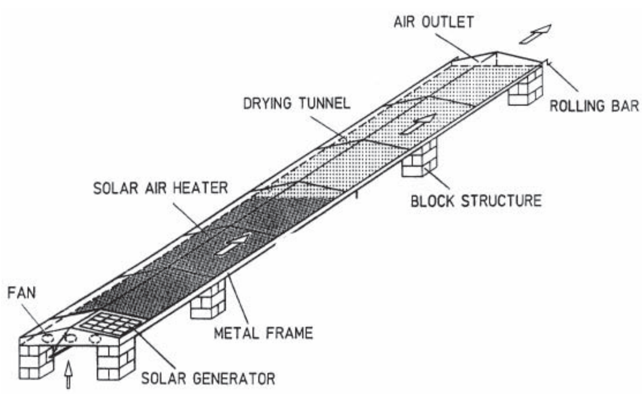
Introduction

Solar Drying is not simply a method for substituting fossil fuels by solar energy, but a technology for producing dried materials of required quality. Preservation of food using solar drying was, presumably, one of the first conscious and purposeful technological activities of the human being. Open-air sun drying has been used since immemorial time by applying traditional methods and means based simply on long-term experiences.

Humanity needs the use of solar energy in the future to a greater extent because of its advantageous characteristics: an environmentally friendly, renewable, abundant energy source that can not be monopolised and which satisfies the global requirements of a sustainable development.

Properties of dried agricultural products, especially fruits and vegetables, are influenced by a variety of physical, chemical, enzymatic

Fig. 1 Solar dryer tip tunnel model Hohenheim



and microbiological reactions and processes. Quality changes during the drying process are of a complex nature as long as several of these processes take place simultaneously. All chemical reactions contribute to the change in the original quality properties of a dry produce: colour, taste, small, nutritional value and shelf life. Physical processes that mainly influence the rehydration properties and the cooking time cause changes in the structure and the shape of the produce. The most important influence on the quality parameters is related to the pretreatment and the temperature treatment of the produce during the drying process.

Materials and Methods

In solar drying processes the energy for moisture removal is provided by sun. There are different ways of classifying the process.

Direct solar drying: the produce is directly exposed to solar radiation, which is absorbed by the product and transferred into heat. This thermal energy is responsible for the moisture removal

Indirect solar drying: in a solar collector the radiation is converted into thermal energy and via the drying air is then transferred to the product for moisture removal.

A promising concept of solar dryers with forced convection represents the solar tunnel dryer developed at the Institute for Agricultural Engineering in the Tropics and Subtropics of Hohenheim University. This tunnel dryer was designed to be used on small farms or by cooperatives. The solar tunnel dryer was designed to be produced using simple tools and locally available materials. The solar tunnel dryer consisted of two small axial flow fans, a solar air heater and a tunnel dryer in which the produce was spread out in a thin layer, **Fig. 1**.

To reduce the air resistance, the solar air heater and the tunnel dryer were arranged in series. Mounting the collector and the dryer on a substructure and rolling up the cover foil by a water tube eased loading and unloading of the crop. The solar air heater and the tunnel dryer consisted of an insulated floor and a metal frame along the sides. Both components were covered with UV-resistant transparent plastic foil. The floor of the solar air heater was painted in black paint or covered with heat resistant black woven fabric. To reduce conductive heat losses on the backside, any kind of heat insulating material could be used underneath the bottom of the dryer. The airflow rate necessary for proper drying also depended on the produce to be dried, the moisture content of the produce, the available solar radiation and the dimension of the dryer. In the standard version an air flow rate of 800 up 1200 m^3/h was sufficient to ensure drying to safe storage conditions before growth of micro organisms or enzymatic reactions lead to spoilage. Axial fans driven by a DC-motor with a power requirement of 50 W were required for an air flow rate of 1200 m^3/h at a pressure drop of 20 Pa.

The availability of electricity was an important and non-renounceable prerequisite for the production of the high quality. The use of photovoltaic seemed to be a promising alternative to the conventional power supply systems with regard to sufficient and reliable supply of electricity, the favourable ecological conditions as well the possibility to scale in each performance. Airflow was directed underneath the solar module to lower the temperature of the solar cells since increasing temperature of the solar cells resulted in lower efficiency of the solar module. In case of the optimised system, the total energy required for driving the fans is about 33 W.

Fig. 2 Drying behaviour of two varieties of plums (Stanley and Anna Späth)

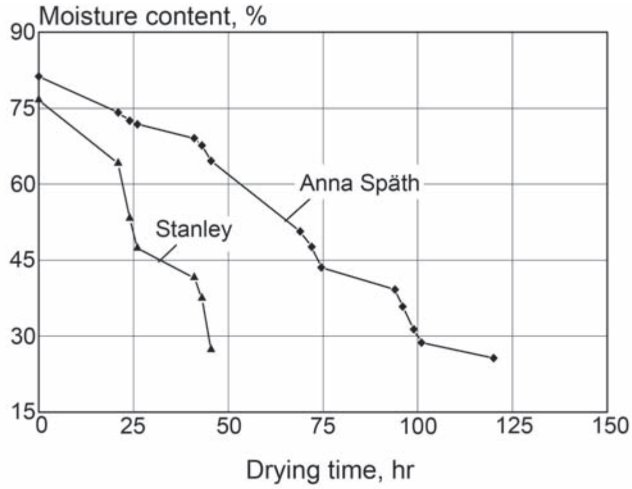
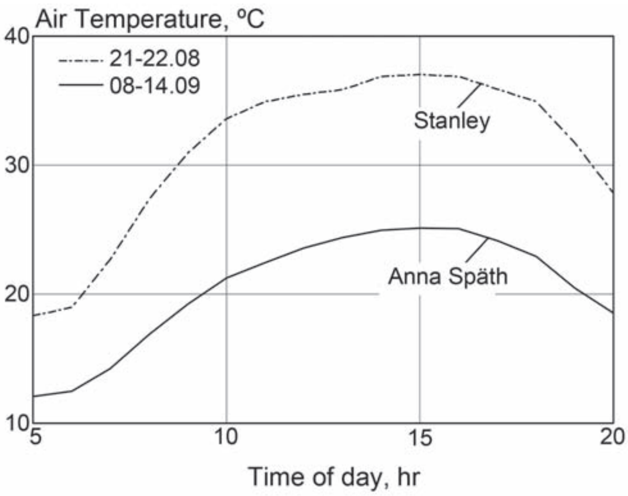


