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VOL.18, NO.2, SPRING 1987

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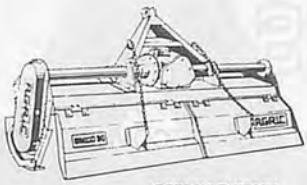
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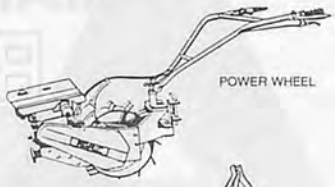
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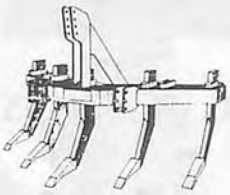
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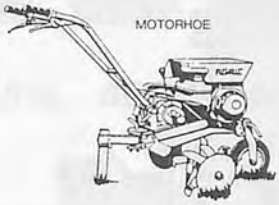
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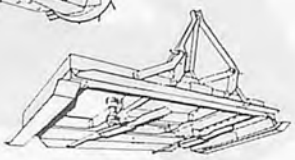
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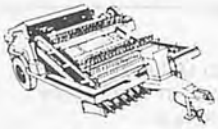
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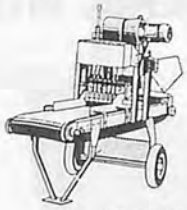
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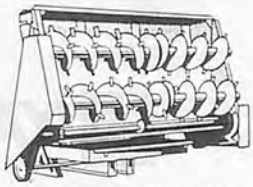
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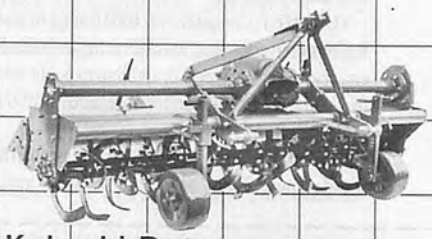

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YOSHISUKE KISHIDA

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EDITORIAL

In Search of Realistic Terms of Trade

The agricultural economic conditions in most of the economically advanced countries of the world seem to have fallen into a state of depression as a result of over-production, hence accumulation of surplus stock of farm products. For example, we have on good authority that even the Soviet Union has recently chalked up a good performance record in agricultural production after some years of lean crops. For another, surplus cheese in many parts of the United States is being given away free of charge to senior citizens for sometime now.

While the concept of surplus farm products augurs well for successful farming, it also signals some failure in farm policies in terms of guarding aginst over-production of particular commodities. Problems are, therefore, created by farm surplus which is not difficult to appreciate when viewed from the basic operation of demand and supply principle, i.e., farm prices decrease in the face of large supply, particularly under conditions of inelastic demand for a given commodity. In the process, farmers suffer. And this means that over-production becomes a disincentive instead because to store excess storable products calls for substantial inventory financing, let alone price uncertainty.

Another irony of the situation is that hunger and starvation stalk populations by the millions in many underdeveloped or developing countries. And the metaphor here implies that farm policies in those countries have equally failed – to spur agricultural productivity and/or other government policies have fallen short of arresting population increase. Of course, it is to be recognized that in many of the famine-striken countries such as those in a number of African states, the vagaries of weather, compounded by indiscrete use of natural resources, e.g., denudation of forests and watersheds stand tall in explaining much of the calamity without having to mention political interference.

The fact remains, however, that technology and investments are concentrated among the rich nations and the gap in this respect between the rich and the poor countries tend to widen. And somewhere in this dichotomy, the terms of trade between agriculture and non-agricultural pursuits need to be reconciled so that greater benefits might have to be given to poorer farmers or poorer nations until such time that they are able to stabilize agricultural productivity.

To be sure, a reasonable and stable prices of farm products that is a vital ingredient in the promotion of agricultural mechanization, for example, needs to be attained. A realistic term of trade between farm production and mechanization should, therefore, be evolved and monitored in a language that is easily understood by farmers and manufacturers of farm machineries, including policy makers.

The AMA calls upon theoreticians and econometricians to adjust prevailing terms of trade, hence propose the establishment of pricing mechanism that will benefit the poorer farmers a little bit more than their rich counterparts. More specifically, the AMA will rally behind contributions of research results affecting farm prices relative to prices of, say, farm machineries.

Yoshisuke Kishida
Chief Editor

Tokyo
April, 1987

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Studies on Basic Knowledge of Plowing Science for Asian Lowland-Paddy Farming

—Appropriate Plow Structures for Farming Requirements—

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Abstract

This paper is a continuation of a previous paper entitled "Study on Basic Knowledge of Plowing Science for Asian Lowland-Paddy Farming – Plow Structures Related to Plowing Principles"(1) The different principles of plowing width and depth of upland farming from lowland-paddy farming are discussed with special reference to the characteristic requirement of appropriate structures of European moldboard plows and Asian plows. The influence of puddling and plow soles on making and maintaining plow-pan (hard pan) in Asian paddy fields is also discussed. The differences of those basic principles between upland farming and lowland-paddy farming have a great influence on the development of Asian and Eropean plow structures.

Introduction

Tillage opertions for preparing seedbed are considered as the fundamental agricultural practice. They play a very important role for other factors to increase agricultural productivity. There are many kinds of tillage implements used for primary or secondary operations. Moldboard plows and disk plows are commonly used for primary tillage, while the disk harrow is for secondary tillage in upland farming. The shape of moldboards is divided into four types according to their steepness. Each type of moldboard is suitable for a specific kind of plowing which is classified by the ratio between plowing width and depth.(2) Rotary tillers are utilized to combine the two operations of plowing and harrowing for reducing time. Moreover, minimum-tillage and no-tillage systems are sometimes done in upland fields in order to prevent soil compaction from big tractors and heavy implements.(3) The compacted soil surface under the top soil will become the firm layer which is called plow-pan or hard pan. In Asian paddy fields, the seedbed or rootbed preparation is done with only one tillage operation by either plows or rotary tillers, and the tillage depth is commonly shallower than upland fields. This is because paddy fields, after plowing, are subsequently flooded and then, the puddling operation is performed for the purpose of leveling field surface, to maintain hard pan and so forth.

The authors hope that fundamental knowledge of plowing science in the previous two reports(1),(4) and this report will be useful to design engineers in Asian countries who are involved in im-

(1) Part of this paper was presented at Annual Meeting of Agricultural Machinery Society, Japan in 1986 and reported in AMA, Vol. 18, No. 1, Winter 1987.
(2) This paper is Part III of the research study on basic design theories of hand tractors and plows for Asian paddy fields.
(3) Mr. Surin Phongsupasamit is from the Mechanical Engineering Department, Faculty of Engineering, Chulalongkorn University, Bangkok 10500, Thailand.

provement of animal-draft plows, hand-tractor plows and plowing wheels.

Plowing Width

Definitions of Actual and Apparent Plowing Widths

In general, plowing width of a single plow means the width of a furrow slice before it is cut out from the unplowed soil. Owing to the rectangular cross-section of European furrow slices, their plowing width is measured using either the upper or the lower surface of the furrow slices which have equal value. In the case of Asian plows, the cross-section of their furrow slices is similar to the parallelogram. In this case, the authors intend to propose two academic names for plowing width of Asian plows as *actual plowing width, Wa* and *apparent plowing width, Wap* as shown in **Fig. 1**. Actual plowing width (of a single plow) means the width of a furrow slice measured between the lower edges of the furrow slice like the plowing width of the European plow. Apparent plowing width means the width of a furrow slice measured from one corner to the farthest corner.

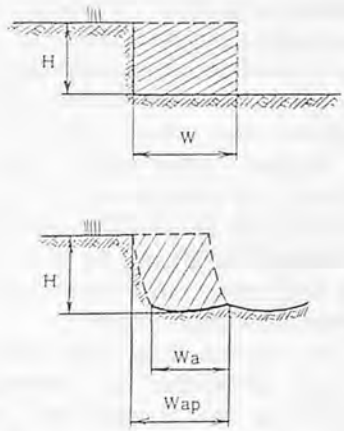

Fig. 1 Comparison between the European and Asian furrow slice cross sections.

Inverting Characteristics of Furrow Slices

Plowing in upland fields, especially in winter, is desirable to make the upper surface of furrow slices as wide as possible, so as to expose them to the action of rainfall and frost, which is favorable to crushing of furrow slices and to the formation of crumbly soil structure.(2) The furrow slice of European plows has rectangular cross section. In this case, after having been cut out from the furrow bottom and the wall, the furrow slice ABCD (**Fig. 2**) is first to turn around point D to the vertical position $DA_1B_1C_1$, and afterward turn around point C_1 and laid on to the previously tilled slice at angle α. Therefore, the greatest upper surface of furrow slices is obtained when the angle α of throwing the furrow slice aside amounts to 45°, which corresponds to the relation W/H = 1.41(2).

In the case of paddy fields in tropical Asian countries, furrow slices should be completely turned over in order to control weed effectively, enabling quick decomposition of plant residues to become humus. Furthermore, the field surface can be easily leveled through puddling after plowing. In comparison to the plowing width of European plows, the changes in plowing width of Asian plows do not significantly affect the soil profile of paddy fields after plowing unlike the soil profile of upland fields. Therefore, the arrangement of furrow slices after plowing between European plow and Asian plow differs markedly as shown in **Fig. 3**. This may be one of the reasons why the plowing width imposes different restrictions on the shape of the share and moldboard of both European and Asian plows.

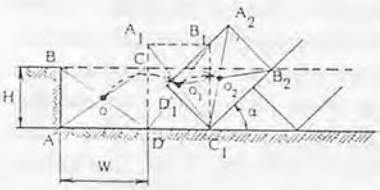

Fig. 2 Theoretical inversion of the furrow slice by the European plow.

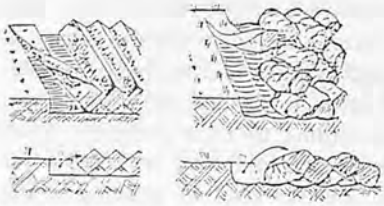

Fig. 3 Comparison of furrow slice inverting patterns between European and Asian plows.

Influence of Plowing Width on Plow Structures

In the case of European plows, the manner in which furrow slices are inverted depends on the form of moldboard, on the lateral dimensions (width and depth) of furrow slices and on plowing speed. The ratio between plowing depth and width is most frequently used in practice to lay out the profilogram of moldboards for various kinds of plows.(2)

In the case of Asian conventional plows, the shape of plowshares is similar to half-oval or isosceles triangle(1) as shown in **Fig. 4**. Those plowshares have two equal-cutting edges (**Fig. 5**); one

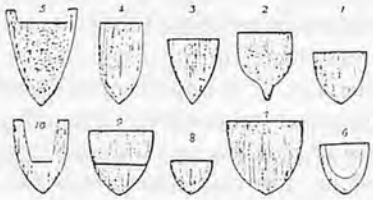

Fig. 4 Various shares of Asian plows (12).

Fig. 5 Two equal-cutting edges of Asian plowshare.

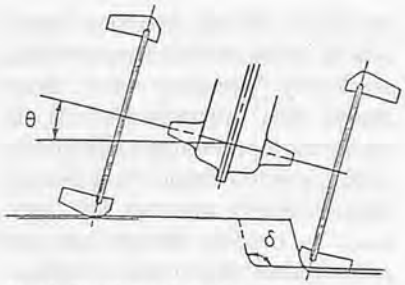

Fig. 6 Profile angle δ of soil furrow.

cuts the bottom of furrow slices, and the other cuts the surface trash and produces a slant furrow wall. The profile angle δ of soil furrow formed by soil cutting-lines of the plowshare (**Fig. 6**) is important in designing the lug shape of plowing wheels for convenience and ease of handling. In plowing, one of the plowshare wings has to appear higher than the field surface by about 20 mm in order to cut stubbles completely so as to achieve good inversion of furrow slices. This special feature of the share enables Asian turn-wrest plows to be formed with simple turn-wrest mechanism.

Plowing Depth

Farming Systems and Soil Types

The principles of plowing depth of upland and paddy-field farming are different. Upland farming is widely practised in semi-arid areas in European countries which have less annual rainfall than Asian countries. In such areas, deep plowing is necessary for better plant growth because it encourages better roots development and penetration. Consequently, it is common to have 20 cm or more depth of plowing in modern upland farming in the U.S.A. and European countries.

In comparison, the traditional paddy-field farming in Asian countries does not require deep plowing because the top soil layer of paddy fields is always saturated with irrigation water, and the plant can get enough moisture through the root in the saturated top soil. Moreover, if semi-dry top soil layer of clayey soil having 20 cm or more plowing depth is saturated with irrigation water, its thickness will become much deeper than 20 cm. Futhermore, men, draft-animals and machines have to work in such muddy top soil. Even when there is hard pan underneath the top soil to support them, such a condition of too deep mud makes it difficult for them to work.

The plowing depth, however, varies depending on types of soil where paddy is cultivated. In general, soils with high holding capacity of plant nutrients may have less plowing depth than others of poor holding capacity. The holding capacity of nutrients is higher in clayey soil than in sandy loam. Also, in Asian countries, paddy cultivation is generally practised in lowland areas of clayey soil and clayey loam.

These are the reasons why Asian plowing depth in paddy field is generally shallower than in upland fields in the U.S.A. and European countries.

Effect of Weather and Plowing Depth on Paddy Growth

In the northern region of Japan, chemical and biological processes are not so active due to low temperature. It is recommended in such environment that early maturing varieties of paddy, as a rule, be grown in paddy fields of deep plowing and heavy fertilizer application in order to attain high yield.

In comparison, chemical and biologicl processes are active in higher temperature as in the southern part of Japan. Therefore, late maturing varieties of paddy is grown as a rule. If deep plowing and heavy fertilizer are applied in this case, the duration of the vegetative growth stage will be prolonged, and the paddy may grow too tall. This causes the rice crop to lodge, hence reduce yield. Moreover, in the panicle formation stage, the paddy has the possibility of forming excess number of flowers on each panicle. This causes poor ripening, and hence, the total yield of paddy will be low.

The growth of paddy roots is rather slow. Under normal conditions, roots start to grow after transplanting, and then, gradually penetrate deeper into the soil. However, roots tend to develop rather radially than vertically. According to plant physiology, it is most desirable for the rice plant to finish developing and spreading its roots by panicle formation.[5]

If the plowing depth is 15 cm in clayey loam fields, the thickness of plowed soil after puddling will become about 20 cm. Such a depth of muddy soil is suitable, in general, for paddy cultivation for achieving effective change from vegetative to reproductive growth stage. This is because all roots can develop and occupy all the space of the tilth of such depth at the end of the vegetative stage.[5] Thus, the traditional plowing depth with animal power in paddy fields, except in poor fields, is generally about 10 cm in many tropical countries and 13 to 18 cm in China, Korea and Japan.

Influence of Plowing Depth on Plow Structures

The magnitude of soil resistance (cutting, deformation and shifting over the plow moldboard, friction as well as throwing-away resistance of furrow slices) acting on the plow bottom mainly depends on the width and depth of furrow slices. In the case of limited drafting power of animals or machines, plowing width is generally adjusted according to the soil hardness, while plowing depth is kept constant.

This is because the depth of plowing directly influences better crop growth. Hence, the size of the Asian plowshare is designed based on the required plowing depth. It is not necessary for animal-draft plows to be equipped with width-regulating mechanism. This is why swing beams associated with width-regulating mechanisms are equipped to hand-tractor plows for efficient plowing.

The depth-adjusting mechanism of the Asian plow is primarily designed for maintaining the required plowing depth. In order to prevent excessive massing of soil caused by poor turning of successive furrow slices, the depth-adjusting mechanism is also used for increasing plowing depth gradually at the start of plowing near levees.

The principal function of the moldboard is to invert furrow slices. During the inversion processes, furrow slices sliding on the surface of the moldboard undergo a certain bending and twisting motion. As shown in **Fig. 3**, in the case of the Asian plow, furrow slices are basically lifted and the turning-over action is not continuous. In comparison with the Asian plow, furrow slices of the European plow are turned continuously without lifting them above the furrow-bottom. The Asian plow moldboard, like the Japanese case, is called "lifting-up and turning type", while that of the European plow is called "twisting and turning type" in China.[6] Therefore, deep plowing with the Japanese plow requires less steep and simple curvature of small twisting of the moldboard in order to avoid falling down of furrow slices in front of the moldboard and later accumulating excessive soil. Of course, the type and state of soil also influence the design of the moldboard. Besides those factors, plowing speed has also a considerable influence on the turning performance of furrow slices, particularly in plowing with hand-tractors and riding tractors.

In general, the plowing speed of Japanese plows is 0.7 to 1 m/sec (2.5 to 3.6 km/h) which is equivalent to the working speed of Japanese draft cattle. Such a speed range of these plows makes walking comfortable for the plowmen.

Hard Pan (Plow-pan)

Influence of Hard Pan on Farming Systems

Hard pan is a compacted surface layer of subsoil. It is formed under normal plowing zone by constant compaction of plowing wheels and heavy farm implements as well as working men and cattle. Therefore, it is sometimes called as "plow-pan". In addition, the colloidal phase of top soil after puddling has a possible feature of sinking down the heavier fertilizer particles of minerals such as iron to the bottom of the top soil layer or the surface of subsoil to form hard pan.[7] Therefore, it is recommended that the surface soil of the hard pan be turned face up every 3 to 4 years.

Hard pan has no advantage to upland fields because it causes an unfavorable environment to plant growth. Therefore, whenever hard pan is formed, it has to be broken through and shattered with a subsoiler or a pan-breaker which is well developed in European countries.

The hard pan of lowland-paddy fields has to be formed and maintained through puddling before transplanting every year. This is is because it supports working men, animals and machines, and also has the advantage of keeping optimum percolation of irrigation water as well as dissolved plant nutrients. When the hard pan of lowland-paddy fields is destroyed by careless deep plowing, irrigation water as well as dissolved nutrients would excessively percolate into deep subsoil and groundwater. As a result, the optimum percolation of irrigation water cannot be attained, and moreover, the top soil layer tends to become deeper year by year because of continuous tillage into the subsoil. Consequently, it becomes inconvenient for men, draft animals and even machines to work in such boggy fields.

Paddy Roots Development in Hard Pan

The general distribution of paddy roots of Japonica rice varieties in Japan is shown in **Fig. 7**. More than 90% of the total weight of the roots is found in tilth of top soil, and less than 10% penetrates through the hard pan into the subsoil.[7] Roots in the hard pan show a different development pattern from roots in the top soil, namely, when roots in the top soil develop and reach the hard pan surface, they cannot penetrate through the hard pan. Therefore, they develop radially and horizontally outside on the hard pan surface and try to seek for spots where they could per-

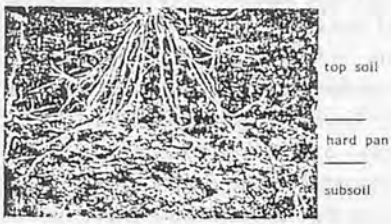

Fig. 7 Distributing pattern of paddy roots (after transplanting 55 days).

Fig. 8 General developing illustration of paddy roots (after transplanting 55 days).

forate as shown in **Fig. 8**. Those spots are mostly the places of the previous paddy root holes which are loosely plugged.[5] The length of roots in the subsoil depends on the level of groundwater. However, the extreme depth of root zone is about 90 cm.[8]

When paddy is harvested, stubbles and roots still remain in lowland-paddy fields but later they will decompose. In tropical Asian countries, soil structure of lowland-paddy fields is changed from wet condition to dry condition in dry season. If those fields are over-dried, soil cracking will occur in the tilth (top soil), particularly for clayey soils which have high percentage of volumetric shrinkage, whose maximum value is 236%[9]. However, soil cracking hardly occurs in the subsoil below the hard pan because of adequate moisture from groundwater. Although the field becomes dry, many small holes perforated by paddy roots still remain in the top soil, hard pan and subsoil.

The senior author observed lowland-paddy fields in the Philippines in 1970 and found that in the dry season, the tilth became a dry, porous structure having many small holes perforated by the previous paddy roots. And the hard pan and subsoil layer still contained good moisture, with some small holes made by long roots. Those existing holes could be observed on soil blocks that are carefully cut out from lowland-paddy fields. Such soil conditions of porous structure could quickly absorb water and easily soften in the next rainy season. This is the general characteristics of natural soil structure in tropical Asian paddy fields just before the rainy season.

In the rainy season, paddy cultivation starts and top soil is tilled again. Those holes of former paddy roots still exist in the hard pan and the subsoil. Therefore, if those holes of the hard pan are not plugged, the rapid percolation of irrigation water with plant nutrients into deep subsoil will reduce paddy yield.

The authors emphasize the following case regarding top soil layer: In many tropical Asian countries, the animal feeding system is destroying such a porous structure of the top soil as large animals, i.e., catlle, swamp buffaloes and horses are free to enter and nibble the grass on the lowland-paddy fields after harvest. Their treading on moist clayey soil will be almost similar to the simple process of making bricks from clayey soil by a squeezing process.

This custom of stepping freely into paddy fields by cattle, men and even carts in tropical Asian countries has high possibilities of making very hard top soil of high tilling resistance in the subsequent crop year.

Influence of Puddling on Hard Pan

In general, the percolation of irrigation water is considered to be undesirable because it causes the loss of plant nutrients. The optimum percolation of irrigation water, however, is necessary in order to supply sufficient dissolved oxygen and nutrients to paddy roots in the top soil and subsoil and remove toxic substances. Therefore, in order to obtain high paddy yield, a suitable percolation rate has to be carefully studied, otherwise the loss of plant nutrients may become a serious problem.

The plowed paddy fields are flooded so that puddling can easily be performed. Therefore, puddling operation is mostly carried out in submerged paddy fields. (This puddling operation is called "shirokaki" in Japanese). As the hard pan is stamped down by working men or animals or by wheels of a puddling machine, root holes in the hardpan are plugged. (This work is called "toko-neri" in Japanese, namely: pan-coating). Furthermore, the plugging of the holes is due to the sediment of top soil particles. Those holes that are loosely plugged will be perforated by roots again. The percolation losses of irrigation water will be remarkably reduced if the paddy field is puddled repeatedly as shown in **Table 1**.[10]

Puddling operation is an important process for rice production. Some advantages of puddling operation are: to prepare an optimum soft mud bed for transplantation; level undulated soil surface of paddy fields; establish better weed control; and to maintain the hard pan by keeping optimum percolation of irrigation water.

The optimum water requirement for most high yielding paddy cultivation (about 7.0 t/ha in Japan) is about 20 to 30 mm depth per day as shown in **Fig. 9**.[11] These values are classified as: percolation losses of about 10 to 20 mm depth of water per day and evapo-transpiration losses of about 10 mm depth of water per day.

Table 1 Number of Repetition of Pudding Operations and Percolation Losses of Water (Yamazaki)

Number of repetition of puddling operation	Daily percolation loss of water	
	For 5 days after puddling	For 10-15 days after puddling
No puddling	0.9 cm	0.6 cm
2 times	0.4 cm	0.5 cm
10 times	0.2 cm	0.2 cm

Note: Sample paddy field is low in percolation.

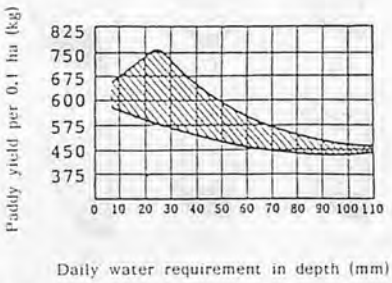

Fig. 9 Relation of yield and duty of water (11).

In Japan, it is found that in lowland-paddy fields where percolation rate is less than 5 mm/day, the breathing action of paddy roots is obstructed, resulting in a low growth rate of paddy. On the other hand, if the percolation rate increases more than 40 mm/day, the irrigation water temperature drops and the leaching away of fertilizer becomes a serious problem. As a result, heavy application of fertilizer does not return in high paddy yield. Optimum percolation may also apply to semi-tropical and tropical Asian countries because paddy cultivation in Japan, for example, starts in the early summer to the end of autumn through a very hot summer. However, it is recommended that the optimum rate of percolation has to be confirmed by field experiments based on varieties of paddy, local soil characteristics and topographic conditions, particularly fertilizer application.

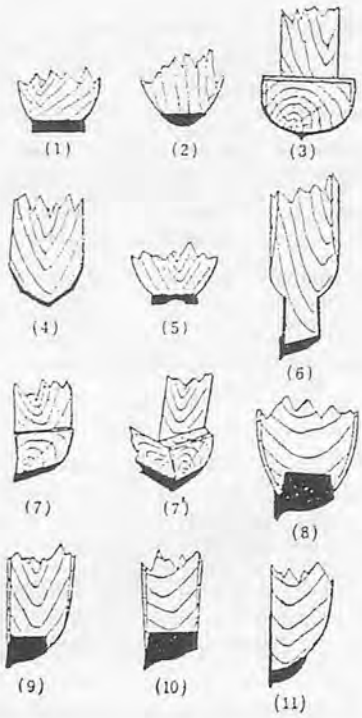

Fig. 10 Various soles of Japanese animal-draft plows.

Influence of Plow Sole on Hard Pan

The plow sole, (lowest part of the plow bottom), not only supports the plow body for stable plowing but also provides a straight plowing direction with minimum soil resistance. Some typical soles of Japanese animal-draft plows having shares of half-oval shape are shown in **Fig. 10.**[12] This paper divides these plow soles into five groups according to their configuration as folows; i) flat sole (1); ii) half-oval sole (2), (3), (4); iii) groove sole (5); iv) slant sole (6), (7), (8), (9); and v) a quarter oval sole (11).

The groove sole may be effective in stabilizing plowing than the flat sole. The slant sole is effective not only in stable plowing but also to straight plowing direction. The symmetrical soles in group ii) is very effective for use in turn-wrest plows. In plowing, the weight of the plow, plowing resistance and weight transfer of the whole machine is distributed on the plow sole so that the hard pan surface is compacted by the bottom surface of the sole. This means that the sole is useful not only in forming but also maintaining the hard pan.

In the case of a European plow, a landside with a small heel is equipped to the left side of plow bottom instead of the sole because the shape of the European plowshare is different from that of the Asian plow. Moreover, the hard pan must not be formed in upland fields. Therefore, supporting or gauge wheels are sometimes needed for European animal-draft plows in order to support the plow in a proper handling position. These wheels are usually fastened to the plow beam in the side-front of the plow bottom. This is one of the reasons why the Asian plow has a rather big and long sole structure, while the European plow has a landside with a small heel.

Conclusions

1) In upland plowing, the maximum contact area between plowland surface and air is desirable, especially in winter, and this depends on the ratio between plowing depth and width. For tropical Asian lowland-paddy fields, furrow slices have to be completely turned in order to control weeds and to level field surface easily through puddling operation.
2) Upland fields in the U.S.A. and European countries have small annual rainfall so that the deep plowing, 20 cm or more depth, in general, is practised for better root growth. In comparison to upland fields, traditional plowing depth of lowland-paddy fields in Asia is not as deep, (10 to 15 cm), because the top soil layer with root is always saturated with irrigation water. Moreover, deep mud of top soil renders working difficult for draft animals, men and machines.
3) Hard pan has no advantage to upland fields because it hinders root growth. However, the hard pan of lowland-paddy fields has to be formed and maintained through puddling because it is a firm layer that supports men, draft-animals and machines and keeps optimum percolation of irrigation water with nutrients and oxygen into the subsoil that is conductive to high paddy yield.
4) The big and long structure of Asian plowsole is useful in forming and maintaining the hard pan. In the case of European plows, a landside with a small heel is used instead of the sole.

A comparison of basic farming principles between European upland and Asian lowland-paddy farming is showin in **Table 2**.

The basic knowledge of plowing science related to plow structures for both distinct farming is useful

Table 2 Comparison of operating principles between upland and lowland-paddy farming

Items	Type of farming	
	Upland	Lowland-paddy
Field size	the larger, the better	less than 1 ha generally 0.1 to 0.3 ha
Field flatness	no need	must be flat
Hard pan	not be formed when formed, must be destroyed	must be formed and maintained
Plowing depth	20 to 30 cm or more	less than 18 cm generally 10 to 15 cm
Plowing method	continuous plowing and return plowing (continuous return plowing)	continuous return plowing (continuous plowing)

for plow manufacturers and others who are engaged in plow science. This should bring about better plows to suit local farming conditions. Subsequent articles will deal with theories on designs for Asian hand-tractor plows and plowing wheels.

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Case Studies on Tractor Utilization for Two Farming Districts in Northern India

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Abstract

In the study, 37 tractor owner farmers from two districts in Northern India were interviewed on the use of their tractors. Field capacity and fuel consumption were measured in the field. The average annual use of tractors was 1 220 hours of which 60% was related to agricultural operations and the remaining 40% was for social and other activities. Transport for agricultural and other activities amounted to 60% of annual use. Tractor use was related to farm size and the number of equipment associated with it. Generally, most of the tractors were being used economically.

Introduction

Agricultural mechanization has grown into a sizable industry in India. Annual sales of mechanization inputs (including fuel and lubricants for farm prime movers) exceed $4 000 million. About 80 000 tractors, 2 000 power tillers and 650 000 pump sets (diesel and electric) are sold annually (Jain, 1984). The tractor population in India rose from 8 635 in 1951 to over 700 000 in 1984. Up to 1961, the requirement of tractors was met entirely through imports, while after 1978 all the requirements of tractors were met from indigenous production. The availability of tractors in selected years is given in **Table 1** (ISAE, 1983). By 1990, the tractor population is expected to cross the million mark and annual tractor sales may be about 100 000 (**Fig. 1**). The power-tiller population is about 30 000 and only about 2 000 units are sold annually.

About 2 000 large and medium scale industries manufacture tractors, power tillers, diesel engines, irrigation equipment, plant protection equipment, post-harvest machinery, electric motors and dairy equipment. About 7 000 small-scall industries produce bullock-drawn and small engine power-operated machinery. In addition, about 3 000 shops in suburban and rural areas repair and fabricate threshers, seeders, trailers and tillage imple-

Table 1 Availability of Tractors in Selected Years in India

Year	Production	Imports	Total availability
1961	880	2,997	3,877
1965	5,714	1,989	7,703
1971	18,100	19,739	37,839
1973	24,425	1,000	25,425
1976	33,146	2,920	26,066
1978	54,146	—	54,322
1980	63,347	—	63,347
1981	82,936	—	82,936
1982	68,037	—	68,037

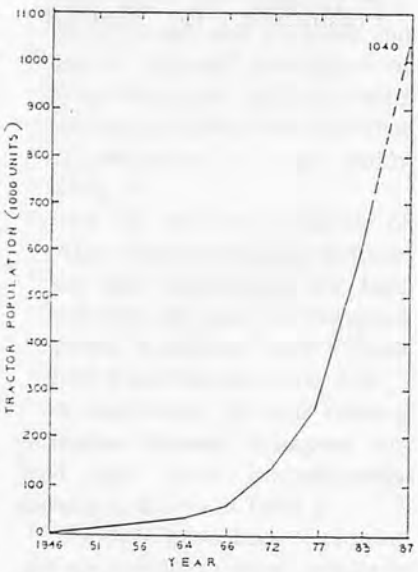

Fig.1 Tractor population growth in India.

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ments. It is estimated that more than 80% of the farm machinery requirement is met by more than one million village artisans who fabricate simple hand tools and animal-drawn implements (Singh, 1985).

The states of Punjab, Haryana and Uttar Pradesh together account for about 60% of the tractors. A large part of the tractor stock in Uttar Pradesh is in the agriculturally advanced districts located in western and northern parts of the state. A number of studies (Singh and Chancellor, 1974; NCAER, 1978) have revealed that tractor owners and users derive higher per hectare gross incomes compared to bullock farms. The use of electric and mechanical energy resources is linked with higher crop yields. This study was undertaken with a view to collecting information on tractor use and associated costs, to determine an economic level of tractor use, and to evaluate the purchase of tractors by the farmers in Uttar Pradesh.

Field Survey

The study was conducted in 1983 in two districts, namely, Kheri and Sitapur, located in the northern part of Uttar Pradesh bordering Nepal (**Fig. 2**). The major crops of the area are paddy, wheat and sugarcane. There are two major crop seasons, namely; winter (rabi) and summer (kharif). As given in **Table 2**, the two districts have very similar profiles. The selection of farmers from the districts was based mainly on two considerations. First, the sample should represent all major brands and sizes of the tractors used in the districts, and second, the tractor owners should be willing to allow field measurements as well as provide details on tractor ownership and their use.

A total of 37 farmers, 26 from the Kheri district and 11 from the Sitapur district, were selected for the study. The tractors included 11 brand names and 12 models. These were: 1 Harsha (18.7 kW), 2 HMT-2511 (18.7 kW), 3 Eicher 241 (19.8 kW), 3 MF 1035 (24.3 kW), 4 International B-275 (26.1 kW), 12 Escrot 335 (26.1 kW), 3 Swaraj 735 (29.1 kW), 1 Kirloskar (32.1 kW), 1 International 434 (33.6 kW), 1 Byelarus (33.6 kW), 2 Ford 3600

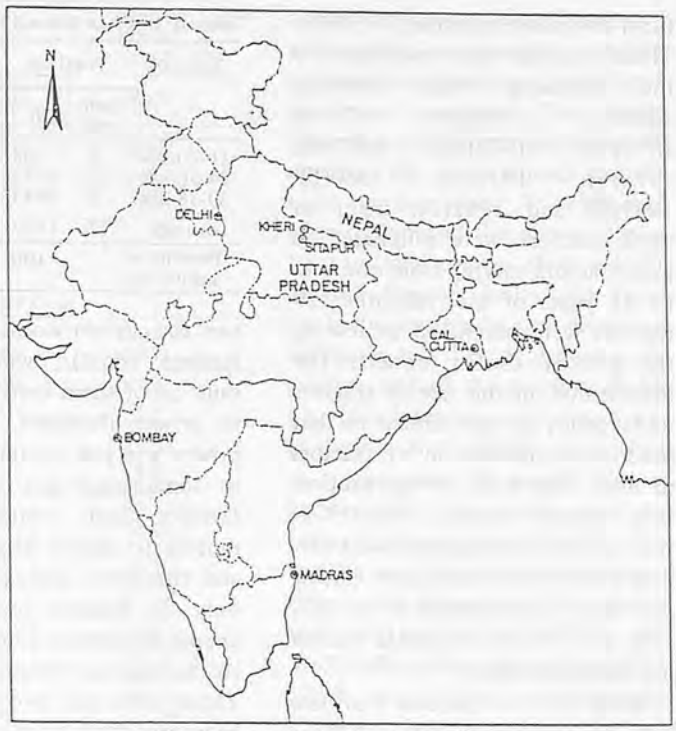

Fig. 2 Map of India showing study area.

