THE DEVELOPMENT AND EVALUATION OF SMALL SCALE THRESHING AND CLEANING MECHANISMS FOR GRAIN LEGUMES.

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I, AMIN MOHAMEDALI ALARAKHIA, DECLARE THAT THIS THESIS HAS NOT BEEN SUBMITTED FOR A DEGREE IN ANY OTHER UNIVERSITY

AMIN MOHAMEDALI ALARAKHIA

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AN ABSTRACT OF THE THESIS

A need was felt to develop locally small scale threshing and cleaning machinery especially in view of the recent orientation towards commercialization of the small scale farming in East Africa. Moreover, the recent drive to increase the cultivation of grain legumes in East Africa provided a stimulus to develop the required machinery for grain legumes.

The study was, therefore, undertaken with a view to look for appropriate mechanisms and to establish operational parameters for the threshing and cleaning of grain legumes using soyabeans as a testing crop. A basic objective was that the equipment should be hand operated.

Work on threshing was divided into two phases. During the first phase, a novel mechanism called the 'Peristaltic' was fabricated locally and then its performance was assessed in comparison with the rasp bar mechanism. Output potential, threshing efficiency and grain damage were assessed at varying revolving speeds of the mechanisms and crop m.c. Most of the second phase consisted of a series of obser-

vations on the toothpeg mechanism to ascertain its suitability and to work out its optimum operational parameters for threshing soyabeans.

The 'peristaltic' mechanism did not prove to be a suitable mechanism for the purpose in view. Its main draw backs were its inability to thresh a crop above 23-25 per cent moisture content and overall high scutcher peripheral speeds required for efficient threshing and high output. Moreover, its construction requirements did not lend themselves very well for local manufacturing.

Both versions of cylinder/concave mechanism, namely the rasp bar and the toothpeg, which were evaluated proved to be suitable for threshing grain legumes. However, the toothpeg appeared to have a marginal advantage over the rasp bar because of its ability to thresh high moisture content crop and to strip groundnut shells from their haulms - a process reputed to be labour demanding when done manually. As a result, the study on the toothpeg was extended to cover the collection of basic operational parameters for designing a toothpeg type of threshing machine.

The study also brought out into light that it may not be very convenient to hand operate these machanisms, largely because of the high amount of energy demanded for rotating them. This was in agreement with a similar type of work undertaken elsewhere. Thus, it is recommended that the machine be power motivated. This machine can then be economically and efficiently operated on hire basis either by a private contractor or a co-operative venture to spread its high initial cost over a large annual produce use. Its likely output can be envisaged within the range of 90-120 kgs/hr. of grain.

Work on cleaning and grading aspects received little attention apart from constructing locally the Universal Cleaner for collecting some basic operational parameters involved in cleaning and grading of the threshed material. This aspect of the study was not pursued in great depth as it was soon realised that a table or stationery screen attached to the thresher and relative simple operations of picking the haulms, would on the whole be adequate, provided that a suitable winnower like the N.I.A.E. winnower could be made available.

The conclusions drawn from the study are summarised in the final chapter. Some tentative recommendations for fabricating a toothpeg type of machine are also suggested in the same chapter.

INTRODUCTION

CHAPTER 1

1:1 Need for Small Scale Processing Machinery

Mechanization of 'barn yard' processes appears to have been somewhat of a neglected branch of Agricultural engineering in East Africa. This is especially true of a subject like threshing, cleaning and grading of crops. The effect of this negligence is very evident at the peasant level of farming where absence of simple but efficient post harvesting machinery is conspicous. Lack of interest in the development of machinery at the local level partly stems from the fact that where cereal crops are cultivated on a commercial scale in East Africa, the machinery imported from overseas has performed well to the satisfaction of the local farmers and the attitude persists that only large scale commercial production justifies the use of special threshing machinery.

A look into the basic economy of three East African countries reveals their heavy reliance on the Agricultural sector both for gross domestic product and for earning foreign exchange (Livingstone et al, 1968). The majority of the population occupies the land, at subsistance or semi-commercial level. The average farm size varies from 2-10 hectares. As a group, farmers with this amount of land have potential to support an intermediate level of mechanization, - although scope for individuals is very much limited due to lack of a cash motive or objective in the farming.

Most processing machines which are popular in the temperate areas, such as combine harvesters, or cotton and corn pickers are a combination of machines which perform a series of operations and require high power to operate. Factors such as cheap manual labour, small land holdings, low crop yields, shortage of power and lack of capital seldom justify the use of similar machines in the tropics. No doubt, in the long run, the more economical larger equipment will play an increasingly important role in the mechanization of tropical agriculture. Meanwhile, the requirement of the medium sized African holdings, which are too large to work economically with manual or animal labour, but too small for the sophisticated equipment, require immediate attention from engineers.

Owing to unavailability of suitable equipment, peasant farmers in East Africa largely rely on primitive methods of threshing. Threshing is done by spreading the ripe crop on a bare piece of hard ground where it is beaten with sticks. (see plate No. 1). In some parts of Ethiopia and Tanzania, the hooves of animals are used to trample on the crop (Kline et al, 1969). (see plate No. 3). Reports suggest that the improved Chinese flail beating method is not commonly seen in East Africa (Kline et al, 1969). When the threshing is presumed to be over, forks and such other implements are used to toss the grain and sort out straw/chaffe from the rest of the material. (see plate No. 2). Cleaning is then accomplished by giving a light and continuous movement to a grain filled basket held chest high to let the grain drop and the chaffe is blown away by wind. In the absence of wind work has to be temporarily abandoned. Grading of seeds has not yet entered prominence in the farming scene of the peasant. He prefers to sell the whole lot as it is.

Though these methods outwardly seem to be cheap and simple, it is repeatedly stated in literature that they are wasteful in that they inevitably cause considerable grain loss and damage. (Abousabe, 1959 and the International Rice Research Institute Technical paper No. 2, 1966), besides being slow and cumbersome. In Malaya, local farmers agreed

PLATE NO. 1

THRESHING BEANS BY BEATING WITH STICKS IN UGANDA.

PLATE NO. 2

WIND WINNOWING AND GRADING

PLATE NO. 3

THRESHING BY DRIVING CATTLE

OVER THE LOOSENED BUNDLES OF GRAIN

that with machine threshing about 5-10 per cent more grain was obtained as compared with hand threshing (Marsden, 1959). In Uganda, where most farmers do not possess a concrete threshing floor, resultant threshed material is reported to be contaminated with foreign material such as small stones and dust particles (Harrison, pers comm. 1969). Such a product when offered in the market fetches a lower price and if specifically required for human consumption needs recleaning at the processing plant.

According to reports, small holders in Asia and Middle East do not solely rely on these completely manual threshing/cleaning methods. During the evolution of farming in their respective countries they have evolved certain hand-powered or animal assisted threshing units, example being the animal drawn Olpad disc thresher in Asia (Agrawal, 1951), or the Norag disc thresher in Near East (Hopfen, 1960), or pedal operated drum thresher for paddy in Japan and the Far East (Seiichi Tobata, 1958).

Whilst his opposite number in the Middle East and Asia has some mechanical aids for preparing his crop for the market, very little appears to have been done to help the small holder in Africa to carry out these operations. Though in recent years, some attempts have been made to develop mechanical aids at local level. The outstanding among them being the successful shelling of dry groundnuts by worn out grinding plates in Ghana (Agr. and Hort. Eng. Abstract, 1956) and the successful development of a hand groundnut sheller made up of old vehicle rims and concrete by volunteers in Sierra Leone(Krusch,-).Where animal power is not available, simple, improved hand operated threshers could greatly increase the productivity of men performing the task. On a strictly subsistence level, the high manpower requirements have not been important, but they are of major concern to the emerging market orientated farmer who has other priorities in which he could use his energy and time profitably.