Fig. 3 Evolution of ambient air temperature, during drying process of Stanley and Anna Späth plums varieties



Photovoltaic drive, solar air heater and solar dryer must act as a single unit, with mutual interaction of the single component. The drying rate was mainly influenced by the air flow rate and the corresponding temperature rise.

Results and Discussion

The harvesting time of plums in Romania covers a period of only three months, starting every year at the beginning of August. Traditionally plums are still shaken from trees and fall directly on the ground, (sometimes also linen sheets are used). After this, the ripe fruit is picked up by hand and collected in trays or baskets.

Due to the steadily increasing demands from importers and final consumers for high quality produce, the traditional open field drying method is not considered as an acceptable drying procedure of high value foodstuff anymore. The solar tunnel dryer developed at the Hohenheim University allows a fast, energy saving and clean drying process. During this procedure every single plum, cut into two halves and without pit, is exposed to hot air and dries between 2 ½ and 5 days to the required final storage moisture of 24 % (**Figs. 2** and **3**). In some instances the dried produce has its own characteristic flavour and may be considered as one independent produce and different from the original.

Conclusion

- The proper airflow rate for the drying process ranged from 800 to 1,200 m^3/h.
- The energy requirement for fan operation was about 33 W at pressure drop of 20 Pa.
- The dried produce had its own characteristic flavour and was considered as one independent produce and different from the original.

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■■

A Methodology for Performance Evaluation of Puddling Equipment

by

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Abstract

A methodology to evaluate the comparative performance of puddling equipment is presented. The expression for puddling performance index is based on the resultant soil physical properties and equipment performance for puddling. It compares the performance of puddling equipment.

Introduction

The puddling performance of puddlers is generally assessed through the resultant soil puddle condition obtained after each pass of the puddler. Several indices such as fractional volume shrinkage (Taneja and Patnaik, 1962) water stable aggregates, water content and specific weight (Pandya, 1963) viscosity and hydraulic conductivity (Bhole and Arya, 1964); volume dispersion (Pandey and Ojha, 1973) plough pan depth and penetration depth of fall cone (Konaka, 1974) energy requirement, cost of puddling, crop output, reduction in percolation loss, depth of puddle, cone index (Rao and Sirohi, 1972; Tyagi et al., 1975; Guruswamy, 1981), Thixotropic effect (Awadhwal and Singh, 1985) and permeability, pore size distribution, water use efficiency and nutrient management (Sharma and De Datta, 1985) have been developed to quantify the state of puddle. Although these indices define the state of puddle for specific conditions, each index may not adequately describe the total condition of puddle bed obtained by different designs of puddlers. The work on development and testing of puddling implements has evolved from many piecemeal indexes to compare the performance of different puddling implements. However, no single index can satisfactorily describe a puddled soil. For example, puddling does not always decrease apparent specific volume. It may cause a decrease or increase, depending on soil aggregates status, the nature of colloids and ionic concentrations in the soil solution. Decline in hydraulic conductivity or percolation rate may not be an unambiguous index of puddling, because soil compaction can also decrease percolation. Sharma and de Datta (1985) have also recommended, for applications in rice research, one should use a combination of indices (bulk density and percolation rate) that characterize both softness and permeability to water. It was, therefore, considered best to develop a puddling performance index that combines the puddling and mechanical performance of puddlers to quantify the state of puddle for softness of soil (to facilitate ease of transplanting) and reduce percolation rate (for economy of water and nutrient use).

Development of Methodology

A methodology for comparative evaluation of puddling equipment has been developed and discussed in this paper. A combined evaluation of bulk density (specific volume), percolation rate, amount of soil dispersion, size of water stable aggregates corresponding to specific operational energy input and effective field capacity of puddling equipment was considered to be more appropriate to quantify the degree of puddling in terms of puddling performance index (Dave et al., 2003).

After the puddling operation and allowing 24 h settling time, the degree of puddle was evaluated jointly by combining the changes in bulk density, amount of dispersion, percolation rate and wet sieving fractions corresponding to the specific operational energy and effective field capacity of the puddling equipment. It was termed as puddling performance index (PPI).

PPI = f [efc, Esp, Di, Vsp, WSF, PR]

where,

PPI = Puddling performance index, No.

efc = Effective field capacity of the puddling equipment, ha/h

Esp = Specific operational energy, MJ/m^3

Vsp = Specific volume, cc/g

WSF = Wet sieving fractions of water stable aggregates, %

PR = Percolation rate of water, mm/h and

Pandey and Ojha, 1973 determined a puddling index, as given below, that has been used in a number of studies (Tiwari and Singh, 1985; Sharma et al., 1991; and Srivastava and Datta, 2001).