Table 2 Profile of the Selected Districts (1983)

Condition	Kheri	Sitapur
Climate: Humid		
Maximum temperature (°C)	40	37
Minimum temperature (°C)	5	7
Annual rainfall (mm)	1 500	970
Soils	alluvial (loams)	alluvial (loams)
Cultivated area (ha)	448 000	391 000
Irrigated area (%)	27	24
Area under main crops (%)		
Rice	36	39
Wheat	37	9
Sugarcane	18	9
Cropping intensity (%)	129	131
Number of farm machines		
Tractors	4 700	3 500
Pumpsets (oil engine)	28 500	16 500
Pumpsets (electric)	2 800	1 800
Threshers	1 500	500

Table 3 Farm Equipment Ownership and Farm Size, 1983

Tractor		Units of					No. of Equip./ Tractor	Average Farm Size (ha)
Size (kW)	Units	Mouldboard Plough	Disc Harrow	Tine Tiller	Thresher	Trailer		
18-20	6	0	6	0	5	4	2.5	13.8
24-30	22	2	18	11	13	19	2.9	14.6
33-38	9	4	9	9	6	8	4.0	31.7
Total	37	6	33	20	24	31		
Percent of total		16	89	54	65	84		

(35.1 kW) and Hindustan (37.3 kW). These tractors were purchased in the following years: 1968(1), 1969(1), 1970(2), 1971(2), 1972(1), 1974(1), 1977(4), 1978(6), 1979(3), 1980(6), 1981(9) and 1982(1). Eight of these tractors were purchased as used tractors varying from one year to 11 years of use. All other 29 tractors were purchased as new by the present owner farmers. The distribution in the size of tractors under study is very similar to that of overall distribution of tractors in India. Based on average production figures during 1975-1979, tractors in size ranges of 14-21 kW, 22-29 kW, 30-37 kW, and 38 kW and above, represented 27%, 51%, 17% and 5% of the total tractor production in India.

Most of the farmers had low educational level and they did not keep records at all. Therefore, most of the information collected was based mainly upon the farmers' recollections. Questions were simple and sequentially connected to each other. The interviews were conducted with the owner and driver of the tractor and in certain cases with the mechanic responsible for the repairs.

Table 3 gives the details of the farm equipment owned and the size of farm holdings of the farmers in the survey. The most common equipment were disc harrows and trailers. Thirty three farmers (89%) owned disc harrows and 31 farmers (84%) owned tractor trailers. Other commonly owned equipments were: 24 threshers (65% of the farmers) and 20 tine tillers (54% of the farmers). There were only six mouldboard ploughs, four of which were owned by large farmers having large size tractors.

Annual Use of Tractors

Out of a total of 37 farmers only 18 of them (49%) used their tractors for custom work. Although 24 farmers (65%) owned threshers only 20 of them used their tractors to power threshers. The electric power was just becoming available in some areas and a number of farmers had installed electric motors to power irrigation pumps and threshers. Though there were only 31 farmers owning trailers, almost all farmers (36) used trailers for agricultural transport purposes. Those who did not own trailers borrowed them from other farmers.

Table 4 Average Annual Use of Tractors, 1982-83

Tractors	Total use		Custom work		Tillage		Threshing		Agri. transport		Other uses	
	Farmers	h	Farmers	h	Farmers	h	Farmers	h	Farmers	h	Farmers	h
18-20 kW	6	708	4	188	5	205	4	41	5	120	6	286
24-30 kW	22	1272	12	354	22	189	12	32	22	221	22	601
33-38 kW	9	1443	2	550	6	343	4	56	6	291	6	745
Average	37	1222	18	338	33	219	20	39	33	218	34	571
Percent of annual use		100		24		16		3		16		41

The total annual use of tractors was obtained from the hour-meter readings. Field capacities for various tillage operations (ploughing, harrowing and tilling) were determined in the field by measuring total area and the total time taken. Knowing the field capacity and the number of times an operation was performed, the total hours of use for each implement were estimated. By summing up the use of a tractor with various tillage implements, the total number of hours on tillage were determined. Threshers were used mainly for the wheat crop. Wheat threshing is concentrated in a few weeks only and it was relatively easy for farmers to remember the hours of use of their tractors in wheat threshing. In transport, tractors were used mainly for two purposes, namely; transporting sugarcane to the sugar-mill and traveling to the nearest market town for selling produce as well as for bringing inputs like seeds, fertilizers and fuel. Farmers remembered the total amount of money they had received for custom hiring. Using the prevailing custom-hire rate, the number of hours of custom work were estimated. Information on the use of tractors for agricultural operation for three farmers with large tractors (33-38 kW) could not be collected.

The average annual use of tractors for various activities is given in **Table 4**. The average annual use of 37 tractors was 1 222 h. The annual use increased with increase in the size of the tractor, mainly because of larger farm size and bigger tractors (33-38 kW) had more equipment (4.0 per tractor) compared to 2.9 for 24-30 kW tractors and only 2.5 for 18-20 kW tractors (**Table 3**). The average use of tractors for agricultural operations on the farmer's own fields was only 35%. Tractor use in tillge and transportation for agricultural purposes was about the same (16% each). Threshing accounted for only 3% of the annual use. The use in custom work amounted to 24% of the total annual use. The largest portion of the use (41%) was for other purposes involving transport for social activities, travel for diesel and spare parts, and travel to numerous farm plots. Transport-related activities, including agricultural and other activities accounted for 59% of the total annual use.

Costs

Estimated values of all tractors in 1983 were used in all cost computations. The annual cost of a tractor consists of fixed costs (de-

Table 5 Annual Use and Hourly Cost of Tractors, 1982-83

Annual use (h)		Tractor		Average hourly cost
Range	Average	Units	Average size (kW)	Rs/h
Below 1000	791	16	25.3	35.60
1001 - 1200	1150	4	28.4	29.50
1301 - 1600	1400	12	31.2	25.90
Above 1700	1945	5	36.0	24.60

1 US$ = 10 Indian Rupees

Table 6 Tractor Size, Year of Purchase, Annual Use and Hourly Cost

Serial No.	Size (kW)	Year	Annual use (h)	Cost/h (Rs)
1	18.65	79	250*	53.4
2	18.65	77	1 500	19.2
3	18.65	78	750	25.73
4	19.77	79	800	27.35
5	19.77	81	250*	54.9
6	19.77	81	700	28.83
7	24.25	80	1 000	32.57
8	24.25	81	800	38.49
9	24.25	77	1 500	23.29
10	26.11	69	1 200	39.16
11	26.11	80	1 600	28.18
12	26.11	81	1 200	29.0
13	26.11	80	1 400	22.81
14	26.11	81	1 000	35.76
15	26.11	79	1 100	25.95
16	26.11	77	1 000	24.70
17	26.11	82	800	31.19
18	26.11	80	1 600	23.49
19	26.11	78	2 000	18.32
20	26.11	78	1 990	19.93
21	26.11	81	1 000	31.80
22	26.11	78	800	33.45
23	26.11	78	1 500	21.21
24	26.11	80	2 000	23.59
25	26.11	72	1 500	25.95
26	29.09	78	1 000	28.53
27	29.09	77	1 500	28.63
28	29.09	81	500*	51.22
29	32.08	81	1 790	31.46
30	33.57	74	1 500	23.68
31	33.57	71	2 000	29.70
32	35.06	80	1 100	33.90
33	35.06	81	1 000*	36.72
34	37.30	70	1 500	29.99
35	37.30	70	1 600	35.93
36	37.30	68	1 500	28.81
37	37.30	71	1 000*	39.50

* Less than annual break-even use. 1 US$ = 10 Indian Rupees (1983)

preciation, interest, taxes, insurance and shelter) and variable costs (repair and maintenance, fuel, lubricants and operator). The hourly cost of a tractor was calculated by dividing the total annual cost by total annual use. As explained earlier (Table 4) the annual use of tractors increased as their size increased. Similar results were found by analyzing the data on an annual use basis and then determining the average size of the tractors (Table 5). An interesting outcome of this analysis is that in spite of increase in tractor size, the hourly cost of tractor use decreased with increased annual use (Fig. 3). The break-even point analysis shows that to be economical the annual use of 18-20 kW, 24-30 kW and 33-38 kW tractors should be 460 h, 780 h, and 1 020 h, respectively. Corresponding values of the annual use of these tractors were 708, 1 272 and 1 443 h, respectively (Table 4), indicating that on average, most of the tractors were operating economically. Details on all the tractors as to their size, year of purchase, annual use and hourly cost are given in Table 6. There were only five tractors the use of which was below the break-even point. Fig. 4 shows a plot of tractor cost per hour in relation to age of tractor indicated by the year of purchase.

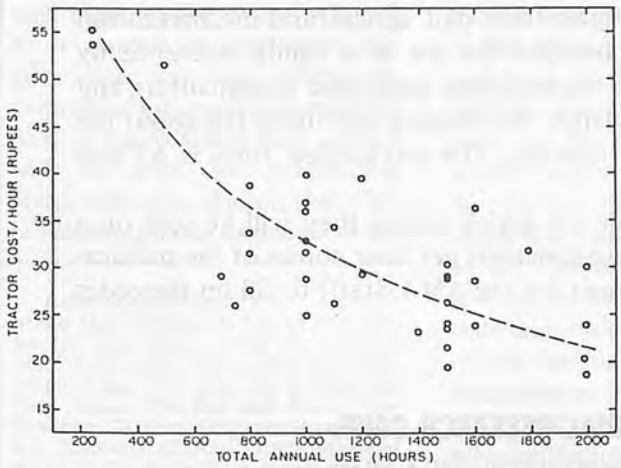

Fig. 3 Total annual use and cost per hour. (1US$ = 10 Rs.)

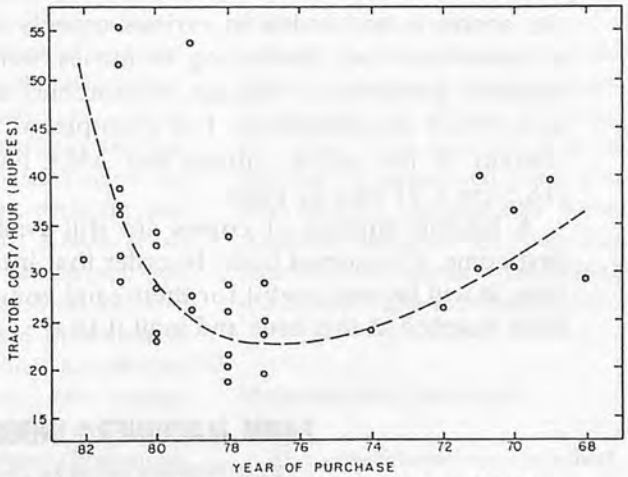

Fig. 4 Cost per hour and age of tractor. (1US$ = 10 Rs.)

Conclusions

The average annual use of tractors was 1 220 h consisting of 35% of use for agricultural related activities on owners' farms, 24% in custom work and 41% in other uses. In agricultural operations, tillage and transport each accounted for 16% of the annual tractor use and 3% was used in threshing. Other uses included transport for social activities, travel for diesel and spare parts, and travel to numerous farm plots.

Tractor utilization was found related to farm size and amount of farm equipment associated with it. Bigger tractors had higher annual use compared to smaller tractors resulting in lower hourly costs. The break-even annual use for 18-20 kW, 24-30 kW and 33-38 kW tractors was 460, 780 and 1 020 h, respectively. However, on the average, these tractors were used for 708, 1 272 and 1 443 h annually, respectively, indicating economic use of most of the tractors.

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AMA ABSTRACTS AND INDEX, 1971–1980

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Effect of Vegetative Cover, Tillage and Planting System on Run-off, Soil Erosion and other Soil Physical Properties

by
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Abstract

An experiment was conducted at Melkassa, a semi-arid region in Ethiopia during 1981 and 1982 to evaluate the effects of vegetative cover, tillage and planting systems on run-off, soil erosion and moisture conservation, bulk density, organic matter content and moistrue infiltration rates. The treatments were: natural grass cover, bare fallow, haricot bean (*Phaseolus vulgaris)* broadcast or ridge planted across the slope. The experiment was conducted on sandy soil of a uniform slope of 10-11%. The quantity of run-off from each test plot was collected by a cylindrical tank with five slot divisors attached to it. Among all treatments, the grass cover was most effective in controlling soil erosion when about 85% of the plots had been covered with the grass. Soil erosion was severe with ridge planting than with broadcasting at the beginning of the cropping season.

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Introduction

The highlands of Ethiopia receive adequate rainfall and they are, therefore, most preferred as agricultural lands. Unfortunately, however, the topography is characterized by numerous hills and steeps. As a consequence, soil erosion in these areas is common and severe (FAO, 1965). The problem of soil erosion is particularly common in Tigraie and Wello administrative regions but some areas in Eritrea, Hararge and Shoa and in almost all regions have very serious erosion problems (Gowans, 1975).

The adverse effects of soil erosion have been well documented. Among other things, soil erosion results in the loss of the top soil which usually contains most of the organic matter, fertilizer and native soil nutrients (Glenn *et al*, 1966). The loss of the top soil also results in the silting of river beds and basins and the exposure of the sub-soil which has adverse consequences on soil tillage (Constantinese, 1976) and moisture infiltration rates (Brakensiek *et al*, 1979).

The control of run-off induced soil erosion has been studied extensively. Lai (1975) reported that greatest deterrent to soil erosion was vegetative cover. It increased water infiltration rate and effectively controlled soil erosion.

On the other hand, the rate of erosion was accelerated when the native vegetative cover was replaced by crop plants. The severest erosion occurred during periods of soil cultivation on bare soils (Kandiah, 1970). Glenn *et al* (1966) and Kandiah (n.d.) reported that vegatative cover and soil management practices affected soil erosion by influencing soil moisture, permeability, bulk density and organic matter content.

Most of the soils on the highlands of Ethiopia have been degraded through soil erosion. However, very little work has been done in this field of agricultural research in this country. Experiments were, therefore, designed to study the most effective means of controlling soil erosion under local conditions.

Materials and Methods

The experiments were conducted at the Institute of Agricultural

Research Station, Melkassa during the 1981 and 1982 "Kremt" (major) cropping seasons. Melkassa is located at an altitude of 1590 m and the total amount of rainfall received during the experimental periods in 1981 and 1982 was 303 and 192 mm, respectively. The mean annual rainfall is 806 mm and the dry season is 6-9 months long.

The experimental design used was a randomized complete block with a single replicate. The soil of the research site is sandy and the experimental plots were laid out on a 10-11% slope. Each plot measured 3.66 m x 22 m (80.52 m^2) and bordered on three sides by concrete blocks, while the lowest side was open. Sedimentation tanks were attached to the open end of each plot to facilitate the collection of run-off and sediment yield (Othieno and Laycock, 1977). The entire experimental area was ploughed on 17 and 19 July in 1981 and 1982. The treatments consisted of: 1) Bare fallow: (The plot was initially ploughed manually and the weeds which emerged later on were subsequently mowed with a sickle at monthly interval throughout the experimental period); 2) A natural grass cover was allowed to establish itself after first clearing on 10 and 8 July in 1981 and 1982. The predominant grass species was *Cynodon dactylon*: 3) A crop of haricot bean (*Phaseolus vulgaris* C.V. Mexican 142) was established by broadcasting at a seed rate of 40 kg of seeds per ha, and 4) Two seeds per hill of the same cultivar of haricot bean were planted on 3.66 m long ridges constructed across the slope and spaced 40 cm apart within row spacing of 10 cm.

The seedlings were thinned out to one plant per hill at the trifoliate leaf stage to give a population of 250 000 plants per ha. Broadcasting of seeds, row cropping and the initial mowing of the bare fallow plot were carried out on 9 June and 6 June in 1981 and 1982.

Rainfall data were recorded with siphon type rain gauge installed at the centre of the experimental area by the method described by Glenn *et al* (1966). Intensity and duration of rainfall were estimated by the methods of Brakenisiek *et al* (1979) and Ponnudurai (1980).

The amount of run-off collected in the tanks was estimated with pre-calibrated measuring sticks (dip-sticks) (Othiene and Laycock, 1977). After stirring the solution thoroughly, run-off samples of 250 cc from each test plot container were collected after each rainfall; dried in a ventilated oven at 105°C for 24 h and weighed to estimate the amount of sediment yield. The data was expressed as t/ha of soil.

Equilibrium infiltration rates of water on each plot was determined with a double-ring infiltrometer as described by Israelsen and Hansen (1962). The inner and outer diameters of the infiltrometer rings were 40 and 60 cm, respectively, and the device was burried to a depth of 10 cm in the soil.

Cylindrical metal pipes measuring 10 cm with an internal diameter of 4 cm were used to collect random samples of soil core from each plot and the soil bulk density was estimated from the cores as described by Israelsen and Hansen (1962) after they have dried at 105°C for 24 h. The gravimetric method as described by Withers and Vipond (1974) was used for the determination of soil moisture content. Two random samples of soil (900 g each) were collected with a Dutch auger at a depth of 0-30 cm, weighed, dried at 105°C for 24 h and reweighed for the estimation of soil moisture.

Three random samples of soil were collected from each plot at a depth of 0-30 cm from the surface of the soil on September 29 and October 7 in 1981 and 1982. The oil was air-dried for about 72 h and passed through a 2 mm sieve. The fraction which passed through the sieve was used for the determination of organic matter. Organic carbon was extracted in potassium dichromate and determined by the method described by Ponnudarai (1980).

The erosivity of storms was estimated from the equation: $Y = 200 + 89 \text{ Log}_I$, where Y = Kinetic energy in J/cm of rainfall on 1 cm^2 surface; and I = Intensity in cm per h (Wischmier and Smith, 1978).

The regression of run-off on amount of rainfall and sediment yield on run-off for each treatment was estimated by the method described by Thomas and Jackson (1978).

Results and Discussions

The data on rainfall for each erosive storm in 1981 and 1982 are summarized in **Table 1**. In the two-year period of the experiment among a total of 80 storms only 25 storms (31.3%) caused erosion. Three modest rainfall events: 13, 14 and 15 and 36, 43 and 45 days after planting occurred in July,

Table 1 Rainfall Data for 1981 and 1982 at Melkassa Research Station

Date	Amount (mm)	Duration (h)	Intensity (mm/h)
22/7/81	26.0	2.05	12.48
23/7/81	33.8	4.50	6.99
24/7/81	25.4	0.20	76.20
27/7/81	1.8	0.30	3.60
29/7/81	22.2	2.30	8.88
6/8/81	25.0	1.50	13.64
15/8/81	37.0	1.45	21.14
16/8/81	4.5	2.00	2.25
17/8/81	17.2	3.30	4.91
28/8/81	23.0	2.30	9.20
1/9/81	19.5	3.30	5.88
8/9/81	13.7	5.15	2.61
13/9/81	17.3	1.45	9.89
15/9/81	17.2	1.00	17.2
19/9/81	–	–	–
26/9/81	–	–	–
24/7/82	26.0	1.0	26.0
31/7/82	26.0	10.30	2.48
2/8/82	60.0	8.30	7.06
9/8/82	17.01	2.15	7.56
18/8/82	23.1	9.0	2.57
27/8/82	19.0	3.0	6.33
7/9/82	11.3	0.45	15.07
16/9/82	10.01	0.30	20.02

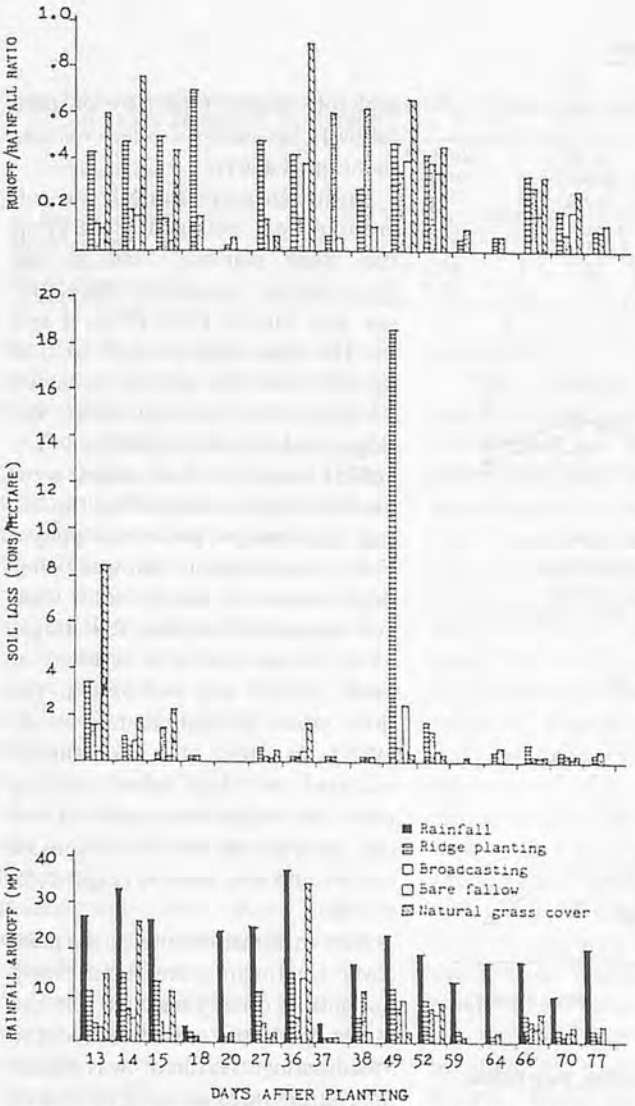

Fig. 1 Rainfall distribution and the influence of ridge planting, broadcasting, bare fallow, and natural grass cover on soil loss and run-off/rainfall ratio at Melkassa (1981).

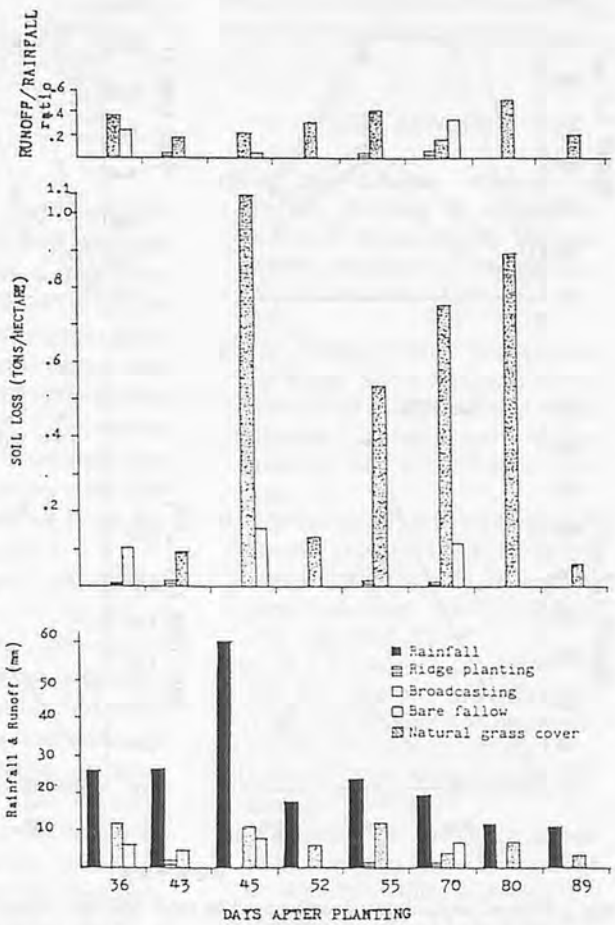

Fig. 2 Rainfall distribution and the influence of ridge planting, broadcasting, bare fallow, and natural grass cover on soil loss and run-off/rainfall ratio at Melkassa (1982).

1981 and 1982, respectively, during the early crop stages when there was little vegetative cover on the land (**Figs. 1** and **2**). Lal and Kowal (1975) and Hudson (1961) reported that the percentage of vegetative ground cover contributed a lot to both run-off and soil erosion. In the present studies surface run-off and soil erosion also occurred whenever rainfall was greater than 1.8 mm. Storms with intensity of less than 2.25 mm/hr were not erosive (**Table 1** and **Fig. 3**). This is in disagreement with Hudson *et al* (1975) who reported in the humid tropics in run-off and soil erosion studies. This was due to differences in ecological zones (vegetation, slope, soil etc.). The occurrence of erosive rains during 1981 and 1982 was more frequent in the last week of July and the first week of August (**Figs. 1**, **2** and **3**).

Run-off and soil erosion were greatest in the first year. In the second year, when the establishment of the grass cover treatment was 85%, there was very rapid reduction in both run-off and soil erosion (Oyegun, 1983). In the first year (1981), when a large proportion of the ground surface was exposed, most of the erosive-raindrops was dissipated by plant canopies it required storms of even longer durations and higher intensities to cause run-off and erosion (**Table 1**). Similar results were obtained by Othieno and Laycock (1977). In the absence of crop cover, at the uniform slope of 10-11%, 45.5% of the total rainfall flowed over the surface as run-off due to the fact that energy of falling raindrops on bare fallow was expended directly on the soil surface, which resulted in the formation of surface seal and increased amount of run-off (FAO, 1965). Rapp (1972) and Treeh (1980) showed that run-off and erosion are most severe on bare soil and vegetation cover on cultivated and grazing lands reduced the damage done by run-off and soil erosion.

Weeding also increased run-off

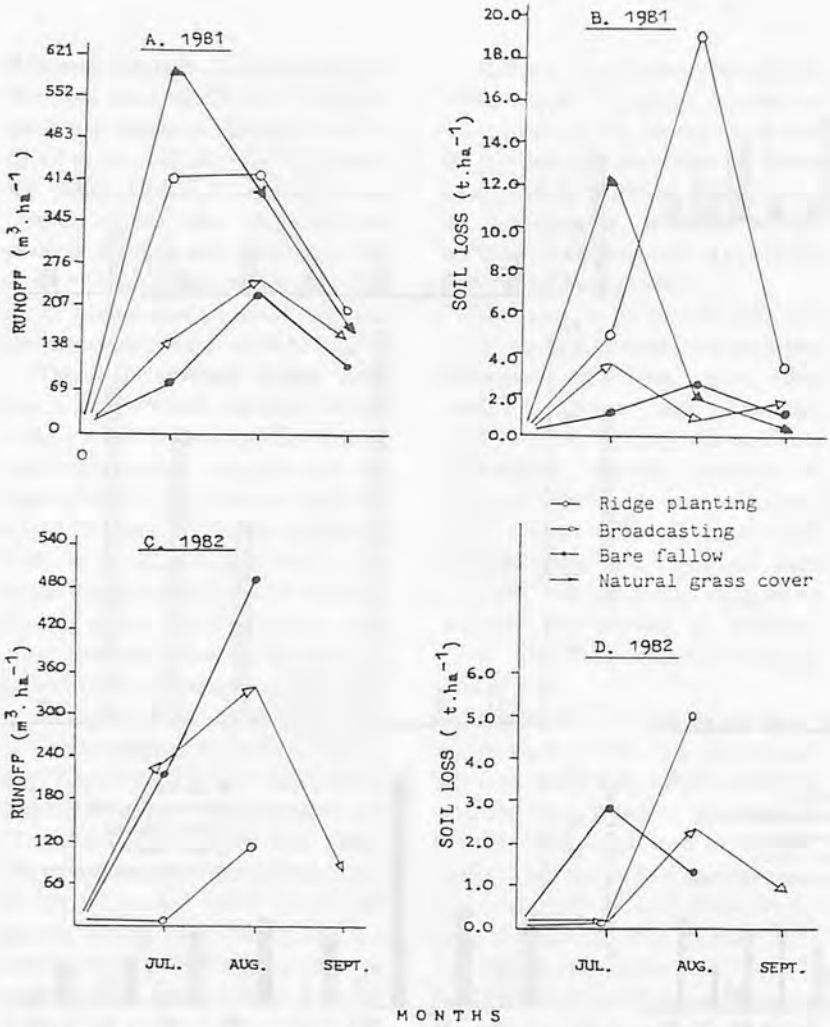

Fig. 3 Run-off and soil loss as influenced by ridge planting, broadcasting, bare fallow, and natural grass cover at Melkassa.

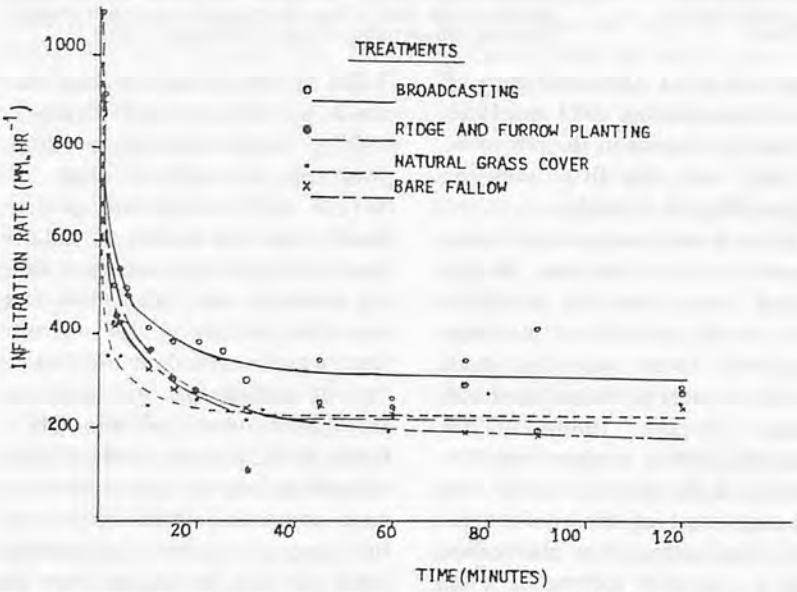

Fig. 4 Equilibrium infiltration rates of soil moisture as influenced by broadcasting, ridge planting, natural grass cover and bare fallow developed from an infiltrometer.

and soil erosion (specially on bare fallow) because of the reasons mentioned above.

Although more run-off and soil erosion were obtained in 1981 in the ridge planting than in the broadcasting treatments, the opposite was true in 1982 (**Figs. 1** and **2**). The main reason could be that in 1981 the first rainfall occurred 13 days after planting, when the ridges had properly stabilized. Lal (1975) reported that ridges were not effective in controlling run-off and soil loss at the initial stages. Field investigation showed that ridges made on sandy soils were not successful because few ridges were broken and this resulted in more run-off and soil loss in the first year (Moldenhauer *et al*, 1975). In 1982 the first rainfall occurred 36 days after planting when the ridges had stabilized and this resulted in the reduction of run-off and soil erosion (**Figs. 1, 2,** and **3**).

The infiltration rates in the grass cover treatment were significantly lower than other treatment. On the other hand, soil moisture for the broadcasting treatment was higher than in the ridge planting treatment because moisture was uniform in the former case while in the latter case it was opposite (**Table 2** and **Fig. 4**). **Table 2** and **Fig. 4** also show that run-off was inversely

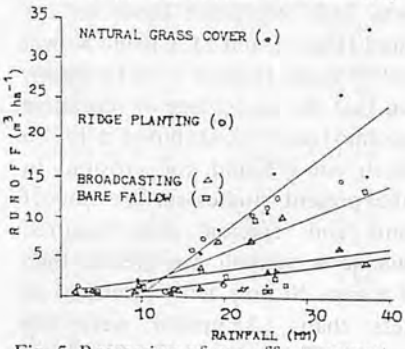

Fig. 5 Regression of run-off on amount of rainfall as influenced by ridge planting: Y = 0.48x−2.956, r = 0.918; natural grass cover: Y = 0.832x−9.731, r = 0.761, broadcasting: Y = 0.137x+0.80, r = 0.819 and bare fallow: Y = 0.248x−1.997, r = 0.754 at Melkassa, 1981.

Table 2 Mean Soil Moisture, Organic Carbon, Bulk Density and Infiltration Rates for Each Treatment, 1981/1982

Treatment	Soil moisture (%)	Organic carbon (%)	Bulk density (g/cc)	Infiltration rate (mm/h)
Ridge planting	11.81	0.47	1.24	248.0
Broadcasting	12.18	0.87	1.35	260.0
Bare fallow	9.92	0.76	1.32	224.0
Natural grass cover	12.34	0.86	1.29	196.0

related to infiltration rates while infiltration rates were inversely proportional to soil moisture levels.

The percentage of organic matter content in the natural grass treatment was higher than in other treatments, except in broadcasting. The reason for such unexpected result is unknown. Compared to bare fallow, natural grass cover decreased bulk density by 49.43% and organic matter by 53.09%. The last amount of organic matter was obtained from ridge planting (0.47%) because a lot of organic matter was eroded with the soil in 1981 (**Table 1** and **Fig. 1**). Ponnudurai (1980) reported that eroded soils have poor organic matter content compared to non-eroded soils.

The interaction effect of kinetic energy and the maximum 30 min. intensity showed a measure of storm (Wischmer and Smith, 1978). Thus, a rainfall of 1.58 and 2.48 cm /h had kinetic energies of 227.68 and 245.11 J/cm falling on 1 cm^2 surface during 1981 and 1982, respectively.

The correlation coefficients between rainfall and run-off, and run-off and soil loss for all treatments were significant for 1981. In the second year the results were significant only for broadcasting and bare fallow. Ridge planting did not show any significance. The correlation coefficient for natural grass cover for 1982 was zero because no run-off was observed from this treatment (**Figs. 6** and **7**).

It can be concluded that natural grass cover at 10-11% slope increased organic matter. This organic matter having a spongy character, encouraged infiltration rates of soils. This increases soil moisture content. During rotation of crops, the organic matter (full of nutrients), which is contributed from the strip of vegetative cover can be used by plants for optimum growth. Ridge planting played a second important role in conserving soil and water at steep slopes. Broadcasting is not recommended at this slope regardless of soil type. Bare fallow should be totally discouraged. Vegatative cover, therefore, has advantages over any other erosion controlling treatments.

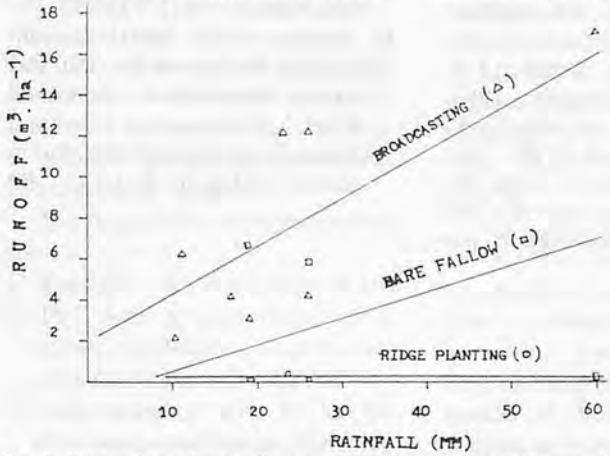

Fig. 6 Regression of run-off on amount of rainfall as influenced by ridge planting: Y = −0.0002x+0.037, r=0.491; natural grass cover: Y = 0, r = 0; broadcasting: Y = 0.243+1.893, r = 0.946 and bare fallow: Y = 0.143x−0.915, r = 0.781 at Melkassa, 1982.

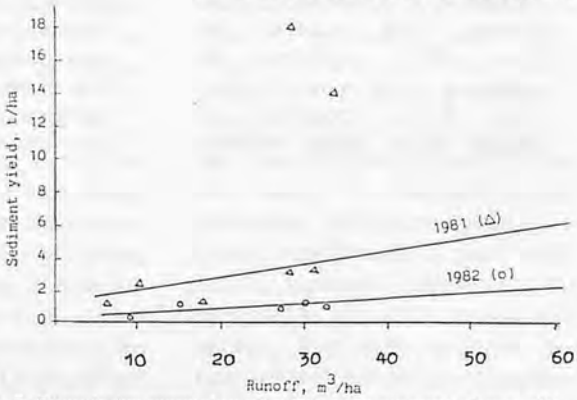

Fig. 7 Cumulative regression of soil loss on amount of run-off: Y = 0.137x+0.604, r = 0.599; and Y = 0.043x+0.096, r = 0.902 at Melkassa for 1981 and 1982.

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Harvesting of Acala Cotton by Machines in Rahad Scheme in the Sudan

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Abstract

Tests were conducted at the Rahad Research Station field and in tenants' fields to investigate the technical and economical feasibility of mechanical harvesting of acala cotton under Rahad conditions and the performance of three makes of cotton harvesters. The objective was to select the appropriate and suitable mechanical harvesting system for the Rahad.