As the costs of labour and buying oxen go up there is a greater advantage in more modern methods. Likewise, as new, higher yielding varieties are introduced, as more agricultural inputs are employed to intensify production, and as cropping areas are expanded, the greater is the comparative advantage of mechanical power and machine assisted methods. Better farming practices mean higher yields and in turn mean more to thresh, as an example, in East Africa, farmers complain that the new higher yielding varieties of wheat take 40 to 60% longer to thresh than the traditional varieties

(Kline et al, 1969).

Whether, machinery so developed should be engine powered or hand motivated, appears to be an open issue. Two distinct trains of thoughts seem to occupy minds of Agricultural Engineers. Khan (1962) strongly recommends development of engine powered machinery at local level. In contrast Gordon (1967) firmly believes that there is wide scope for improvement of existing farm implements and introduction of hand powered machinery at intermediate levels. Allen (196 suggests that before the farmer is introduced to engine powered machinery, it should be a wise step forward if he were first introduced to improved hand operated machinery. Moreover, labour in the tropical zone of Africa is generally underemployed except for seasonal peak demands. Many basic farm operations can still be done economically by improved hand-powered implements.

However, recent trends indicate that small scale development is increasingly leaning towards engine powered machinery (Dept. of Agriculture India, 1967. Saxena et al, 1970). In particular, mechanisation of small rice fields in the Far East, and on the Indian sub-continent seems to have attracted attention of many agricultural Engineers (Khan, 1970).

According to Harrington (1970), in India, the number of small holders buying this sort of machinery is on the increase. However, the other side of the coin reveals that there have been successful hand operated threshing machines for crops like maize and groundnuts (Munobwa, 1968).

The whole issue is well summed up in the United Nations study No. 67, in the following words.

"Agricultural evolution seems to suggest that at every new stage there came into existence the need for new kind of technology. At the same time older ones continued to develop. Agricultural production methods are elastic by nature, therefore, the same product can be produced in a number of different systems. The mechanisation of agriculture will, therefore, not render man powered methods superfluous; there is scope for the development of both. A critical evaluation, will show that in many cases where improved hand powered and animal powered implements are the best means to advancement for small farmers, many of whom are not in a position to benefit directly from motorization, particularly in areas lacking a well established industry".

An urgent need to look into the problems of providing small scale post-harvesting machinery for the small holder is quite evident from the above quotation. Unfortunately, the machinery developed in the Far East and India is not being introduced in East Africa as yet. Therefore, it falls on the local personnel to probe into this problem and locally develop machinery which could be fabricated at home. In addition, the long range socio-economic implications of displacing field labour by imported agricultural machines will also necessitate the development of local manufacturing industries to provide some alternate employment and create wealth for the country. A lack of acceptable agricultural machinery designs that could be produced by simple fabrication methods has hampered the growth of local machinery manufacturers.

1:2. Need For Small Scale Grain Legume Threshers And Winnowers

In as far as the cereal crops like rice and wheat are concerned, at present quite tremendous development work is being undertaken in the Far East and on the Indian sub- continent. There are a number of threshing units available on the market, being fabricated by the local manufacturers in their respective countries. (Testing reports Government of

India, 1969 and Khan, 1970). Most of these machines are based on the conventional drum/concave threshing principles. These mechanisms have been tested and perfected for cereals. It appears though that very few attempts, if any have been made to establish elementary parameters which affect threshing of grain legumes. Alternatively, if such work has been carried out somewhere, the data so collected, appears not to have been published.

It is a pity that legume crops which are more valuable from a nutritional point of view than cereals, have failed to attract the attention of machine designers. Apart from a few isolated attempts (Owen et al, 1953, Lamp et al, 1961, Bachansingh et al, 1968), to develop machinery specifically for grain legumes by and large the machinery initially designed for cereals has been adopted to thresh grain legumes (Bolen, 1969). Moreover, apart from Bachansingh et al (1968) and Lamp et al (1961), the rest of the attempts have been directed to cater either for experimental small plots or very large scale threshing. (Gunkel, 1962, Report to Readers, A.E. 1964). Bachansingh and co-worker (1968) during the course of their research have successfully developed an engine powered thresher for soyabeans, based on the rasp bar mechanism. They too appear to have directly adopted the design originally perfected for cereals and give no demonstration of having worked on basic data collection for parameters involved in crop-thresher reaction.

The podded legume crops when mature split open along both dorsal and ventral sutures. It is reported (Landarbeit, 1955) that this characteristics can be utilized to achieve a threshing efficiency of up to a hundred per cent with practically no loss through damage, if the bean crop is spread on the firm ground in a 2-3 m. wide circular strip, 30-40 cms. high and a tractor is repeatedly run over it. Once it is found that threshing is over, the straws are removed by forks, seeds together with chaffe are passed over a winnower for separating seeds from the rest of the foreign material. This method, though reported to be successful, does not show much hopes for being applicable to a small farmer, since the requirements like a firm ground and a tractor may not be readily available.

The need for developing machinery for threshing grain legumes is made more strong by the present diversification policy of the Agricultural Departments of the three East African countries. Their extension staff is actively engaged in advocating to the farmers to grow a wide range of crops on a commercial level. Crops like Soyabeans (Glycine soja) and French Beans (Phaseolus vulgaris) which are largely grown for the home consumption, are likely to have their acreages increased for commercial production, especially as these crops are able to supply the much needed protein in the local diet. The international agencies like FAO and UNICEF are very much interested in increasing the production of grain legumes in East Africa, and have already submitted their plans for the same to the three East African Governments (Stanton, 1966).

There are chances, therefore, that legumes will assume increasing importance in small scale farming. This is very true of a legume crop like soyabeans, since its protein content of 34-40 per cent is the highest among all the legumes and is relatively cheap in comparison with the meat protein (Rubaihayo, 1968). In addition, a processing plant has been put up near Kampala (Uganda), to manufacture protein rich soyabean products and a factory in Jinja has started using soyabean for manufacturing animal feeds. It is felt that these two enterprises are likely to provide a continuous outlet for soyabeans. A ready market for soyabeans means that more and more farmers will be tempted to grow this crop, and this presents an excellent case for awarding a high priority to small scale processing investigations for this crop.

1:3 Development Limitations For Small Scale Processing Machinery In East Africa.

Though there appears to be a chronic need to develop at the local level small scale post harvesting machinery, any development work undertaken for this purpose must be guided by the technical know-how of the small farmer.

Machine farming is still a young concept for the simple minded peasant farmer, who incidently, constitutes the largest segment of rural households in Uganda. Hand tools have been used for ages and are still his sole farming aids. With such a background, it is obvious that extreme caution will have to be exercised to orientate the small holder from the use of a simple hand tool to the use of mechanical aids. Any piece of machinery presented to him, ought, for that reason to be of necessity simple to use and maintain, robust, inexpensive, capable of being repaired locally and of a higher standard of efficiency than what is being replaced. Thoughtless designing and fabrication of machinery, based on advanced technology of the Western world is more likely to lead to the path of failure than success. High first costs, followed by complexity in operation, may so much bewilder the small farmer that his immediate response may not be very warm, and is likely to turn him against its use.

Improvements in traditional farming in past have come mainly from the farmer's increased manual skill in using traditional tools rather than from developing improved tools. (FAO, 1966). Chances for introducing new and more efficient, simple mechanical aids, appear to be wide open. What appears to be required in the first place is a simple piece of equipment like the "kano" groundnut sheller (see Plate No. 4), with as few moving parts as possible and preferably hand operated

Initiation of development work on Agricultural equipment has just begun in East Africa and has not gone much beyond infancy stage. For example, there are no published records of any attempts having been made to locally develop any post harvesting machinery. Consequently, any start made in this direction, will have to be right from the scratch in most cases, and perhaps, elementary in earlier stages but by no means primitive or sub-standard in its efficiency or output.