PI = (Vs − Vc) / Vs × 100

where,

PI = puddling index;

Vs = Volume of settled soil in the sample and

Vc = Volume of clean water

This relationship gives negative values of PI when Vs < Vc. Another relationship was suggested for calculation of puddling index.

PI = Vs / V × 100

where,

PI = puddling index;

Vs = Volume of settled soil in the sample and

V = Total volume of dispersed soil sample

This relationship holds good from no puddling condition, i.e. Vs = 0 to full churning of soil in water. This major drawback of this relationship is that the value of PI is dependent on the depth of standing water in the field.

The amount of dispersion was considered a measure of puddling due to actions of puddling equipment besides self-dispersion during saturation. The volume of settled soil in the sample was dependent on the amount of standing water in the field as it gave thinner or thicker sample due to higher or lower amount of water, respectively. For the same degree of puddle, the amount of settled soil was found less in the sample under more water condition during sampling and vice versa. Therefore, it was considered appropriate to specify the depth of

Table 1 Initial properties of experimental soil

Particulars	Value
Texture, %	Sand: 14.79, slit: 30.51, clay: 154.70
Structure	Sub-angular blocky, Slity clay soil
Atterberg limit, %	Plastic limit: 22.62, liquid limit: 42.49, plasticity index: 19.87
Porosity, %	41.90
Field capacity, %	30.86
Wilting point, %	19.22
pH	7.94
Percolation late of saturated nonpuddled soil, mm/day	9.80

Table 2 Specification of tractor operated puddling equipment

Particulars	Puddling equipment			
	Rotary puddler	Peg type puddler	Shovel type cultivator	Cage wheel in conjunction with pneumatic wheel
Source of power*, hp (kW)	18.5 (13.8)	18.5 (13.8)	18.5 (13.8)	18.5 (13.8)
Overall dimensions, mm				
Length	1,650	1,550	1,200	-
Width	1,250	520	480	450
Height	850	420	750	-
Diameter	400	-	-	685
Working width, mm	1,100	1,500	1,080	880
Soil working parts				
Number	28 blade	16	05 tine-shovel	12 lugs
Shape	"C" type	Round	Reversible type	Rectangular and 45º at soil contact
Size, mm	Effective length = 200	Effective length = 150 and diameter = 25	Effective width = 105	Size of section = 240 × 125 × 3
Spacing, mm	50	300	225	180
Weight, kg	131	80	100	60

*Tractor: 4-wheel drive having gross weight = 625 kg soil suspended water during sampling. Further, the amount of dispersion was also found to be dependent on the depth of puddling as measured for the volume of settled soil in the sample. Therefore, the earlier developed model (PI = Vs / V) was modified by incorporating the factors of depth of puddling, which contributed to mechanical dispersion and depth of water during sampling to specify the density of the soil suspended water medium to quantify the subsequent volume of settled soil. The amount of dispersion was expressed as the amount of settled soil at a given depth of soil suspended water in the total volume of the sample with respect to the depth of puddling. The higher value of dispersion was desirable and so placed in the numerator of the equation 1.

Di = Amount of dispersion of soil,

$\% = [(Vs / dw) / V] \times (ds) \times 100$

where,

Vs = Volume of settled soil in the sample, cc

V = Total volume of soil suspended water sample, cc

dw = Depth of water in the field at the time of sampling, mm and

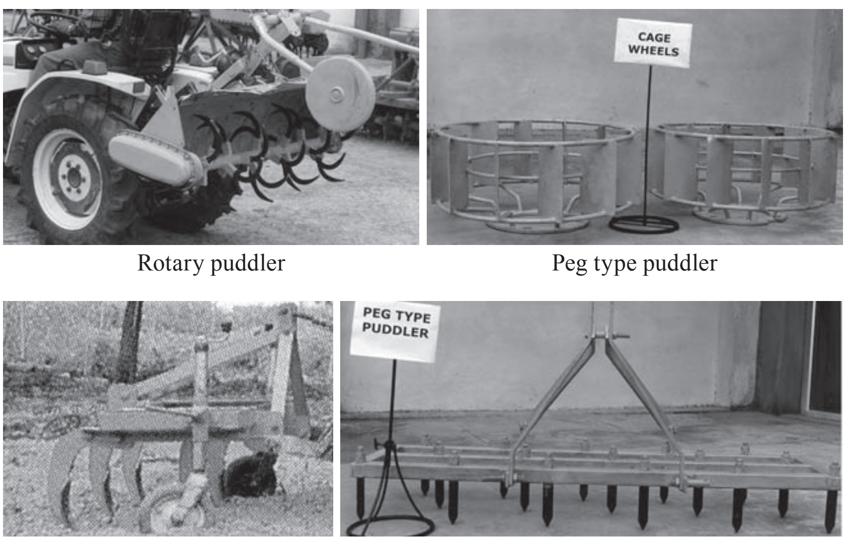
ds = Depth of soil puddle, mm

The effective field capacity is the network rate of the puddling equipment after each pass of the puddler negotiating the slippage and sinkage in the field. The slippage and sinkage parameters have contributed to dispersion of soil to some extent. The higher capacity from equipment is desirable and is placed in the numerator of equation 1.

The specific energy is described as the operational energy per unit volume of soil puddle. The operational energy was estimated from the value(s) of fuel consumption with equivalent energy units (Mittal and Dhawan, 1988). Higher volume of soil puddle obviously gave lower values of specific energy and placed in denominator of equation 1 contributing to a higher puddling performance number.