Introduction

The Rahad project is an irrigated agricultural scheme at the eastern side of River Rahad (one of the tributaries of the Blue Nile). The total area of the scheme is 300 000 feddans (126 000 ha). Half of the area is planted to acala cotton (medium staple) and the rest is planted to peanuts, sorghum and horticultural crops.

The main features of the project are:

1) The high level of mechanization.
2) The well levelled topography which facilitates long furrow irrigation and mechanization.
3) Large tenancy area (9 ha for cotton/peanut/fodders for each tenant)
4) Scarcity of labour at the critical periods (weeding, cotton harvesting).
5) Most of the tenants (former nomads) are not familiar with irrigated agriculture.

Rahad management has been faced with problems of labour shortage for cotton picking since the first season in 1977 due to the continuously tightening labour situation at cotton harvest in the country.

A field of cotton does not mature uniformly: between the maturation of the first and last bolls two to three months elapse. Postponing harvesting until all the bolls are ripe is impractical as losses due to boll shedding would be excessive, and lint quality would deteriorate. Hence, two or more pickings are the rule, especially with manual picking.

All cotton in the Sudan is still harvested by hand. Manual picking accounts for 50 to 80% of the total labour invested in cotton growing.

The objective of the work reported in this paper was to investigate the technical and economical feasibility of mechanization of cotton picking in the Rahad Scheme, and to evaluate the performance of three makes of cotton pickers in order to recommend the most suitable machine (or machines) under Rahad conditions.

Review of Literature

Many factors affect the performance of mechanical cotton harvesters. Studies in the USA (1, 2, 3, 4) show that such factors as variety, plant spacing and cultural practices affected the performance of both spindle picker and stripper-type cotton harvesters. These studies also show that each area has climatic conditions, soil types, topography and farming practices peculiar to its own location, that affect mechanized production and harvesting of cotton.

Results of irrigation experiments in Alabama showed that large amount of nitrogen needed for maximum production frequently produce large plants, cause lodging and make harvesting difficult (5). Studies conducted in Auburn University Agriculture Experiment Station in cooperation with ARS, USDA, showed that the performance of two types of mechanical cotton harvesters, picker and stripper, was affected by plant spacing and variety. In irrigated cotton, harvesting efficiency (picker) increased significantly as plant population increased. However, the increase in efficiency varied with variety. For both irrigated and non-irrigated cotton, the characteristics of the cotton plant were materially altered by plant spacing.

As plant population increased, plant height and limb length decreased, while height of fruiting increased. These characteristics were considered desirable for mechanical harvesting and were obtained at no significant sacrifice in yield (6).

Machine-picked cotton averaged lower in one grade than hand-picked cotton. Although improvements in harvester operation, cultural practices, chemical defoliation, and ginning facilities have helped to narrow the difference, there is, on the average, about a one-grade differential (7, 8).

General experience with mechanical pickers indicates that with careful attention to the various production and machine-operating factors involved, machine losses will usually range from 5 to 10% of the yield (9). Under less favorable conditions, picker losses may be as great as 15 to 20%, or even more.

Chemical defoliation of cotton has been used in various parts of the world as a harvest practice to facilitate mechanical harvesting. A wide variety of chemicals have been used for defoliating cotton. Calcium cyanamide, magnesium chlorate, sodium chlorate, and amino triazote are among those used in various formulations and under different trade names.

The results of trials conducted in the Gezira Research Station (Sudan) showed the phosphate defoliants (DEF) and (Folex) gave adequate defoliation when used at the rate of 1.5 pints per acre, but the addition of 0.75 pints of gramoxone slightly increased both the final leaf loss and the rate of defoliation (10).

Experimental Measurements

A series of tests were run in the Rahad Research Station and in the field to investigate the performance of three makes of spindle-type, high-drum, 2-row, self-propelled cotton pickers, namely; John Deere 9910 (JD); International Harvester 782 (IH); and Ben Pearson 827 (BP).

The tests consisted of:

I. Machine performance:
   i) Field capacity,
   ii) Fuel consumption,
   iii) Cotton losses.

II. Quality of lint:
   i) Grade,
   ii) Loss in weight,
   iii) Fibre specifications.

In addition, the tests investigated the technical and economical factors such as plant population, cultural practices, and defoliation which affect the introduction of cotton harvesting in the Rahad Scheme.

Procedure

Machine Performance Tests

The total area for the test was 920 feddans (384 ha). Machine-delinted cottonseeds were drilled at the rate of 10 g/feddan (approximately 40 000 plants/feddan), on rows (ridges) 97 cm (38 cm) apart. The variety of cotton was acala 4/42. Fertilizer was applied to the cotton plants according to the Agricultural Research Corporation recommendations (2N of nitrogen (urea) 6 weeks after sowing). Weeds were controlled by herbicides, sweep cultivation (green ridging) and hand-hoeing. Insecticides were applied as needed. The method of irrigation practised was long furrow (280 m, length of the furrow). Chemical defoliant, mixture of DEF6 and gramoxone at the rate of 0.86 and 0.48 *l* per feddan, respectively, was applied when approximately 80% of the bolls opened.

The total area was divided into plots each of 1 feddan. When the cotton was ready for harvest, each machine was assigned a number of plots, at random, every day. To avoid border and end effects the cotton, 4 m from the side of the water course was hand-picked and the irrigation border was levelled out all along the plots.

Daily data for each machine consisted of the total area picked, total time spent in the field, breakdown time, service time, blockage time, fuel consumption and seed loss were recorded. Cotton picked by each machine of the three makes from each plot was collected separately, pressed in big sacks, weighed and transported to the ginning factories.

For the cotton loss the following procedure was followed:

Preharvest loss: Squares (2 m x 2 m) of round steel were used to select sampling areas at random. The cotton on the ground was collected from the selected area before the start of machine harvesting. The collected cotton was weighed and recorded for each machine separately.

Harvest loss: The cotton left on

Table 1 Machine Field Capacity

Feddans/h

Item	John Deere	International Harvester	Ben Pearson
Total area picked (feddan)	20	20	20
Total time spent (h)	11.6	12.1	14.4
Field capacity (feddan/h)	1.72	1.65	1.4

Feddan = 0.42 ha

Table 2 Time efficiency (area was 12 feddans for each machine)

Unit: min

Item	John Deere	International Harvester	Ben Pearson
Breakdown time	7.5	14.8	56.2
Cleaning time	49.2	44	90.5
Total lost time	56.7	58.9	146.7
Average lost time (min/feddan)	5.7	5.9	14.7
Average total picking time/feddan	48.1	54.1	54.1
Time efficiency (decimal)	0.88	0.89	0.73

Table 3 Seed Cotton Losses

Unit: kg/0.1 feddan

Feddan No.	John Deere			International Harvester			Ben Pearson		
	Tree	Ground	Total	Tree	Ground	Total	Tree	Ground	Total
(1)	10.2	2.9	13.1	7.5	1.2	8.7	16.6	2.8	19.4
(2)	4.7	4.2	8.9	11.2	0.8	12	7.5	12.6	20.1
(3)	4.3	0.5	4.8	11.2	3.1	14.3	12.1	3.3	15.4
(4)	7.9	1.5	9.4	10.1	1.4	11.5	10.0	3.0	13.0
(5)	6.1	1.0	7.1	10.3	4.5	14.8	27.0	11.3	38.3
(6)	8.4	2.0	10.4	7.0	5.7	12.7	18.0	5.7	23.7
(7)	8.0	4.6	12.6	8.0	5	13.5	10.2	6.5	16.7
(8)	9.3	4.9	14.2	4.7	2.2	6.9	14.4	3.5	17.9
(9)	7.0	3.8	10.8	6.0	1.6	7.6	16.3	0.8	17.1
(10)	5.9	2	7.9	5.8	1.9	7.7	15.9	2.8	18.7
Average	7.2	3	10.2	8.2	7.7	10.9	14.8	5.2	20.0
Percentage of losses	–	–	12%	–	–	12%	–	–	23%

Average yield was 860 kg/feddan of seed cotton

Table 4 Summary of Machine Performance Test Data

Machine	Total area picked feddan	Total working hours	Field capacity feddans/h	Time efficiency	Average fuel consumption gal/feddan	Average percent of seed cotton losses
John Deere (9910)	448	264	1.72	0.88	3.0	12%
International Harvester (782)	373	226	1.65	0.89	3.2	12.6%
Ben Pearson (827)	99	71	1.4	0.73	2.9	23%

the plants and on the ground was collected immediately after machine harvesting, weighed and recorded for each machine separately.

Data for machine performance are shown in **Tables 1, 2** and **3** and summarized in **Table 4**.

Quality Tests

Samples were taken at random during classification and the ginning of seed cotton from cotton picked by each machine of the three makes, together with samples from hand-picked cotton in the same locality. All samples were sent to the spinning and fibre testing laboratory of cotton breeding department at Wad Medani, to be tested for changes in grade and lint quality. The test results are shown in **Table 5**.

Results and Discussion

The results of performance test presented demonstrate that the John Deere 9910 and International Harvester 782 pickers showed almost similar field capacity and time efficiency. However, the Ben Pearson 827 picker's field performance was comparatively poorer. This was due to the fact that both John Deere 9910 and International harvester 782 pickers used the same picking mechanism, namely; the tapered spindles and drum-type spindle bars while the Ben Pearson picker used small diameter straight spindles on vertical slats attached to endless chain. The system of John Deere and International Harvester pickers seemed to be superior to the system used in Ben Pearson machine under Rahad conditions.

In the John Deere and International Harvester pickers the seed cotton was removed from spindles

Table 5 Quality Test Results

Samples description	Seed cotton weight	Output			Ginning P.C.			Stickiness	Fibre Test					Bundle Strength Analysis		
									Fibrograph 2.5%		IIC shirley					
	kg	B/L	Lint kg.	Seed	Lint	Seed	Trashes	Degree at R.H.L.60	S.L.	U.R.	M.V.	MAT	Fine	Strg.	Elong.	Trash
											M	M	M	Y80	%	Card
John Deere	866	1	345.5	455	39.8	52.4	7.8	Light	33	42	2.85	0.71	132	18.4	6.8	7.0
International	1086	1	420	572	38.6	52.7	8.7	Light	32	43	3.46	0.8	137	16.5	6.8	6.1
Ben Pearson	848	1	325	457	38.3	53.9	7.8	Light	32	41	2.88	0.79	122	17.9	7.0	8.7
Hand Picked	976	1	404	545	41.4	55.9	2.7	Light	33	44	3.26	0.78	145	18.5	7.0	5.2

This report is issued according to:
1) Spinning test report No. Sc 43 dated 24.9.79 (spinning & fiber testing lab.). 2) Stickiness test report No. Sc 43 data 24.9.79 (spinning & fiber testing lab.). 3) Daily ginning report (classification section, Rahad ginning factories).

Key: R.H.L.60 – Relative humidity level 60%; S.L. – Span length; – U.R. – Uniformity ratio; M.V. – Micronier value; MAT (or M) – Maturity; Y80 – Yarn 80 counts; Card – Machine for trashes separation; IIC – Shirley – Finess/maturity tester.

by means of rotating doffer plates, and the cotton was forced off as the doffer lug moved over the spindle surface toward the tip while with the Ben Pearson picker stripping was accomplished by moving the spindles axially through the spaces between closely fitted stripper shoes. Seed cotton losses in the case of John Deere 9910 and International Harvester 782 pickers were insignificantly different and in the range of economically acceptable losses. However, the losses of the Ben Pearson picker was higher and economically unacceptable. This was also due to the picking systems adopted in the three makes.

Fuel consumption results indicated that the difference between the three makes was insignificant.

Quality Results

Grade: Machine-picked cotton averaged lower in grade than hand-picked cotton. The principal ways in which mechanical pickers can reduce grades of lint below the grades that might be obtained by hand picking are:

1. Discolouration of lint by green leaves and by oil and grease from the machine.
2. Introduction of additional amounts of weeds, grass and trash from the cotton plant.
3. Addition of excessive moisture (from spindle moistening) to the lint and trash, thus making trash removal at the gin more difficult, including graying or mildew if ginning is delayed.
4. Twisting or tangling of the lint by the spindles, thereby increasing difficulties associated with ginning.

Gin turn-out (or lint turn-out) is the ratio of the mass of the recovered lint to the mass of the field-run seed cotton. The presence of excessive amount of trash and other foreign matter reduced the gin turn-out in the case of machine picked cotton. Results showed that the average gin turn-out for machine-picked cotton was 39% while for the hand-picker it was 41.4%. For the three makes of cotton pickers the difference was insignificant.

Stickiness

The results indicate that there was no affect on the machine-picked cotton as far as the stickiness degree is concerned.

The cost of mechanical picking is characterized by high fixed charges, because of the high purchasing price of the machine and service-supporting equipment, and by high repair costs. The amount of cotton harvested per season is an important factor in determining the harvesting cost. When comparing mechanical picking and hand-picking, charges for field losses, grade loss, and increase in ginning costs, must be added to the harvesting costs.

For the Rahad scheme case, because of scarcity of labour and the failure to recruit enough hand-pickers in the previous three seasons **(Table 6)**, the cost of seed cotton losses and deterioration in lint quality due to prolonged period of picking, should be considered in comparing hand picking and machine picking.

Table 6 Number of Hand-Pickers Recruited by Rahad Management in the Previous Two Seasons

Season	Total cotton area, feddans	No. of pickers required	Actual no. of pickers recruited	Percentage of recruited pickers
1978/79	80 000	80 000	45207	56%
1978/80	80 000	88 000	62956	72%

Conclusions

1. The trials have shown that cotton mechanical picking in the Rahad Scheme is technically feasible. The results also confirmed that the spindle-type machine was most suitable for irrigated cotton.
2. The results of the test for the three makes of cotton pickers showed that there was no significant difference between the John Deere 9910 and International Harvester 782 pickers as far as the field performance was concerned.
3. Several of the cultural practices such as seedbed preparation, weed control, cotton stand establishment and defoliation are more critical and require better management for machine picking than for hand picking.
4. The results indicate that mechanical picking has minor effect on lint quality.
5. Cost estimates indicate that hand-picking would have been cheaper than mechanical-picking had the required number of hand-pickers been secured at the optimum time.
6. When comparing hand-picking, and machine-picking, charges for seed cotton losses, grade loss, and increase in ginning costs, must be added to the machine harvesting costs.
7. Observations during the test indicate that back-up service facilities, well-trained operators, and mechanics are of vital importance to the success of mechanical picking of cotton.

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(Continued on page 36)

Development and Evaluation of Wide-Swath, Tractor-Mounted Sprayer for Cotton Crop

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Abstract

A tractor-mounted sprayer for cotton was developed and evaluated in the field. The sprayer boom has 13 triple action nozzles and two spray guns. It has a swath width of 12 m and covered 1.2 ha/h while operating at a speed of 3.5 km/h. The field performance and effectiveness of spray on yield of this sprayer was compared with that of the knapsack sprayer. There was a net increase in yield of 29.6% in the field sprayed by tractor-mounted sprayer as compared to the field sprayed by knapsack sprayer. Pest control was better in the case of the tractor-mounted sprayer as compared to knapsack sprayer.

Introduction

Chemicals are widely used for increasing agricultural production through better insect-pest management. They are applied in varying amounts, depending upon the type and concentration of active ingradients. For cotton crop, the recommended application rate (8) ranges from 125 to 310 *l*/ha depending upon the equipment used. Equipment used by the farmers in India are manually-operated knapsack sprayers, power-operated pneumatic sprayer-cum-duster and tractor-mounted sprayer. A very limited aerial spraying is practised in some cotton growing areas. Sprayer performance depends upon the type of nozzle, nozzle spacing and its orientation on the boom, boom height over the crop along with operational parameters like discharge pressure, forward speed and field layout.

Black et al (1954) developed a self-propelled high clearance sprayer to cover six rows of sweet corn crop. The boom of the sprayer could be adjusted to a maximum height of 2 m. The sprayer was tested in the field and its performance was quite satisfactory. Johnstone (1975) developed a sprayer for applying fungicides on groundnut crop.

Cannon *et al* (1978) developed a sprayer for the experimental cotton plots which could apply different chemicals. Srivastava (1978) developed a manually-operated wide-swath sprayer for sugarcane that required four persons for its working and covered a swath width of 20.4 m.

Cannon (1979) designed, developed and tested a wide-boom ground sprayer for its effectiveness, field capacity and reliability. The machine was wide enough to cover 24 rows spaced 1.106 m apart. The actual field capacity of the sprayer was 23.8 ha/h at the ground speed of 16 km/h.

Verma and Singh (1979) developed a power tiller-operated sprayer for spraying of herbicides with swath width of 4 m. The sprayer was mounted on a power tiller of 7.5 hp. The field tests gave good results. Ahuja (1979) developed a tractor-mounted high clearance sprayer with effective swath width of 20 m. The field performance of the sprayer was quite satisfactory except for time loss in filling the tank, limited speed of operation and limited height adjustments. Twenty meter-

wide boom on the sprayer posed operational problems under Ludhiana conditions.

A tractor-mounted sprayer was introduced recently in Punjab for spraying cotton crop. However, it is used for only first 2-3 sprays. The limited use is due to the fear of damage to the crop by tractor chassis, tyres and lack of height adjustment of the boom. The machine also lacks in uniform spray, adjustment for nozzle spacing and has limited swath width (8 m). The tractor-mounted sprayer was modified to overcome the above limitations. Experiments were set up to establish the crop damage due to the machine and its effect on crop yield in comparison to the knapsack sprayer.

Materials and Methods

Description of Machine

The tractor-mounted sprayer (Fig. 1) consisted of a centrifugal pump, a tank and a boom fitted on a frame which can be attached to 3-point linkage of a tractor. The pump was driven from tractor p.t.o. through a set of gears. There was flexible hose on which nozzles were mounted. The flexible hose was clamped to a rigid pipe. The spacing betweeen the nozzle could be adjusted by loosening the clamps. Spray guns were provided at both ends of the hose. To cover the gap in spray created by the spray guns, the nozzle adjacent to the spray gun was provided at an angle of 30° with the boom. The supply of solution to the boom was provided at two points for even distribution. A pressure regulator was provided in between the pump and the boom to adjust the desired pressure. Boom height can be adjusted at an interval of 10 cm up to 2.25 m to suit crop conditions. The major specifications of the machine are given in Table 1

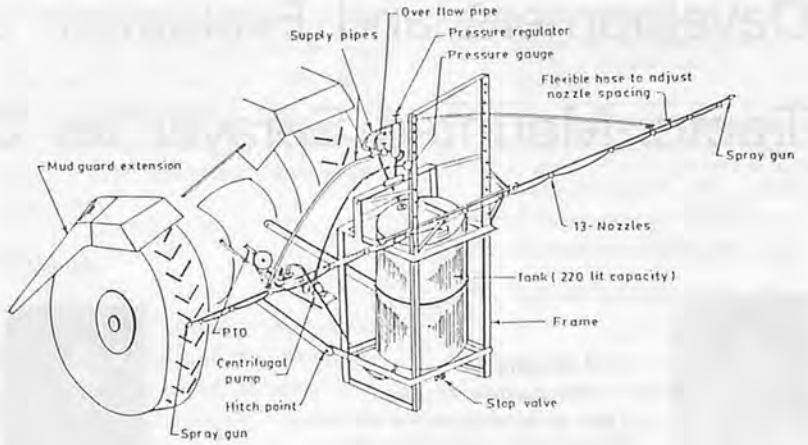

Fig. 1 Tractor-mounted sprayer.

Table 1 Major specifications of Tractor-mounted Sprayer.

Power source	23-30 hp tractor
Type of pump	Centrifugal pump
No. of nozzles	13
Type of nozzles	ASPEE (Triple action)
No. of spray guns	2
Nozzle spacing	75 cm (adjustable)
Height adjustment	10 cm interval. Max. height upto 225 cm from ground
Tank capacity	220 *l*
Pump speed	1 725 rpm
Pump discharge	18.24 *l*/min at 3kg/cm²
Swath width	12 m

and stationary view of tractor-mounted sprayer is shown in Fig. 2.

Fig.2 Tractor-mounted sprayer.

Test Procedure

The sprayer was calibrated in the laboratory at a pump speed of 1 725 rpm and varying supply pressures. Discharge from individual nozzle and spray gun was collected separately and analyzed for its variation.

The sprayer was evaluated on cotton crop at village Khunda Halal, Punjab, India. Three plots each measuring 0.6 ha were marked. The first plot was sprayed with the use of a knapsack sprayer, the second with the tractor-mounted sprayer having mudguard extension; and the third, with the tractor-mounted sprayer without mud-guard extension. As per the recommendation of Punjab Agricultural University (8) the spray rate with the knapsack sprayer was 250 *l*/ha and 185 *l*/ha with the tractor mounted sprayer. However, the quantity of chemical sprayed per ha in both cases was similar. The spray supply pressure for the tractor-mounted sprayer was 3 kg/cm². All the seven sprays were done with the use of the tractor-mounted sprayer. The chemicals Monocrotophos and Fenvalerate were used alternatively. No traffic zone was left for the tractor in the field. However, the tractor followed same pathways and direction for all seven sprays (Fig. 3). Experimental data regarding plant damage, pest control and yield was taken from the rows coming directly under the tractor, side of the tractor and away from the tractor. Similar data was taken from the plot sprayed with the use of the kanpsack sprayer and compared with that of tractor-mounted sprayer.

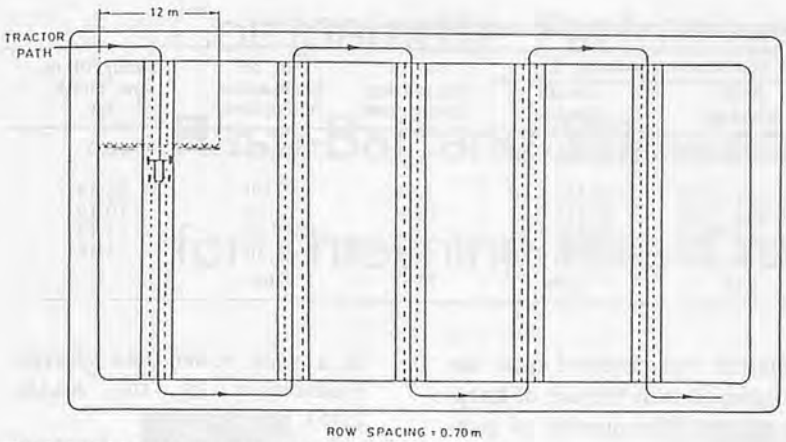

Fig. 3 Field layout for evaluation of tractor-mounted sprayer.

For the pest control data, the plot under particular treatment was divided into 10 equal parts. Two plants at random were selected from each part of the treatment which were considered as a replication. Thus, each treatment consisted of 10 such replications. All the matured bolls from each test plant were removed and put into polythene bags. These were examined for pink boll-worm incidence both on boll and loculi basis and carry over of diapausing larvae.

Results and Discussions

Lab Results

The discharge rates from different nozzles at various pressures and their variations are given in **Table 2**. The pump speed during the tests was 1 725 rpm and tractor engine speed was 1 500 rpm. The average nozzle discharge varied from 0.458 *l*/min to 0.820 *l*/min as the pressure was increased from 2.0 kg/cm^2 to 4.0 kg/cm^2. The coefficient of variations of nozzle discharge at a field spray pressure of 3 kg/cm^2 was 6.76% which is acceptable under field conditions. In the case of spray guns the average discharge varied from 1.78 *l*/min to 2.45 *l*/min with the increase in pressure from 2.0 kg/cm^2 to 4.0 kg/cm^2. The coefficient of variation of the spray gun discharge at the field spray pressure was 0%. The effective swath width was 12 m.

Field Results

While operating the tractor-mounted sprayer in the field (**Figs. 3** and **4**) two rows were under the tractor chassis and two side rows (one on each side of the tractor) were partly affected during each pass of the machine. The crop damage, yield and pest control data are given in **Table 3**. For rows under the tractor chassis, there was a loss of 61.6% in yield while for side rows, it was 41.4% in comparison with the crop away from the tractor. However, inspite of the damage to the crop due to tractor, there was a net increase in yield of 29.6% in comparison with the crop sprayed with knapsack sprayer. The field capacity of the tractor-mounted sprayer was 2.2 ha/h at the speed of 3.5 km/h and that of knapsack sprayer was 0.08 ha/h. The operating cost of the tractor-mounted sprayer was Rs. 18/ha and that of the knapsack sprayer was Rs.28/ha. No significant difference in crop damage was observed due to the use of mudguard extension. This may be due to the shape of the mudguard extension used which needs further investigation.

Fig. 4 Tractor-mounted sprayer in operation on cotton crop.

Incidence of Bollworm Under Different Spraying Methods

The data presented in **Table 3** shows that plants sprayed with

Table 2 Discharge Rate of Nozzles and Spray Guns on Tractor-mounted Sprayer

Discharge pressure kg/cm^2	Discharge rate, *l*/min															C.V. among nozzles %	C.V. between spray guns %
	SP1*	N1**	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	SP2		
2.0	1.84	0.44	0.42	0.52	0.48	0.52	0.44	0.38	0.52	0.44	0.44	0.46	0.38	0.52	1.72	10.61 (0.458)	3.37 (1.78)
3.0	2.14	0.60	0.58	0.64	0.66	0.56	0.56	0.58	0.66	0.62	0.56	0.58	0.58	0.68	2.14	6.76 (0.60)	0.00 (2.14)
4.0	2.40	0.76	0.86	0.74	0.78	0.84	0.88	0.84	0.78	0.96	0.84	0.86	0.80	0.84	2.50	6.70 (0.82)	2.04 (2.45)

*SP – Spray gun, **N – Nozzles
Note: (1) Pump speed 2 725 rpm; Tractor engine speed 1 500 rpm.
(2) Figures in parentheses are the average discharge rates.

Table 3 Incidence of Pink Bollworm and Crop Yield under Different Techniques on Hirsutum Variety F 414

Treatment	(Bollworm incidence, %) Bolls attacked	Loculi attacked	No. of diapouring larvae/plant	No. of harvestable bolls/plant	Yield/100 m row length kg
Knapsack sprayer	(24.74) 17.00	(15.96) 7.10	4.17	39.50	16.0
Tractor-mounted sprayer					
a) Away from the tractor	(14.40) 5.70	(9.44) 2.50	1.63	57.00	26.55
b) Under the tractor	(10.94) 3.10	(8.21) 1.55	0.99	22.30	10.19
c) Side of the tractor with mudguard	(17.01) 8.05	(10.53) 2.85	0.74	41.30	15.15
d) Side of the tractor without mudguard	(18.33) 9.40	(11.85) 3.70	1.28	43.30	15.56
C.D. (P=0.05)	2.44	2.26	N.S.	2.64	

Note: Figures in parentheses are arc-sin values.

the use of the knapsack sprayer carried significantly higher bollworm (*Pectinophera gossypiella* Saunders) incidence both on boll and loculi basis than the crop sprayed with the use of the tractor-mounted sprayer. The crop under the tractor path suffered significantly loss from bollworm attack as compared with the plants on side rows with mudguard and without mudguard. The pink bollworm incidence on boll basis was also significantly less in plants under the tractor path than the plants away from the tractor. But when the bollworm incidence was considered on loculi basis the difference in these two treatments were non-significant.

The number of diapausing larvae population per plant under different treatments was non-significant but numerically higher larvae population was obtained from the crop sprayed with the use of knapsack sprayer. The number of pickable bolls per plant were significantly higher in the crop sprayed with the use of the tractor-mounted sprayer.

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Harvesting of Acala Cotton by Machines in Rahad Scheme in the Sudan

(*Continued from page 32*)

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Comparative Performance of Rasp-Bar and Wire-Loop Cylinders for Threshing Rice Crop

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Abstract

In a comparative study the wire-loop, irrespective of feed-rate and moisture content, showed higher threshing efficiency at lower speeds and at all concave settings. The peripheral speed of 3688 fpm (18.63 m/s) became the transitional speed beyond which the rasp-bar excelled wire-loop in performance.

The rasp-bar gave higher percentage of husked grain than wire-loop for all levels of peripheral speeds and at all three concave settings. At lower concave clearance of 1/8" (3.1 mm) and the peripheral speed of 4425 fpm (22.35 m/s), the grain damage of rasp-bar was seven times than wire-loop at dry moisture content and eight times at wet moisture content. However, this difference decreased as the concave clearance increased and the peripheral speed decreased.

Introduction

Various designs of threshing mechanisms have been developed to thresh cereal crops and to obtain maximum threshing efficiency with reasonably less grain damage. The physio-mechanical properties of the crop like the type of ear-head and bond-strength of the grain in the panicle are the main characteristics which determine the selection of proper threshing mechanism for getting maximum results.

The threshing mechanism of mechanical threshers utilizes either rasp-bars or wire-loops as a functional component of the threshing mechanism. Concave clearance and cylinder peripheral speed are the operational parameters associated with threshing mechanism. Therefore mechanical threshers utilizing either of the threshing mechanisms; concave clearance and cylinder peripheral speed are to be optimized for maximum and damage-free threshing. In order to investigate the compatibility of wire-loop and rasp-bar cylinders, a comparative study was conducted for threshing rice crop.

Objectives

The main objectives of this study were to compare the performance of wire-loop and rasp-bar threshing cylinders in terms of (i) amount of grain threshed; (ii) amount of grain un-threshed; and (iii) husked grain percentage as effected by the following operating parameters: cylinder speed, concave clearance, grain moisture content and feed rate.

Review of Literature

A few designs of mechanical threshers were tried before the introduction of the rasp-bar and it has basically continued unchanged up to the present day. To obtain maximum threshing efficiency for wheat, rasp-bar cylinders have been tried in various combinations of concave clearances and cylinder peripheral speeds (King and Riddols, 1963 and Arnold, 1964). In earlier studies, the effect of peripheral speed on the grain damage have been evaluated for wheat (Tauri 1962) and rice (Mardsen 1959) crops.

In an attempt to reduce the mechanical damage to the grain, the rasp-bars have been lined with rubber (Lalor and Buclele, 1963) but this practice has been discontinued as no resilient or synthetic material

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was found to withstand threshing without a high rate of wear (Hebblewaite and Arnold, 1962).

Wire-loop cylinder came into existence as an alternate design to rasp-bar. Loops of different configurations and in different setups have been used to increase the threshing efficiency (Sakun 1963) and in a comparative study using combine, wire-loop cylinder used 23.4% less fuel and gave higher threshing performance than the rasp-bar cylinder (Sakun, 1963).

Apart from conventional cylinder designs Khan (1971) designed a table type thresher incorporating wire-loop as a threshing mechanism for threshing rice crop. In a test it showed the threshing capacity of 350 kg/h (Khan, 1972).

Since higher peripheral speed of rasp-bar causes grain damage (Sakun, 1963), a two-stage thresher with lower peripheral speeds have been tried (Kolganov and Chetyrkin 1962) for different cereal crops in order to reduce the grain damage.

Experimental Setup

Both cylinders of identical dimensions each measuring 17" (44.45 cm) in diameter and 20" (50.8 cm) long were fitted in identical test stands.

The rasp-bar cylinder was fitted with four rasp-bars whereas the wire loop was fitted with 1 7/8" (4.73 cm) loops which were placed in rows at a spacing of 2" (5.08 cm). Both cylinders were fitted with concaves of identical dimensions and covered 105 degrees of the cylinder surface.

A belt conveyor measuring 12' (3.66 m) long, 22" (58.88 cm) wide and height equal to test stands was used for feeding the crop. The threshers were powered by 10 hp motor. In order to adjust the feed-rate, the belt conveyor was powered by 1/2 hp variable speed motor.

A. Independent variables:

1. Six levels of peripheral speed 2010 fpm (10.16 m/s), 2478 fpm (12.4 m/s), 2766 fpm (13.97 m/s), 3162 fpm (15.97 m/s), 3688 fpm (18.63 m/s) and 4425 fpm (22.35 m/s) were obtained by changing the pulley sizes.
2. Three concave clearances 1/8" (3.1 mm), 1/4" (6.3 mm) and 3/8" (9.5 mm) were obtained by adjusting the concaves. The clearance was measured with reference to the tip of rasp-bar or wire-loop.
3. Moisture content: wet 24% (w.b) and dry 16% (w.b) were used.
4. Feed rate: Basing on previous studies, the feed-rates of 3 kg/25 s and 6 kg/25 s were suggested.

B. Dependent variables.

1. Threshing efficiency calculation based on:
   a. Grain threshed
   b. Grain unthreshed ie grain obtained by rethreshing the straws manually after one pass through the thresher.

$$\text{Eff} = \frac{W_{tp} + W_{ts}}{W_{tp} + W_{ts} + W_u}$$

Where

W_{tp} : Grain threshed and collected in pan.

W_{ts} : Grain threshed but collected by shaking.

W_u : Unthreshed grain.

2. Husked grain: 50 g sample was taken with sample divider and the sample was checked with naked eye for any broken grain and the results were calculated on percentage basis.

Results and Discussions

Performance at 3 kg/25 s feed-rate, two levels of moisture contents and three concave settings

The graphical representation of data (**Figs. 1, 2 and 3**) show that at both wet (24%) as well as dry (16

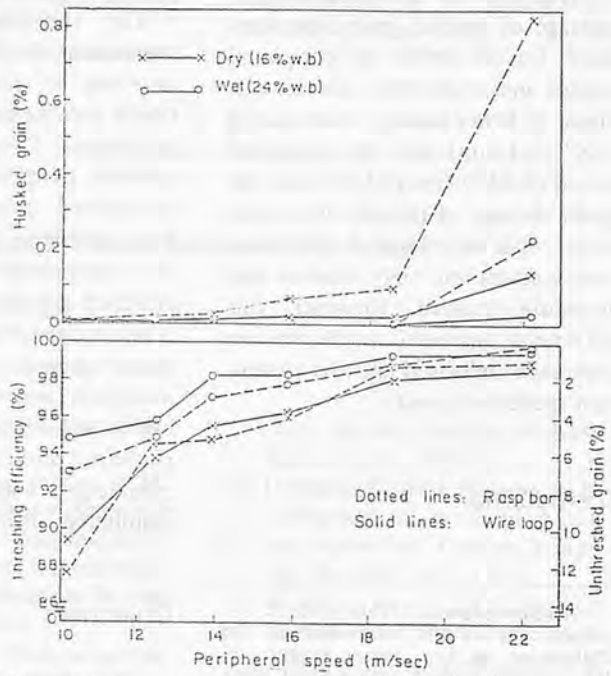

Fig. 1 Perforamnce of cylinders at 1/8" (3.1 mm) concave clearance and 3kg/25s feed rate.

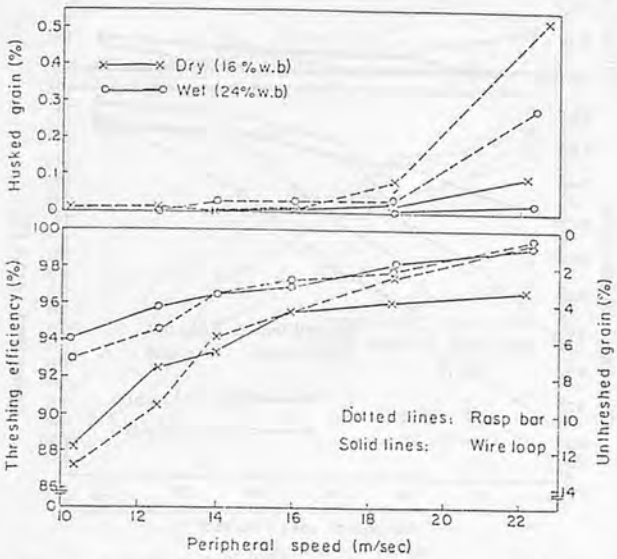

Fig. 2 Performance of cylinders at 1/4" (6.3 mm) concave clearance and 3kg/25sec feed rate.