Though need exists in developing countries for local fabrication of agricultural machinery including threshers and cleaners, earlier active participation of commercial firms cannot be expected largely for the reason that the demand in the initial stages of development may not be adequate enough for a commercial firm to manufacture sale, service or distribute them. Fabrication will have largely to be carried out by either Government agencies or institutions with a very active support from the extension service. Threshers designed for small scale farming, therefore, should be simple to fabricate, in order that maximum utilisation of available equipment, manpower, and skill at the above mentioned institutions could be achieved.

1:4 Purpose Of The Present Study

Keeping in view the development characteristics and requirements mentioned in the preceding sections, work was initiated with the objective of assessing the factors affecting threshing and cleaning of grain legumes with special emphasis on soyabeans. The following pattern of investigation was adopted to fulfil the above objectives.

(a) Critical comparison of various mechanisms to establish their suitability for threshing and cleaning grain legumes.

(b) Establishment of critical design parameters for simple hand operated machines, that lend themselves to local manufacture.

(c) To establish how the predicted designs would perform in practice, when using pilot models.

PLATE NO. 4

KANO GROUNDNUT HAND SHELLER

A REVIEW OF DIFFERING APPROACHES TO THRESHING AND CLEANING

CHAPTER 2

The object of threshing is to separate the crop into grain or seed, straw, chaffe, cavings and other impurities. Threshing originally meant the simple operation of knocking grain free from the ears, but the term now embraces the processes of separating the grain or seed from its straw, and chaffe, freeing it from impurities and grading it ready for use (Culpin, 1963). Perhaps, it may be worth mentioning here, that, for the purpose of this study, the older concept of threshing i.e. simply knocking out of grains from the ears is followed. Cleaning and grading are treated as separate processes. Though harvesting procedures do not fall within the scope of this study, they are inevitably considered where found to have a significant influence on the threshing process.

During the past thirty years there has occurred a steady change in crop harvesting and processing techniques. Before 1938, for example, the final threshing of most crops was completed in the barnyard including threshing small grains, bailing hay, chopping ensilage for silos and shelling corn. New machines developed since then, however, have transferred the barnyard operations to combine them with primary harvesting processes, through the development of combine harvesters, hay balers and forage harvesters. At present, a wide range of machinery is available to suit individual farmer's requirements (Byg, 1968). This is very well illustrated by the wide range of machinery used to prepare maize (*Zea mays*) for the consumer's market. In the advanced mechanized stage of its production, the crop is mechanically harvested, and at the same time shelled, in other words, "combine harvested". These field shellers, as they are usually called, are of two-types (Park et al, 1966). They could be exclusively made for maize picking and shelling or the recent development has been to attach a maize header to the grain combine for harvesting maize. Alternatively, the crop may be picked and shelled in two separate operations; or even picked, dehusked and shelled in three operations.

In the more labour intensive systems all three operations are performed by hand labour, with shelling being the prime bottleneck.

Since the dawn of civilization, the sickle - the most ancient of harvesting tools, the scythe or modified scythe called the cradle, have been and are in use for reaping cereals. Though outmoded in advanced countries they are still seen to be in use in tropics (Kline et al, 1969).

The traditional hand harvesting methods have been evolved in accordance with climatic conditions, local customs and trades such as rope and mat making (Marsden, 1959). For example, in rice there are many variations of two basic techniques, which can be directly related to areas of low and high humidity (Marsden, 1959). Where the humidity is high the grain must be threshed immediately after reaping, presumably, to avoid biological processes, which are hastened up in a humid environment if the crop is staked in a heap for a prolonged time. The women using a small knife reap the crop, leaving it in small bundles or sheaves with the heads together. The men follow the reapers around the field threshing out sieves by swinging them over their shoulders and beating them down into a wooden tub or tong. With this method grain losses are high because of shedding and incomplete threshing. Where the humidity is lower, the paddy is carried to a central site, where it is placed in a heap and threshed out by treading usually by buffaloes or oxen. With this method incidence of damage can be high and there are also shedding losses arising from the amount of handling involved.

In Japan, Taiwan and to some extent in India rice harvesting and threshing is being quite successfully performed with windrowers, bundlers, combines and pedal threshers. (McColly, 1965). The choice of a particular mechanism depends on the size of the holding. Strohman et al (1967) report of successfully designing a small grain harvester for rice. The striking feature is that unlike conventional threshers, the motion of the head is opposed to that of the beaters.

Stone et al (1963) state that two paths of progress lead to the modern harvesters cum threshers known as grain combines. The development of implements for reaping and the development of implements for threshing.

The first bold stride towards combine mechanization was the birth of a reaper in 1830s in America. Nearly twenty years latter the first patent was issued for a reaper binder in America.

The attempts to use threshing machines to replace hand threshing began in 1730 and between 1730 and 1850, many ingenious attempts were made to develop stationery threshers (Fussell, 1952).

Information published by Case Co. of America relates the story in the following words (Stone et al, 1963).

"Small stationery threshers called 'ground hogs' were commonly used in America in 1800 (see Plate No. 5). Their spike tooth cylinder, set in a wooden frame, threshed the grain. But separating the grain from the chaffe and straw was done by hand-winnowing. Ground-hogs were usually operated by animal sweep powers or tread powers, although some were turned by hand. The next step in thresher design featured a shaker device for separating grain from straw and chaffe. This type of rig required a four men crew, consisting of a feeder, band cutter and two straw tenders".

The stationery threshing era had a life span of 200 years, lasting till 1930s when grain combines began to become popular in large scale farming. This was about hundred years after the first successful combine was put on the market in Michigan state. Stationery threshers are still in use to some extent in the U.S.A; where fields are