Specific volume being the reciprocal of bulk density is placed at the denominator of the puddling performance number. With increase in time after puddling the specific volume decreased due to thixotrophic effect giving more uniform packing of soil particles in the profile prior to transplanting. It may be a measure of softness of puddle profile at the top followed by relative increase in strength to the bottom. A lower value of specific volume of soil puddle to the required degree was desirable

Fig. 1 View of the equipment used for puddling operation



Rotary puddler

Peg type puddler

Shovel cultivator

Cage wheel

Wet sieving fraction is a measure of stability of the water stable aggregates. A lower percentage of water stable aggregates retained on sieves indicated higher amount of dispersion and was desirable. Due to puddling, the mean weight diameter of water stable aggregates were broken down to smaller fractions. Percent reduction of aggregate size due to puddling compared to those of a non-puddle sample indicated the measure of mechanical dispersion. The lower value of wet sieving fraction is desirable and placed in the denominator of equation 1.

Reduction in percolation rate of water is due to the combined action of dispersion - settlement of soil particles with time dependent changes of specific volume. The reduction of percolation rate of water through the puddle profile may be due to the imperviousness of the puddle surface developed after settlement of dispersed soil particles. A lower value of percolation is desirable for higher quantification of the degree of puddle and the total condition of the puddle bed. The percolation rate of water is also placed in the denominator to achieve higher puddling performance index.

Considering the above facts and discussion the puddling performance index was developed, which was a non-dimensional number. It described the qualitative and quantitative measures of puddling per unit specific energy. It combined the changes in pertinent physical properties of soil puddle: specific volume, wet sieving fractions and percolation rate to show the combined effect of the puddle profile due to mechanical performance (work rate and specific operational energy) and puddling performance (amount of dispersion) of the puddlers. Higher work rate of puddlers with minimum specific operational energy was desirable for higher performance index with degree of puddle that usually supported mechanized transplanting of rice.

PPI = (efc × Di) / (Esp × Vsp × WSF × PR) ....(1)

where,

PPI = Puddling performance index, No.

Materials and Methods

Puddling experiments were conducted at CIAE farm in plots measuring 40 × 10 m by using four equipments (**Fig. 1**). The properties of soil are presented in **Table 1**. The evaluation of puddle was based on the changes of physical properties of soil puddle after 24 h of settlement of dispersed soil particles. The pre puddling treatment: one shallow dry tillage, flooding the tilled soil to saturation (24 h) and maintaining 100 mm standing water was uniform to all the treatments. A brief specification of puddling equipments used in the experiment is given in **Table 2**. The changes in soil properties: amount of dispersion, percolation rate of water, specific volume (1/ bulk density) and wet sieving fraction and the performance of the equipment: effective field capacity and specific operational energy were obtained following the standard procedure after 24 h of puddling operation.

Results and Discussion

Puddling performance index (PPI) for all the eight treatments were determined by using the model; PPI = (efc × Di) / (Esp × Vsp × WSF × PR) after 24 hours of settling period. Depending on the mechanical and puddling performances of puddlers and with resultant soil puddle condition in each treatment, the values of PPI were determined and presented in **Table 3**.

The highest value of PPI (0.982) was obtained from T_4 and may be attributed to the highest amount of soil dispersion (48.01 %) with maximum reduction of wet sieving fractions and minimum value of percolation losses through the puddle profile. Due to the rotary action of the puddler with two passes the saturated weak soils were dispersed easily compared to the dispersion with linear tools and partially covered by cage wheels. The rotary action could facilitate more reduction of size of water stable aggregates with resultant effect after 24 h of settlement of dispersed soil particles on percolation losses to be the minimum.

Similar trends were noted in other test treatments. The minimum value of PPI (0.149) for T_5 showed inadequate puddling by cage wheels alone. On the basis of combined evaluation of different puddling treatments by puddling performance index approach, the performance of the tested treatments followed the trend: $T_4 > T_3 > T_2 > T_1 > T_8 > T_7 > T_5 > T_6$. The indices were verified in reference to the mechanical and transplanting performance of self-propelled rice transplanters. It may, therefore, be recommended that two passes of the rotary puddler were sufficient to develop puddle bed suitable for mechanized transplanting of rice.

Conclusion

A comparative performance of puddling equipment and resultant puddle bed can be evaluated by measuring resultant soil properties and equipment performance. The higher the value of index the better the performance of equipment.

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(continued on page60)

Table 3 Comparative evaluation of puddling performance index

Treatment	Effective field capacity, ha/h	Specific energy, MJ/m³	Specific volime, cc/g	Wet sieving fraction, %	Amount of dispersion, %	Percolation rate, mm/h	Puddling perfomance index, No.
T_1	0.1610	0.751	1.079	28.46	27.79	0.361	0.537
T_2	0.1158	0.854	1.126	21.80	43.91	0.301	0.805
T_3	0.1189	0.823	1.113	19.53	39.99	0.309	0.860
T_4	0.0903	0.878	1.127	15.11	48.01	0.295	0.982
T_5	0.1056	1.185	1.039	42.74	28.90	0.388	0.149
T_6	0.0739	1.560	1.043	31.45	34.91	0.360	0.140
T_7	0.1130	1.114	1.108	29.85	23.60	0.379	0.190
T_8	0.0813	1.311	1.114	25.88	38.05	0.347	0.235

*for saturated non puddle soil: wet sieving fraction = 46.67 %; specific volume = 0.91 cc/g and percolation rate of water = 0.408 mm/h

Effect of Relative of Picking Tyne, Ground Clearance and Quantity of Trash Left on Collection Efficiency of the Sugarcane Trash Collector