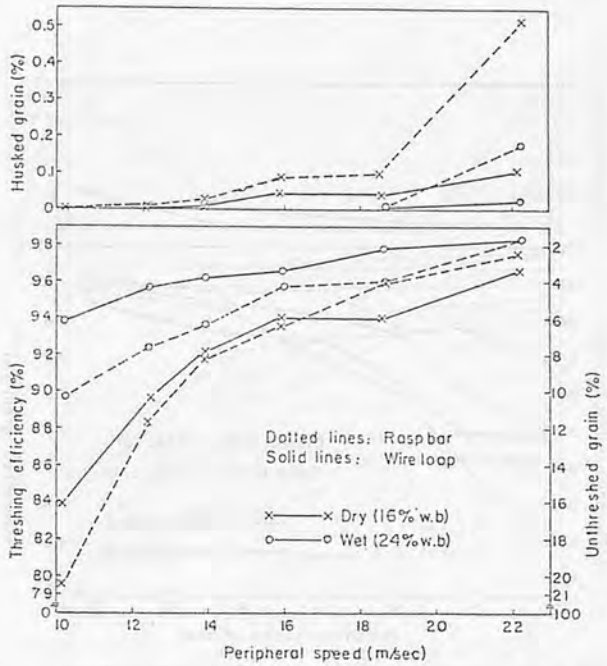

Fig. 3 Performance of cylinders at 3/8" (9.5 mm) concave clearance and 3kg/25s feed rate.

%) moisture contents, the performance of wire-loop was better than raspbar for all the concave settings and lower peripheral speeds. However, the trend of performance changed at higher speeds.

Comparing the performance at a particular set of operating conditions (i.e., moisture content, concave clearance or peripheral speed) different peripheral speeds were observed as transitional speed below which the performance of wire-loop was higher than rasp-bar but above that transitional speed the performance of rasp-bar excelled wire-loop (**Fig. 1, 2 and 3**).

At both levels of moisture contents, the magnitude of grain damage for rasp-bar was higher than the wire-loop, especially at 1/7" (3.1 mm) concave clearance and dry (16 %) moisture content, where the rasp-bar gave 0.83% grain damage which was 7 times greater than wire loop. On the other hand, whereas at wet (24%) moisture content, the rasp-bar gave 8 times higher grain damage than the wire-loop (**Fig. 1**). This difference of grain damage decreased as the concave clearance increased (**Figs. 2 and 3**).

Performance at 6 kg/25 s feed-rate, two moisture contents and three concave settings

At dry (16%) moisture content and all the concave settings, the performance of wire-loop was superior than rasp-bar **Fig.s 4, 5 and 6**). The peripheral speed of 3688 fpm (18.63 m/s) at 1/8" (3.1 mm) and 1/4" (6.3 mm) concave clearances (**Figs. 4 and 5**) were observed as the transitional speeds beyond which the rasp-bar excelled in performance.

At wet (24%) moisture content and all the three concave settings, the performance of wire-loop was higher than rasp-bar for lower speeds but 3688 fpm (18.63 m/s) at 1/8" (3.1 mm) concave clearance (**Fig. 4**), 2766 fpm (13.97 m/s) at 1/4" concave clearance (**Fig. 6**)

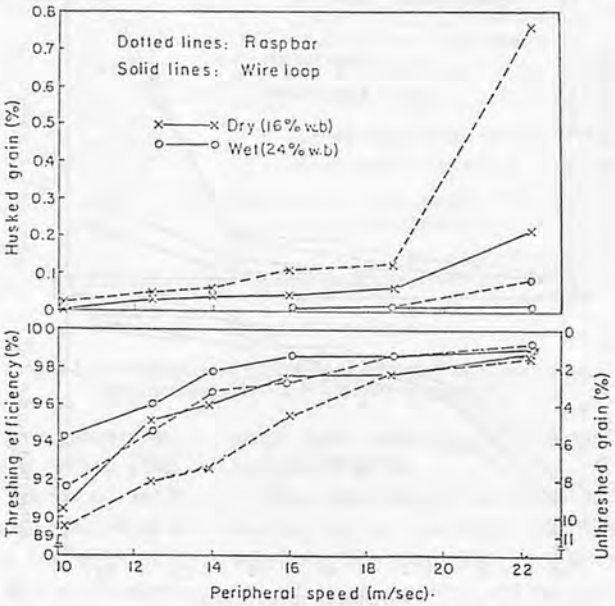

Fig. 4 Performance of cylinders at 1/8" (3.1 mm) concave clearance and 6kg/25s feed rate.

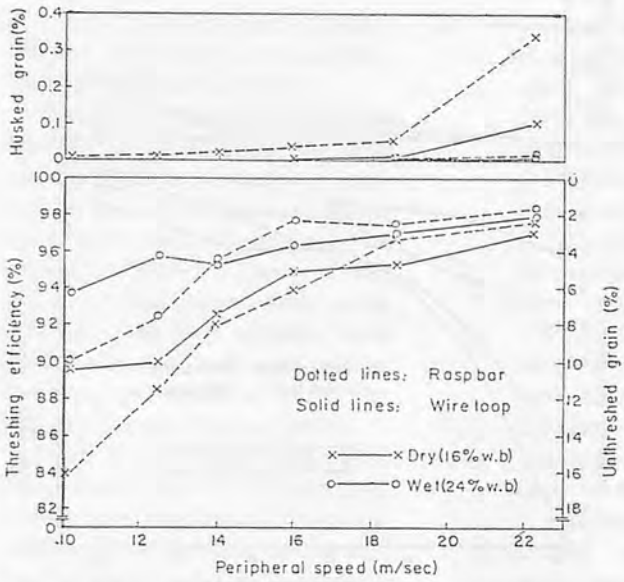

Fig. 5 Performance of cylinders at 1/4" (6.3 mm) concave clearance and 6kg/25s feed rate.

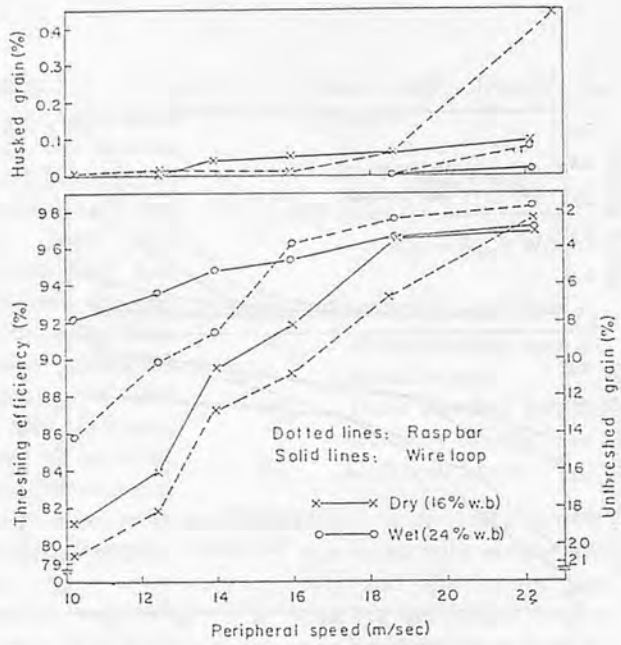

Fig. 6 Performance of cylinders at 3/8" (9.5 mm) concave clearance and 6kg/25s feed rate.

and 3162 fpm (15.97 m/s) at 3/8" (9.5 mm) concave clearance (Fig. 6) became the transitional speeds beyond which the rasp-bar gave better performance than the wire-loop.

The component of grain damage for both moisture contents was higher for rasp-bar than for the wire-loop. As the speed increased beyond 3688 fpm (18.63 m/s) the rasp-bar gave multi-fold grain damage than the wire-loop (Figs. 4, 5 and 6).

Performance at dry (16%) moisture content, two feed-rates and three concave settings

At 6 kg/25 s feed-rate, the wire-loop gave higher threshing efficiency than the rasp-bar at lower peripheral speeds (Figs. 7, 8 and 9). However, 3688 fpm (18.64 m/s) peripheral speeds appeared to be a transitional speed beyond which the rasp-bar excelled in performance (Figs. 7 and 8). At 3/8" (9.5 mm) concave clearance, the wire-loop gave higher threshing efficiency for whole range of peripheral speeds (Fig. 9).

Visualizing the performance at 3

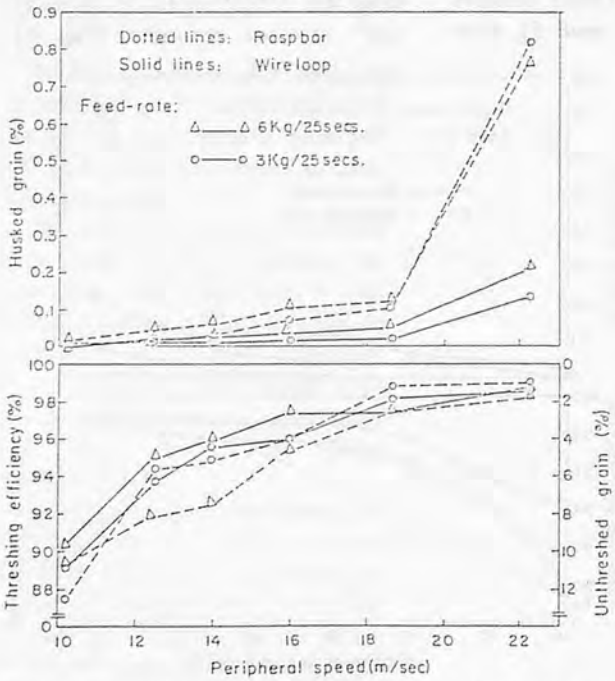

Fig. 7 Performance of cylinders at 1/8" (3.1 mm) concave clearance and 16% (w.b.) moisture content.

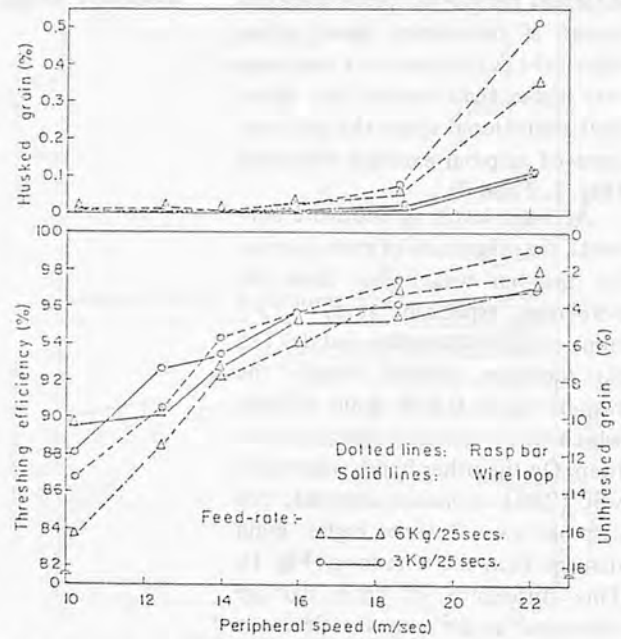

Fig. 8 Performance of cylinders at 1/4" (6.3 mm) concave clearance and 16% (w.b.) moisture content.

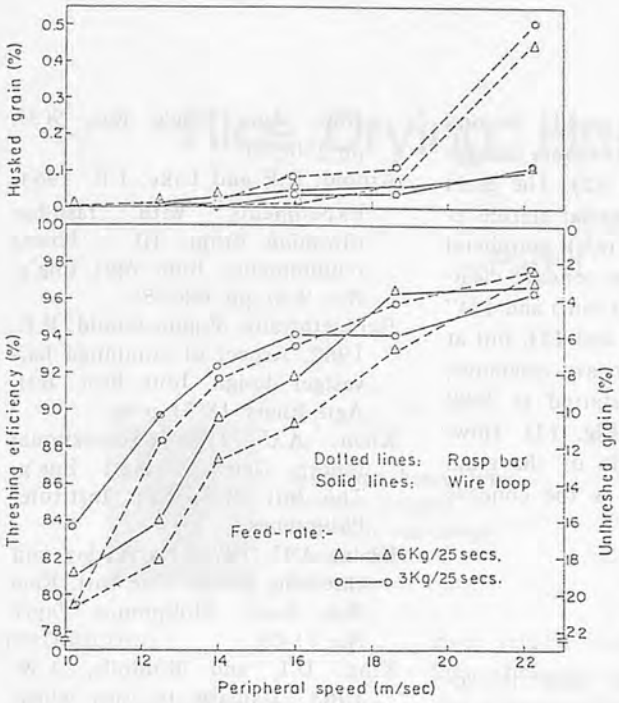

Fig. 9 Performance of cylinders at 3/8" (9.5 mm) concave clearance and 16% (w.b.) moisture content.

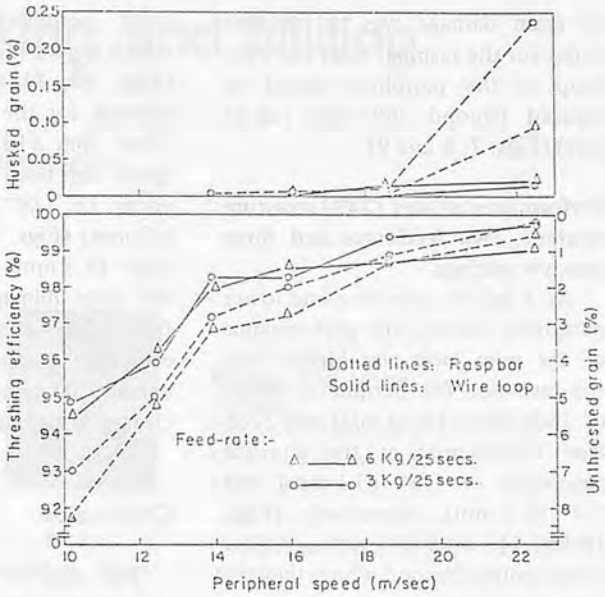

Fig. 10 Performance of cylinders at 1/8" (3.1 mm) concave clearance and 24% (w.b.) moisture content.

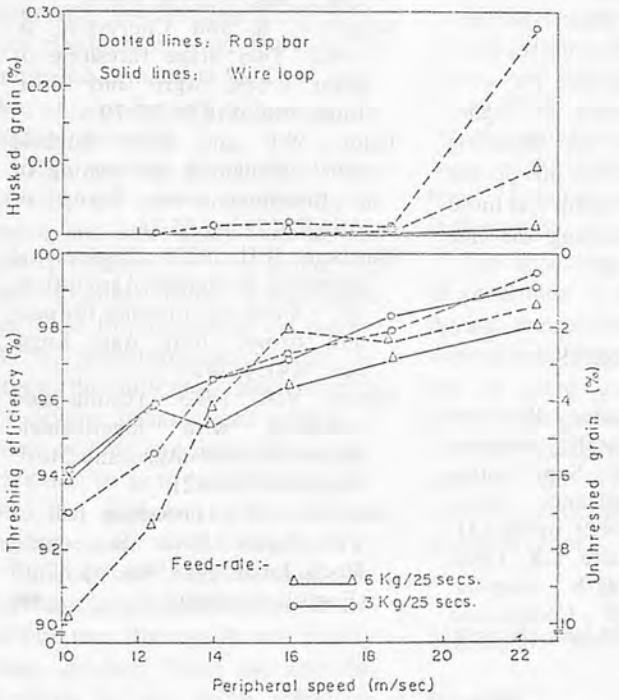

Fig. 11 Performance of cylinders at 1/4" (6.3 mm) concave clearance and 24% (w.b.) moisture content.

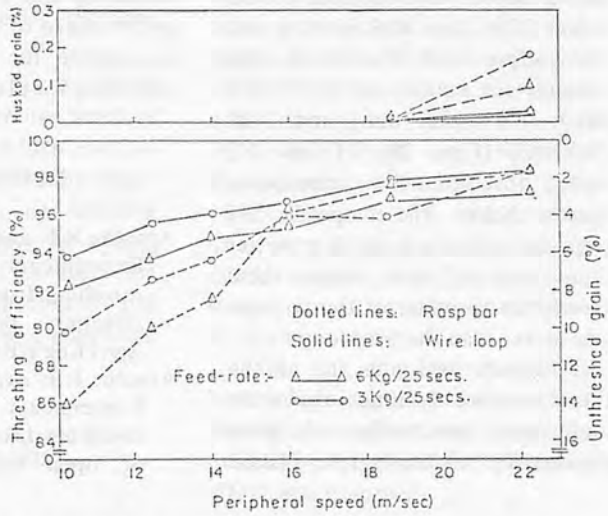

Fig. 12 Performance of cylinders at 3/8" (9.5 mm) concave clearance and 24% (w.b.) moisture content.

kg/25 s feed-rate, the performance became indistinguishable at 1/8" (3.1 mm) concave clearance (Fig. 7). At 1/4" (6.3 mm) concave clearance and lower peripheral speeds the wire-loop gave better performance but as the speed increased beyond 3162 fpm (15.97 m/s), the rasp-bar gave better performance than the wire-loop (Fig. 8). The peripheral speeds of 3688 fpm (18.63 m/s) was observed as a transitional speed at 3/8" (9.5 mm) concave clearance. Below this speed the performance of the wire-loop was higher than the rasp-bar but above this speed the performance reversed (Fig. 9).

The magnitude of grain damage for the rasp-bar was higher than the wire-loop for both the feed-rates for all three concave settings and all the peripheral speeds. Irrespective of the feed-rate, the component

of grain damage was of multiple order for the rasp-bar than the wire-loop as the peripheral speed increased beyond 3688 fpm (18.63 m/s) **(Figs. 7, 8 and 9)**.

Performance at wet (24%) moisture content, two feed-rates and three concave settings

At 3 kg/25 s feed-rate and lower peripheral speeds, the performance of the wire loop was higher than the rasp-bar. The peripheral speeds of 3688 fpm (18.63 m/s) and 2766 fpm (13.66 m/s) at the concave clearances of 1/8" (3.1 mm) and 1/4" (5.3 mm), respectively, **(Figs. 10 and 11)** were observed as transitional points beyond which the performance either became indistinguishable or the rasp-bar gave better performance. However, the wire-loop gave better results than the rasp-bar at 3/8" (9.5 mm) concave clearance and for a whole range of peripheral speeds.

At 6 kg/25 s feed-rate, the peripheral speeds of 3688 fpm (18.63 m/s), 2766 fpm (13.66 m/s) and 3162 fpm (15.97 m/s) at the concave clearances of 1/8" (3.1 mm), 1/4" (5.3 mm) and 3/8" (9.5 mm) **(Figs. 10, 11 and 12)** were observed the transitional speeds below these speeds the response of wire-loop was better than rasp-bar but above these speeds the response of the rasp-bar was better than the wire-loop.

For both feed-rates and all the three concave settings, the wire-loop gave practically no grain damage up to 3688 fpm (18.63 m/s) peripheral speed beyond which it gave traces of grain damage **(Figs. 10, 11 and 12)**. The grain damage for the rasp-bar started at 2766 fpm (13.97 m/s) peripheral speed for both the concave clearances, i.e, 1/8" (3.1 mm) and 1/4" 6.3 mm) **(Figs. 10 and 11)**, but at 3/8" (9.5 mm) concave clearance, the grain damage started at 3688 fpm (18.63 m/s) **(Fig. 12)**. However, the magnitude of the grain damage decreased as the concave clearance increased.

Conclusion

The rasp-bar has higher threshing efficiency than the wire-loop but at the same operating conditions the grain damage for the latter was considerably high. The performance characteristic curves show that still there is avenue for wire-loop to be operated at higher speeds to increase the threshing efficiency and with this margin the performance of wire-loop was more compatible for threshing the rice crop than for rasp-bar.

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Rice Drying, Husking and Milling

—Part I Drying—

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Introduction

Rice production is one of the largest agricultural industries in both developed and developing countries. Due to large increases in rice production, there has been an increased demand in kind and number of post-harvest equipment for paddy processing.

Rice grains, like many other cereals, are not homogeneous in shape and size. Many varieties are short, medium or long grains (1). And so many types of machinery are used for processing the paddy. It is, therefore, worthwhile to study the different characteristics of drying, husking and milling of some of long and short grain paddy varieties, so as to help in determining the appropriate post-harvest equipment for various varieties.

Indica rice varieties come in different length, width, breadth and colour that distinguish one variety from another. There are also differences in the hull's thickness, moisture content during harvest and the rate at which one variety can release moisture during drying.

In drying paddy, it is natural that high temperature air drying can cause quicker moisture evaporation from the grain and later can cause cracking to the grain (1). Different kinds of seeds have different equilibrium moisture contents at given relative humidity because of their chemical composition. Some rice cultivars have varying equilibrium moisture contents at varying relative humidity levels (2).

This paper reports on the study on rice drying, the experiments of which used long grain paddy of IR-8 and IR-36 varieties of three different moisture content levels. Some of the drying data of "Nihonbare" (Japonica) were also included in the study.

The objectives of the study are to determine i) optimum level of drying temperature which can reduce as much as possible the fissuring of dried grain; ii) fissuring effects of high humidity air drying; iii) the drying rates of each rice variety; and iv) difference and effect of continuous and tempering drying practice.

Materials and Methods

Materials

Drying experiments were performed using long grain varieties with different initial moisture content levels. The varieties used were IR-8 (28.18% MC), IR-8 (23.76% MC) and IR-36 (26.09% MC), all on dry basis. The samples were newly harvested grains. The Japonica variety's data from other experiment was included for comparison.

Method

Experiment A (Effect of temperature) – The experiments were of thin layer drying so that enough air flow was provided to the drying samples throughout the drying period. Paddy samples of 60 g of each variety were used for each drying experiment. Each sample of moisture content level was dried with drying air temperature of 35°C, 45°C, 54°C and 65°C with the air relative humidity of 22%, 18%, 12% and 15%, respectively. They were dried continuously but a quick weight recording of each sample was done after every specific drying interval.

After all the experiments, a hundred grains sample from each of the dried samples, were carefully husked by hand and their fissuring effect was observed.

Experiment B (Effect of tempering) – Samples of 60 g of each variety were used for drying experiments. Samples of each paddy moisture content level was dried with drying air temperature of 35°C, 45°C, 54°C and 65°C with air relative humidity of 22%, 18%, 12% and 15%, respectively. They were dried for certain periods of time and

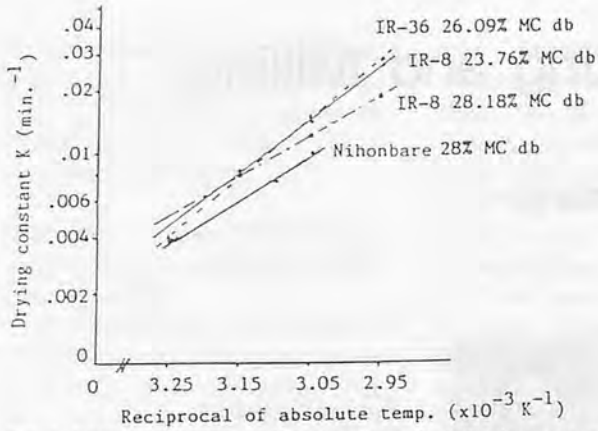

Fig. 1 Relation of constant K and reciprocal of absolute temperature.

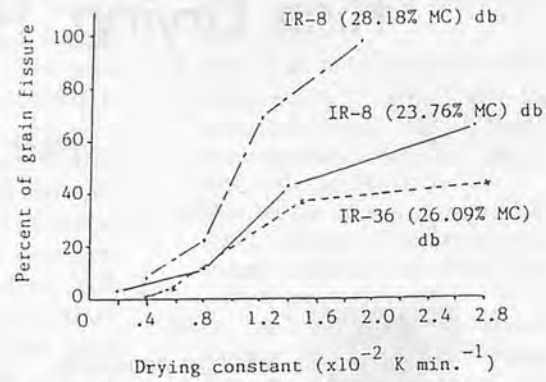

Fig. 2 Effect of drying constant K on grain fissure.

tempered for other periods of time. This process continued to the end of drying experiment. The sample weights were recorded after every drying time and after tempering time. After the experiments a hundred grain sample from each paddy sample group were carefully husked by hand and their fissuring effect was observed.

Experiment C (Effect of humidity)– In these experiments, the 60 g samples of each variety were used for drying at a constant drying air temperature of 45°C. In these experiments, the relative humidity was controlled at 33%, 45%, 60% and 70%. After the experiments, 100- grain samples from each of the experimental samples were carefully hand-husked and the grains fissuring effects were observed.

Results and Discussion

Experiment A

In the drying experiments, the drying curve was estimated using the following equation (6):

$$M\text{-}Me/Mo\text{-}Me = A.e^{-kt}$$

Where

Mo = initial moisture content (dry basis), %

Me = equilibrium moisture content, %

M = moisture content after time t, %

A = constant dependent on particle shape

6 = time, h

k = drying constant, h^{-1}

The relation of drying constant, (k) and the reciprocal of absolute temperature is shown in **Fig. 1**. The relation of constant (k) and the reciprocal of absolute temperature shows straight line results. Between the two varieties of three different moisture contents, there were no significant differences in the drying constant as the temperature increased. At higher temperature of 2.95 (x 10^{-3} K^{-1}) the variety IR-8 (28.18%) moisture content, showed slight less value of (k) due perhaps to the variety's high moisture content or a recording error. The value of K in Nihonbare variety seems to be smaller than those of IR-8 and IR-36 which were dried under the similar conditions. In general, the constant (k) value increase as the reciprocal of absolute temperature decrease. This relation can be expressed by an Arrhenius equation (6):

$$K = C_1 \cdot e^{-C_2/T}$$

Fig. 2 shows the effect of the

Table 1 Drying Characteristics* and Performance

Variety	Time (min.)	Wt. of Samples Contin.	Wt. of Samples Temp.	Moist. cont. Z (db) Contin.	Moist. cont. Z (db) Temp.	M-Me/Mo-Me Contin.		M-Me/Mo-Me Temp.
IR-8	0	60.00	60.00	23.76	23.76	1.00	ON	1.00
	60	57.51	57.47	18.63	18.54	0.68	OFF	0.68
	120	56.60	57.34	16.75	18.28	0.57	ON	0.66
	210	55.97	56.17	15.45	15.86	0.49	OFF	0.51
	300	55.54	56.11	14.56	15.74	0.43	ON	0.51
	390	55.29	55.49	14.05	14.46	0.40	OFF	0.43
	450	54.99	54.25	13.43	14.34	0.37		0.42
IR-36	0	60.00	60.00	26.09	26.09	1.00	ON	1.00
	45	57.16	57.17	20.01	20.13	0.67	OFF	0.68
	90	56.34	57.11	17.82	20.00	0.56	ON	0.67
	135	55.77	56.12	17.19	17.92	0.52	OFF	0.56
	180	55.24	55.97	16.07	17.61	0.42		0.54
IR-8 (High MC)	0	60.00	60.00	28.18	28.18	1.00	ON	1.00
	45	56.77	56.90	21.30	21.58	0.67	OFF	0.68
	90	55.75	56.71	19.12	21.18	0.56	ON	0.66
	135	54.82	55.28	17.14	18.12	0.47		0.51
	180	54.24	55.08	15.90	17.69	0.41	ON	0.49
	235	53.75	54.04	14.85	15.47	0.36		0.39
	280	53.34	53.95	13.97	15.28	0.31	ON	0.38
	340	–	53.35	–	14.00	–		0.31

* Dry bulb temp. 15°C; Wet bulb temp. 21°C; Relative humidity 22% Eq. moisture cont. 7.48%.

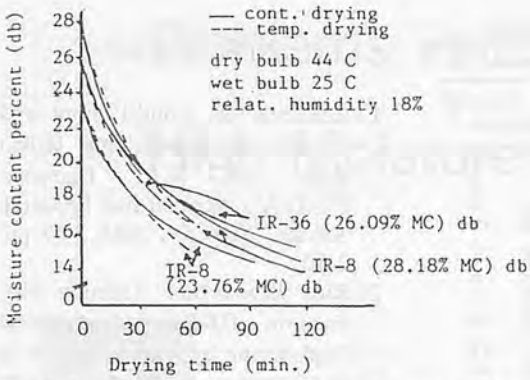

Fig. 3 Drying curves for continuous and tempering drying of paddy.

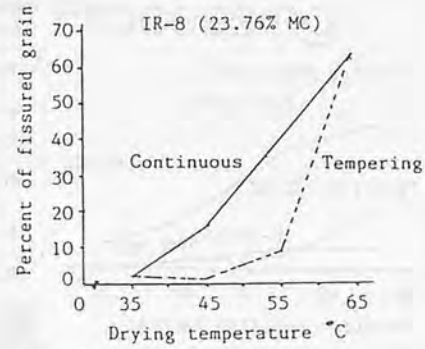

Fig. 4 Effect of tempering on fissuring.

drying constant on fissuring. At (K) value of 0.4 ($\times 10^{-2}$ min^{-1}), all the two varieties of three different moisture content levels had the lowest fissuring effect.

In all the cases, the IR-8 (28.18% MC) had the highest fissuring effect and IR-36 (26.09% MC) had the lowest. The IR-8 (23.76% MC) had intermediate fissuring effects.

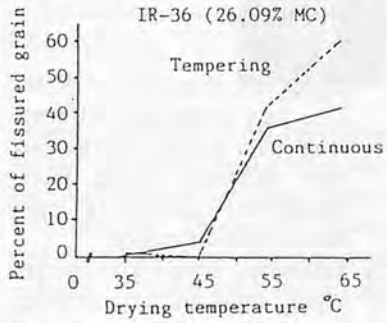

Fig. 5 Effect of tempering on fissuring.

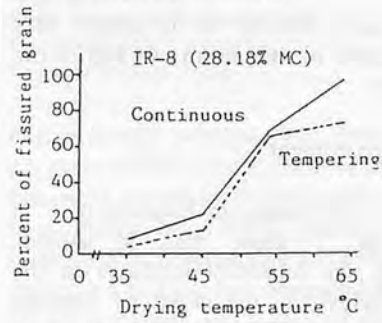

Fig. 6 Effect of tempering on fissuring.

Experiment B

Table 1 shows that IR-8 of 23.7% MC was dried to 14.56% with continuous heating for 300 min., while with tempering drying, the moisture was dried to 14.46% after net drying time of 240 min. The IR-8 (28.18% MC) was dried to 13.97% after continuous drying for 280 min., while with tempering drying dried it to 14.0% after a net drying time of 195 min.

The IR-36 (26.09% MC) was dried to 16.0% after a continuous drying time of 180 min., while IR-8 (28.18 MC) was dried to 15.90% after drying for the same length of time.

Table 2, IR-36 (26.09% MC) was dried to 15.07% and IR-8 (28.18% MC) was dried to 14.36% after a drying time of 120 min each. The drying speed comparison between continuous and tempering drying methods is shown in **Fig. 3**. Tempering drying dried the grains faster than the continuous method in all cases.

Fig. 4 shows the result of grain 55°C drying temperature.

Fig. 5 shows IR-36 (26.09% MC) that, at drying temperatures of 35°C to 45°C, fissuring was much less than continuous and tempering drying but increased markedly at 45°C drying temperature for both continuous and tempering drying. fissure from the continuous and tempering drying experiments with IR-8 (23.76% MC). With continuous drying, the percentage of fissured grains is greater than that from tempering drying. Tempering drying at 35°C to 45°C drying temperatures fissured less than as at

Fig. 6 shows IR-8 (28.18% MC) with the same pattern of fissuring effect at 35°C to 45°C for continuous and tempering drying. However, with high initial moisture content, the percentage of fissued

Table 2 Drying Characteristics* and Performance

Variety	Time (min.)	Wt. of Samples		Moist. cont. Z (db)		M-Me/Mo-Me		
		Contin.	Temp.	Contin.	Temp.	Contin.		Temp.
IR 8	0	60.00	60.00	23.76	23.76	1.00	ON	1.00
	30	57.11	57.24	17.80	17.90	0.66	OFF	0.67
	60	56.19	57.09	15.90	17.76	0.55	ON	0.56
	90	55.42	55.77	14.31	15.04	0.46		0.46
IR 36	0	60.00	60.00	26.09	26.09	1.00	ON	1.00
	30	56.97	56.85	19.17	19.45	0.65	OFF	0.67
	60	56.03	56.74	17.73	19.23	0.58	ON	0.66
	90	55.23	55.48	16.05	16.58	0.50	OFF	0.52
	120	54.76	55.34	15.07	16.28	0.45		0.51
IR-8 (High MC)	0	60.00	60.00	28.18	28.18	1.00	ON	1.00
	30	56.16	56.26	20.00	20.21	0.63	OFF	0.64
	60	54.99	56.15	17.50	19.98	0.52	ON	0.63
	90	54.04	54.57	15.47	16.60	0.42	OFF	0.48
	120	53.52	54.50	14.36	16.45	0.37		0.47

* Dry bult temp. 45°C, Wet bulb temp. 25°C; Relative humidity 18%; and Eq. moisture cont. 6.12%.

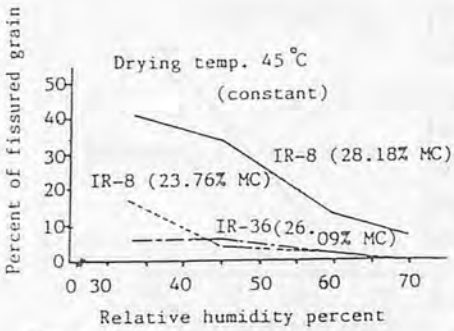

Fig. 7 Effect of humidity on fissuring.

grains seemed to be greater than those of the results in **Fig. 4** and 5.

Experiment C

The results of Experiment C in **Fig. 7** show that, in general, as the humidity increases in the drying air, the effect of fissuring decreases. With low humidity drying air but high moisture content, IR-8 had the highest fissuring effect followed by IR-8 (23.76% MC). IR-36 (26.09% MC) had the least fissuring effect. At 70% humidity in drying air, there was no fissure in IR-36 and IR-8 low moisture. However, drying grain with high himidity with its true equilibrium moisture content may cause respiration problems in storage. Another problem is that it takes longer to dry, in which case, more drying time and more energy is necessary.

Table 3 shows the effect of humidity on drying constant (k). With the change on humidity, the value of constant (k) does not seem to change much. This indicates that change of humidity in the drying air does not have much change effect one the value of constant (k).

Table 3 Effect of Humidity on Fissuring (drying temp. – constant 45°C)

Variety	R.H. %	Eq. MC %	Constant (K)	Fissured grain, %
IR-8 (23.76% MC)	33	8.67	0.00733	17
	45	10.54	0.00711	4
	60	13.03	0.00946	2
	70	15.18	0.00800	nil
IR-36 (26.09% MC)	33	8.67	0.00746	6
	45	10.54	0.00613	6
	60	13.03	0.00673	2
	70	15.18	0.00544	nil
IR-8 (28.18% MC)	33	8.67	0.00911	41
	45	10.54	0.00789	34
	60	13.03	0.00767	13
	70	15.18	0.00901	7

Conclusion

(1) The IR-8 variety has a higher drying rate than that of IR-36. This may mean that different long grain paddy varieties can have different drying rates, though the constant (k) may have a little difference.