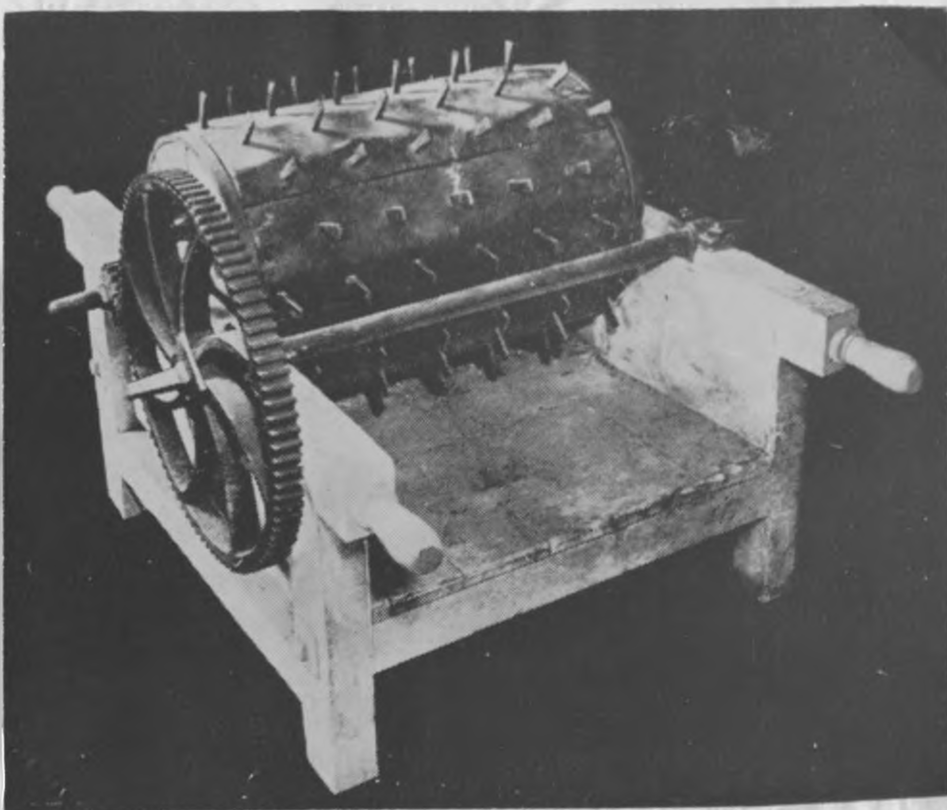


PLATE NO. 5

GROUND HOG THRESHER

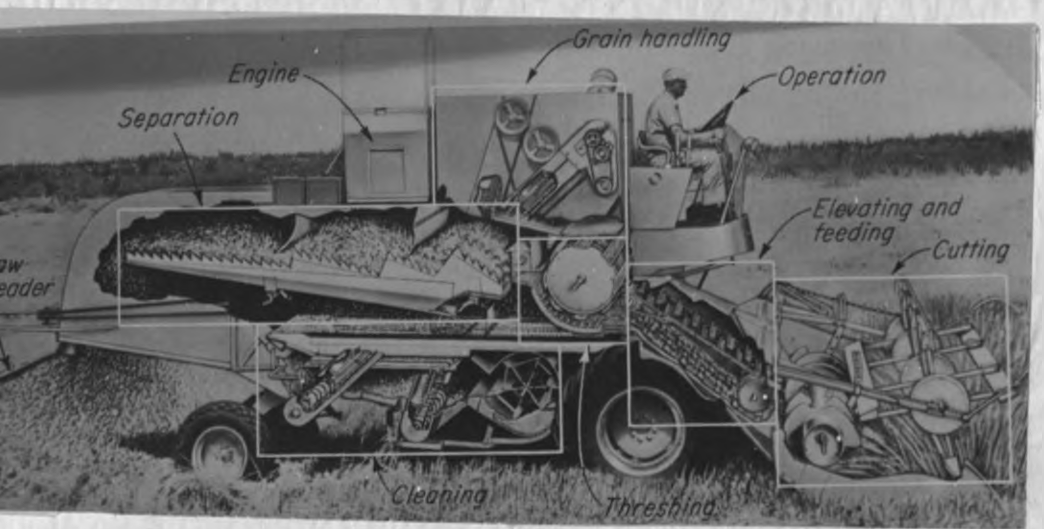


PLATE NO. 6

CROSS SECTION OF A SELF-PROPELLED COMBINE SHOWING THE FUNCTIONAL AREAS FOR CUTTING, ELEVATING AND FEEDING, THRESHING, SEPARATING, CLEANING AND GRAIN HANDLING.

small or inaccessible for even the smallest combine. In 1935, Allis Chalmers changed the old pattern and introduced into the market a one man combine harvester (Stone and Gulvin, 1963). Combines of to-day are highly sophisticated, performing varieties of tasks simultaneously, - including that of controlling feeding rate, and the height of the head-cutter by itself (Friesen, 1966; Kaminski, 1965). More and more farmers the world over are using combines now, for example in the United States in 1950, 85 to 95 per cent of the barley, wheat and soyabeans were harvested with combines (Bainer et al, 1965 - see Plate No. 6).

The hand harvesting methods are laborious. Reports from India (Saran and Ojha, 1967) state that in the long run harvesting costs by reaper are less than by sickle, but it's the initial outlay which prohibits farmers to acquire it. To overcome this prohibitive cost Saran and Ojha (1967) at the Indian Institute of Technology, Kharg-pur, India have successfully developed a simple but in-expensive hand powered grain harvester which is capable of harvesting a wide variety of crops.

Though combines have become very popular in certain parts of the world, stationery threshers are still in use in East Europe (Podlipenskii, 1960, Grone, 1961, Podlipeskii, 1963), especially chop threshing (Harris, 1959).

A study of literature on threshing mechanisms revealed that over a number of years, the agricultural engineers working in the various sectors of the world have designed and developed numerous threshing mechanisms for doing the simple job of knocking out grains from ears or pods. The working principles of some of these mechanisms, and their uses are discussed in the succeeding sections. This discussion is largely based on the literature review of the su subject.

2:1 The Cylinder/Concave Threshing Mechanisms

Of all the mechanisms used for threshing the cylinder/concave mechanisms are by far the most commonly used (Smith, 1964). Their almost universal adoption appears to be as a result of their ability to thresh a wide range of crops, and their maximum threshing efficiency, with a low degree of injury to the seeds, if used skillfully. In addition it is easy to maintain continuity in feeding and it is easy to feed into this mechanism (Arnold, 1966). Though, according to the literature reports, these mechanisms were originally designed and perfected for temperate cereal crops, they have lent themselves extremely well to thresh tropical cereals like finger millet (Eleusine corocana) sorghum (sorghum vulgare) and rice (Oryza sativa) (Munobwa, 1968). These tropical crops in comparison with temperate crops seem to have received very little attention from the machine designers.

Basically, two components constitute this conventional threshing mechanism - namely a cylinder/or drum and a concave. The concave which is located below or above the cylinder, is curved inwards and surrounds about one quarter of the cylinder circumference. Hence it is named "Concave". Removal of seeds from the heads or pods is ordinarily accomplished with rotating cylinders. The threshing action of these cylinders is primarily derived from the force of impact. When the relatively slow moving material comes in contact with the high speed cylinder (peripheral speed of 1000 m/min to 2000 m/min) the force of impact shatters the heads or pods and free a considerable portion of the seed from the straw. Further threshing is obtained by the rubbing action as the material is accelerated and passes through the restricted clearance space between the cylinder and the concave.

The mechanism, since its first appearance, has constantly been subjected to modifications with an aim of perfecting its performance. As a result, it is now available in varying designs. (Fussell, 1952) to suit the individual's choice. A brief discussion, mentioning the relative merits of each is given below.

a) Spike Tooth or Peg Tooth Cylinder/Concave

This is the oldest type of threshing mechanism (Stone et al, 1963). It has heavy steel teeth or pegs bolted to the periphery of the drum and to the inside of the concave. The arrangement of the spike tooth cylinder and concave (see Plate No. 7 and 33) is such that the cylinder teeth pass midway between staggered teeth on the concave, (or vice versa) thus producing a combing action. Provision is usually made for control of the overlapping of the cylinder and concave teeth. (Bainer et al, 1965). The shape and size of the teeth vary somewhat depending upon a particular design. Some have rounded teeth, others possess tapered teeth. The teeth in the concave are mounted on perforated or solid removable sections. The total number of rows of teeth needed in the concave (usually two, four or six) depends upon the crop and the threshing conditions. Teeth with corrugated sides are sometimes installed for difficult threshing conditions (Bainer et al, 1965). Most of the pedal threshers used for threshing rice are equipped with the tooth peg type of mechanism (Hopfen, 1953).

The spike tooth type of mechanism has proved suitable for threshing most grain crops (Stone et al, 1963). They have a tendency to break up the straw much more than the beater type (Culpin, 1963) and it is also said they are more drastic in their treatment of delicate cereals like malting barley (Davies, 1949). Garrie et al (1967) report that the tooth peg type of mechanism often does not draw straws through the machine readily, hence usually the straws are arranged by hand and the heads only are fed into the machine - the straws being withdrawn after threshing. According to Khan, (1968, 1969, 1970) the spike tooth type of drum has a better ability to thresh wet material than either rasp bar or wire loop types of drums. According to Hawkins (1949) the basic threshing principle and construction of the mechanism appear to allow a higher feeding rate because of more feeding space between the drum and the concave. As a result it is likely to have a higher output than the raspbar mechanism. (Compare Plate Nos. 8 and 9). Khan further reports of having successfully developed a peg type of thresher, to thresh wet paddy. The machine has been designed for local fabrication by interested commercial firms.