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Abstract

The collection of sugarcane trash is a labour intensive operation. After harvesting, large quantities of sugarcane trash are unutilized because of handling, storage and management difficulties. By burning of trash, the nitrogen content of cane trash is lost and also removed the natural trash mulch from the field. Usually the sugarcane trash after harvesting and chopping of the top will be left in the field in spread form. For shredding, the sugarcane trash has to be collected and fed into the shredding unit. A sugarcane trash collector was developed and the effect of relative velocity of picking tynes (2.4, 3.0 and 3.7 m s^{-1}), ground clearance (20, 30 and 40 mm) and quantity of trash left in the field (0.50, 0.75 and 1.00 kg m^{-2}) on the collection efficiency of the sugarcane trash collector was analyzed and optimized for maximum collection efficiency. The increase in relative velocity of the picking tynes from 2.4 to 3.0 m s^{-1} resulted in increase in collection efficiency of 96.6 and 96.7 % for 20 and 30 mm ground clearance, respectively, at 0.5 kg m^{-2}. For the weight of trash at 0.75 kg m^{-2}, the collection efficiency was higher for 20 mm ground clearance. The increase in relative velocity of picking tyne from 2.4 to 3.0 m s^{-1} resulted in gradual increase in collection efficiency for 20 and 40 mm ground clearance. The increase in relative velocity of picking tynes from 3.0 to 3.7 m s^{-1}, resulted in uniform increase in collection efficiency for 0.5 and 0.75 kg m^{-2} weight of trash, whereas, 1.0 kg m^{-2} weight of trash had almost no effect on collection efficiency. The performance of the trash collector was affected by the relative velocity of the pick-up unit, ground clearance between the tyne and the ground level and the weight of trash. The optimized combination of relative picking velocity of tynes with 3.7 m s^{-1}, ground clearance of 20 mm and 0.75 kg m^{-2} weight of trash yielded the maximum collection efficiency of 96.5 %.

Introduction

In sugarcane cultivation, collection and disposal of trash in the field after harvest of sugarcane is a problem. In the conventional method, after harvesting and de-topping, dried and semidried cane trash is left in the field. The trash is collected and heaped or spread as it is in the field. The cane is usually burnt in the field if the farmer does not require it for fuel. The nitrogen content of cane trash was found to be lost to the atmosphere due to burning. In the interest of enriching the soil with different nutrients, it appears desirable to conserve the cane trash and apply into the cane fields instead of adopting the wasteful practice of burning. Burning removes the natural trash mulch from the field (Brain and Chase, 1973). These dried trash are simply burnt in the field with the belief that the heat generated probably eradicated disease pathogens and the nutrients of trash are added to the soil in the form of ash. The trash contains good quantity of lingo-cellulose and mineral matter and, therefore, considerable efforts are being made to use this crop residue for the production of organic fertilizers (Singh and Soloman, 1995). Sugarcane trash collection is a labour intensive operation. To alleviate the labour problem and to improve the fertility status of the soil by quick decomposition of trash, the trash left in the field has to be collected and shredded into small pieces. The present migration of labour from rural sector to scholastic jobs in urban areas necessitates the need for mechanizing the farming operation of sugarcane trash collection and shredding.

Review of literature

Bosoi et al. (1990) suggested that drum diameter for rake finger type hay harvesting machine could be between 550 and 660 mm and the speed of rotation of the rake drum should be 98 rpm for windrowing and 165 rpm for spreading. Tempered spring loaded tines 6 mm thick were coupled together and mounted on four horizontal rotating shafts. Each rotating shaft was fixed with 10 spring-loaded tines for windrowing. The pickup cylinder was driven by sprocket and chain from the crankshaft and consisted of a series of spring tines that pass through stripper bars and leave the crop on the feeding platform. The pickup cylinder was set to clear the ground by about 25 mm. Taganrog (1990) recommended 72 to 190 rpm speeds for the picker shafts of grain harvesting machines and self-propelled machines . However, it was better not to exceed 125 rpm since the components of the picker unit would rapidly wear out.

The rake with spring loaded pick-up teeth was employed in chamber rolling baler, self propelled baler, hay conditioning machine, self propelled forage harvester, hay making machine and forage harvester and blower types (Rider and barr, 1976). The ramp type pick-up baler was employed with rake and spring loaded pick-up teeth as pick-up mechanism (Claude Culpin, 1982). For wheat straw combine, also a rake with spring loaded pick-up teeth was employed for picking the straw (Manjeet Singh, et al., 1994). The rake with spring loaded pick-up teeth mechanism consisted of a cylindrical drum with projecting tynes, which were mounted on the shafts. The shafts are fixed at equal intervals on the periphery of the two discs attached to the main rotating axle fixed eccentrically below the centre of the drum. The pick-up tyne rotated in the opposite direction to the direction of travel so that the tynes were guided in the gap provided between the fingers to collect the trash. Because of the eccentricity, when the pick-up tyne was rotated, the tynes were projected maximum at the bottom to collect the trash from the ground. At the top of the drum the projecting length of the tyne was minimum so as to toss up and release the collected trash (Khurmi and Gupta, 2003).