(2) Tempering drying gave shorter drying time and less fissuring, hence safer with less grain loss and greater energy saving.

(3) Drying temperatures between 35°C and 45°C showed less fissuring effect, depending on varieties.

(4) Drying temperatures of more than 45°C resulted in more grain fissure, which cause more grain loss.

(5) Since drying time increased with the increase in relative humidity in drying air, then for energy saving and safe storability, it is better to dry with less relative humidity drying air.

(6) Since IR-8 showed higher drying rate and higher fissuring effect, it can, therefore, be assumed that this higher drying rate caused higher fissuring effect.

(7) Change of relative humidity in drying air does not have much effect on the value of constant (k).

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Problems in Storing and Processing High-Moisture Paddy

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Abstract

Paddy harvested in wet season amidst humid rainy weather poses problems like losses in storage and processing. To reduce the losses, freshly harvested paddy should be allowed for post harvest ripening by aging/storage to realize maximum rice outturn. This period should be 15–30 days for 18% moisture paddy. However, for 22% it should not be stored beyond 15 days. Processing losses in different methods of parboiling and suitable method of processing for different moisture level paddy are also discussed in this paper.

Introduction

Paddy is extensively cultivated and the bulk of the crop is harvested in a short span of time. The entire harvest is not processed immediately but a part stored for future use. Paddy harvested in dry season withstand storage due to drying and cleaning in threshing floor itself and sustain no substantial loss in storage or processing. However, paddy harvested during wet season in humid rainy weather poses problems. When humid rainy weather prevails for 7-10 days interfering with harvest and drying leading to a moisture content as high as 25% in grains. Frequently, paddy with 18-22% moisture is marketed although the safer limit for storage is 14%.

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Materials and Methods

Freshly harvested ADT 31 paddy at 17.8% moisture was stored without drying for 90 days. At 30 days interval the dry matter contents were determined in 100-g lots after parboiling in different methods. Paddy was pressure-parboiled after water circulation for 5 min followed by steaming at 0.35 kg/cm^2 for 20 min and then at 1.76 kg/cm^2 for 5 min. In hot soaking, hot water (95°C) was poured to paddy, maintained at 65-70°C for 4 h and open steamed for 10 min. In cold soaking, paddy was soaked in cold water for 72 h and open steamed for 10 min. The losses were deduced and expressed as percent from the dry weight initially taken and that observed after parboiling. Similar 20 g lots were processed in these methods and milled directly in McGill Miller No.1 to simulate Engelberg hulling in vogue.

ADT 31 and TKM 9 paddy with four different moisture levels were stored for 30 days without drying during humid weather (90% RH). At each moisture level, two 50-kg lots were stored in B Twill gunny bags. Paddy lots (250 g) taken in cloth bags from respective lots were embedded in bulk and processed at 15 days interval by cold soaking. The percentage of milled rice realized from the originally stored 250 g was expressed as "Absolute outturn". Fungi on grains were determined by standard techniques. The sugars formed due to breakdown of starch was determined as described earlier (Anthoni Raj and Singaravadivel, 1980).

Results and Discussion

Processing Paddy with 18% Moisture

Paddy is generally processed just after harvest to meet the demand. However, a few tonnes of paddy at or above 18% moisture are stored awaiting processing. Due to high moisture and external humidity the respiration and seed activity increase and paddy sustains loss in dry matter. Raw milling of fresh paddy with 16-18% moisture results in heavy breakage and, consequently, milled only after parboiling. When raw milled, ADT 31 paddy at 17.9% moisture showed 40.9% breakage which decreased to 28.4% after 30 days storage (**Table**

Table 1 Influence of Storage on Processing in ADT 31 Paddy (17.8% moisture) Stored without Drying

Storage (Days)	Processing method	Dry matter content (%)	Loss in parboiling (%)	Outturn* (%)	Gain in out turn (%)	Breakage (%)
0	Raw	82.3	–	62.6	–	40.9
	Pressure parboiling	81.7	0.7	67.5	7.8	0.5
	Hot soaking	81.0	1.5	66.6	6.3	0.6
	Cold soaking	80.7	1.9	66.4	6.0	0.8
15	Raw	85.0	–	66.0	–	38.0
	Pressure parboiling	84.4	0.7	69.8	5.8	0.6
	Hot soaking	84.3	0.7	70.1	6.2	0.5
	Cold soaking	83.6	1.6	69.4	5.1	0.7
30	Raw	84.7	–	63.8	–	28.4
	Pressure parboiling	84.6	0.1	69.6	9.0	0.3
	Hot soaking	84.3	0.5	69.3	8.6	0.5
	Cold soaking	83.7	1.2	68.7	7.7	0.1
60	Raw	85.7	–	63.2	–	29.9
	Pressure parboiling	85.1	0.7	69.9	8.8	1.0
	Hot soaking	84.8	1.0	69.6	8.4	1.1
	Cold soaking	84.5	1.4	68.0	5.9	0.5
90	Raw	87.6	–	65.6	–	25.4
	Pressure parboiling	87.5	0.1	68.3	4.5	1.3
	Hot soaking	87.5	0.1	67.5	2.9	1.7
	Cold soaking	85.4	2.4	66.5	1.0	0.9

* Expressed on the weight taken for processing (apparent out turn)

1). It is evident that a short storage improved grain hardness through textural changes in aging. An improvement in texture and hardness of grains during storage or aging increasing the resistance to milling and reducing the breakage was also reported (Kunze and Choudhuri, 1982; Perez and Juliano, 1981). The green grains present in wet season paddy might also get fully ripened and hardened in storage and becoming less prone to breakage. The same trend of increased yield due to 30 days storage were also observed in 14.5% moisture paddy.

Parboiling fresh ADT 31 paddy (17.8% m.c.) enhanced parboiling losses than stored paddy. When parboiled just after harvest the losses were 0.7, 1.5 and 1.9%, respectively, in pressure parboiling, hot and cold soaking methods. After 15 and 30 days the losses were 0.7, 0.7 and 1.6% and 0.1, 0.5 and 1.2%, respectively, in these methods suggesting decreased losses in processing due to short storage. Although reduced losses were observed up to 90 days in pressure parboiling and hot soaking, the same was observed up to 60 days only in cold soaking. The increased loss observed in the latter after 60 days might be due to changes brought about by infection. The microbes in paddy remain active during cold soaking for 3 days while they are partially destroyed in other methods due to elevated temperatures. Interestingly, in freshly harvested paddy losses in hot and cold soaking were almost equal than in aged paddy. As hot soaking hydrolyses starch (Singaravadivel et al, 1977) much of it from fresh paddy might have been hydrolyzed than aged or stored paddy. Shivanna (1976) also reported a lesser leachate loss after storage in low moisture paddy than with high moisture. This phenomenon is of particular significance in milling as dried stored paddy shall be diverted to modern rice mills employing hot soaking and fresh paddy to cold soaking in conventional mills to minimize losses. The increased outturn after storage might be due to a higher dry matter processed as unit weight represented a lesser dry matter in fresh paddy due to high moisture and a larger dry matter after storage as grains lost moisture due to description. (The outturn expressed here are on weight taken for processing as in trade and has to be considered only "Apparent" as against "Absolute" outturn expressed over the weight stored.)

Storing and Processing Paddy with Moisture above 18%

Paddy with moisture above 18% if marketed undried exhibit heat development, germination and mould growth associated with dry matter loss and kernel discolouration. Paddy with 18-22% moisture might dry up to desorption. However, paddy with moisture above 22% has to be dried or dewatered by salt-husk powder technique (Anthoni Raj et al, 1980) otherwise losses occur in storage and processing. Moulds increased manifold in paddy with moisture above 22% in 15 days itself (**Table 2**), while at 18% moisture they did not increase rapidly. TKM 9 paddy, probably due to its thicker husk coat, harboured lesser fungi than ADT 31. Concomittent with the fungal growth, more of sugars formed. In grains stored without drying, depending on moisture and external humidity, fungi might increase and the fungal and seed enzymes might contribute to breakdown of starch and formation of sugars that diffuse readily in soaking water.

The absolute outturn decreased heavily in paddy with 25% moisture. At 18-22% range there was a slight increase in raw milling up to 15 days in ADT 31 and up to 30 days in TKM 9. In parboiling this increase was observed up to 30 days in TKM 9 at both the moisture and only at 18% moisture in ADT 31. Despite the dry matter loss that might occur in 18-22% moist paddy 15-30 days storage improved grain hardness. Hence, it is preferable to process paddy with 18% moisture after 15-30 days of harvest instead of just after harvest. When paddy with 22% moisture is marketed it has to be processed in 15 days as processing losses enhanced after-

Table 2 Outturn of Paddy, Fungal Growth and Breakdown of Starch to Sugars in ADT 31 and TKM 9 Paddy Stored with Different Moisture Content

Particulars	Days Stored	ADT 31			TKM 9		
		17.9	22.8	25.7	18.2	21.6	24.7
Raw milling outturn (%)*	0	61.6	57.4	52.5	61.9	60.0	55.4
	15	62.8	58.4	46.9	62.4	61.7	54.1
	30	59.9	56.0	43.4	63.8	60.8	53.7
Parboiled milling outturn (%)*	0	64.7	60.6	55.2	64.1	61.2	58.3
	15	64.3	61.2	45.9	65.2	64.2	57.9
	30	65.1	58.7	44.5	65.4	62.8	57.8
Fungi (10^5/g)	0	14.1	27.5	32.4	8.3	28.8	19.7
	15	12.2	31.4	20.9	5.8	22.7	12.9
	30	13.4	62.3	61.8	4.6	27.3	40.5
Sugars (mg/g)	0	6.5	4.2	5.2	6.4	6.8	5.2
	15	5.6	6.9	5.8	6.8	6.1	7.0
	30	8.2	8.9	6.5	8.4	7.8	8.2

* Expressed on the initial rice weight stored (absolute outturn)

wards. Paddy with 25% moisture should be processed immediately and not stored.

Processing Paddy with High Moisture

Double steaming where paddy is presteamed and soaked is followed in conventional mills besides cold soaking. Pre-steaming hastens hydration, partially eliminates contaminating microorganisms and kill seed activity (Singaravadivel and Anthoni Raj, 1984). About 1-2% husk opening occurs in pre-steaming and this increased with grain moisture. Although fresh paddy at 18-22% moisture can be pre-steamed and soaked without larger husk opening there is a greater degree of husk opening when 25% moisture paddy or rain drenched germinated grains are pre-steamed. The kernel exposure and hot soak water enhanced leachate losses. As the temperature remains at 45°C or more for a few hours the grains burst under water. Subsequent steaming cooks the kernel and they become misshapen due to husk opening. Hence cold soaking is resorted to high moisture paddy. However, in order to arrest germination activity and to retard microbial growth common salt 1% (W/W) on paddy might be added. Salt at this level does not retard soaking but due to increase in specific gravity facilitates easy removal of floating chaff and ill filled grains and thus reducing black grains in milled rice. Paddy developing heat also has to be cold soaked as double steaming intensified kernel discolouration already occurred.

Conclusion

Post-harvest ripening due to aging in storage increased the absolute outturn due to hardening than processing just after harvest. This period should be limited to 15-30 days in ADT 31 and TKM 9 paddy with 18% moisture. Enhanced processing losses occured beyond 15 days at 22% moisture and hence should not be stored beyond 15 days. Paddy with 25% moisture or rain-drenched paddy should be processed immediately by cold soaking with 1% salt as losses are enhanced in storage and in other processing methods. Dried or stored paddy should be diverted to hot soaking instead of freshly harvested paddy as the latter sustained higher loss in hot soaking than the former.

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A Study of Mechanism for Measuring Draft of Single-Bullock Cart

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Introduction

In India more than 80 million draught animals are available for verious farm operations. It is equivalent to nearly 30% of the total power available for agriculture. The use of animal power has been static so far. It is difficult to replace it by mechanical power due to the small size of landholdings and substantial investment required for buying farm machinery. Moreover, energy crisis is perpetual and so there is need to utilize the animal power more efficiently by introducing implements suitable for various operations.

In rural areas the bullock cart is still the main component of the farming system for handling and transportation of agricultural products and such other activities at various stages of crop production. According to a survey conducted by India's Planning Commission in 1959-60 the bullock carts carry 58-96% of the total arrivals of products in the markets located in different regions of the country. All carts remain in operation for more than 240 days in a year (Despande and Ojha, 1982).

Research in animal traction has primarily been focused on determining the tractive efforts through performance trials and improvement of yoke, harness and implements. It is difficult to quantify the average performance of animals as there is a wide range among the reported values due to inconsistent measurements. The draft necessary to pull a wagon or a cart is influenced by grade and rolling resistance and to some extent by axle friction. The use of poorly designed harness and yoke causes inefficient transfer of power from the animal to the cart. Improper hitching requires the animal to exert more tractive effort than actually needed to pull the cart. Therefore, the rate of work done by an animal is one of the major areas which needs further investigation. Consideration of the energy principles involved in transferring power from an animal to the unit behind will call for an improved yoke, harness and cart design. A yoke with suitable haulage capacity measuring device has been designed, developed and evaluated.

Constructional Details

A conventional wooden wheel cart 180 x 140 x 62 cm was modified by replacing the wooden beams and yoke with telescopic arrangement made from mild steel angle and G.I. pipes to operate with single bullock. The details of necessary modifications carried out in the hitching mechanism to measure haulage load capacity of bullock and male buffaloes are shown in **Figs. 1** and 2. The frame for attaching the dynamometer/spring balance between the cart chassis and the telescopic sliding beams was fabricated from two 50 x 50 x 6 mm mild steel angles, 110 cm long, one end of which was bolted with the axle of the cart while on the other end, a 7.5 cm diameter G.I. pipe was welded for easy sliding and proper alignment of G.I. pipe beams. Both the angles were fitted about 80 cm apart so that, a bullock can be hitched properly between the two beams. These angles were kept apart by welding another angle of 50 x 50 x 6 mm in the centre of which a hitch point for the dynamometer/spring balance was provided. The beams made from 6.25 cm diameter G.I. pipes, slided in or out of the fixed pipes (O.D.=7.5 cm). Pins were provided at the rear ends of the beam so that they may not come out of the fixed pipes and cause accident. A cross pipe was also fitted on the two beams near the fixed pipes, with the help of pins to provide a second hitch point for the dynamometer. A hydraulic dynamometer/spring balance could be connected between the fixed point on the angle iron and other point on the telescopic assembly. At the end of the beams a curved yoke was fitted with the help of

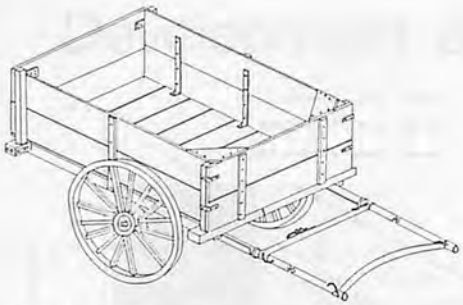

Fig. 1 A bullock cart.

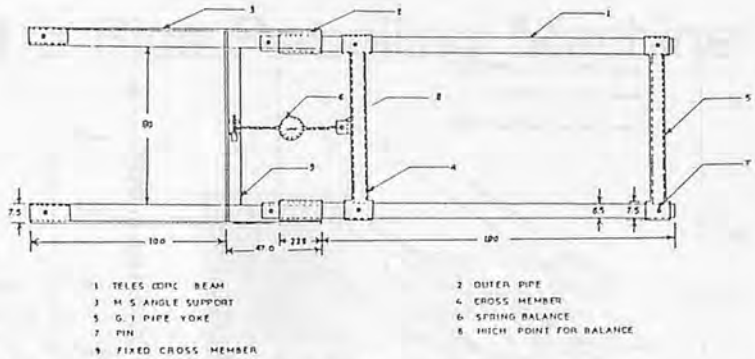

Fig. 2 Yoke assembly with pull measuring device.

bolts/pins.

The distance between the yoke and the cross-pipe was kept at 180 cm so that the bullock could be hitched to the cart without any obstruction. The yoke is fabricated in such a way that it rests on the neck of the bullock comfortably and does not cause pain to the neck. When the cart is pulled, the load is transmitted through the dynamometer/balance to the beam and the yoke or vice-versa. As there was negligible resistance between the two beams and out-pipes, the losses/error in measurement of draft/pull was also negligible.

Animal Draft Evaluation

The draftability of four male buffaloes of Murrah breed, 6-7 years of age and weighing 400 to 530 kgs each was measured by yoking them to modified bullock cart specially designed to hold a dynamometer or a spring balance to record the pull. A 200 kg capacity salter balance was attached to the cart and yoke to measure the pull. An animal was yoked to the cart and was made to haul the cart on plane tar road covering a distance of 2 km; on "Katcha" ground covering a distance of 0.5 km and an uphill slope of 27 m with a gradient of 10.6 cm/m. Each animal was made to work with 350, 500, 650 and 800 kg load of sand bags on the cart. Each animal was given a rest of at least one week between two load trials. During haulage several readings of the pull as depicted by the balance were recorded on different terrains. The average of these readings was taken as the pull for that paticular load and track condition. Simultaneously, the time taken to cover the distance and speed of the animal was noted. Knowing the pull and speed of the animal, the draft in terms of horsepower and work done was calculated by the following formulas;

Horsepower = [Pull(kg) x Speed (km/h)]/270

Work done (kg-m/h) = Pull (kg) x Speed (m/h) x 1000

Results and Discussion

The modified cart with draft measuring mechanism was used to measure the draftability of four male buffaloes. The average speed, pull, horsepower developed and work done by the buffaloes during haulage for one hour under different terrains are given in **Table 1**. Their values on tar road and uphill slope were quite high. On katcha fields, these values are slightly lower. This may be due to higher rolling resistance causing reduced speed and due to poor condition of the terrain. The poor terrain condition results in jerks coming on the measuring device (spring balance) making it difficult to record correct reading. This can be further improved by replacing the spring balance with a hydraulic dynamometer as the jerks are absorbed by the hydraulic fluid and correct measurement of pull is possible. However, it is still giving the fair estimate of all the parameters like pull, horse power and work done. The results obtained by this me-

Table 1 Effect of Payload and Terrain on Speed and Draftability of Buffaloes (n=4)

Terrain	Load (kg)	Speed (km/h)	Pull recorded (kg)	Power developed (hp)	Work done (kg-m/h)
Tar raod	350	6.6	39.7	0.98	2.65×10^5
	500	6.1	60.7	1.39	3.75×15^5
	650	5.8	75.7	1.60	4.41×10^5
	800	5.7	99.7	2.10	5.68×10^5
Statistical mean:		6.09	69.0	1.52	4.13×10^5
r values		-0.97	0.997	0.99	0.994
Katcha field	350	2.6	57.7	0.54	1.47×10^5
	500	2.8	83.7	0.84	2.40×10^5
	650	2.3	92.0	0.78	2.14×10^5
	800	2.3	112.0	0.96	2.58×10^5
Statistical mean:		2.54	86.0	0.79	2.15×10^5
r values		-0.75	0.98	0.80	0.81
Uphill slope	350	4.7	64.5	1.12	3.06×10^5
	500	4.4	104.2	1.71	4.74×10^5
	650	4.0	128.0	1.91	5.21×10^5
	800	3.8	150.0	2.10	5.83×10^5
Statistical mean:		4.3	111.8	1.73	4.69×10^5
r values		-0.994	0.99	0.97	0.97

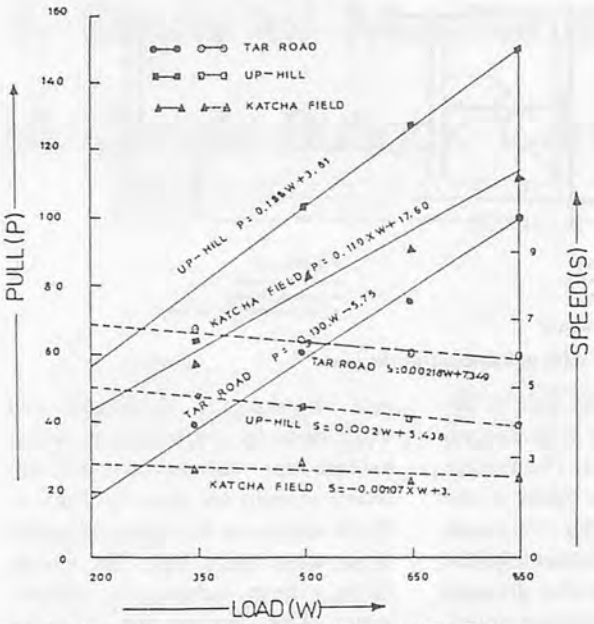

Fig. 3 Effect of payload on pull and speed of buffaloes.

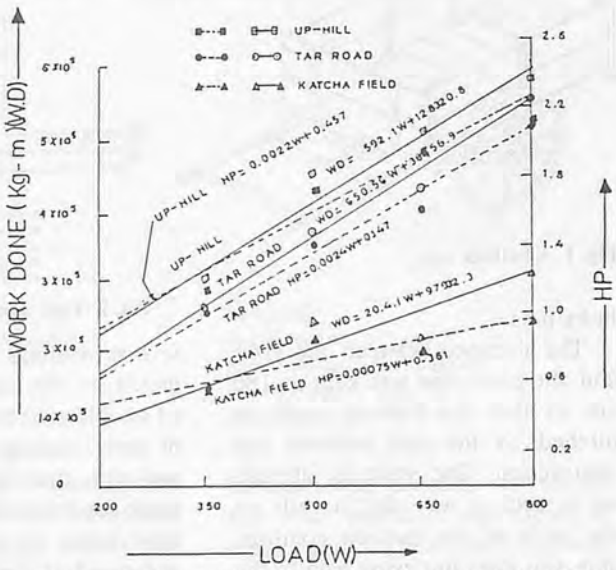

Fig. 4 Effect of payload on work done and horsepower of buffaloes.

chanism are quite close to those reported by Agarwal et al FAO Report (1976), Maurya (1982), Devadatta and Maurya (1978), Bishen et al (1982) and Sighal and Tomer (1982).

The regression equations developed on the basis of tests conducted under different loads and terrains are given in Figs. 3 and 4. These equations can be used to predict speed, pull, horsepower developed and work done by the buffaloes under any pay load and terrian condition.

Conclusions

A draft measuring mechanism for conventional single bullock cart has been designed, developed and tested. This device can be used to measure draftability, speed, horsepower and work done by draft animals under different load conditions. Hydraulic dynamometer may be used for recording draft more accurately.

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Development of a Rice Parboiling Machine

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Abstract

This article briefly describes the development of a rice parboiling machine. Compared with the traditional and commercial systems of rice parboiling in Nigeria, the newly developed parboiler has a medium capacity, a medium cost of construction and a medium cost of parboiling. The quality of rice parboiled with the machine meets the consumer tastes and acceptance standards.

Introduction

Demand for rice in Nigeria is much higher than local production. To minimize the huge amount of foreign exchange spent in rice importation into Nigeria, Federal and State Governments have given substantial encouragement for increases rice production locally.

While rice is milled raw for eating in some oriental countries, Nigerian consumers prefer milled rice that is parboiled before milling. Rice farmers in Nigeria parboil the bulk of their rice by a batch process in small half drums each of which handles about 75 kg of paddy at a time and about one to two batches a day. The traditional parboiling system is shown in Fig. 1.

The New Machine

The machine designed to parboil 0.15 t of paddy per batch occupies 4.3 m^2 of space and consists of three major units made of 2.5 mm galvanized iron sheets which are connected by 5.0 cm galvanized iron pipes and six suitably located 2.5 cm control valves. The new parboiling machine is shown in Fig. 2. The component parts are one 0.26 m^3 parboiling compartment which holds 150 kg of paddy; one 261 *l* boiler and one 188 *l* water reservoir. An automatic whistle warning relief valve located at the top of the steam pipe line, protects the machine and guides the operator. The general features of the machine are shown in Fig. 3 while the pipelines, valves and whistle warning device are shown in Fig. 4.

The three component units of the machine are connected by a single line of 5 cm galvanized iron pipes so designed to reduce the production cost, and to direct the

Fig. 1 Rice parboiling using drum fired with wood.

Fig. 2 The newly designed and developed rice parboiling equipment.

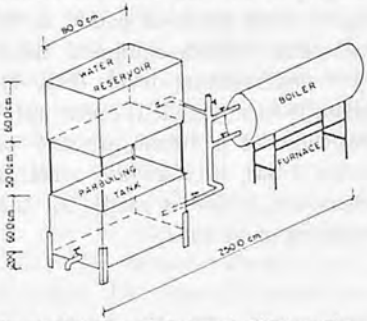

Fig. 3 Outline of rice parboiling equipment.

Fig. 4 The parboiling tank with pipelines, valves and the whistle warning device.

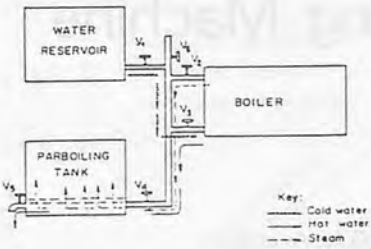

Fig. 5 Control valves and route of fluid flow.

flow of cold water, hot water and steam as desired by the operator. The supply and direction of flow of each fluid is controlled by the right manipulation of the six control valves (Figs. 4 and 5). The whole system is designed to provide steam at the rate of 1.0 – 1.5 kg of steam per min for effective steaming of each batch of paddy in 44 min. The whistle-equipped relief valve and warning device (Fig. 4), which is spring loaded, opens automatically at a steam pressure of about 2 bar, to warn the operator when the boiler is ready for the steaming operation.

Comparative Quality and Economic Evaluation

A detailed study of the quality of rice parboiled, cost of construction and cost of operating the newly developed machine as compared to those of the traditional and commercial systems was made by the first author in partial fulfilment of the requirement of an M.Sc. degree in Agricultural Engineering under the supervision of the second author.

Panel assessment tests show a favourable level of acceptance by the consumers of the rice parboiled with the new machine. Moreover, all the tests carried out show that there was no significant difference between the quality of the rice parboiled in the new machine and those parboiled with the conventional commercial system.

With a medium initial production cost of ₦700 (of US $1028), an annual output capacity of 200 t and a medium output cost of ₦35.41 (or US $51.99) per t, this new machine compares favourably well with the traditional parboiler which cost ₦100 (or US $146.81) initially with ₦110.9 (or US $162.81) per t output cost and an annual output capacity of 20.0 t; and the imported parboiling system with an initial cost of ₦20 000 (or US $29 362), an annual output capacity of 12 000 metric tonnes and an output cost of ₦11.82 (or US $17.35) per t of milled rice. ■■

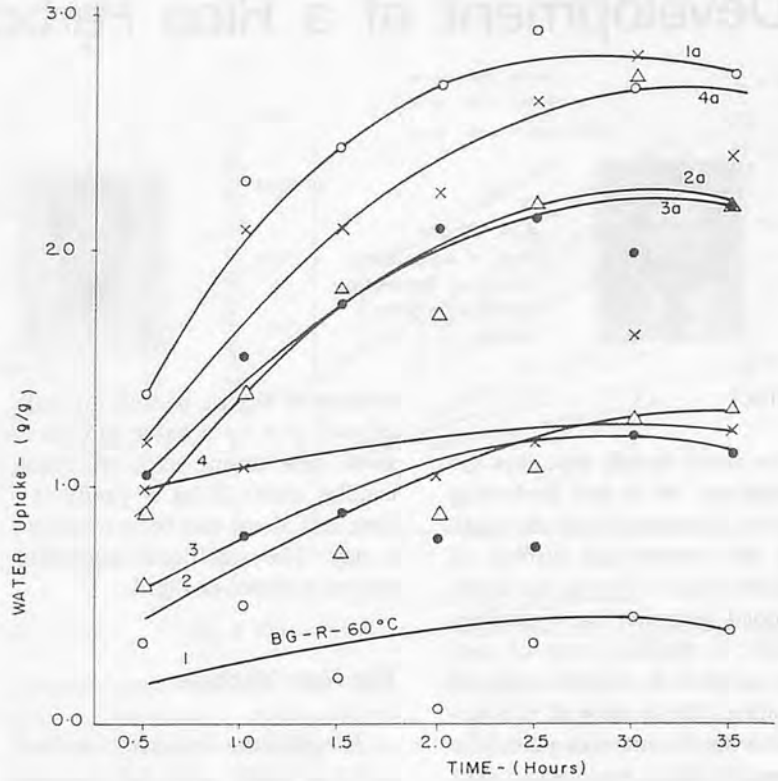

Fig. 6 Water uptake ratios for raw and parboiled BG 95-2 variety of rice at 60°C and 100°C.

Cardamom Processing in South India

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Abstract

Cardamom, an important spice, is cultivated on 89 000 ha in India. The annual production is estimated to be 5 300 t of which 2 700 t are exported that earn about Rs.335 million. This constitutes 25% of total spice export ernings of the country. The processed cardamom capsules may be bleached (white cardamom) or green (green cardamom). The unit operations in the processing are pre-treatment, drying, cleaning, packing and grading. The bleached cardamom is generally sun-dried, and green cardamom is dried under controlled conditions in kilns or cross-flow electrical driers. Drying is the most important operation as it determines the colour of end product which is the attractive and most important quality character. This paper discusses in detail cardamom processing and drying systems followed in South India.

Introduction

Cardamom (*Elettaria cardamomum* L), considered as the queen of spices, is grown in 89 000 ha area in India producing annually 5 300 t of dried capsules, 2 700 t of the cardamom is exported every year, earning about Rs.335 million (1). Cardamom capsules when harvested contain 80% moisture (wb). These green capsules are processed in two ways: bleaching and green curing. Both processes involve the operation of drying the capsules to safe storage moisture level of 10% (wb). Harvesting of the capsules commences in September and continues through January. The peak season of harvest coincides with the NE monsoon when about 68% of the total production is harvested. After harvesting cardamom is subjected to processing within 24 to 36 h to avoid deterioration. The processing includes pre-treatment, drying, cleaning, packing and grading.

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Processing Methods

White Cardamom (Bleached Cardamom)

This product is sold mainly in the domestic market. The processing is resorted to especially in the case of varieties which either do not retain their colour during drying or lose the colour during storage. Another advantage with this process is that the drying operation is simple and open sundrying can be practised. The processing consists of pretreating the freshly harvested capsules by soaking them in 1% solution of bleaching powder for 30 to 60 min followed by dipping the lot in dilute HCl solution (0.2±0.05% concentration) for 2 to 3 min. The treated capsules are washed and sun-dried to 8 to 10% moisture content. In some areas bleaching is achieved by exposing the capsules to sulphur dioxide fumes by burning sulphur below the trays containing cardamom capsules. The cardamom thus obtained has good white colour.

There are different methods used to achieve the desired bleaching effect (**Table 1**) (3). The main advantage is that even after prolonged storage of cardamon the

Table 1 Treatments for Bleaching of Cardamom

Treatment	Concentration of bleaching agent	Contact lime in mm	Remarks
Steeping in H_2O_2 containing 0.5% sodium silicate	6% H_2O_2	15	For dry cardamom
Bleaching with H_2O_2 with SO_2 fuming	0.3%	60	Dry cardamom
Steeping in acidified bleaching powder solution	20 g/l	75 min	Fresh cardamom
Subsequent steeping in H_2O_2 containing 0.5% sodium silicate	1% H_2O_2	30 min	

Source: A. George Varkey et al, 1980.

consumers acceptance is not affected because of the white colour. But this processing method suffers from certain disadvantages, viz, (1) the samples of commerce show high sulphur dioxide content from 80 to 800 ppm and in some cases as high as 1 200 ppm(3); (2) bleaching showed slight reduction in oil content; (3) it may also have an adverse effect on the characteristic aroma and flavour; and (4) the loss of oil from bleached cardamon over a storage period of one year has been reported to be as high as 40%. However, to reduce the sulpher dioxide level in the cardamon, RRL Trivandrum has standardized a simple treatment with hydrogen peroxide (steeping in H_2O_2 solution of 0.05% concentration) (3).

Green Cardamom (Green Curing)

Freshly harvested capsules are dried to reduce the moisture content from 80% to 10% without affecting the colour. The colour of cardamom is very easily bleached if exposed to sunlight. As sundry-mature green capsules retain good curing, artificial drying in this case becomes a necessity. The fully-mature green capsules retain good colour after drying while slightly over-riped capsules which have turned yellowish on the panicle give golden yellow colour after drying. The variety of the cardamom preferred for this method of processing is the Mysore variety grown in Kerala as it retains good green colour during drying and during storage. The drying operation in green curing is done under controlled conditions of temperature and airflow. There are kiln driers and electrical cross-flow driers in use in the plantations for this purpose. In kiln driers temperature is maintained at 45 to 55°C and air circulation is achieved by natural convection or with exhaust fans. In electrical driers temperature is kept at 50 to 65°C and air circulation is done by an electrically operated fan. The time required for drying varies from 24 to 36 h in kiln driers and 12 to 24 h in electrical driers.

Drying Systems for Cardamom

Barbecues of Beaten Earth

In small holdings cardamom capsules are dried by conduction heating. A hollow mud platform is constructed in one side of the room adjacent to one wall. The platform is heated up by burning wood from one end of the hollow platform and allowing hot gases to go out from the other end. Cardamom capsules are spread on the platform and stirred frequently to avoid charring.

Kiln Dryers

Kiln driers are used by the planter having about 25-30 acres of cardamom plantation. The kiln dryers as shown in **Fig. 1** consists of a wood burning furnace, flue pipe and drying racks in a chamber. The furnace is made of fire bricks or ordinary bricks having about 8′ x 2′ grate size to facilitate charging with big logs. The hot flue gases escape through the chimney after circulating through 9″-12″ diam. flue pipe made of MS sheets placed in the centre of the room. The heat energy is transferred to the air in the chamber by radiation from hot surface of the flue pipe. The racks are kept at 12″ distance from the flue pipe to avoid the over-heating. The drying trays of 3′ x 3′ each containing 3 to 4 kg of fresh cardamom are arranged on the racks and 4 to 5 trays/tier. The distance (vertical) between two-tiers is generally kept at 12″. But in compact structures vertical distance is only 9″ and hence more tier of trays is accommodated. The roofing of the chamber is insulated from inside with wooden planks or AC-sheets. The temperature inside the chamber is maintained at 45 to 55°C by controlling the supply of wood in the furnace.

The moisture holding capacity of the air is increased by heating it to 45°C by radiation. After absorbing the moisture from the fresh capsules the saturated air escapes through the ventilating tiles. The capacity of the kiln depends on the size of the plantation. The time required varies from 24 to 36 h depending upon the efficiency of the drier. It was observed that the kilns have very low thermal efficiency. The average firewood requirement is 1-quintal/100 kg of fresh cardamom. Since wood is plentiful in cardamom plantation, little attention has been given so far to improve the thermal efficiency of the kiln dryers.

As about 80% of the cardamom produced is processed as green cardamom, the total fire wood consumed per year would be of the order of 21 200 t (estimated). There is need for modernizing the existing kilns to economise on the use of firewood and also achieve more uniform drying of cardamom.

The following suggestions are made to improve the existing kilns.

1. The furnace should be made of fire bricks and should have provision to regulate the air for combustion.

2. The walls of the drying chamber may be provided with thermal insulation panelling to avoid heat loss during night when the difference between chamber temperature and outside is as high as 30 to 40°C.