The combing principle of threshing crops of peg type of mechanism can be utilized to strip the groundnut shells from their haulms. Though hand labour plays a major role in processing of groundnuts, in recent years, however, new machinery developments have provided partial or complete mechanized harvesting of groundnuts. A machine performing a combination of digging, shaking and windrowing has been developed in recent years. (Bainer et al, 1965 - see plate No. 11). Especially designed digger blades cut the tape roots and lift the groundnuts. The chain and slat conveyor picks up the plants, elevates them to a height of about six feet, shaking off most of the soil in the process. The rods attached at the discharge end move the rows towards the centre, thus achieving windrowing of plants. The usual procedure is to allow the peanuts to dry or partially dry in stacks or windrows in the field before picking.

Peanuts are then removed from the vines either with cylinder type machines, similar to grain threshers and combines or with pickers that employ combing principle (see Plate No. 12). Cylinder type machines may be equipped with a conventional spike tooth cylinder from which part of the teeth have been removed or spring teeth may be used on the cylinder and in the concaves (Goldin et al, 1966). Cylinder peripheral speeds of 350 m/min to 600 m/min are typical (Smith, 1948). Separation is then accomplished by means of a series of spring tooth cylinders, operating over expanded metal concaves, after which the peanuts fall through an airblast and go to the stemmer saws for cleaning.

b) Rasp Bar Cylinder Concave

This type has transverse bars with grooved metal faces. These bars are parallel to the shafts and to each other. The grooves are cut diagonally in opposite directions, across adjacent bars (see Plate No. 13). Corrugated bars are occasionally used on the concave as well as on the cylinder. The evolution history of this mechanism shows that the earlier models had flat solid bars (Fussell, 1952) and grooves were later on cut to reduce the damage incidence to seeds.