Methods and Materials

The functional elements of the sugarcane trash collector (**Fig. 1**) are as follows.

i. Sugar cane trash pick-up unit
ii. Reeling unit
i. Main frame
i. Power transmission system

The sugarcane trash pickup unit consisted of mainly two components, viz.; picking drum and picking tyne. The picker was used to gather the sugarcane trash and deliver it to the shredding unit, which was also mounted on the main frame. The picker was a drum type and fitted with four shafts with spring-loaded tynes. The tynes ran along the grooves of the picking drum. The profile of the groove and spring loaded tynes were selected in such a way that they provided effective gathering of the sugarcane trash from the field. It lifted the trash to the required height and delivered to the reel that was provided on the top of the picking drum, which pushed the trash to the shredding unit. The picking drum was 1460 mm length and consisted of 21 guide leaves made of 1700 × 40 × 2 mm flat mild steel with an oblong/elliptical shape connected to the angular flat of the main frame. The gap between the two leaves was about 25 mm for the movement of picking tines. Tempered spring loaded tines 6 mm thick were coupled together and mounted on four horizontal rotating shafts. Each rotating shaft was fixed with 10 spring-loaded tines (Bosoi et al., 1990). These horizontal rotating shafts were fixed at equal intervals on the periphery of a circular disc at both ends of the main shaft. The main shaft was mounted eccentrically below the centre of the drum and the power was transmitted from the PTO of the tractor through sprocket and chain transmission system. Because of the eccentricity when the pick-up tyne was rotated, the tynes were projected to a maximum length of 50 mm at the bottom to collect the trash from the ground. As the tyne moved up, the projecting length decreased and at the top, the tynes moved completely inside the drum releasing the collected trash. The function of the reel was to push the trash released by the tynes into the shredder. The reel consisted of four 1410 × 50 × 3 mm paddles mounted on the main reeling shaft at 90 degrees. The shaft was mounted on two ball bearings provided at both ends (**Fig. 1**). A frame was fabricated with 75 × 40 × 6 mm mild steel channel with width of 1,550 mm and length of 1,700 mm. A standard three-point hitch arrangement was provided for hitching the frame to the tractor. A 3:1 reduction gearbox was mounted on

Fig. 1 Sugarcane trash collector

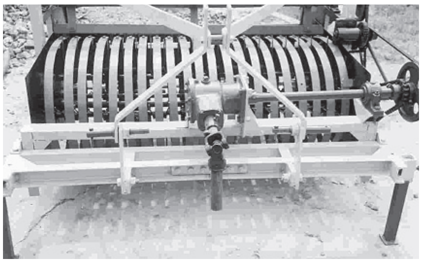
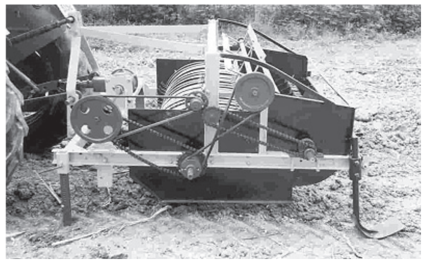


Fig. 2 Power transmission system



a channel section 100 mm above the main frame to transmit the drive to the trash collector unit. The pick-up and the reeling units were mounted on the main frame with necessary supports. Two floats were provided at the two ends of the main frame to adjust the clearance between the tyne and the ground level.

For the pick-up unit tyne, the speed of rotation of the tyne was 100 rpm based on work by Bosoi et al. (1990). The power from the tractor PTO was transmitted to the pick-up unit main shaft through 3:1 reduction gear shaft and chain and sprocket transmission system. The drive was further transmitted from the gearbox out put shaft to the picking unit shaft through sprocket and chain at a ratio of 16:26, so that the speed of the picking unit was 100 rpm. The drive for the reeling unit was provided with a twisted V belt pulley from the picking unit drive shaft (**Fig. 2**). The pulley raito was 2:1 so that the maximum speed would be about 50 rpm to facilitate the conveying of trash into the shredder unit. The direction of rotation was changed to counter clockwise as in shredder unit.

The investigation was carried out with 2.4 m s^{-1} (V_1), 3.0 m s^{-1} (V_2) and 3.7 m s^{-1} (V_3) relative velocity of picking tyne. Ground clearance was 20 mm (C_1), 30 mm (C_2) and 40 mm (C_3) and trash weight was 0.5 kg m^{-2} (W_1), 0.75 kg m^{-2} (W_2) and 1.0 kg m^{-2} (W_3). The influence of the relative velocity of picking tyne, ground clearance and weight of trash on the efficiency of the trash collector were recorded for all the treatments of the investigation. These variables were optimized to achieve maximum efficiency of the collector.

Results and Discussion

Effect of Relative Velocity of Picking Tyne on Collection Efficiency for Different Levels of Weight of Trash

The effect of relative velocity of picking tyne on collection efficiency of the sugarcane trash collector for different levels of weight of trash at the selected levels of ground clearance is illustrated in **Fig. 3**. For the weight of trash of 0.5 kg m^{-2}, the collection efficiency was higher for 20 mm ground clearance when compared to 30 and 40 mm. At 2.4 m s^{-1} relative velocity of the tyne the collection efficiency was 94.9 % for C_1 ground clearance followed by 94.2 and 93.6 % for C_2 and C_3 ground clearance, respectively. The increase in relative velocity of picking tyne from 2.4 to 3.0 m s^{-1} increased collection efficiency to 96.6 and 96.7 % for C_1 and C_2 ground clearance, respectively, but for C_3 ground clearance the collection efficiency was 95 %. Further increase in relative velocity of tyne up to 3.7 m s^{-1} had marginal increase of collection efficiency for C_1 and C_2 ground clearance, where as for C_3 ground clearance the collection efficiency increased to 96.3 %.

For the weight of trash at 0.75 kg m^{-2}, the collection efficiency was higher for C_1 ground clearance when compared to C_2 and C_3 at all levels of relative velocity of picking tyne. At 2.4 m s^{-1} relative velocity of picking tyne the collection efficiency was higher for 20 mm ground clearance, where as for 30 and 40 mm ground clearance the collection efficiency was almost same and lower. The increase in relative velocity of picking tyne from V_1 to V_2 resulted in gradual increase in collection efficiency for 20 and 40 mm ground clearance, but for 30 mm the increase of about 2 % in collection efficiency. For further increase in relative velocity of picking tyne up to V_3, the increase in collection efficiency for C_1 and C_2 ground clearance was less than 1 %, but for C_3 ground clearance the increase of collection efficiency was about 2 %. At 3.7 m s^{-1} relative velocity of picking tyne the collection efficiency was almost same for all levels of ground clearance.