3. The drying chamber should be compact with lesser height to avoid heat losses. The wooden plank and AC sheet ceiling just below the roof may be lowered down by 2′ to 3′ to reduce the volume of air to be heated.

4. At the bottom of the walls the adjustable openings may be

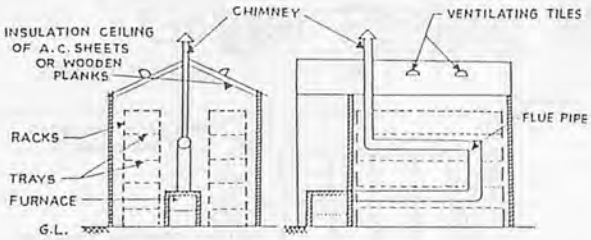

Fig. 1 Kiln dryer for cardamom drying.

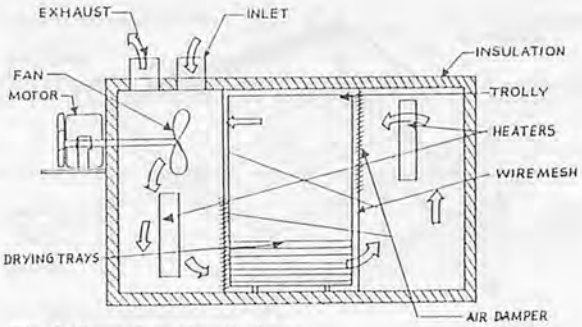

Fig. 2 Cross-flow electric dryer.

provided for entry of the fresh air.

5. Proper arrangement should be made to let out the saturated air from the top of the chamber.

Cross-flow Electrical Driers

These type of dryers are installed by the cardamom board at central locations to facilitate drying of cardamom by small farmers. These are the tray type cross-flow driers shown in **Fig. 2**. The capacity of these driers is about 200 kg and are available in different capacities ranging from 25 to 400 kg. The air is heated by 15 kW air heaters and circulated over the material by a fan operated by 1/2 hp motor. The temperature of drying air is kept at 40°C. At full loading capacity, the drying time required is about 18 to 20 h. After completing the drying at 50°C, the drier is run at 60°C for 1 h for easy removal of the flower stalks. The trays are then cooled for 1 h and the stalks are removed by a wiremesh cleaner. At reduced capacity of 100 kg of cardamom the drying time required is 12 h. The quality of the product was found slightly better when the drier was loaded at full capacity.

Slow drying gives a better product. Since drying is a function of two factors, namely; temperature and relative humidity at constant air flow rate, it means that at temperature of 50°C in higher capacity, the air had higher relative humidity than in lower capacity and this may be the reason for more drying time and better quality. The same reason may be attributed to the better colour of the cardamom picked and processed during rainy season than the cardamom picked after the rains are over (last pickings).

Other important points to be considered while drying are that there should not be excessive shrinkage of cardamom capsules and splitting of capsules should not occur during drying.

Infra-red Driers

These types of driers are new in the market wherein the temperature of cardamom is raised to 35 to 40°C both by pad heaters and the infra-red lamp. To remove the moisture, vacuum pump is provided. The heating sources are thermostatically controlled. These driers are available in 50 *l* holding chamber size and take 8 h for drying (4).

Solar Drier for Cardamom Drying

Since the exposure of capsules to sunlight bleaches the colour of cardamom only indirect type solar driers can be used for green curing. About 32% of the total production in December and January when the use of solar driers can be feasible. Direct type solar driers can be used effectively for bleached cardamom drying. Though the partial bleaching of cardamom is affected by the sunlight, bleaching is not uniform and complete by the time the material is dried. If during solar drying more sunlight is focused on the cardamom to have the accelerated bleaching, it may produce good, white cardamom which will have natural aroma and flavour without the danger of SO_2 level or residual effect as in chemical bleaching.

A direct type solar drier developed for copra was used for drying of green cardamom. The area of the drying surface of 1 m^2 was made of black painted wiremesh tray over black painted corrugated GI sheet inclined at 12.5°. The aluminium foil reflectors of 1.5 m^2 area were provided from 3 sides of the drier. Caster wheels were provided for manual sun tracking throughout the day (**Fig. 3**). The spreading density in the drier was 3 times higher compared to outside open drying (12 kg/m^2). The complete drying of cardamom could be achieved within 3 days in solar cabinet drier compared to 5 days in the open sun (**Table 2**). The colour of the cardamom from solar cabinet was good white while that outside dried was non-uniform straw colour. To check the discolouration of cardamom by a particular wave length, if any, in solar radiation spectrum, three glass paper filters, namely; blue, green and red were used on small samples of 500 g in open sun. The red filter was found effective up to a certain extent in retaining the green colour during open sun drying. This shows that solar drier (direct type) with radiation shield of red transparent glass (which helps in cutting off the radiation responsible for discolouration or

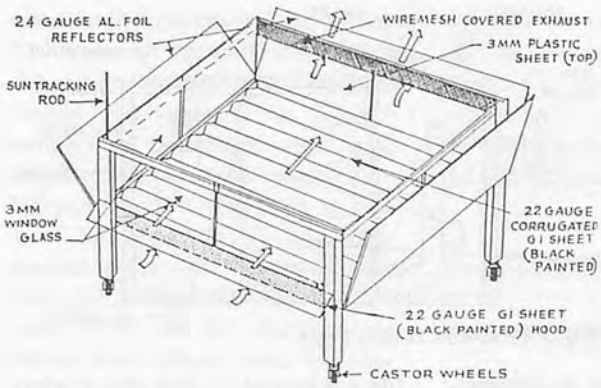

Fig. 3 Solar dryer used for cardamom drying.

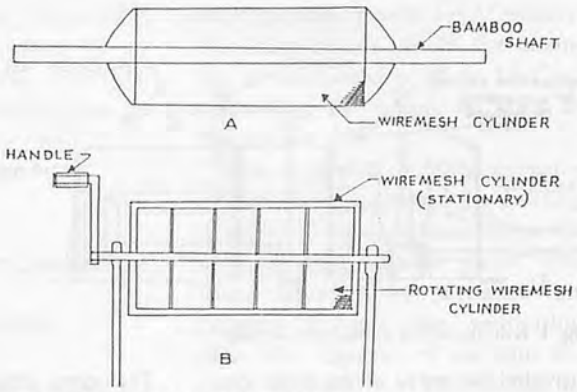

Fig. 4 Garbling devices for dried cardamom.

Table 2 Solar Drying of Cardamom: Initial Moisture Content 80% (wb), Spreading Density: 12 kg/m² (cabinet) 4 kg/m² (open)

Drying system	Moisture content (wb)					Remarks
	1st	2nd	3rd	4th	5th	
	day of drying					
Solar cabinet drier	50	21.8	10	–	–	Uniform white colour
Opening sun drying	68	50	27	26	111	Non-uniform straw colour

Average Temperature in the Cabinet and of Ambient Air during Drying (0830-1700)

Drying system	Av. Maximum	Av. Minimum	Average
Solar drier	45°C	35°C	39.4°C
Ambient	26°C	21°C	23°C

bleaching) may be effective in sun drying of the green cardamom without changing the colour.

Carbling or cleaning – About 3 to 5 kg of dried cardamom/batch is put into the wiremesh cleaner as shown in Fig. 4, where during swinging the rubbing action between the capsules and wiremesh and within the capsules, the flower stalks are separated.

Packing of cardamom – After cleaning the dried cardamom is packed in gunny bags lined with black polyethelene sheet for better retention of green colour during storage.

Grading – Grading is done according to the Agmark specifications at the exporters' level. Extra bold are the most superior qualities.

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Ginger Peeling Machine Parameters

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Abstract

Operational parameters of the abrasive brush-type ginger peeling machine developed by Agrawal et al (1983) were evaluated and established for maximum efficiency with minimum ginger meat loss. The capacity of the machine operated at the recommended machine parameters was determined.

Introduction

The abrasive brush-type ginger peeling machine (**Fig. 1**) essentially consisted of two continuous brush belts being driven in opposite directions with a downward relative velocity by a variable-speed motor. The movement of the two brush belts in opposite directions provided the abrasive action on the ginger passing in between while the downward relative velocity provided the downward flow of ginger. The spacing between the belts and the belts velocity could be varied. The machine was reported to functionally operate satisfactorily during the limited tests performed on stored ginger.

Evaluating and establishing the machine parameters was, however, essential because peeling of skin is associated with the loss of ginger meat from underneath the skin. The epidermal cells in ginger contain most of the essential oil which imparts the ginger it's characteristic aroma and is perhaps the most important factor in determining it's market price (Jaiswal, 1980). Therefore, loss of ginger meat from underneath the skin would result in not only the loss of weight but also in heavy loss of economic value of ginger. In general, high peeling efficiency would be associated with high material loss. Consequently, the machine parameters require to be so established as to obtain as high a peeling efficiency as possible with minimum loss of ginger meat.

The main objective of this paper, therefore, was to evaluate and establish the operational parameters of the abrasive brush-type ginger peeling machine for maximum peeling efficiency with minimum ginger meat loss. The other objective was to determine the capacity of the machine operating at the recommended machine parameters.

Materials and Methods

Ginger peeling experiments were conducted to determine the effects on peeling efficiency and ginger meat loss at the following machine parameter values:

Brush belt spacing – 1.0, 1.25 and 1.5 cm.

Belt speed – 45, 64 and 85 rpm of the driving brush belt resulting in 60, 86.7 and 113.3 rpm of the driven belt and the belts relative speeds of 137, 199 and 260 cm/s, respectively.

Number of passes – 1,2,3,4 and 5.

Fresh, graded ginger, average thickness of pawns ranging from 1.9 to 2.2 cm was procured from the market and was stored in moist sand during the experimentation.

For each peeling trial, a sample of about 200 g ginger was soaked in water overnight as per conventional practice (Nambiar, 1980), the excess moisture was removed by a

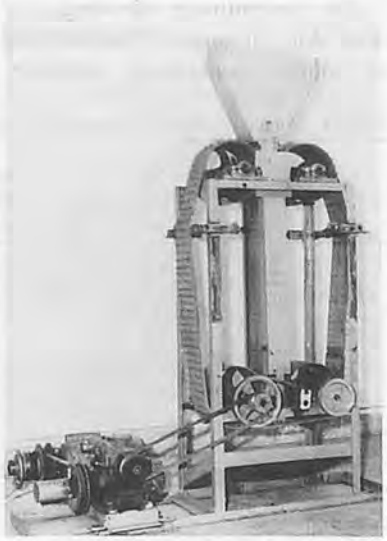

Fig. 1 Abrasive brush-type ginger peeling machine.

towel, and the sample was peeled in the machine. The sample was weighed before and after machine peeling on a triple beam balance with 0.05 g accuracy. The difference yielded the weight of skin peeled by machine plus the meat loss, w. The sample was then hand-trimmed carefully and was again weighed. Each experiment was replicated thrice. The peeling efficiency and the ginger meat loss were calculated as follows:

Peeling Efficiency = (Weight of skin removed by machine)/(Weight of total skin on ginger) x 100 = $(Y - X)/Y \times 100\%$. . . . . .(1)

where,

Y = Weight of total skin on ginger, g

X = Weight of skin removed by hand trimming after mechanical peeling, g

and,

Meat loss = (Weight of ginger meat lost during mechanical peeling)/(Total weight of the sample) x 100 = $[W - (Y - X)]/W \times 100\%$ . . . . . (2)

where,

w = Total reduction in weight during mechanical peeling, g

W = Total weight of the sample, g

For determining the weight of total skin on ginger, Y, about 1 kg of ginger containing randomly sampled pawns of all sizes from the lot was hand-trimmed carefully after overnight soaking in water and removing the excess moisture. Each pawn was weighed before and after hand-peeling on the triple beam balance. The difference in weight divided by the original weight of each pawn yielded the skin weight per unit weight of ginger pawn. The average of the skin weight on each pawn was considered to represent weight of skin per unit weight of ginger in the whole experimental lot. This average unit skin weight, when multiplied by the weight of ginger peeled in each experiment, yielded the weight of total skin on ginger, Y.

The capacity of the peeling machine at the recommended machine parameters was determined by conducting the peeling experiment at full hopper capacity of 6 kg and noting the peeling time. The peeling efficiency and meat loss at the full hopper capacity were also determined. The time taken for hand-trimming was noted in order to determine the hand-trimming costs.

Results and Discussion

The average skin weight per unit weight of ginger was 0.164 g/g. The skin weight on individual pawns varied from 3 to 17% from this average value. Further, the variation of skin weight as observed had no relationship with pawn size.

The average peeling efficiency and the average meat loss during peeling by the abrasive brush-type ginger peeling machine at different machine parameter values as calculated from the data on ginger weights before peeling, after machine peeling and after hand trimming (Hiran and Galundia, 1981) are tabulated in **Table 1**.

Number of Passes

The effect of the number of passes on peeling efficiency and

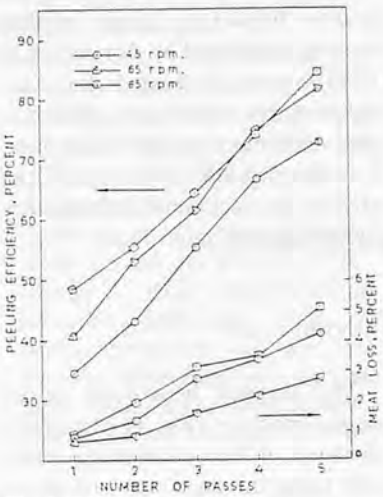

Fig. 2 Effect of number of passes on machines performance at 1 cm belts spacing.

Table 1 Ginger Peeling Efficiency and Ginger Meat Loss, %

unit: percent

Belt speed rpm	No. of passes	Belt spacing 1.0 cm		Belt spacing 1.25 cm		Belt spacing 1.50 cm	
		Average peeling eff.	Average meat loss	Average peeling eff.	Average meat loss	Average peeling eff.	Average meat loss
45 (137 cm/s)*	1	34.81	0.78	26.89	0.47	23.03	0.60
	2	43.11	1.33	46.77	0.70	32.54	1.37
	3	55.42	2.77	50.49	0.88	42.26	1.86
	4	66.83	3.40	55.22	1.65	49.40	2.38
	5	70.28	4.20	62.60	2.96	61.48	2.79
65 (199 cm/s)	1	40.73	0.66	36.45	1.06	28.29	0.74
	2	53.36	0.83	50.80	1.39	40.60	1.09
	3	61.48	1.59	55.32	1.95	43.00	1.50
	4	74.94	2.15	58.73	2.50	58.80	2.34
	5	81.82	2.73	69.72	3.41	67.19	2.70
85 (260 cm/s)	1	48.47	0.82	36.34	1.12	36.87	0.71
	2	55.58	1.96	48.23	2.11	46.51	2.37
	3	64.49	3.14	56.33	2.36	54.99	3.38
	4	74.38	3.49	67.81	2.97	63.71	4.42
	5	84.33	5.11	76.97	4.74	69.83	5.69

* Values of linear relative velocity between the brush-belts.

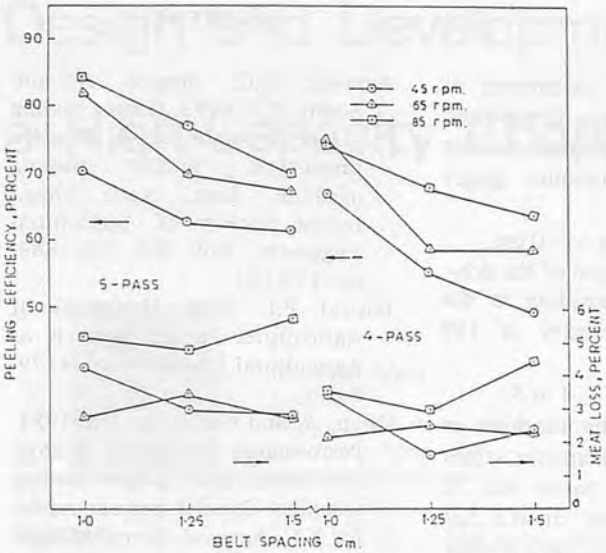

Fig. 3 Effect of belts spacing on machine performance at 4 and 5 passes.

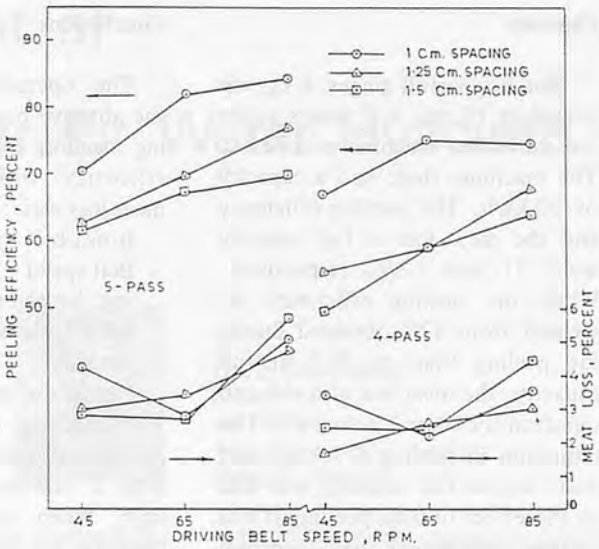

Fig. 4 Effect of belt speed on machine performance at 4 and 5 passes. (Driving belt speeds of 45, 65, 85 rpm result in the belt relative speeds of 137, 199 and 260 cm/s, respectively.)

meat loss is illustrated in Fig. 2 at one of the belt spacings. Increasing the number of passes increased the peeling efficiency and the meat loss as well. Four or five passes were, nonetheless, required to obtain a reasonable peeling efficiency. Similar effect was observed at other belt spacings (Table 1).

Brush-Belts Spacing

Fig. 3 shows the effect of spacing between the brush-belts on the machine performance at 4 and 5 of passes. The peeling efficiency, in general, decreased with increasing belt spacing; the effect being more pronounced from 1.0 to 1.25 cm spacing. The meat loss had a general trend of decreasing when the spacing was increased from 1.0 to 1.25 cm but of increasing or remaining the same at 1.5 cm spacing. It was concluded that a brush belt spacing of 1 cm would be better in view of a significantly higher peeling efficiency, although a spacing of 1.25 cm may result in somewhat lower meat losses.

Belt Speed

The peeling efficiency, in general, increased with the increase in belt speed, the effect being more prominent from 45 to 65 rpm of the driving brush-belt (Fig. 4). The meat loss, on the other hand, increased substantially when the speed was increased from 65 to 85 rpm. It was concluded, therefore, that a driving brush-belt speed of 65 rpm resulting in the belts relative velocity of 199 cm/s was the best since increasing the velocity further increased the meat loss significantly while increasing the peeling efficiency only marginally.

Recommended Machine Parameters

Brush-belt spacing of 1 cm, driving belt speed of 65 rpm speed of 199 cm/s and 4 to 5 of passes are recommended. The average peeling efficiency and the meat loss at these recommended parameters were 82 and 2.7%, respectively, with 5 passes and 75 and 2.2% with 4 passes. The samples of fresh ginger and the ginger peeled at these recommended parameters with 5 passes are shown in Fig. 5 for comparison.

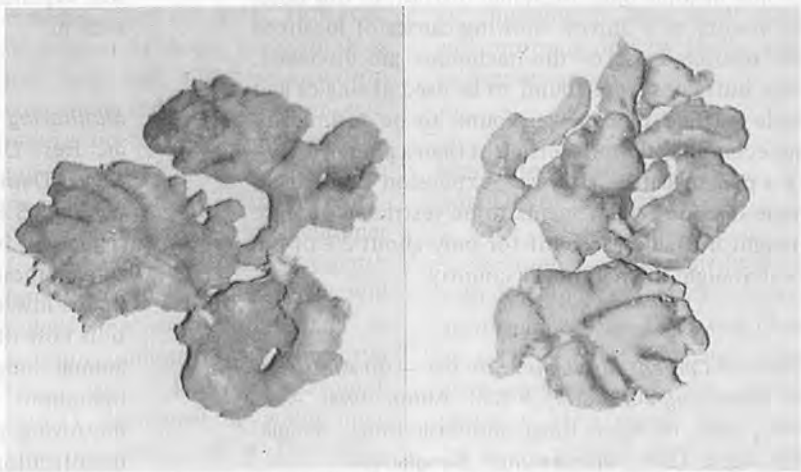

Fig. 5 Samples of fresh ginger and the ginger peeled at recommended machine parameter.

Capacity

One hopperfull ginger, 6 kg, was peeled in 18 min in 5 passes at the recommended machine parameters. The machine, thus, had a capacity of 20 kg/h. The peeling efficiency and the meat loss at full capacity were 71 and 1.6%, respectively. While the peeling efficiency decreased from 82% obtained during the peeling trials to 71% at full capacity, the meat loss also reduced significantly from 2.2 to 1.6%. The reduction in peeling efficiency and meat loss at full capacity was due to the effect of bulk peeling. It was further determined that 16 man-h would be required to hand-trim the lot of 20 kg ginger peeled by the machine. Assuming the cost of labour to be US$0.20/h in local conditions, the cost of hand-trimming would be US$0.16/kg when peeling at full capacity.

Conclusions

The operational parameters of the abrasive brush-type ginger peeling machine for maximum possible efficiency with minimum ginger meat loss were:

Brush-belt spacing – 1.0 cm.

Belt speed – 65 rpm of the driving brush-belt resulting in the belts relative velocity of 199 cm/s.

Number of passes – 4 or 5.

The capacity of the machine at the recommended parameter values with 5 number of passes was 20 kg/h. When operated at it's full capacity, the machine had a peeling efficiency of 71% with ginger meat loss of 1.6%. The hand trimming cost of the peeled ginger was US$0.16/kg under Indian conditions.

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ABSTRACTS

The ABSTRACT pages is to introduce the abstracts of the article which cannot be published in whole contents owing to the limited publication space and so many contributions to AMA. The readers who wish to know the contents of the article more in detail are kindly requested to contact the authors. The requests from the readers for publishing the whole contents among the articles introduced here may also be sent to editorial staff. Regarding the article of many requests, the publication of whole contents will be reconsidered.

Potential of Single Animal Ploughing in Bangladesh: M.A. Jabbar, Asst. Prof., Dept. of Agric. Economics Bangladesh Agric. Univ., Mymensingh, Bangladesh.

In Bangladesh, single animal ploughing is practised only in some parts of Sylhet district. In this note, the results of a survey showing causes of localized and restricted use of this technique are discussed. Only buffaloes were found to be used as singles and single buffalo plough was found to be technically and economically more efficient than a plough drawn by a pair of cattle. However, expansion of the technique outside Sylhet seems to be restricted because draught buffaloes account for only about 2% of the total draught animals in the country.

Effect of Cement Mixing on Soil pH – An Approach for Imrpvoing Acid Soil: A.S.M. Abdul Awal, Asst. Prof., Dept. of Agric. Engg. and Basic Engg., Bangladesh Agric. Univ., Mymensingh, Bangladesh

An investigation was carried out with the acid sulphate soil of Bangkok Plain in order to determine the effects of adding varying amounts of portland cement on soil pH. It was found that cement, the major component of which is calcium oxide, provided some liming effect by increasing the pH of the soil depending upon the quantity of cement mixed with it.

Monitoring Bio Gas Plants in Hills: D.P. Darmora, Jr. Res. Officer, and Bachchan Singh, Prof. and Head, Dept. of Farm Machinery and Power Engineering, G.B. Pant Univ. of Agriculture and Technology, Pant Nagar-263145, Nainital, India.

Common problems of reduced biogas production under low temperature conditions are high installation cost of biogas plants and scarcity of sufficient animal dung to keep the plants in optimum level of operation. This paper explores the possibilities of improving plant functioning through plant design modification, maintaining digester temperature above ambient temperature and using suitable additives to stimulate gas production. ■■

Design and Development of a High-Capacity Chopper for Water Hyacinth

by
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Abstract

A high-capacity chopper was designed, fabricated, tested and evaluated for chopping water hyacinth. The chopper was designed with 27 circular saw blades of 254 mm diameter. Chopping tests were conducted at different chopper speeds with individual plants of different mass. Peak power requirements were measured for chopping. A floating test was conducted to measure the degree of comminution of the chopped materials. Regression analysis of the total peak power requirements of different components for cutting a water hyacinth plant was done. The machine offered a very good capacity, 25 t/h or 31.25 t/h/m of conveyor width at 120 RPM conveyor speed. The peak power consumption in chopping was 3.98 kW with energy requirement of 0.16 kWh/t.

Introduction

Water hyacinth *(Eichhornia crassipes)* is of the pickerel weed family, (**Fig. 1**). It is a vigorous fast growing plant. Two plants of water hyacinth can multiply to 1200 in 130 days (Evans, 1963) and the plant contains 95% moisture (Gopal and Sharma, 1981). The fresh intact water hyacinth has a density of about 167 kg/m^3, (Bangall, 1982). Water hyacinth creates a lot of problems, clogging of irrigation pumps and hydroelectric systems, obstruction to water flow, reduction of fish yields and prevention of fishing activities, interference with navigation, public health problems, and retardation of cultivated aquatic macrophyte crops. However, this aquatic plant may actually be used as a renewable natural resource whose applications may include bedding material for mushroom culture, feed for bio-gas plant, pulp and paper production, fertilizer, animal feed, handicrafts, etc (Gopal and Sharma, 1981). All the above require that the plant be removed from the water. However, because of its shape, the plant does not pack well into transportation containers and transportation economics becomes a problem as containers quickly fill with only a small number of plants. Hence, it is necessary to develop a chopper for reducing the water hyacinth into very small pieces which will reduce the empty space and as a result minimize the transportation cost. Kaewprakaisaengkul (1984) developed a water hyacinth harvester on a laboratory basis. Average harvesting capacity was 6.5 t/h/m width of the conveyor when the travelling speed was 0.56 km/h in simulated real-life conditions. Handaya (1984) developed a water hyacinth chopper and blender but the capacity of the chopper was only 0.74 t/h. So we need to develop a chopper with much higher capacity than the one developed by Handaya.

Fig. 1 Water hyacinth in a small river in Thailand.

The plant may also be controlled by chopping it into small pieces and returning directly to the water to degrade and sink.

Machine Design and Development

A chopper was designed to work with Kaewprakaisaengkul's harvesting machine (**Fig. 2**). It was placed in an area where hyacinth plants were collected in the existing harvester. The plants fell directly on to 27 circular saws which were fixed on two contra-rotating shafts, 14 saws on one shaft and 13 on

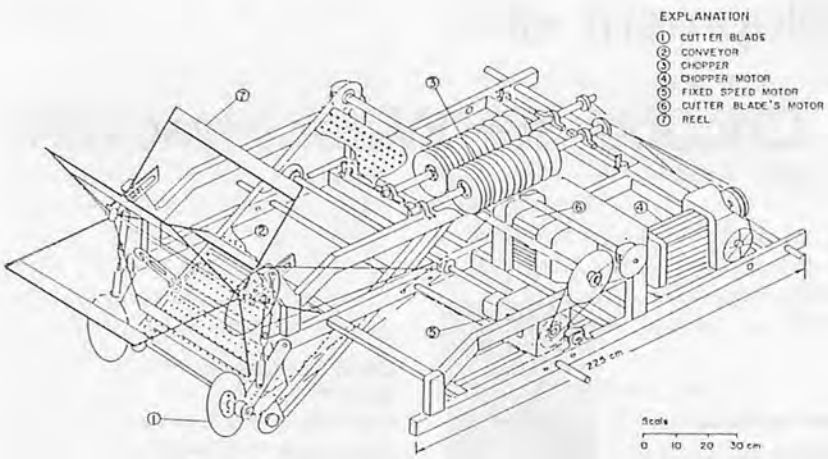

Fig. 2 Harvester and chopper.

Fig. 3 Difference of chopped materials when feeding was horizontal (left) and vertical (right).

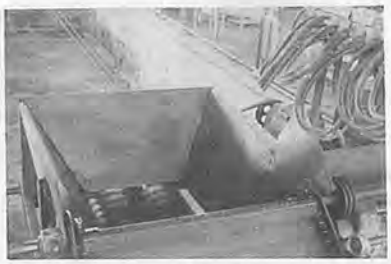

Fig. 4 Top view of the chopper.

the other. The shafts were rotated at different speeds which gave better shearing forces for cutting. In order to obtain an opposite rotation of the shafts, the slower shaft was rotated by a direct belt drive and the faster shaft was rotated by a cross-looped belt. The gaps between the adjacent saw blades were not uniform: initially the gaps were 26 mm and gradually increased to 57 mm. The small gap at the beginning was for fine chopping of the root systems which made sure the plant would not regrow if returned to the water after chopping. The overlapping of two saw blades from the two shafts was 64 mm. Thus, the length of the chopper was 485 mm and 444 mm in width. The saws were fixed to the shaft by hubs. Mostly gravitional feed with a little thrust from the conveyor comb was used. In the first arrangement, the chopper shafts were made parallel with the conveyor shaft. The harvested plant was fed vertically, i.e., root first, from the conveyor and it was observed that when the plant was fed some stems were not properly chopped. However, with horizontal feeding, the result was satisfactory. Horizontal feeding was obtained by changing the position of the chopper shafts into a perpendicular direction vis-à-vis the conveyor shaft and by setting a deflector plate of 15 cm length at an angle of 40°. The chopped water hyacinth for the two different feeding methods is shown in **Fig. 3**. After chopping, the hyacinth was flung out by centrifugal force. Th top view of the chopper is shown in **Fig. 4**.

Methodology

In the chopping experiments, the water hyacinth plants were collected from a nearby canal and graded into nominal sizes of 100, 400, 800, and 1200 g of which three replications for each weight were used. Each sample size was chopped at 6 different chopper RPM speeds: 817, 945, 1022, 1093, 1167, and 1217. The total peak power requirement was measured by a wattmeter and broken down into: (a) peak power for chopping a plant of water hyacinth, i.e., difference between total peak power when cutting and total mechanical power requirement for operating the chopper at no-load condition and (b) total power requirement for operating the chopper at no-load condition which consists of: (i) power loss for overcoming the friction loss of the chopper shaft mechanically and aerodynamically, plus belt slippage losses and (ii) for overcoming the power loss of the driving system, i.e., in the motor friction and ohmic losses.

Two kinds of floating test were conducted to measure the degree of comminution of the chopped materials: (a) short term floating test and (b) long term floating test. Two hundred and fifty grams of chopped sample was taken after chopping, at different chopper speeds, different individual plants of different mass.

The cutting time for each plant was very short and chopping capacity was determined by placing fixed amounts of water hyacinth on one side of the conveyor by hand. The chopping time was calculated from the time required to pass three combs which were on one side of the conveyor.

Results and Discussion

The regression analysis of total mechanical power requirement vs motor speed, total mechanical power requirement vs. chopper (faster shaft) speed, power required to run the motor vs. motor speed and power losses from the chopper

shaft friction, belt slippage and windage vs. chopper speeds were:

$$P_t = 281.67 + 0.66\,N_{mb} \quad . (1)$$
$$P_t = 274.88 + 0.29\,N_{cs} \quad .. (2)$$
$$P_m = 183.97 + 0.20\,N_m \quad .. (3)$$
$$Pl = 73.51 + 0.51\,N_{mb} \quad . (4)$$

where

P_t = Power requirement for operating the chopper, W

P_m = Power required to run the chopper motor, W

P_l = Power losses from the chopper shaft friction + windage + belt slippage, W

N_m = Motor speed (without belt attached), RPM

N_{cs} = Chopper (faster shaft) speed, RPM

N_{mb} = Motor speed (with belt attached), RPM

The coefficient of correlation was 0.99 for all the above equations. A graphical representation of equations 1 and 3 is shown in **Fig. 5**. In all the equations, there are intercepts that may be due to ohmic losses from the motor and belt slippage.

It was found that the total peak power for cutting a water hyacinth plant was quadratic with chopper speed and the relationship between total peak power required for chopping a plant of 1200 g and motor speed was:

$$P_{1200} = 700.83 + 0.01\,N_{mb}^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The coefficient of correlation (r) is 0.98 and the graphical representation of the equation 5 is shown in **Fig. 5**.

The peak power requirement as a function of the plant mass at different chopper speeds was determined. It is shown in **Table 1** and in **Fig. 6**.

The mean percentages of all floating fractions after 10 min and 24 h were 94.89% and 92.28%, respectively. The average of two results from the long term floating test at the same speed is shown in **Fig. 7**. It took 28 days for the chopped hyacinth to sink – too long for a control situation in which hyacinth is chopped and put back into the water. For this situation blades would have to be much closer together.

A load of 15 kg of plants on one side of the conveyor was satisfactorily chopped and the time required to clear one side of the conveyor was 2.163s. Thus, the capacity of the chopper was at least 6.94 kg/s (31.24 t/h per meter of converyor width). Total peak power requirement for that amount (15 kg) of chopping was 3.98 kw with the equivalent amount of energy of 0.16 kWh/t.

The total power required is the sum of the total mechanical power requirement for operating the chopper, equation 2, and peak cutting power, equations of **Table 1**. The calculated energy is presented in **Table 2**.

Although the total energy required for cutting a plant is quite small, the total mechanical loss (66%) is high in comparison to the required energy for cutting. Invariably, these losses are required to overcome the electrical resistance in the motor, shaft friction, belt slippage, and windage.

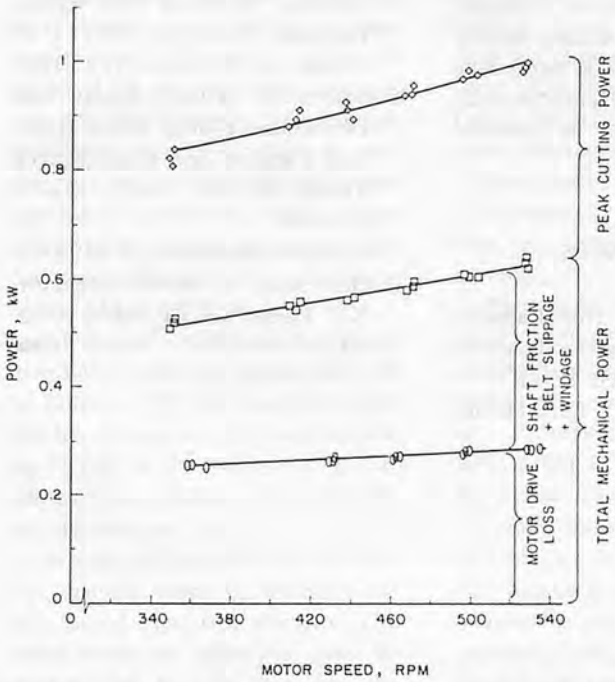

Fig. 5 Peak total and component of chopping power vs motor speed relationship for chopping 1.2kg plant of water hyacinth.