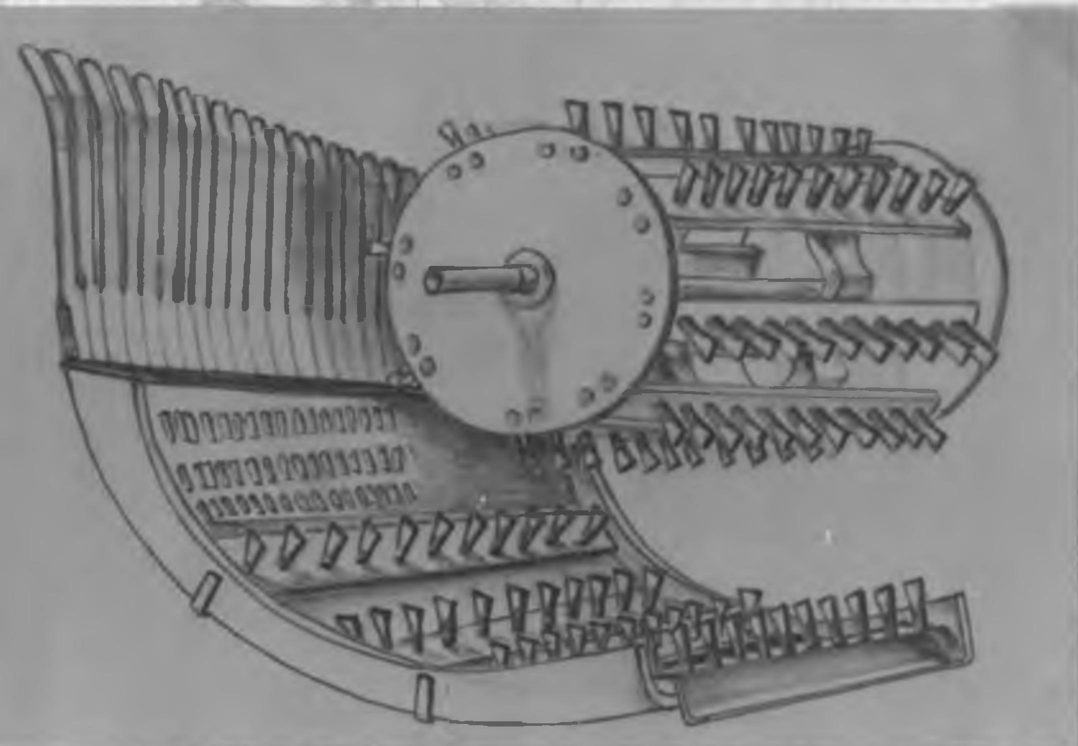


PLATE NO. 7

SPIKE TOOTH TYPE DRUM AND CONCAVE

TOOTH PEG THRESHING CYLINDER

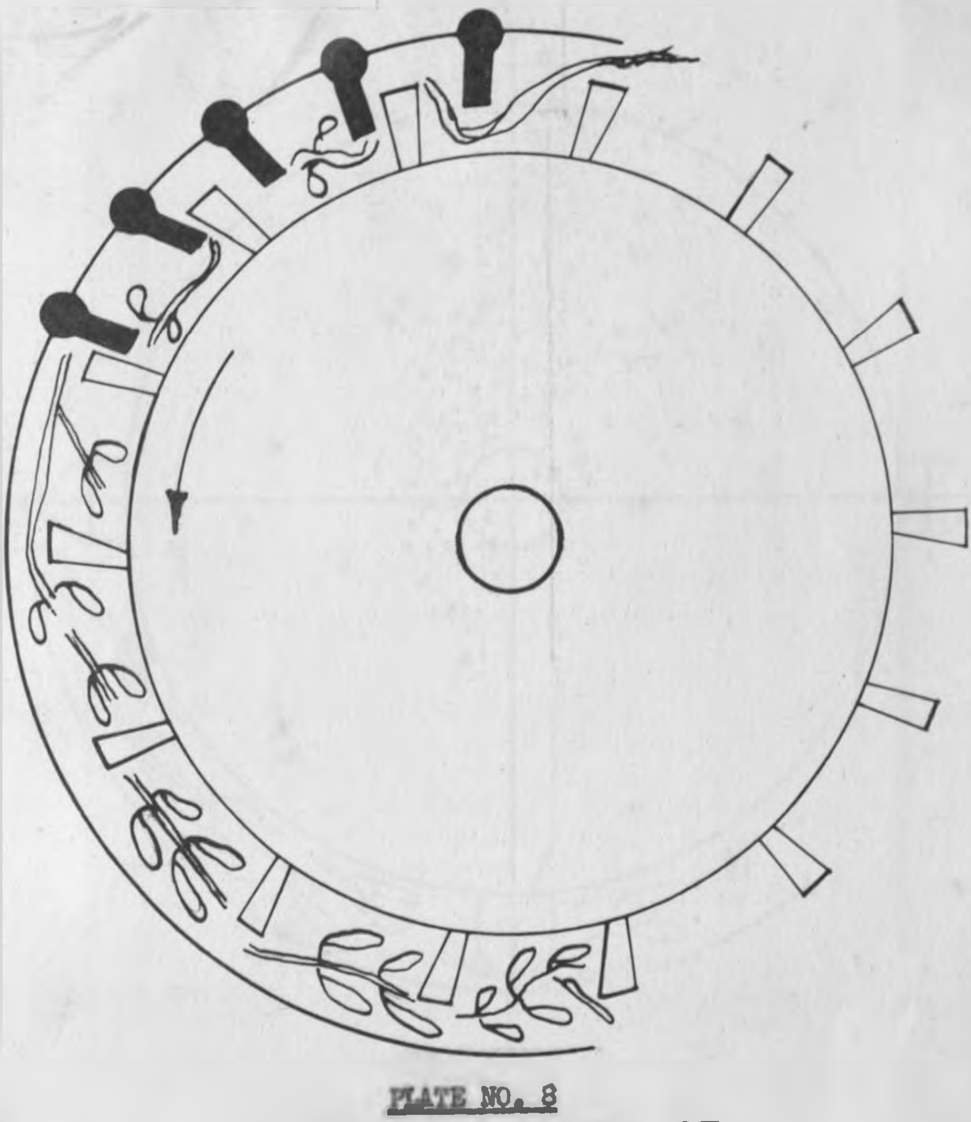


PLATE NO. 8

CROSS SECTION OF THRESHING DRUM AND CONCAVE

RASP BAR THRESHING CYLINDER

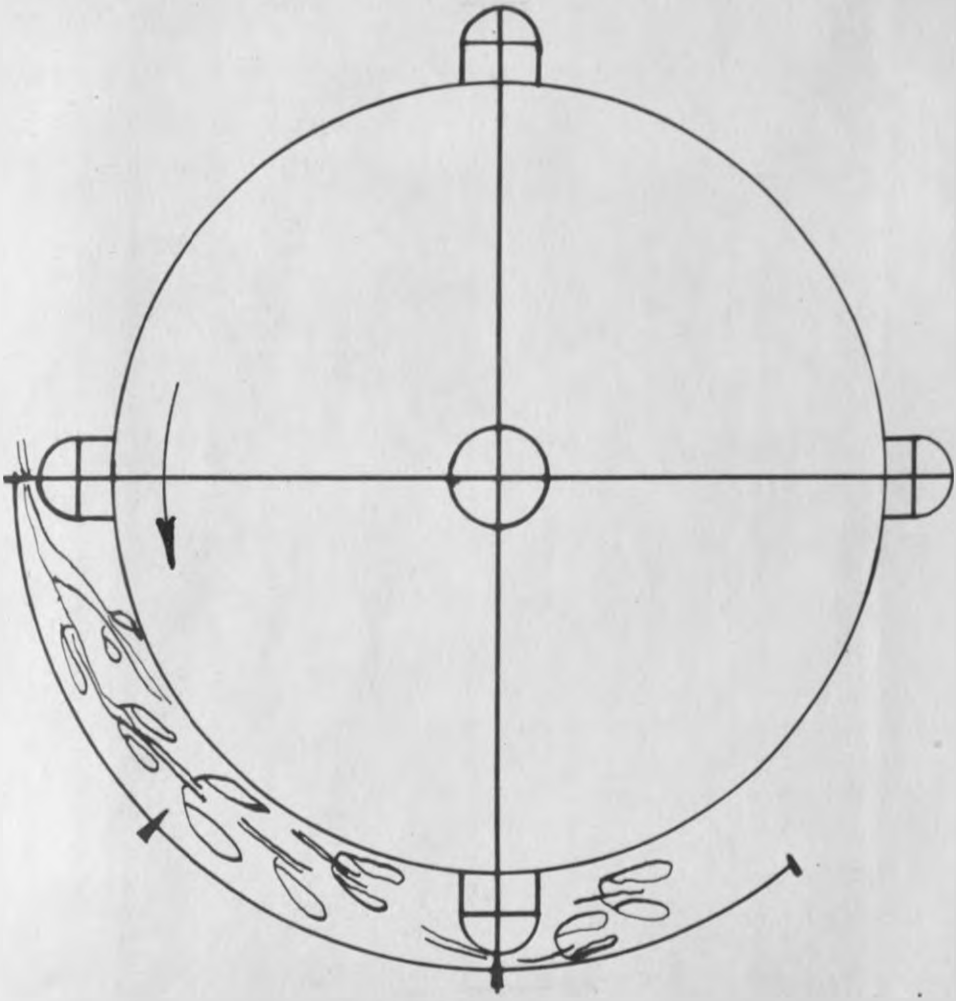


PLATE NO. 9

CROSS SECTION OF THRESHING DRUM AND CONCAVE

PLATE NO. 10

GROUND PLANT. NOTE THE THICK BRANCHING PATTERN AND RELATIVE POSITION OF THE NUTS.

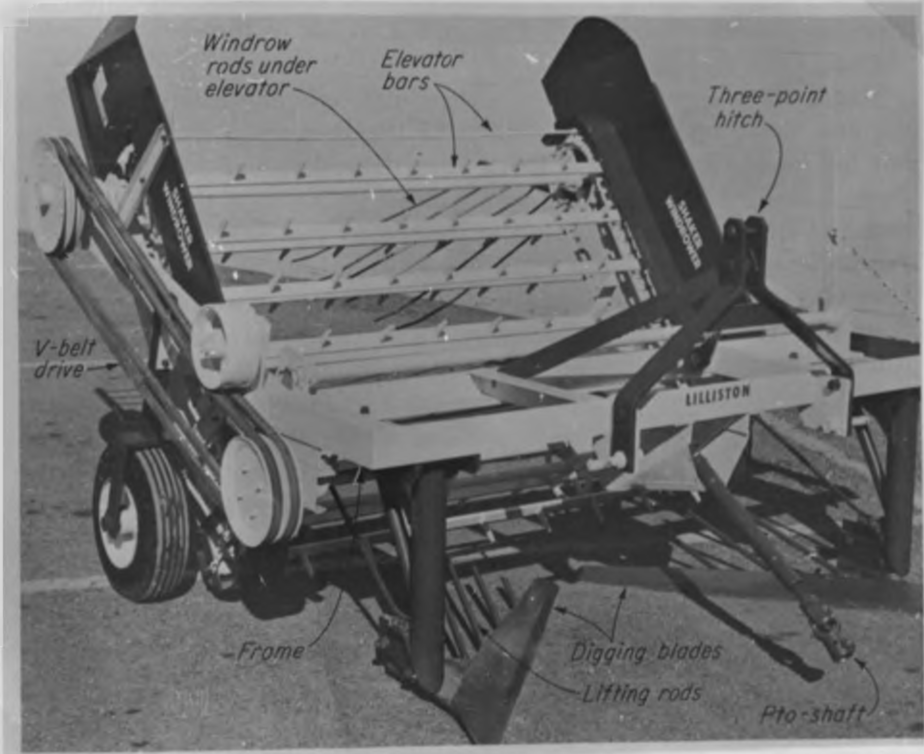


PLATE NO. 11

GROUNDNUT DIGGER. SHAKER AND WINDROWER.

PLATE NO. 12

A GROUNDNUT COMBINE EMPLOYING THE COMBING PRINCIPLE OF STRIPPING GROUNDNUT SHELLS.