For weight of trash at 1 kg m^{-2}, the collection efficiency was higher at 20 mm ground clearance when

Fig. 3 Relative velocity of picking tyne Vs collection efficiency for different levels of weight of trash

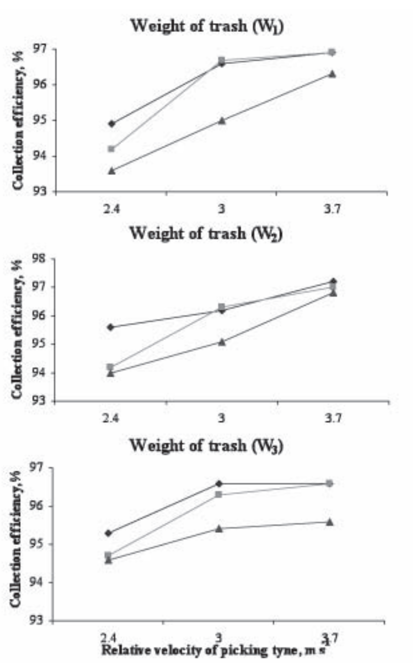
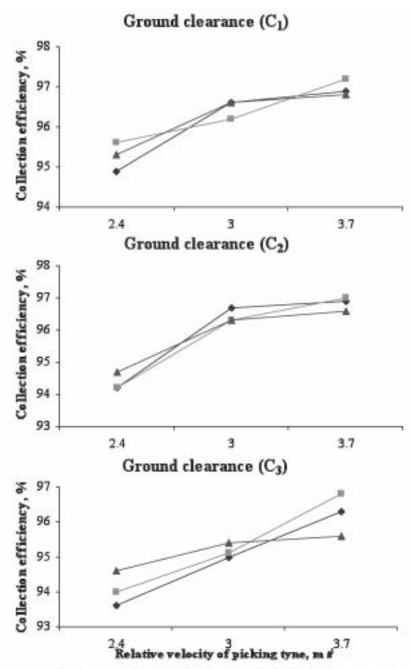


Fig. 4 Relative velocity of picking tyne Vs collection efficiency for different levels of ground clearance



compared to 30 and 40 mm ground clearance. The increase in relative velocity of picking tyne from 2.4 to 3.0 m s^{-1} increased the collection efficiency by 1.3, 1.6 and 0.8 % for C_1, C_2 and C_3 ground clearance, respectively. For further increase in velocity up to 3.7 m s^{-1}, the collection efficiency was almost same for C_1 and C_2 ground clearance.

Effect of Relative Velocity of Picking Tyne on Collection Efficiency for Different Levels of Ground Clearance

The effect of relative velocity of picking tyne on collection efficiency of the sugarcane trash collector for different levels of ground clearance at the selected levels of weight of trash is illustrated in **Fig. 4**. For the ground clearance C_1 the collection was marginally differed at all levels of weight of sugarcane trash. The increase in relative velocity of picking tyne from V_1 to V_2 resulted in increase of collection efficiency approximately by 2 % at all levels of weight of trash. For further increase in relative velocity of picking tyne V_2 to V_3 the collection efficiency increase was less than 1 %.

The collection efficiency had no effect on weight of trash at all levels of relative velocity of picking tyne for ground clearance C_2. The increase in relative velocity of picking from V_1 to V_2 resulted in increase of more than 2 % collection efficiency at all levels of weight of trash. Further increase in relative velocity of picking tyne up to V_3 there was not much variation in collection efficiency for all levels of weight of trash.

For ground clearance C_3, the collection efficiency had marginal effect on weight of trash at all levels of relative velocity of picking tyne. The increase in relative velocity of picking tyne from 2.4 to 3.0 m s^{-1} resulted in gradual and uniform increase in collection efficiency at all levels of weight of trash. For further increase in relative velocity of picking tyne from 3.0 to 3.7 m s^{-1}, a uniform increase in collection efficiency for 0.5 and 0.75 kg m^{-2} weight of trash, whereas 1.0 kg m^{-2} weight of trash had almost no effect on collection efficiency.

Optimization of Level of Variables

The selected levels of variables were optimized for achieving the maximum collection efficiency reflected in terms of weight of sugarcane trash collected by the collector. The highest mean value of operational parameter for different interaction for V × C and V × W table of means for collection efficiency was 96.97 and 97.01 % for V_3C_1 and V_3W_2 respectively for all the selected level of variables. Hence, the optimized combination of $V_3C_1W_2$, i.e. 3.7 m s^{-1} relative velocity of tyne, 20 mm ground clearance and 0.75 kg m^{-2} was chosen for the prototype in evaluating the performance of sugarcane trash collector cum shredder.