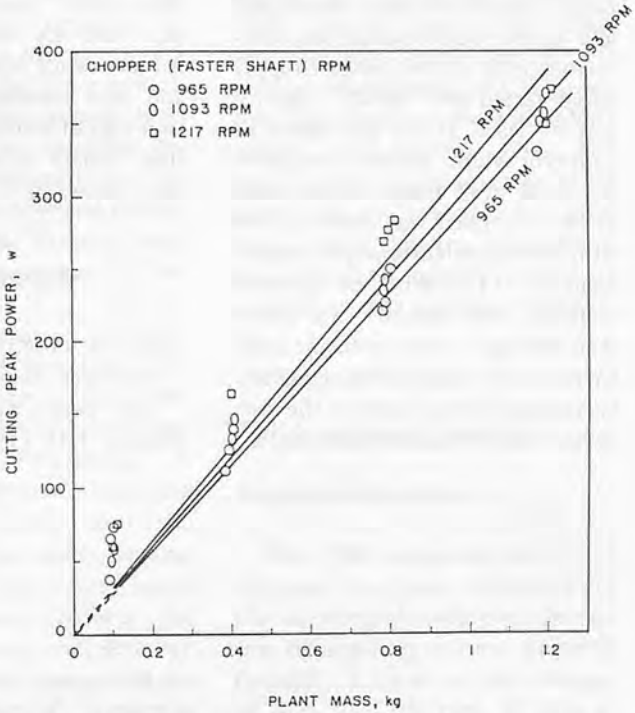

Fig. 6 Regression of the peak power for cutting an individual plant of water hyacinth vs plant mass at different (965, 1093, 1217) chopper (faster shaft) RPM.

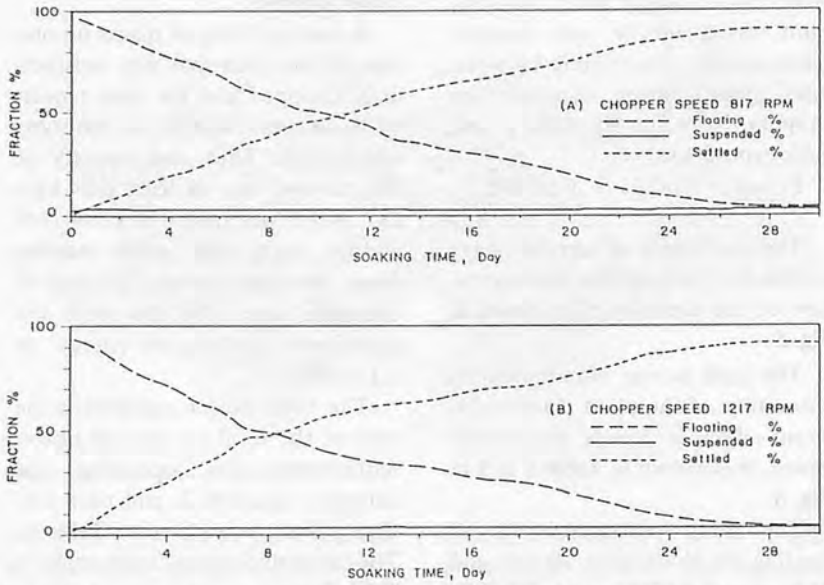

Fig. 7 Fraction percentage of long term floating test vs soaking time at lowest and highest chopper speeds, (A) Lowest chopper speed, 817 RPM, (B) Highest chopper speed, 1217 RPM.

Table 1 Regression of Peak Power for Cutting a Plant against the Plant Mass

Chopper (RPM)	Peak cutting power (W)	r
817	0.246 G*	0.996
965	0.293 G	0.996
1022	0.299 G	0.995
1093	0.308 G	0.998
1167	0.311 G	0.995
1217	0.322 G	0.992

*G = plant mass, (g)
r = coefficient of correlation

Table 2 Total Power and Total Energy for Cutting a Plant of 1 kg at Different Chopper Speeds

Chopper (RPM)	Peak cutting power (W)	Total loss (W)	Total power (W)	Total energy (kWh/t)
817	246	512	758	0.030
965	293	555	848	0.034
1022	299	571	870	0.035
1093	308	592	900	0.036
1167	311	613	924	0.037
1217	312	628	950	0.038

Conclusions

A high capacity chopper for water hyacinth, consisting of two rows of contra-rotating circular saw blades, was successfully constructed and tested. Performance was satisfactory even at the lowest chopper speed tested (817 RPM). Capacity was at least 31 t/h per meter of conveyor width. At this throughput the total peak power requirement of the chopper was about 4 kW with an equivalent energy requirement of 0.16 kWh/t of chopped material. The capacity was more than enough to cope with the mass harvested by Kaewprakaisaengkul's harvesting machine and so the two devices may be successfully matched together. As tested the chopped hyacinth was not finely done as to degrade quickly and sink from the water surface when placed back into the water after chopping. However, this could be rectified by adding more saw blades and placing them closer together. Performance was perfectly adequate, however, for increasing the packing density and thus reducing the transportation cost of water hyacinth in situations where it must be removed from the water.

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Design of FMI Sugarcane Planter

by
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Abstract

The sugarcane planter described in this paper is a two-row machine integrally mounted on the rear of a tractor through 3-point linkage. It opens the furrows, cuts the sets and directs them into the furrows, applies fertilizer and covers the setts with soil. Row to row distance is fixed at 1 000 mm. The machine is designed to plant double setts end to end but can be adjusted to give desired seed rate.

Sugarcane Production in Pakistan

Sugarcane is a major cash crop in Pakistan. In 1983-84 it was grown on 897 000 ha which is about 4.7% of the total cropped area of the country. The average yield was 38.2 t/ha which is one-third of that in Australia and other developed countries. Low plant population, inadequate inputs and poor management are the major causes of low yield.

At present, sugarcane is planted manually with a population of 45 000 to 50 000 two-eyed setts per hectare against the recommended 75 000 to 100 000 setts. Under the current situation of low supply of agricultural labour, it seems impossible to increase the seed rate by manual planting necessitating the use of sugarcane planters. The importance of planting can be accentuated by the fact that the crop, once planted remains in the field for at least two years.

Status of Sugarcane Planters

Traditionally, sugarcane has been planted manually. However, in order to reduce the cost of planting and overcome labour shortage, machinery for sugarcane planting has recently been introduced in the country.

Millat Tractors Ltd is currently marketing a tractor rear-mounted, single row sugarcane planter imported from Australia. The cane is stored in a trolley behind the planter and two persons feed whole canes horizontally to the machine. The machine opens a furrow, cuts the setts, places them in the furrow and applies the fertilizer. The machine with trolley is available for US$3 750 and can plant up to 0.5 ha/h as claimed by the manufacturer. The machine requires large fields for efficient operation because of its working length made up of the tractor, machine and trolley, all attached in line. There are only two of these machines in the country.

The Farm Machinery Institute (FMI) imported a two row semi-automatic sugarcane planter from India under the Mutual Exchange of Prototypes Programme of RNAM/ESCAP. Two workers, one for each row, meter the setts manually into the chutes leading to the furrows. The planter opens the furrows, places fertilizer and covers the setts with soil. Setts are manually cut and transported to the machine in baskets. The planter was tested for its field performance by FMI in 1983. Test results indicate field capacity of 0.26 ha/h and labour requirement of 51 man-h/ha with double setts placed end to end in furrows spaced at 914 mm (1).

The planter based on Indian design is being manufactured by one company. The sales volume is about 20 units per year. The major drawbacks with this machine are non-uniformity of sett placement and operator fatigue. In addition, labour requirements for cutting the setts and their transport to the machine are high.

The sugarcane planter developed recently by the Agricultural Mechanization Research Institute (AMRI), Multan is a three-row machine. Three persons feed whole canes vertically into three units of sett cutting mechanisms, one for each row. The planting rate with AMRI planter is 0.125 ha/h (20). The major drawbacks of this planter are short row to row distance (760 mm), high labour requirement (56 man-h/ha), and lack of fertilizer application and sett covering facilities.

FMI Sugarcane Planter

Design Considerations

The FMI sugarcane planter is designed to plant according to the recommendations compiled by the Pakistan Agricultural Research Council, i.e., row to row distance of 900 to 1 050 mm, 75 000 to 100 000 two-eyed setts per hectare and double setts placed end to end.

Fig. 1 FMI sugarcane planter.

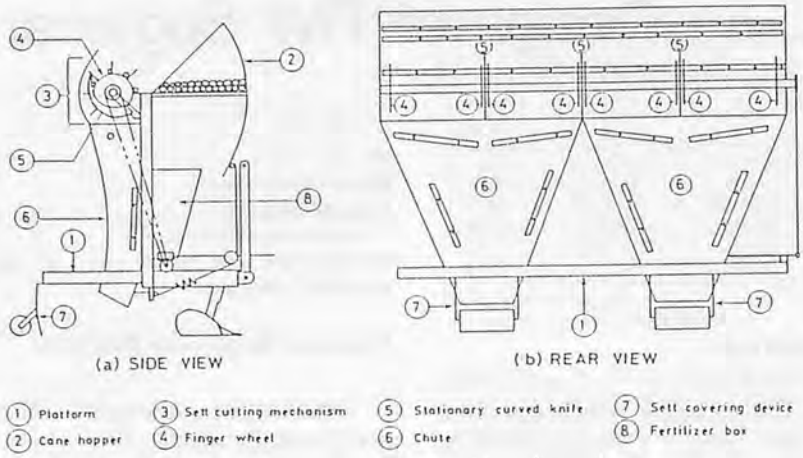

Fig. 2 FMI sugarcane planter, side and rear views.

The design criteria are summarized below:

1. The setts are planted according to the recommendations.
2. Machine integrally mounted on a 35 kW tractor.
3. Machine cuts the setts from cane.
4. Fertilizer attachment.
5. Low labour requirements and less operator fatigue.
6. Simple mechanisms which can be fabricated from locally available raw materials and workmanship.

Machine Description

The FMI sugarcane planter (**Fig. 1**) is a two row machine integrally mounted on the rear of a tractor. It is powered from tractor PTO through a universal shaft which drives the worm gear. The worm gear shaft drives the fertilizer metering mechanisms as well supplies power to the sett cutting mechanism through chain drive.

With reference to **Fig. 2** the operator standing on the platform (1) on the rear of the machine feeds the canes from the hopper (2) to the sett cutting mechanism (3). The rotating finger-wheels (4) hold the whole cane and press it against the stationary curved knives (5) resulting in progressive cutting of the cane. The position of the knives is staggered to avoid jamming of the cane setts between the knives. The cane is cut into four pieces. The inner two pieces are 450 mm each and the length of outer two pieces depends on the actual length of individual canes. The setts, when cut, are perpendicular to the furrow direction. The chutes (6) guide the setts as they fall through them into the furrows. Fertilizer is placed and the setts are covered with soil by a covering device (7) provided for each row. The covering device consists of two cultivator tines which scrape soil from the sides of the furrow into the furrow bottom followed by a steel roller which packs it slightly.

The cane hopper can accommodate about 300 canes sufficient for about 150 m long strip. The hopper is hinged near the sett cutting mechanism and supported on spring at the other end. This helps in keeping the cane level constant with respect to the position of the operator. Fertilizer is stored in two boxes (9), one for each row. Each box has two fluted-wheel metering mechanisms which apply the fertilizer on each side of the row of setts in the form of bands.

Performance of FMI Sugarcane Planter

Limited field tests have been made to evaluate the performance of the machine. The machine was tested at the Sugar Crops Research Institute, Mardan and at a farmer's field in Faisalabad. In addition to the tractor operator, one person to feed canes into sett cutting mechanism and two to refill the cane hopper were required. The machine was tested with straight cane at various ground speeds and 1.75 km/h was selected as the best speed from the view point of operator comfort and sett placement. Field capacity was 0.25 ha/h. The cost of the machine is US$500. Labour requirements and planting cost with FMI sugarcane planter are estimated to be 20 man-h/ha and US$20/ha, respectively.

Several demonstration plots have been planted and are planned at the farmer fields. The planter is currently in the industrial extension stage.

The limitations of FMI sugarcane planter are relatively straight canes or cane pieces 1.5 to 2.0 m in length.

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Mechanization of Sugarcane Farming at Komenda, Ghana

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Introduction

Sugar has long been one of the basic components of the essential commodities that are required for the home. Sugar consumption in Ghana over the past 20 years is shown in **Table 1**.

Based on assumptions by the International Bank for Reconstruction and Development (1972), the projected demand for sugar in Ghana was estimated at 200 000 t for 1985.

The Sugar Products Corporation was created in 1963 to help ease Ghana's dependence on imported sugar by setting up sugar mills and sugarcane plantations to provide raw materials to feed the mills. Two mills were constructed at Asutuare in the Eastern Region and Komenda in the Central Region. These mills started operation in February 1966 and July 1967, respectively, under the management of the State Sugar Corporation. After going through various management changes the Ghana Sugar Estates Ltd. (Ghasel) was formed in November 1971 to take over the management of the both the Asutuare and Komenda sugar mills.

Table 1 Sugar Consumption in Ghana 1955–75 (Unit: t)

Year	Local Production	Imports
1955	–	31,000
1960	–	60,000
1965	–	63,900
1970	5,500	88,300
1975	11,300	43,700

Source: Japan International Co-operation Agency feasibility report on the Aveyime: Sugar production project in Accra plains; Ministry of Economic Planning, June 1976, cited by W.A. Okyere 1979.

Raw materials for these mills were to be supplied from mechanized sugarcane plantations of the factories and from private individual farmers. The factories also offer mechanization services to the private farmers to boost production.

Justification for Mechanization

Agricultural mechanization may be defined as the study, manufacture, utlization, maintenance and repair of all tools, implements, machines and equipment which enable the farmer to raise economically the productivity of human labour (FAO 1971).

A hectare of sugarcane crop of 70 t normally requires 105 man days for harvesting (M.P. Sharma 1985). While 6.5 men produce 1 000 t of sugarcane manually, in a fully mechanized industry such as pertains in Australia, one man produces more than 1 000 t. Mechanization would thus reduce labour requirements very considerably.

Howevaer, due to various factors growers are experiencing labour shortages and labour problems. An example of rising labour costs is the increase of more than 70% in recent times of the basic rates. Increasing salaries and improving fringe benefits is not an answer to retaining labour. In many parts of the world, cane cutters are getting scarce notwithstanding bonus incentives and good basic salaries. Some countries such as Puerto Rico have experienced a near collapse in recent years of their sugar industries because of the unwillingness of labourers to cut cane by hand. This situation will be worse as the general educational standards of agricultural workers increase.

The rapid rise in wages, coupled with an uncertain labour supply is causing renewed interest in mechanization in sugarcane production the world over. The grower sees in mechanization a promise of security which will enable him to overcome the uncertainty associated with labour supply.

In February 1986, a study was conducted to determine the types and numbers of equipment available for sugarcane farming in the Komenda area, their ownership and utilization and to determine the general state of mechanized practices on sugar farms in the study area.

The study area is defined as all the land within 30 km of the Komenda sugar factory. Komenda

Table 2 Status of Mechanized Sugarcane Farm Operations

Operation	Implement available
Land preparation	Caterpillar tractor Plough Harrow Ridger
Planting	Planter
Irrigation	Sprinkler system
Harvesting	Knife
Loading	Grab loader
Hauling	Tractor trailer Trucks
Ratooning	–
Bagasse handling	–

Table 3 Additional Implements Required for Effective Mechanization of Sugarcane Production

Operation	Implement
1. Land preparation	Sub-soiler Riper Cultivator Rotary cultivator
2. Planting	Sett treatment
3. Interculture	Fertilizer applicator High clearance cultivator
4. Harvesting	Harvester
5. Ratoonning	Stubble shaver
6. Bagasse handling	Baler

Table 4 Cost of Manual Field Operations in Komenda Area

Operation	Cost/ha (¢)*
Land clearing	7 500
Ridging	
Planting	3 700
Cultivation	2 500
Harvesting	14 500

*Exchange rate: 1US$ = ¢ 90

Table 6 Cost of Mechanized Field Operations

Operation	Cost/ha (¢)*
Land clearing	3 700
Ploughing	3 700
Harrowing	1 800
Ridging	1 800

* 1US$ = ¢90

Table 5 Tractors and Equipment Available for Sugar Cane Farming in Komenda Area

Item	Make	Number	Owner
Crawler	Caterpillar	2	Ghasel
Tractor	Fortschritt	11	Ghasel
Tractor	Massey Ferguson	3	Private
Tractor	Universal	2	Private
Plough	Fortschritt	2	Ghasel
Plough	Massey Ferguson	6	Ghasel
Harrow	Fortschritt	2	Ghasel
Harrow	Massey Ferguson	6	Ghasel
Ridger	Massey Ferguson	2	Ghasel

is 192 km from Accra. Questionnaires were prepared for the survey. Thirty sugarcane farmers were located in Komenda area and the questionnaire completed during the interview by the interviewer. The farm manager of Komenda sugar factory was also interviewed.

A review of the present status in regard to mechanization of sugarcane farm operations in Komenda area is summarized in **Table 2**.

Land cleaning is done with a Caterpillar tractor with a dozer blade attached. Levelling of cleared land is done on land belonging to 'Ghasel' but not on the outgrowers farms. This is attributed to the high cost of the services of tractors and levellers. Outgrowers, therefore, depend heavily on manual labour for land clearing and levelling.

Ploughs, harrows and ridgers are available to both Ghasel and outgrowers for primary and secondary tillage operations. **Table 5** shows the distribution of tractors and implements available for sugarcane production in the study area.

Mechanized cane planting and fertilizer application is practised on Ghasel farms with the outgrowers depending mainly on manual labour for planting. Most outgrowers do not apply fertilizer to their cane crops. Ghasel used to supply fertilizer to the outgrowers free of charge to boost production. This practice has been abandoned because of the rising cost of fertilizer.

Sugarcane plants are pre-burnt to destroy trash and to ensure that clean canes are delivered to the mill. Cane cutting is done manually. Loading of cut cane on 'Ghasel' plantations is done with a grab-loader which gathers the canes into heaps before loading onto tractor trailers and trucks for transportation to the mills. The Komenda sugar factory has been closed down for some years now because of lack of spare parts to rehabilitate broken down equipment. Cane produced, therefore, is sold to private crushers who produce, after distillation, the local gin "Akpeteshie".

Recently the Agricultural Engineering Company has introduced to the Ghanaian market a small sugar plant capable of producing 3 t of raw sugar per day. It is hoped this will rekindle interest in sugarcane production.

A popular bias against mechanization is the displacement of labour. Today in the Komenda area farmers are complaining of labour shortage and high wages. There is, therefore, a pressing need to mechanize sugarcane production in Ghana to increase yield and guarantee a continuous supply of cane to the mills. With two decades of mechanization of agriculture, Ghana still seems to be in the first stage of providing better power input and tillage and haulage. It is time the country graduate into the second stage of crop specific mechanization, introducing a whole range of equipment for different farm operations.

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Methods of Determining Heat Potentials of Agricultural Biomass

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Abstract

The heat capacities of products of combustion vary with temperature. The temperature of the products which corresponds to the total heat liberated during combustion is calorimetric temperature. The different methods of determining the calorific value of agricultural biomass and its calorimetric temperature are discussed in this paper with special reference to jute stick and paddy straw.

Introduction

The agricultural biomass, as a substitute of fossil fuel, has been greatly considered by energy experts of modern times. Extraction of electrical energy, heat energy and use of biomass for gasification is fast gaining momentum. An average amount of over 200 million of agricultural residues (2) are produced in the country annually which equals to 100 million of coal or 66 million of petroleum oil every year. This amount of residue, if converted to energy, is capable of meeting the major part of the energy required by the Indian agriculture.

The agricultural residue used for energy production demands accurate determination of its calorific value and calorimetric temperature. The different possible methods suitable for residues are discussed in this paper. The heat values of jute sticks and paddy straw, calculated by different methods, are shown in **Table 1**. A comparative study of all the possible methods made and shown with the help of bar diagrams (**Figs. 1** and **2**).

Methodology

Calorific Value

The calorific value or heating value of fuel is generally expressed in kcal/kg. Heating values (including the latent heat of the water vapour in the products of combustion) are called higher or gross calorific values. The gross calorific value minus latent heat of water vapour is termed as net or lower calorific value. Calorific value is commonly reported on dry basis. The calorific value of residues calculated by different methods is shown in **Table 1**.

There are three methods for determining the calorific value of agricultural residues: experimental; empirical formula; and ultimate analysis methods.

Experimental Method – The experimental procedure for the determination of the calorific value of the fuel is well explained by Sarkar (3) and Himus (1).

Empirical Formula Method – Several methods for calculating the calorific value of fuel are reported by Himus and recommends two of them; the Dulong formula and a formula proposed by E.S. Grummel and I.A. Davies in 1933.

The Dulong formula is expressed as follows:

$$\text{HHV}^* \text{ in kcal/kg} = [145.4\,C + 620.3\,(H - \frac{O}{8}) + 40.5\,S]\ 0.5556$$

Table 1 Calorific Value of Agricultural Biomass Calculated by Various Methods and their Deviation with Respect to Experimental Value

Method	Paddy straw (Moisture content 10.83%, w.b.)						Jute stick (Moisture content 11.65%, w.b.)					
	HHV, k cal/kg	% error	LHV, k cal/kg	% error	HHV,* k cal/kg	% error	HHV, k cal/kg	% error	LHV, k cal/kg	% error	HHV*, k cal/kg	% error
Experimental method	3442.11		3165.84		3860.17		4075.67		3746.76		4619.10	
Empirical formula method												
i) Dulong formula	3268.66	– 5.0			3665.65	– 5.04	4011.78	–1.56			4540.78	– 1.69
ii) Grummel and Davies formula	3158.26	– 8.24			3541.84	– 8.24	3956.55	–2.92			4478.27	– 3.04
iii) Tillman formula	3368.70	– 2.13			3777.84	– 2.13	4172.80	2.38			4723.03	2.25
iv) I.G.T. formula	3467.78	0.74			3888.95	0.74	4317.00	5.92			4886.15	5.78
v) Pavlov formula	2522.76	–26.7	2210.19	–30.18	2829.16	–26.7	4034.93	–0.99	3645.90	–2.69	4126.64	–10.66
Ultimate analysis method	3227.73	– 6.2	2981.60	– 5.8	3619.75	– 6.22	3954.90	–2.96	3652.42	–2.5	4476.38	– 3.09

HHV = Higher heating value (Gross calorific value); LHV = Lower heating value (Net calorific value); HHV* = Higher heating value on moisture free basis.
Error indicates that the calculated calorific values are less than the experimental values.

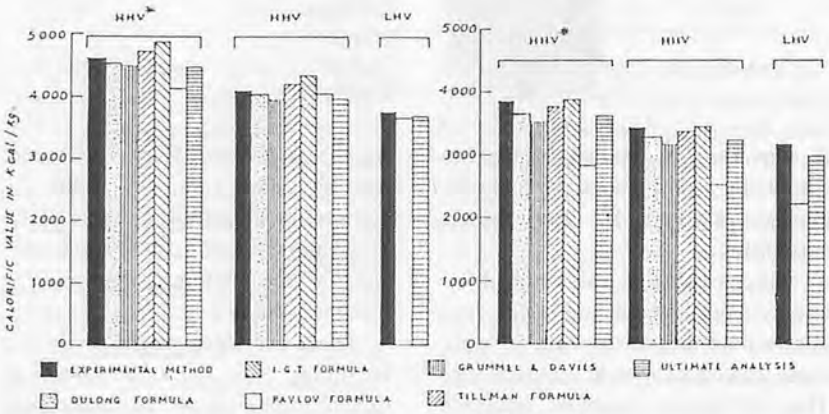

Fig. 1 Calorific value of jute stick and paddy straw worked out by different methods.

Where C, H, O and S are the percentages by weight of carbon, hidrogen, oxygen and sulphur, respectively, on dry basis from the ultimate analysis of fuel. This formula is only useful for oxygen content less than 7%.

The Grummel and Davies formula, on the other hand, is expressed as follows:

$$\text{HHV}^* \text{ in kcal/kg} = [(6.54\,H + 403)(\frac{C}{3} + H - \frac{O-S}{8})] \times 0.5556$$

This formula is recommended for fuels with carbon contents between 67 and 92%.

Seri (4) has proposed two methods for calculating gross calorific values from the ultimate analysis of fuel: formula proposed by Tillman (1978) which uses only the carbon content of the fuel; and another formula proposed by I.G.T. (Institute of Gas Technology) in 1978.

The Tillman formula is expressed in the following equation:

$$\text{HHV}^* \text{ in kcal/kg} = (188\,C - 718)\,0.5556$$

I.G.T. formula:

$$\text{HHV}^* \text{ in kcal/kg} = [146.58\,C + 568.78\,H + 29.45 - 6.58\,A - 51.53\,(O + N)]\,0.5556$$

Where A is the percent ash on dry basis and others are as explained above.

An empirical relationship given by Pavlov (5) has been used to compute higher and lower calorific values of fuel as follows:

$$\text{Higher calorific value } Q_h = 81.4\,C + 342\,(H - \frac{O}{8}) + 25\,S \text{ kcal/kg}$$

$$\text{Lower calorific value } Q_l = Q_h - 6\,(9H + W)$$

Where C, H, O, S and W are the percentages of carbon, hydrogen, oxygen, sulphur and moisture content, respectively.

Ultimate Analysis Method – Carbon, hydrogen and sulphur when burnt, generate heat of the order of 97 650 kcal per kg mole, 57 810 kcal per kg mole and 69 800 kcal per kg mole, respectively. The water vapour would use heat of evaporation of 10 550 kcal per kg mole of water vapour in fuel (5).

Therefore, carbon on combustion develops

$$= \text{Carbon in residue in kg mole} \times 97\,650/100 = \text{a kcal}$$

Hydrogen on combustion develops

= available hydrogen in fuel for reaction with O_2 in kg mole x 57 810 /100 = b kcal

= kg mole x 57 810/100 = b kcal

Sulphur on combustion develops

= sulphur in residue in kg mole x 69 800/100 = c kcal

∴ Higher calorific value = a + b + c = 3 954.90 kcal/kg (for jute stick)

The total quantity of water formed due to chemical reaction would use heat of evaporation from the total quantity of heat developed, as follows:

total quantity of water formed in kg mole x 10 550/100 = d kcal

Therefore, the lower calorific value is

= (Higher calorific value – d), kcal
= (3 954.90 – 302.47)
= 3 652.42 kcal/kg (for jute stick)

For paddy straw the values of HHV and LHV were 3 227.73 and 2 981.60 kcal/kg, respectively.

Calorimetric Temperature of Agricultural Biomass

The temperature attained when fuel is burnt in air or oxygen without gain or loss of heat is termed as calorimetric temperature. This is also termed as 'theoretical flame temperature. The maximum adiabatic flame temperature is reached when the fuel is burnt with theoretically required amount of pure oxygen. Because of the necessity of using excess air in order to ensure complete combustion, the adiabatic flame temperature of actual combustion are always much less than the maximum values.

The heating capacities of products of combustion vary with temperature. The heat capacity of different gases as a function of temperature is listed in **Table 2**.

Table 2 Heat Content of g-Mole of Different Gases at Various Temperature in kcal*

Temp. °C	O_2	H_2, CO and N_2	H_2O	CO_2 and SO_2	Air
100	693	673	810	912	677
300	2106	2046	2461	2926	2059
500	3555	3455	4162	5139	3476
700	5040	4900	5928	7519	4929
900	6591	6381	7781	10027	6419
1100	8115	7898	9753	12625	7944
1300	9711	9451	11881	15275	9506
1500	11340	11040	14212	17938	11103
1700	13005	12665	16801	20640	12736
1900	14706	14326	19707	23391	14406

*Shaha, A.K. Combustion Engineering and Fuel Technology, pp 77, Oxford and IBM Publishing Co., New Delhi.

Methodology

The method of computing calorimetric temperature of agricultural residues used jute stick. The fuel gases, after combustion of 100 kg of jute stick contain CO_2, N_2, H_2O and SO_2 in order of 3.61 kg mole, 15.0 kg mode, 2 867 kg mole and 0.0069 kg mole, respectively.

Assuming the calorimetric temperature of jute sticks to be 1 900°C, the quantity of heat required to develop this temperature would be (from **Table 2**):

CO_2 : 3 61 x 23 391/100
= 844.42 kcal

N_2 : 15 x 14 326/100
= 2 148.90 kcal

H_2O: 2.867 x 19 707/100
= 565.00 kcal

SO_2 : 0.0069 x 23391/100
= 1.60 kcal

Total: 3 559.92 kcal

This heat is less than the lower calorific value of jute stick obtained on the basis of ultimate analysis, which is 3 652.42 kcal/kg. By trial and error method, the calorimetric temperature of jute stick was found to be 1 942.82°C.

Similarly, calorimetric temperature of paddy straw was calculated and found to be 1 940.64°C.

Conclusion

For paddy straw, the I.G.T. formula was found most suitable whereas for jute stick Pavlov formula gave good results for calculating HHV and LHV. In general, the Tillman formula gave uniform and reasonable results for both residues.

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A Comparative Study on the Effects of Four Drying Methods on Germination of Paddy

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Abstract

A comparative study was conducted to establish the effects of four drying methods, namely; rice hull fired drier, natural sun, shade, and ceiling fan on germination of paddy. Nine sets of data were analyzed and results thus obtained show no statistically significant difference on seed viability.

The study also shows that even if the drying air temperature was above 45°C (drier 46°C, sun 60°C) there was no harmful effect on germination of paddy.

Introduction

Rice is the main staple in Bangladesh. About 80% of the population depend on agriculture directly or indirectly for their livelihood. The country is not self-sufficient in food, and the shortfall can reach up to 2 million t in a year of adverse agro-climate.

The production and post-production processes are traditional with possibility of grain losses (both quantitative and qualitative) from harvest to storage. Post-harvest losses of paddy is estimated to be as high as 22% (Farouk, 1975). The losses mostly occur in Aus and Boro paddies as most of the harvest is done during the rainy season.

In the rural areas, on sunny days farmers use mudfloor for drying paddy. From the mudfloor various losses occur due to birds, rodents and contamination. Such losses may range from 10 to 25% (Excell, 1978). During prolonged rainy days farmers use covered areas for drying paddy. However, by this process moisture cannot be removed quickly enough to prevent fungal growth. In areas where electricity is available ceiling fans are used for drying. But the results are not very encouraging because the process is totally dependent on the ambient conditions, particularly on humidity.

To overcome the drying problem, an artificial drier has been developed and constructed by BRRI. Quasem (1979) and Mollah (1981) reported that artificial drying below 50°C has no adverse effect on viability of seed.

Materials and Methods

During the experiment, modern high-yielding cultivars of rice viz, BR3, BR8, BR9 developed by BRRI and a mixture of these were used as drying materials. After threshing and initial cleaning, freshly harvested paddy was dried in the (a) BRRI- rice hull fired batch drier; (b) sun; (c) under shade; and (d) under ceiling fan. The schematic diagram of the drier is shown in **Fig. 1**.

The initial moisture content range of paddy was 16.6% to 25.5% and final moisture content range was 9.1% to 15.2% (Log Book, 1982). The temperature and relative humidity of ambient air and grain mass were recorded with the help of thermocouple with Comark digital recorder and stem hygrometer, respectively. After drying 1.5 kg, sample was collected from each method of drying for germi-

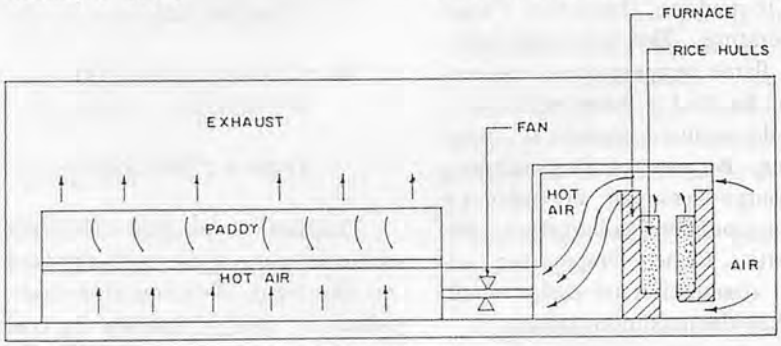

Fig. 1 Sketch of BRRI rice hull-fired batch dryer.

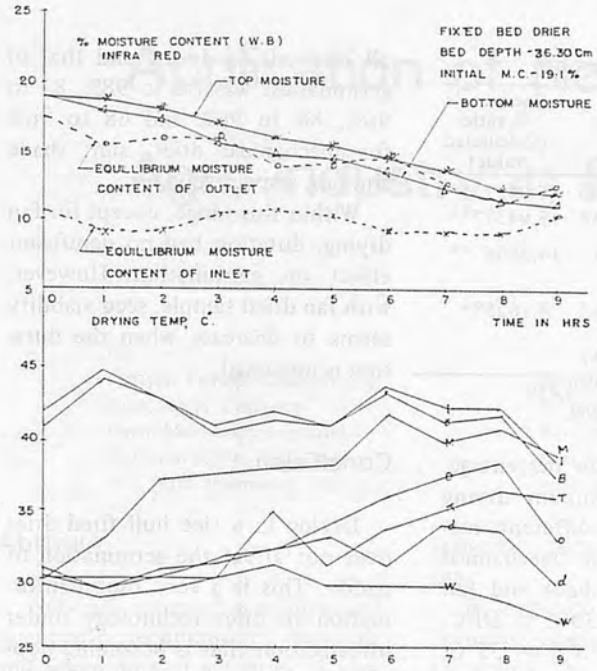

Fig. 2 Drying curves. I–inlet temp.; B–bottom temp.; M–middle temp.; O–outlet temp.; T–top temp.; D–dry bulb temp.; W–wet bulb temp.

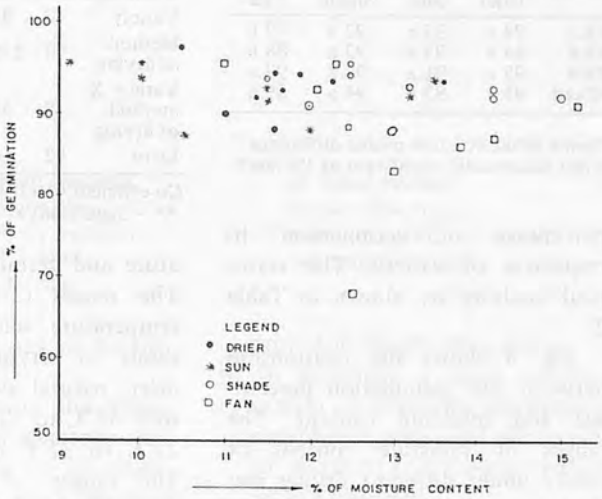

Fig. 3 Germination vs moisture content.

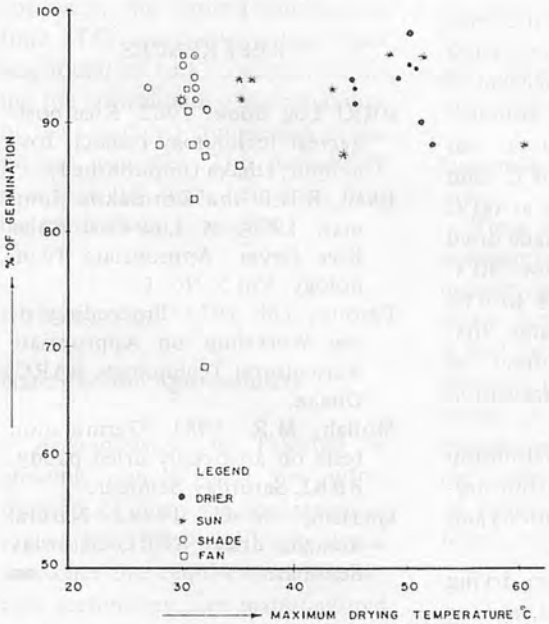

Fig. 4 Germination vs max. drying temperature.