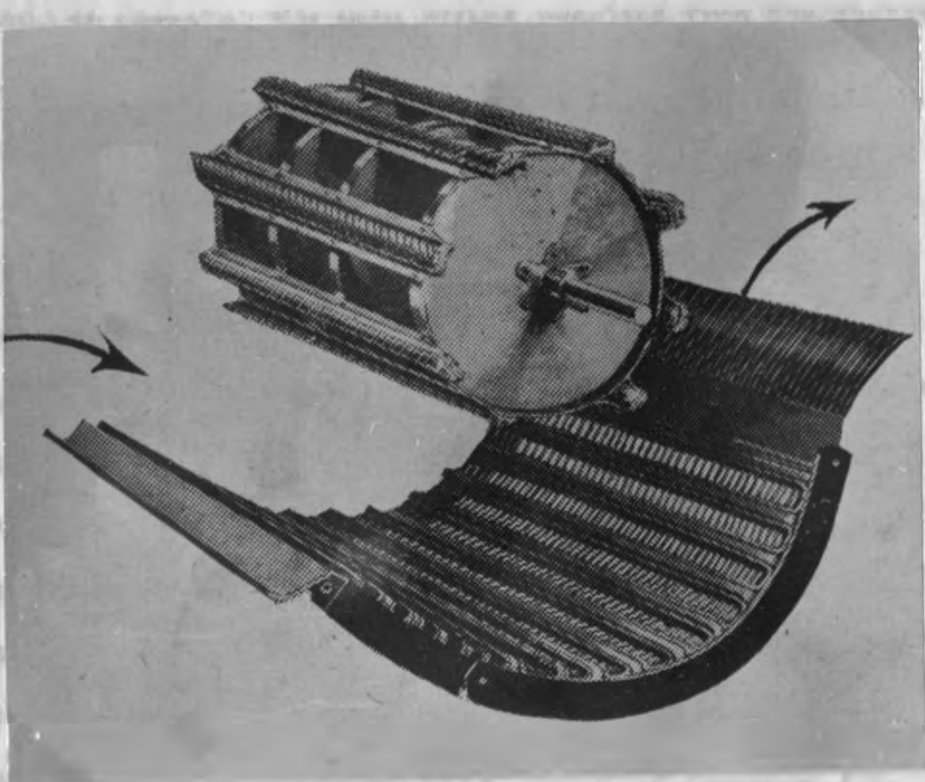


PLATE NO. 13

RASP BAR TYPE DRUM AND CONCAVE

Threshing is done by the rasping action between the cylinder bars of the drum and the concave. Schultze (1956) using very high speed cinematography (32,000 frame/sec.), clarified the mode of action within a rasp bar drum. This showed that, in cereals, the main effect resulted from the shattering action of the fast moving beater bars on the relatively slow moving ears of the crop.

The cylinder/concave clearance is adjustable. There are two types of concaves associated with rasp bar drums. The open type concave is usually located below the cylinder where-as the closed type concave is located usually above the cylinder. Experiments undertaken by Arnold (1964) showed that there were four times as many broken wheat grains in the samples produced, using the closed concave as those produced by the open version. Also in the case of an easily threshed crop of wheat no difference in the threshing efficiency of the two types was revealed. Arnold (1964) as a result of his experiments concluded that the length of the concave is important in threshing efficiency and controls the degree of separation in the drum. Long concaves should be used in conjunction with the smallest diameter cylinder with which satisfactory operation can be assured. In some models rasp bars are completely done away with and wire types of concave are instead fitted, for example, the Landmaster threshing unit, which was available for the present investigations. Studies by Schultze (1956) revealed that a surface against which the beaters could rub the material was not of a prime importance so long as some means existed for bringing the ears into their paths. The cylinder itself varies in construction in different models. In some the space in between the rasp bars is open, in others it is closed. It is claimed that the former is less likely to damage the seeds. Evidence is lacking to substantiate this claim.

In recent years the rasp bar mechanism appears to have gained a substantial amount of popularity over other cylinder/concave types of mechanism. to thresh both cereal crops and legumes (Bainer et al, 1965, Marsdew, 1959, Goss 1961, Arnold 1959).
Arnold (1964) quotes the reasons for its popularity as follows:

"The hardwearing simplicity of the rasp bar system, its flexibility and high general level of efficiency have resulted in its almost universal adoption for threshing since the process was first mechanized".

a) A special type of rasp bar cylinder known as V-bar cylinder, has V shaped rasp bars. The bars are attached to the cylinder so that the points of the V are leading as the cylinder rotates. The two ends of each V-bar are about in line with the point of the following bar (Bainer et al, 1965).

Arnold (1964) at the National Institute of Agricultural Engineering, Silsoe has done considerable amount of work to exploit the full potential of the mechanism in order to reduce the severity of threshing (i.e. to reduce seed damage) without losing or affecting the standard of threshing efficiency. As a result of these experiments he expressed his doubts regarding the feasibility of ensuring damage free samples of damage susceptible varieties employing low drum speeds under all conditions. From his work it appears that other factors besides drum speed exert a sizeable amount of influence on the extent of damage. It is suggested in the literature that the extent of seed damage can be reduced by replacing metal bars with rubber lined beaters. However, practical implication of this suggestion is doubtful in view of the considerable wear on the rubber beaters, necessitating their frequent renewal (Degenhardt, et al, 1955).

c) Angle Bar Cylinder/Concave. (Smith 1965; Bainer et al, 1965).

The angle bar mechanism is equipped with helically, or straight mounted, rubber faced bars, the rubber being vulcanised to metal. The concave is ordinarily fitted with a rubber faced shelling plate (See Plate No. 14) and steel jackated rubber bars. The seeds are threshed by being flailed out between the revolving cylinder bars and the stationery shelling plate, and the steal jackated rubber bars. According to Melkyuti (1957) this mechanism only threshes by impact. It does not seem to be as popular as the two described earlier and has failed to attract research interest, though Klein et al (1966) did detailed work to establish its optimum settings to combine harvest crimson clover. From its mode of action, i.e. flailing, it does not appear to be as harsh in its treatment to crops, and therefore could be a possible mechanism for threshing grain legumes, which are on the whole very susceptible to damage, if treated severely whilst threshing.

d) Wire Loop Cylinder. (Khan, 1968, 1969, 1970)

In this type of mechanism wire loops are fitted transversly at intervals across the face of the cylinder. (see plate No. 15). Unlike the first three types, the presence of the concave is not essential. Even, if it is incorporated in the mechanism it usually is quite plain without any loops, attached on it. Perhaps, threshing in this type of mechanism is obtained through a "forking" action of the loops at a high speed. For this mode of action a "hold on" method appears to be more suitable than "throw in" feeding method. The mechanism is widely used in pedal threshers, for threshing rice (Vaugh, 1962). It is also under test in the Phillipines for developing a rice thresher for local fabrication (Khan, 1969).

e) <u>Star and Bar Pattern Maize Cylinder</u>

Though on the whole maize is shelled by either a beater bar type cylinder (Gurov, 1965) or a peg-studded cylinder (Smith, 1965), a drum called star and bar type has been evolved to specially shell maize. (Ransome's power husker and maize sheller - see Plate No. 16). The accompanying concave is either made from round bars or from a perforated metal sheet. As the cobs enter the space between drum and concave, the star and bar projections on the drum rub the seeds off the cobs. It is doubtful, whether this rubbing action by itself (since there is no squeezing action) would be able to thresh open legume pods.

f) Modified Cylinder and Concave Mechanisms

The shattering principle of threshing common to most of the cylinder concave threshing mechanisms has been slightly altered to that of rubbing action to crack open the groundnut shells.

The groundnut (Arachis hypogaea) is member of the leguminosae family. It is an annual plant and the cultivated types show wide variation, both in growth habits, plant form, and fruit and seed characters. The height of the plant varies from six to twelve inches. (see Plate No. 10). After fertilization the receptacle turn downwards into the earth, where the ovary is developed into an elongated oblong indehiscent pod, containing from one to four seeds depending on the variety. (Cobley, 1963).