Conclusions

A sugarcane trash collector was developed and the effect of relative velocity of picking tyne (2.4, 3.0 and 3.7 m s^{-1}), ground clearance (20, 30 and 40 mm) and quantity of trash left in the field (0.50, 0.75 and 1.00 kg m^{-2}) on the collection efficiency of the sugarcane trash collector was analyzed and optimized for maximum collection efficiency. The increase in relative velocity of picking tyne from 2.4 to 3.0 m s^{-1} resulted in increase in collection efficiency of 96.6 and 96.7 % for 20 and 30 mm ground clearance respectively at 0.5 kg m^{-2}. For the weight of trash at 0.75 kg m^{-2}, the collection efficiency was higher for 20 mm ground clearance. The increase in relative velocity of picking tyne from 2.4 to 3.0 ms^{-1} resulted in gradual increase in collection efficiency for 20 and 40 mm ground clearance. The increase in relative velocity of picking tyne from 3.0 to 3.7 m s^{-1}, resulted in uniform increase in collection efficiency for 0.5 and 0.75 kg m^{-2} weight of trash whereas 1.0 kg m^{-2} weight of trash had almost no effect on collection efficiency. The performance of trash collector was affected by the relative velocity of the pick-up unit, ground clearance between the tyne and the ground level and the weight of trash. The optimized combination of relative picking velocity of tyne with a 3.7 m s^{-1}, ground clearance of 20 mm and 0.75 kg m^{-2} weight of trash yielded the maximum collection efficiency of 96.5 %.

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NEWS

World Congress of Computers in Agriculture and Natural Resources

June 22-24, 2009; Grand Sierra Resort, Reno, Nevada

ASABE is excited to announce the call for papers is available for the 2009 ASABE World Congress of Computers in Agriculture and Natural Resources to be held at the Grand Sierra Resort in Reno, Nevada concurrently with the 2009 ASABE Annual International Meeting, June 21-24. Deadline for proposal submission is January 16, 2009.

Topics include:

- Adoption, Extension and Rural Development
- Data Mining and Pattern Recognition
- Decision Support Systems
- e-AgBusiness and Production Chain Management
- Education/Training, Distance Learning and Professional Accreditation
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- Emerging ICT Technologies
- Farm Management
- Field Data Acquisition and Recording
- Food Safety Control/Tracking-Tracing
- GIS
- Grid Computing Applications
- Information Systems and Databases
- Instrumentation and Control/Data Acquisition, Monitoring and Sensing
- Knowledge Management, Ontologies, Semantics and Text Mining
- Web Services, Portals, Internet and Web 2.0 Applications
- Library Science and Knowledge Representation
- Modeling and Simulation; Packaging Science and Technology
- Portable and Nomadic Computing; Precision Agriculture
- Rural and Environmental Development and Policy
- Traceability, Food Safety and Marketing
- Wireless and Sensor Network

WCCA is a collaborative effort among agricultural information technology associations worldwide. This congress provides a forum for agriculture related professionals to exchange information on applications and developments in the use of Information Technologies. It covers a wide array of topics. These include new applications of well established and understood technologies to innovative and entrepreneurial applications of emerging technologies, in addition to issues related to policy and knowledge dissemination. Contributions from various countries will allow a broadened perspective for all attending.

From ASAEB News: Ting, Zazueta Named Winners of International Engineering Award

June 30, 2008

The American Society of Agricultural and Biological Engineers has named K.C. Ting and Fedro Zazueta co-winners of the 2008 Kishida International Award. The award honors outstanding contributions toward food and fiber production, improved living, and education outside the United States. It will be presented Jury 2, at the 2008 Annual International Meeting, taking place in Providence, Rhode Island.

Professor and head of the agricultural and biological engineering department at the University of Illinois, K.C. Ting is being honored for his outstanding global accomplishments in administration, teaching, research, public service and economic development. For more than thirty years, Ting has devoted himself to the advancement of agricultural and biological engineering education and research on automation, systems analysis, alternative energy and thermal control, computerized simulation, optimization and decision support for bio-production and bioprocessing systems. He is currently leading a BP Energy Biosciences Institute program on Engineering Solutions for Biomass Feedstock Production. Ting is acclaimed for his leadership in connecting U.S. institutions and colleagues with their counterparts in Europe, Asia, South American, and Africa, hosting international visiting scholars and rending his expertise to the review of academic and research programs at college and department levels in the U.S., Japan, Taiwan, and China. He is currently serving as a member of the African Scientific Committee for the establishment of future African institutes of Science and Technology.

Pedro S. Zazueta, P.E., ASABE Fellow, is being recognized for his outstanding worldwide accomplishments in information technology in agriculture and natural resources through research, teaching, extension programs, and technology transfer. Director and professor, Office of Academic Technology, University of Florida, he is known internationally for his applied research programs involving irrigation and water management technology, information technologies education and instruction innovations, and program administration. In addition to computer hardware toots and software, he has developed teaching and extension programs and continuing education programs that have resulted in major cost savings and new technologies. Zazueta's information technology program in agriculture is considered a model for land grant institutions and has benefited people in various developing and developed countries.

The Kishida International Award is endowed by the publishing company Shin-Norinsha Co., Ltd., of Japan, and comprises a plaque and a cash award of $1000.

The American Society of Agricultural and Biological Engineers is an international educational and scientific organization dedicated to the advancement of engineering applicable agricultural. food. and biological systems. Founded in 1907 and headquartered in St Joseph, Michigan, ASABE comprises nearly 10,000 members representing more than 100 countries. Further information on ASABE can be obtained by contacting the Society at (269) 429-0300 (phone) or (269) 429-3852 (fax); hq@asabe.org. Details can also be found at http://www.asabe.org.


G R Quick


S M Farouk


Daoulat Hussain


M A Mazed


Chetem Wangchen


Wang Wanjun


S Illangantileke


S M Ilyas


A M Michael


G Singh


T P Ojha


S R Verma


Soedjatmiko


M Behroozi-Lar


Saeid Minaei


J Sakai


B A Snorbar


C J Chung


C C Lee


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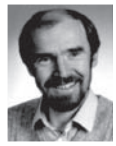
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