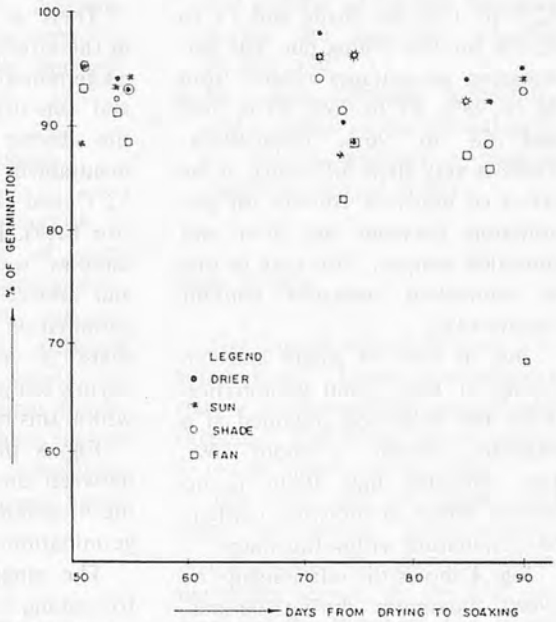

Fig. 5 Germination vs days from drying to soaking.

nation test. Petri dish and control temperature method were used for germination test. Paddy samples for germination were kept in sealed polythene bag for 8 to 13 weeks to check dormancy. Drying curves of one test run are shown in Fig. 2.

Results and Discussions

The effect of different drying methods on germination percentage is shown in Table 1. For all varieties under study, germination percentage is higher (above 90%) when paddy is dried either by mechanical drier or sun or under the shade. But in case of fan drying, except BR9, the germination was less than 90% for all other varieties ranging from 77% for BR3 to 89% for mixed paddy.

Although no significant difference in germination percentage among mechanical drier, sun and shade was observed, the results indicate that drier fired by rice hull, dried samples had higher

Table 1 Average Germination Percentage under Different Methods of Drying for Different Varieties of (Boro) Paddy, 1982

Variety	Method of drying			
	Drier	Sun	Shade	Fan
BR3	94 a	93 a	92 a	77 b
BR8	94 a	93 a	93 a	88 b
BR9	95 a	91 a	94 a	92 a
Mixed	95 a	93 a	94 a	89 b

*Same letter in a row means difference is not statistically significant at 1% level.

percentage of germination irrespective of variety. The statistical analysis are shown in **Table 2**.

Fig. 3 shows the relationship between the germination percentage and moisture content. The ranges of moisture content of paddy under different drying methods were 10.5 to 13.6% for the drier, 9.1 to 13.5% for the sun, 12.5 to 15% for shade and 11 to 15.2% for the ceiling fan. The germination percentages ranged from 88 to 98%, 87 to 96%, 88 to 96% and 68 to 96%, respectively. There is very little difference in the effect of moisture content on germination between the drier and sun-dried samples. This may be due to controlled moisture content (below 14%).

But in case of shade and fan drying of BR9, good germination (92% and 91%) was obtained at a moisture content of about 15%. This indicates that there is no adverse effect of moisture content on germination within this range.

Fig. 4 shows the relationship between maximum drying temperature and germination percentage. The ranges of maximum drying temperature under different methods of drying by mechanical drier, natural sun, shade and fan were 45°C to 52°C, 30°C to 60°C, 27°C to 32°C and 28°C to 35°C. The ranges of germination was from 88 to 98%, 87 to 96%, 88 to 96% and 68%, respectively.

Table 2 Analysis of Variance

Source	Degree of freedom	M.S	Snedecor's F. ratio (Calculated value)
Total	107	28.9843	5.04377**
Variety	3	83.4948	5.04377**
Method of drying	3	235.901	14.2504 **
Variety X method of drying	9	68.9063	4.1625**
Error	92	16.5541	

Co-efficient of variation = 4.45%
** = Significant at 1% level.

There is a very little difference in the effect of drying temperature on germination between mechanical and sun drying samples, although the drying air temperature was maintained between 46.4°C and 52°C and the sun drying at 60°C (for BR9). The fan and shade dried samples were dried below 40°C and showed an average 88 to 93% germination. This indicates that there is not adverse effect of drying temperature on germination within this range.

Fig. 5 presents the relationship between duration (days from drying to soaking for germination) and germination.

The range of days from drying to soaking was from 51-90 days for all methods of drying and that of germination was 88 to 98%, 87 to 96%, 88 to 96% and 68 to 96% for mechanical drier, sun, shade and fan, respectively.

Within this range, except for fan drying, duration had no significant effect on germination. However, with fan dried sample, seed viability seems to decrease when the duration is increased.

Conclusion

Drying in a rice hull fired drier does not affect the germination of paddy. This is a very useful information in drier technology under investigation that is becoming popular to the users, particularly the rice millers and the farmers.

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Application of Network Approach in Agro-Industry in Pakistan

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Abstract

Network approach is an advanced systematic technique of planning and scheduling of activities. A case study of a reaper manufacturing firm is cited. By applying network approach, the earliest completion time (TE) along the critical path was found to be 87.5 days. Following the critical path, the probability of the scheduled completion of the project was 90%. This probability is sufficiently high, hence the firm has good future prospects.

Introduction

Nature of the Agro-Industry

Agro-industry in Pakistan is growing rapidly with the introduction of farm mechanization in recent years. The small agricultural machines that require small production technology, are manufactured in the country. The success of any manufacturing project is very much dependent upon the quality of planning, scheduling and controlling of the various phases of the project.

The up-to-date planning of manufacturing project play an important role in agro-industrial development of the country. Due to lack of proper planning and management the overall performance of this important sector is not so promising.

In order to control the manufacturing work, management needs to know the progress of work. When the work is small planning is not so necessary but as the work becomes more complex, planning becomes essential. Special scientific and systematic tool like the network technique is needed.

Uncertainty in Manufacturing

Time is the most uncertain in a manufacturing work of agro-industry because it is influenced by many factors like skilled and unskilled labour availability, seasonal demand of machines, timely delivery, etc. Without proper timely management each of these factors can cause delay in the completion of project which can mean heavy loss to the industry.

Objective of the Study

1. To propose guidelines for agro-industry management by providing preferably optimal project plan during the planning stage;
2. To pinpoint critical areas before the start of a project which might cause delay in project completion time;
3. To determine the probability of scheduled completion of the project in the planning stage;
4. To recognize a more realistic system of estimating the project completion time and allocation of resources to various activities and alternatives;
5. To provide a basis for evaluation and control of activity progress during the execution of the project; and
6. By using network technique, and a review of the critical path to decide whether a project should be started or not.

Case Study

The United Agro-Engineers, Circular Road, Daska manufacture tractor front-mounted reapers and threshers. The study was restricted to reaper manufacturing only.

The firm had to supply 200 units of tractor front-mounted reaper before the start of wheat harvesting season. As the firm also manufacture threshers the reaper project must start in January and had to be completed by the end of March for timely delivery or a scheduled completion time of 90 days.

Network Technique

Network approach is an advanced technique of planning and schedul-

ing of project[1]. It is very useful, especially during the planning stage, in identifying the important activities which might cause delay to the project completion time.

The process of network analysis for manufacturing involves breaking down the manufacturing or fabrication work into activities and arranging them according to their precedence relations forming into a network.

The most important network techniques are classified into deterministic procedure designated as critical path method (CPM), or probabilistic procedures designated programme evaluation and review technique (PERT).

The PERT technique was used to pinpoint critical areas in the project so that necessary adjustments can be made in order to meet the scheduled completion date of the project.

Developing Network Model Using PERT Method

The project was composed of a series of activities directed to the accomplishment of the desired objectives. For the purpose of developing a network model, each activity in the project was assumed to be defined by two events, the start of activity and the completion of the activity.

The physical nature of the manufacturing project constrained the execution of activities to some specified order which gave rise to the precedence and succession relationships between the events and the activities. The principal relationships are:

1. The start event of an activity precedes the end event for the same activity by a time duration.
2. The start event of an activity succeeds events for all activities proceeding it.
3. The event project start precedes all activities and events in the project.
4. The event project end succeeds all events and activities in the project.

PERT Analysis

The first phase of any PERT analysis is to identify the subproject or tasks which must be accomplished before the completion of overall project[2]. Each task, which is called an activity, requires time and resources. It represent work that must be done. Resources might be personnel, money, materials, facilities and /or space.

Time Estimates for Activities

Time estimates for each activity in a PERT network must be supplied before the network becomes a useful planning and co-ordinating tool[3]. Three time estimates are:

i. Optimistic time(to). Shortest possible time estimate if every thing goes under ideal condition. No provision for delays and set-backs.
ii. Pessimistic time(tp). Estimate of maximum possible time it could take to accomplish the job. If everything went wrong and abnormal situation prevailed.
iii. Most likely time ($t\ell$). Estimate which lies between the optimistic and pessimistic time estimaties. It assumes that things go in normal way with a few set-backs.

Expected Time or Average Time (tE)

Based on the three estimates to, tp and tl the expected completion time for each activity was estimated as:

$$tE = \frac{1}{6}\,to + \frac{2}{3}\,t\ell + \frac{1}{6}\,tp$$

$$tE = \frac{to + 4t\ell + tp}{6}$$

Like-wise, the variance of the completion time of each activity was estimated to be

$$\partial^2 = \frac{(tp - to)^2}{(6)}$$

$$\text{Standard deviation } \partial = \frac{tp - to}{6}$$

Earliest Expected Completion Time of Event (TE)

This refers to the time when an event can be expected. It is computed by adding the expected time TE,s of the activity path leading to the event (forward pass).

$$TE(J) = \max TE(i) + TE(ij)$$

Where:

TE(J) = earliest expected completion time of even J.

TE(i, j) = expected completion time of activity (i, j).

Latest Allowable Event Completion Time (TL)

The latest time by which an event must occur to keep the project on schedule.

$$TL(i) = \min\,(TL(J) - TE(i, j))$$

Where:

TL(i) = latest allowable event completion time of event i.

Event Slack Times (SE)

The event slack time SE for each event is the amount of time the event can be delayed without affecting the scheduled completion time for the project.

$$SE(J) = TL(J) - TE(J)$$

Event that have "small" slack times are considered to be "critical".

Critical Path

The longest path through a PERT network is referred to as the critical path. The critical path is obtained from the activities having zero slack.

Annexure I Reaper Manufacturing

Activity Name	Code	Predecessor	to (Days)	tl (Days)	tp (Days)
List of material	A	–	0.5	1.0	1.5
Estimate cost of material	B	A	0.5	1.0	1.5
Purchase of material	C	B	1.0	2.0	3.0
Delivery of material	D	A	2.0	3.0	4.0
Receive of material	E	C, D	0.5	1.5	2.5
Start casting work	F	E	0.5	1.5	2.5
Start cutting of material	G	E	1.0	2.0	3.0
Casting of stationary guards and parts	H	F	1.0	2.0	3.0
Casting of star-wheel and parts	I	H	1.0	2.0	3.0
Casting of conveyor pulleys	J	F	0.5	1.5	2.5
Casting of V-belt pulleys	K	J	1.0	2.0	3.0
Casting of bearing housing	L	I, K	1.0	2.0	3.0
Casting of cutter (knife)	M	H	0.75	1.75	2.75
Casting of gear box and its parts	N	I, K	1.0	2.0	3.0
Fabrication of main frame parts	O	G	4.0	5.0	6.0
Fabrication of header parts	P	G	1.0	2.0	3.0
Fabrication of header shields	Q	R	0.5	1.5	2.5
Fabrication of front crop support shield	R	P	0.5	1.5	2.5
Fabrication of deflector and discharge plates	S	P	0.5	1.5	2.5
Fabrication of conveyor lugs	T	P	1.0	2.0	3.0
Fabrication of belt tensioner parts	U	Z	2.0	3.0	4.0
Fabrication of skid parts	V	G	1.5	2.5	3.5
Fabrication of Conveyor shafts	W	V	1.0	2.0	3.0
Fabrication of reaper drive shafts	X	O	1.0	2.0	3.0
Fabrication of main drive shafts	Y	AA	2.0	3.0	4.0
Fabrication of connecting rod and parts	Z	X	1.0	2.0	3.0
Fabrication of drive lever and pin	AA	U	1.5	2.5	3.5
Fabrication of gear box supports	AC	AB	0.5	1.5	2.5
Fabrication of cutter bar	AB	W	0.5	1.5	2.5
Fabrication of star-wheel cups and pins	AD	Q, S	0.5	1.5	2.5
Fabrication of pressure spring	AE	AD, T, R	1.0	2.0	3.0
Fabrication and casting of U-joint and parts	AF	L, M	1.0	2.0	3.0
Fabrication of tractor rear plate parts	AG	AE, AF, Y, AC, N	1.0	2.0	3.0
Fabrication of tractor front plate parts	AH	AG, AN	0.5	1.5	2.5
Fabrication of mounting or hitching links parts	AI	AK, BD	0.75	1.65	2.75
Fabrication of lower and lifting links parts	AJ	AH	0.75	1.75	2.75
Fabrication of steel rope and parts	AK	AJ, AL	0.75	1.75	2.75
Fabrication of steel rope sliding pulleys and support	AL	AN, AG	1.0	2.0	3.0
Fabrication and cutting of conveyor belts	AM	AF, AC, Y, N, AE	0.75	1.75	2.75
Fabrication and cutting of material for gears	AN	AF, AC, Y, N, AE	1.0	2.0	3.0
Finish and making of bevel gears	AO	AN	4.0	5.0	6.0
Finish work of star-wheel and parts	AP	AQ	2.0	3.0	4.0
Finish work of stationary guards and parts	AQ	AO	2.5	3.5	4.5
Finish work of conveyor pulleys	AR	AP	2.0	3.0	4.0
Finish work of V-belt pulleys	AS	AU	1.0	2.0	3.0
Finish work of gear box and parts	AT	AO	1.0	2.0	3.0
Finish work of bearing housing	AU	AT	1.0	2.0	3.0
Finish work of U-joint and parts	AV	AR	2.5	3.5	4.5
Finish work of reaper drive shaft	AW	AX, AB	0.75	1.75	2.75
Finish work of conveyor drive shaft	AX	AV, AS, AI, BF	1.5	2.5	3.5
Finish work of main frame parts	AY	AO	1.0	2.0	3.0
Finish work of header parts	AZ	AY	0.5	1.5	2.5
Finish work of header shield	BA	AZ	0.5	1.0	1.5
Finish work of belt lugs	BC	AZ	0.5	1.5	2.5
Finish work of main drive shaft	BD	AU	1.0	2.0	3.0
Finish work of hitching and mounting parts	BE	BD, AK, AL	0.5	1.5	2.5
Finish work of lower and lifting parts	BF	BE	0.5	1.5	2.5
Assembling of main frame sub-assemblies	BG	AX, BA	2.0	3.0	4.0
Assembling of guard sub-assembly	BH	BG, BC, AW	2.5	3.5	4.5
Assembling of header shield sub-assembly	BI	BG, BC, AW	1.0	2.0	3.0
Assembling of front crop shield sub-assembly	BJ	BI	1.0	2.0	3.0
Assembling of bolt tensioner sub-assembly	BK	BX	0.5	1.5	2.5
Assembling of star-wheel sub-assembly	BL	BK	0.5	1.5	2.5
Assembling of conveyor pulleys	BM	BV	0.5	1.0	1.5
Assembling of conveyor shaft	BN	BO	0.5	1.0	1.5
Assembling of pressure spring	BO	BV	0.5	1.0	1.5
Assembling of U-joints	BP	BU, BL, BM, BN	0.75	1.75	2.75
Assembling of discharge and deflecting plates	BQ	BJ	0.5	1.0	1.5
Fixation of lugs on conveyor belt	BR	BW	1.5	2.5	3.5
Fixation of knife on cutter bar	BS	BW	1.0	2.0	3.0
Assembly of connecting rod	BT	BR	1.0	2.0	3.0
Assembly of drive lever and pin	BU	BQ, BT	1.5	2.5	3.5
Assembly of reaper drive shaft	BV	BK	1.0	2.0	3.0
Assembly of gears and gear box	BW	BS	2.5	3.5	4.5
Assembly of skid sub-assembly	BX	BG, BC, AW	1.0	2.0	3.0
Assembling of tractor main drive shaft and other reaper attachment	BY	BU, BM, BL, BN	1.0	2.0	3.0
Build reaper main frame sub-assembly	BZ	BU, BM, BL, BN	3.5	4.5	5.5
Build reaper hitching and mounting assembly	CA	BY, BZ	1.5	2.5	3.5
Build reaper drive sub-assembly	CB	CD	2.5	3.5	4.5
Build reaper cutter bar sub assembly	CC	BP, BZ	2.0	3.0	4.0
Build reaper conveyor sub-assembly	CD	BZ	2.5	3.5	4.5
Pre-inspection of sub-assemblies	CE	CA	0.5	1.0	1.5
Final assembly of reaper	CF	CB, CC, CE	2.0	3.0	4.0
Final inspection	CG	CE, CB, CC	0.5	1.0	1.5
Pretesting	CH	CG, CF	2.0	3.0	4.0
Painting of reapers	CI	CH	1.0	2.0	3.0
Painting of reaper accessories, hitching and mounting parts	CJ	CA	0.5	1.0	1.5
Industry trade mark	CK	CI	0.5	1.5	2.5
Delivery to warehouse	CL	CK, CJ	0.5	1.0	1.5

Annexure-II Activities along Critical Path

Activity	Code	TE (days)	to (days)	tp (days)	$\delta^2 (\frac{tp-to^2}{6})$
0 – 1	A	1.0	0.5	1.5	0.0277
1 – 3	D	4.0	2.0	4.0	0.1111
3 – 4	E	5.5	0.5	2.5	0.1111
4 – 5	G	7.5	1.0	3.0	0.1111
5 – 12	O	12.5	4.0	6.0	0.1111
12 – 19	X	14.5	1.0	3.0	0.1111
19 – 20	Z	16.5	1.0	3.0	0.1111
20 – 21	U	19.5	2.0	4.0	0.1111
21 – 22	AA	22.0	1.5	3.5	0.1111
22 – 23	Y	25.0	2.0	4.0	0.1111
23 – 24	AN	27.0	1.0	3.0	0.1111
24 – 28	AO	32.0	4.0	6.0	0.1111
28 – 38	AQ	35.5	2.5	4.5	0.1111
35 – 36	AP	38.5	2.0	4.0	0.1111
36 – 37	AR	41.5	2.0	4.0	0.1111
37 – 38	AV	44.0	2.5	4.5	0.1111
38 – 39	AX	46.5	1.5	3.5	0.1111
39 – 41	BG	49.5	2.0	4.0	0.1111
41 – 43	BH	53.0	2.5	4.5	0.1111
43 – 48	BS	55.0	1.0	3.0	0.1111
48 – 50	BR	61.0	1.5	3.5	0.1111
50 – 52	BT	63.0	1.0	3.0	0.1111
52 – 53	BU	65.5	1.5	3.5	0.1111
53 – 54	BZ	70.0	3.5	5.5	0.1111
54 – 58	D	73.5	2.5	4.5	0.1111
58 – 59	CB	77.0	2.5	4.5	0.1111
59 – 61	CF	80.0	2.0	4.0	0.1111
61 – 62	CH	83.0	2.0	4.0	0.1111
62 – 63	CI	85.0	1.0	3.0	0.1111
63 – 65	CL	87.5	0.5	1.5	0.277

TE = 87.5 days; δ^2 = 3.3884; $\delta = \sqrt{3.3884}$; δ = 1.84

Project scheduled completion time = ts = 90 days; Project expected completion time = TE = 87.5 days; Normal deviate =(Ts−TE)/δ =(90 − 87.5)/ 1.84 = +1.35; From normal distribution function table, probability = 90.33%; Thus project completion probability within schedule time = 90%

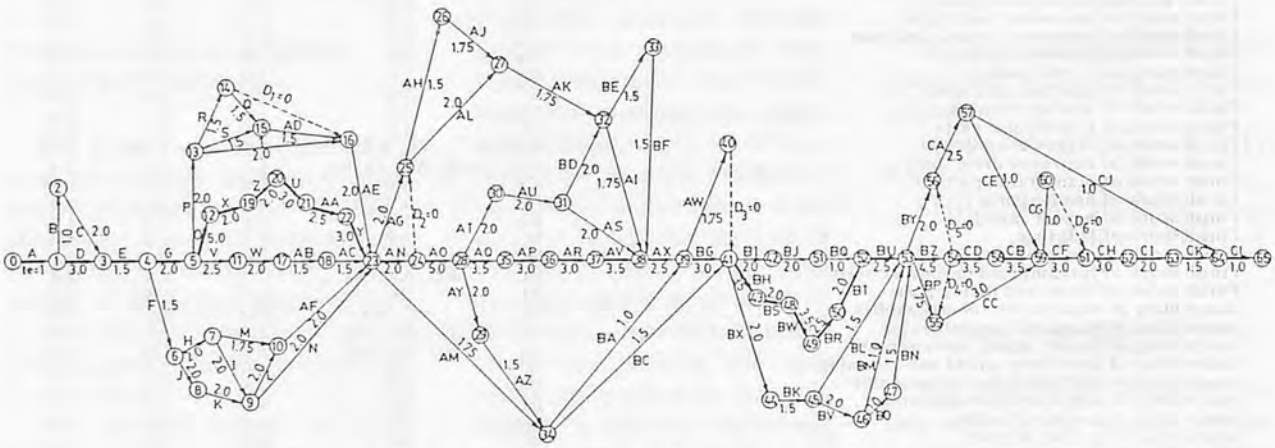

Fig. 1 Reaper manufacturing network with critical path.

Probability of Meeting the Scheduled Time

Normal deviate = scheduled time (TS) – Earliest expected time (TE)/$\sqrt{\text{sum of variance}}$

Probability of project completion is determined from normal curve table corresponding to normal deviate.

Methodology

For network analysis the reaper manufacturing project was broken down into various main components as shown in diagram (Fig. 1). Only the main parts of reaper manufacturing were considered and about 90 activities were used in network analysis.

The three time estimates to each activity are assigned according to information available about the particular agro-industry.

By applying the PERT network technique:

1. The network of reaper manufacturing project was constructed.
2. Then by using three time estimate the expected time tE was calculated.
3. Then calculated the TE.
4. Then calculated the TL.
5. Determined the slack SE.
6. Through events having zero

slack, critical path was constructed.

7. Then knowing the project schedule completion time TS; i.e. 90 days and TE, i.e., earliest completion of event and variance, the normal deviation was calculated. Then from normal distribution curve the probability of scheduled completion of project was determined.

Results and Discussion

1. The complete network alongwith critical path and marked activities duration are shown in diagram (1).
2. The longest and the earliest completion time TE along critical path was found to be 87.5 days which is less than the scheduled completion date of the reaper manufacturing project.
3. Following the critical path the probability of the scheduled completion of the project was about 90% from the normal distribution curve table.
4. As the probability of the completion of project is sufficiently high so the work should start on this project.
5. With network approach, if during planning the probability is less than acceptable range i.e. below 40% then work should not be started and critical path should be reviewed with suitable time allocation to activities.
6. The good experience of the manager play, an important role in estimating the activity time and ultimately to achieved desired objective.
7. The process of network analysis can be repeated until the manager is convinced of the feasibility of the project schedule.
8. With this technique during the development phase, the progress of any activity or performance can be evaluated.

Advantages

1. The netowrk concepts are easy to understand and apply for the planning and control of a even large-scale project.
2. It introduces objectivity in planning and control.
3. The network approach reduces the complexity of the planning process by breaking the project into individual component activities.
4. During the planning stage, the approach provides the optimal project plan.
5. During the execution phase of a project this approach provides a good basis for evaluation and control of activity progress against the plan.

Disadvantages

In spite of many advantages of the network technique, the main disadvantage is that the construction of network diagram becomes a major problem for more complex process.

Recommendations

1. The technique should be applied to all manufacturing projects in their planning stage.
2. This approach can be successfully applied to help the agro-industry with respect to;
   i. decision making for maximizing profit, and
   ii. meet the schedule.

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

Criteria for Article Selection

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

a. are written in the English language ;
b. are relevant to the promotion of agricultural mechanization, particularly for the developing countries ;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission ;
d. deal with practical and adoptable innovations by small farmers with a minimum of complicated formulas, theories and schematic diagrams ;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article ;
f. are typewritten, double-spaced, about 4,000 words (approximately equivalent to 8 pages of AMA-size paper) ; and those that
g. are supported by authentic sources, reference or bibliography.

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a. As a rule, articles that are not chosen for AMA publication are not returned unless the writer(s) asks for their return and are covered with adequate postage stamps. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
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   ii) the writer(s) name, designation/title, office/organization ; and mailing address ;
   iii) an abstract following ii) above ;
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   v) conclusion/recommendation ; and a
   vi) bibliography
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d. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
e. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
f. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
g. Convert national currencies in US dollars and use the later consistently.
h. Round off numbers, if possible, to one or two decimal units, e.g., 45.5kg/ha instead of 45.4762kg/ha.
i. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers . . . , or Five tractors . . ." instead of 45 workers . . , or, 5 tractors.

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Prof. Gajendra Singh was appointed as Vice President for Academic Affairs, Asian Institute of Technology, Bangkok/Thailand

Prof. Singh first joined AIT as an Assistant Professor of Agricultural Engineering in June 1975. In January 1978, he was promoted to Associate Professor and in April 1984 to Full Professor. During August 1979 to June 1984, he also served as chairman of the Division of Agricultural & Food Engineering. Having served on the faculty of Cook College, Rutgers University, New Jersey, U.S.A., from November 1984 to July 1986, Prof. Singh resumed his duties as Professor of Agricultural Engineering on July 23, 1986. On September 8, 1986 he was appointed as Vice President for Academic Affairs.

His main fields of research are agricultural mechanization in Asian countries, energy in agriculture, machinery selection and management, design of appropriate farm machines, and application of systems techniques to agricultural production systems. He has published many papers on these topics in international journals and has presented his work at various international conferences. He is a co-operating editor of the Agricultural Mechanization in Asia, Africa and Latin America (AMA) Journal.

The 9th International ISTVS Conference

Aug. 31-Sept. 4, 1987, Barcelona, Spain

The INTERNATIONAL SOCIETY FOR TERRAIN - VEHICLE SYSTEMS has as principal objective to promote progress of research and development in land locomotion. This wide field concerns several different branches such as agriculture, forestry, transportation, construction, earth-moving and the military. It covers different disciplines -soil and terrain properties, soil-vehicle interaction, vehicle and machinery design, ergonomy, environment and transportation systems.

Every three years an international state-of-the Art conference is arranged.

The 9th International ISTVS Conference-Barcelona, August 31st - September 4th 1987 will be hosted by the Government of Spain, the Government of the province of Catalonia and the City of Barcelona.

Theme: Terramechanics, Mobility and Non-Conventional Vehicles.

Topics: The papers submitted will be grouped under the following topics which will treat applications, measuring, testing as well as analytical methods:

- Terrain evaluation.–Morphology. soil, snow, ice and frost.
- Soil-vehicle interaction. Tyres and tracks.
- Vehicle dynamics. Steering.
- Vehicle and machinery design. Implements.
- Non Conventional guided transportation systems.– (Tyres on concrete, Tyres on steel, Air cushion support. Magnetic levitation support).

For further information contact:
D. Julio Pinto Silva
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Madrid, Spain

AGROTEC'87, The 4th International Fair for the Agricultural and Livestock Industries

November 20-29, 1987, Lima/Peru

AGROTEC'86, held from 23rd to 30th November last, has reconfirmed the need to continue boosting development of the agricultural and livestock sector, and has permitted Government authorities to renew the granting of priority to this important sector of the Peruvian economy, considering it to be in the national interest. There is still much to be done to revitalise the sector, and we will continue to give it all the impulse necessary to reach its objectives.

We have therefore decided to hold the 4th International Fair for the Agricultural and Livestock Industries AGROTEC'87 as a specialised event within the framework of the XVII PACIFIC INTERNATIONAL TRADE FAIR (November 20 – 29, 1987).

Simultaneously, the 2nd National Exposition of Cattle will be held, as also a programme of congress, lectures and technical talks related to the sectors mentioned.

For further information contact:
Ragfael Talavera
International Promotions Manager
Pacific International Trade Fair
Apartado (P.B.O.): 4900
Lima, Peru

NEWS

SIMA'87
March 8-15, 1987, Paris/France

The 8th International Exhibition of Farm Machinery (SIMA) was held in Paris.

With a wide choice of equipment: under 2 300 trademarks originating from 30 countries, almost 20 000 machines and items of equipment are exhibited covering all types of use, all requirements for all countries.

The total number of the visitors amounted to more than 900 000 people.

This year's medal-winning machines (four gold, four silver and thirteen noteworthy) were selected by the Committee to Encourage Technical Research.

Gold Medal Winning Machines at 58th SIMA appear on the next page.

The Verona FIERAGRICOLE Fair
March 8-12, 1987, Verona/Italy

The Verona FIERAGRICOLA Fair was established in 1898. It is held for 8 days in March and so far about 500 000 visitors from all over the world have inspected the latest developments in all aspects of agriculture and livestock rearing.

The fact that the Fair takes place in the "heartland" of one of the world's most noteworthy agricultural areas, namely the Po valley in Northern Italy, where highly mechanized modern agricultural methods give one of the best yields per hectare in the world, gives this enormous display of machines and products from all the major production areas in Europe and elsewhere its character of authentic world showcase for the agriculture of the Mediterranean basin.

It has 300 000 m^2 of stands and more than 2 000 exhibitos, including all the "household" names from Italy and abroad.

The Verona FIERAGRICOLA Fair is an ideal meeting place for growers and producers. Here they can obtain a full and up-to-date picture of both present and future

agricultural trends.

The Trade Sections

- Farming foodstuff products;
- Seeds, nursery, flower growing and greenhouse goods;
- Prefabricated products for rural buildings;
- Machines and tools for working terrain, including fertilization, seeding, plant cultivation and protection, harvesting, primary processing, grading and preserving farm products, machinery for lifting and transporting loads;
- Materials and products for livestock breeding establishments, livestock, poultry and rabbit breeding systems;
- Feeds, additives, veterinary products;
- International cattle sheep, goat and swine markets. ■■

NEW PRODUCTS

No. 1 GOLD MEDAL at 58 SIMA
Electronic Transmission Controller

Designed for a new tractor range, that system contributes to:

- Improve Safety
  - Differential lock disengages above 14 km/h.
  - Front wheel drive engages automatically when braking.
  - PTO remains always stopped at engine start-up.
  - PTO does not engage if implement shaft is locked.
  - PTO disengages in case of a 20% overspeed if Economy PTO is engaged.
- Decrease Dead Times.
  - By automatic control of front wheel drive and differential lock (linked to hitch commands and/or braking).
  - By controlled engagement of PTO.

Sté Massy Ferguson – Avenue Blaise Pascal–BP 307-60026 Beauvais Cedex

No. 2 GOLD MEDAL at 58 SIMA
Large-Surface Fertilizer Distributer

Extracted from the hopper and measured out by a lugged dosing cylinder, the granules of fertilizer, distributed by the DR 612 pass between two cylinders turning at great speed. Redirected by a de-

flector and caught between the upper cylinder and a speeding-up cylinder, they form a sheet projected perpendicularly forward and upward, making an angle of 15 degrees with the horizontal.

This sheet of fertilizer is divided into multiple equal parts, each following a very precise orientation so that the large surface desired will be covered uniformly.

In this way we can spread different types of fertilizer over 24 metres or more, with spreading curves analogous to those of pneumatic distributors, without being obliged to use large-size ramps.

Sté Nodet Gougis – 5, bd du Général Leclerk–77130, Montreau

No. 3 GOLD MEDAL at 58 SIMA
"Low-Frequency" Cabin Suspension

Four combined helical shock-absorbing springs provide a large-clearance connection between the cabin and the front and back mounts, fixed to the tractor. Two longitudinal bars and two transversal bars guide the cabin in the course of its movements. A stabilizing bar limits by its torsion the rolling movements. Elastic pins and bearings are placed between the principal parts.

In comparison with the "high-frequency" connections that normally equip tractors, this kind of suspension reduced the frequency of resonance of the suspended parts. It improves the comfort for works done at equal speeds. The fatigue-limit is pushed back by nearly 50%. With the same working comfort the execution of works can be speeded up by between 20 and 30%.

Renault Agriculture – 7, rue Dewoitine–BP92–78141 Vélizy Vellacoublay Cedex

No. 4 GOLD MEDAL at 58 SIMA
Standing Cereal Sheller

This cereal (corn, rice) harvester does not cut the straws; the thresher is positioned at the same height as the ears or the paniclels to carry out the shelling.

In front the supplying prongs isolate the strip of cereals to be threshed, lift up the drooping straws when necessary and present them to the threshing chamber. The upper part of the straws meet a longitudinal spiralled thresher (parallel with the movement of the device). The seeds torn from the straws pass through a perforated counter-thresher and then are packed into sacks.

The harvesting head whose height is adjustable is fixed on a motorized chassis with three wheels equipped with low-pressure tires. The back wheels can be equipped with cage wheels.

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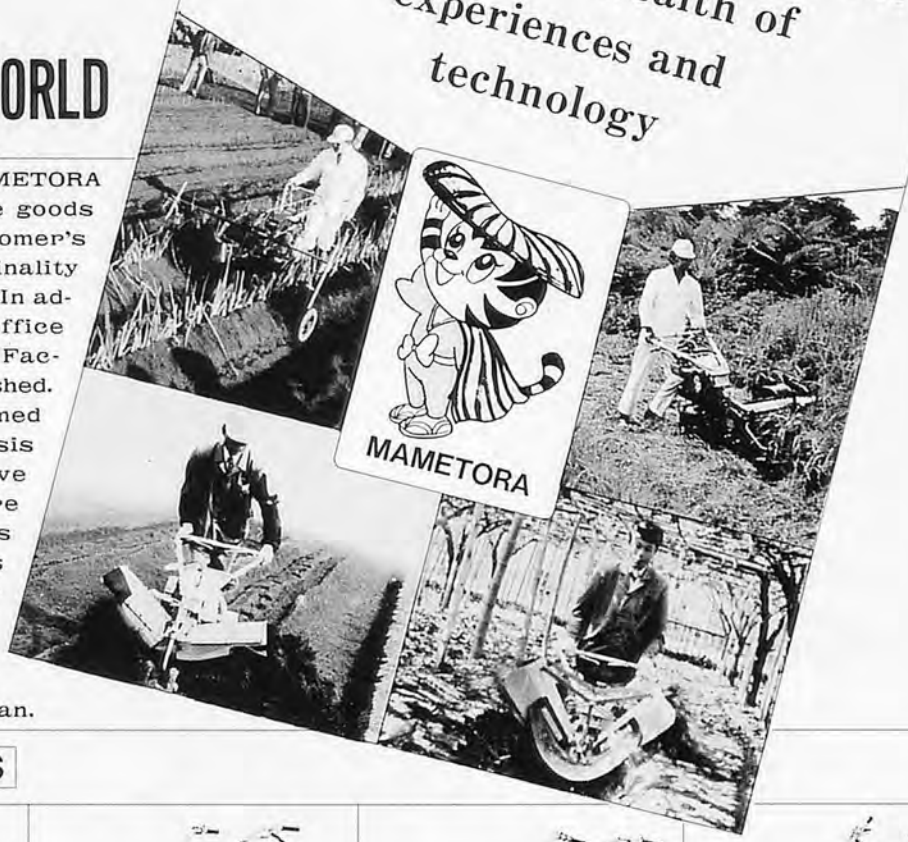

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