Shelling at peasant level is largely carried out by manual labour after the plants have been uprooted, and allowed to be dried or partially dried in windrows or stacks before being finally picked. Prior to shelling, the strip-

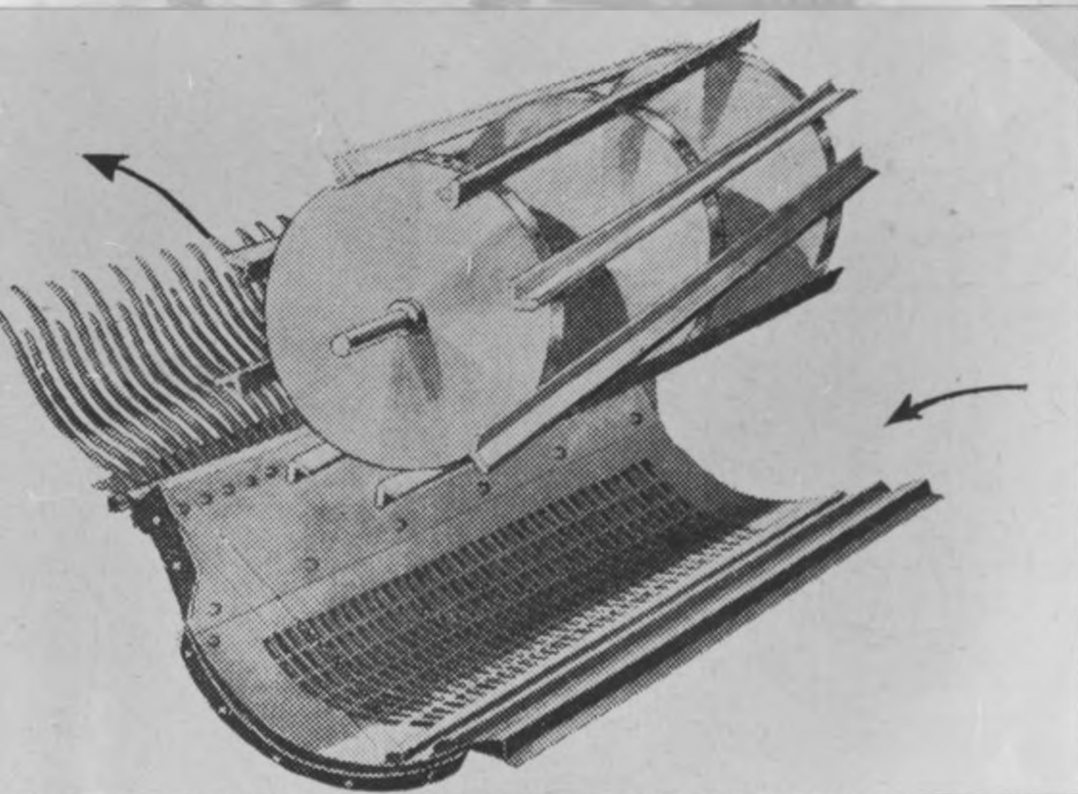


PLATE NO. 14

ANGLE OR FLAIL TYPE DRUM AND CONCAVE

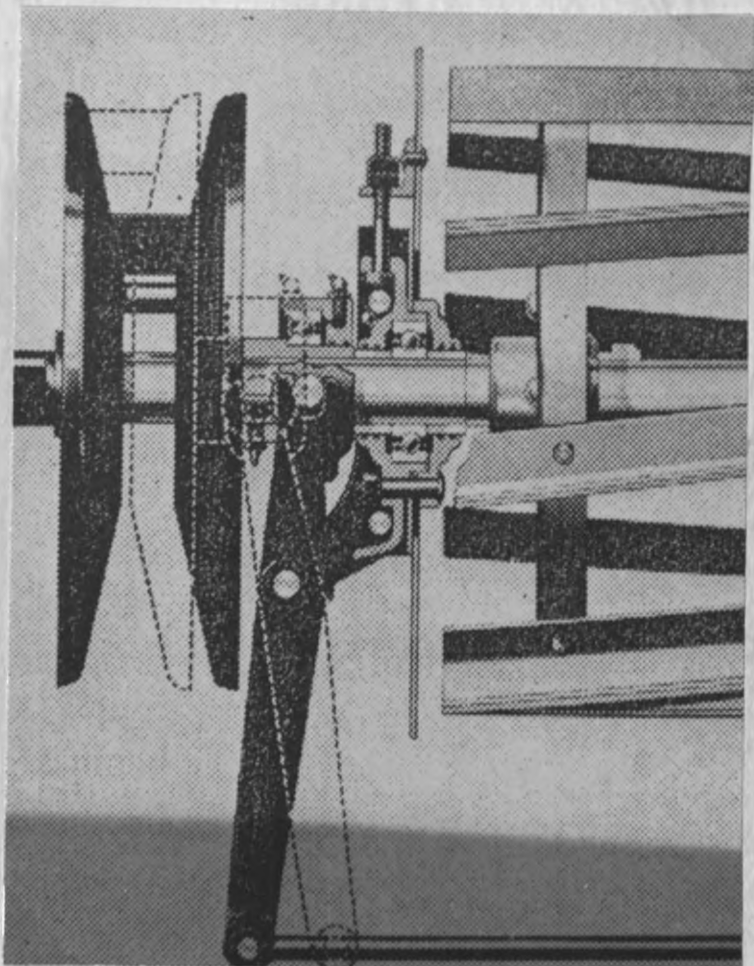


PLATE NO. 14 A

NOTE STEEL JACKETED RUBBER BARS.

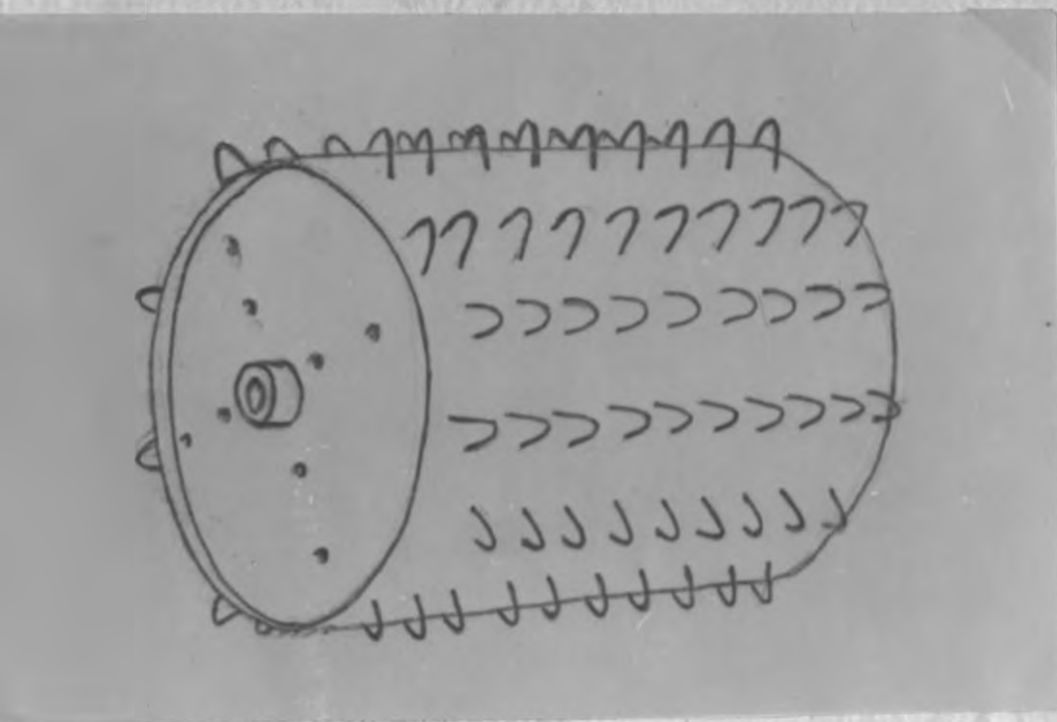


PLATE NO. 15

WIRE LOOP TYPE DRUM

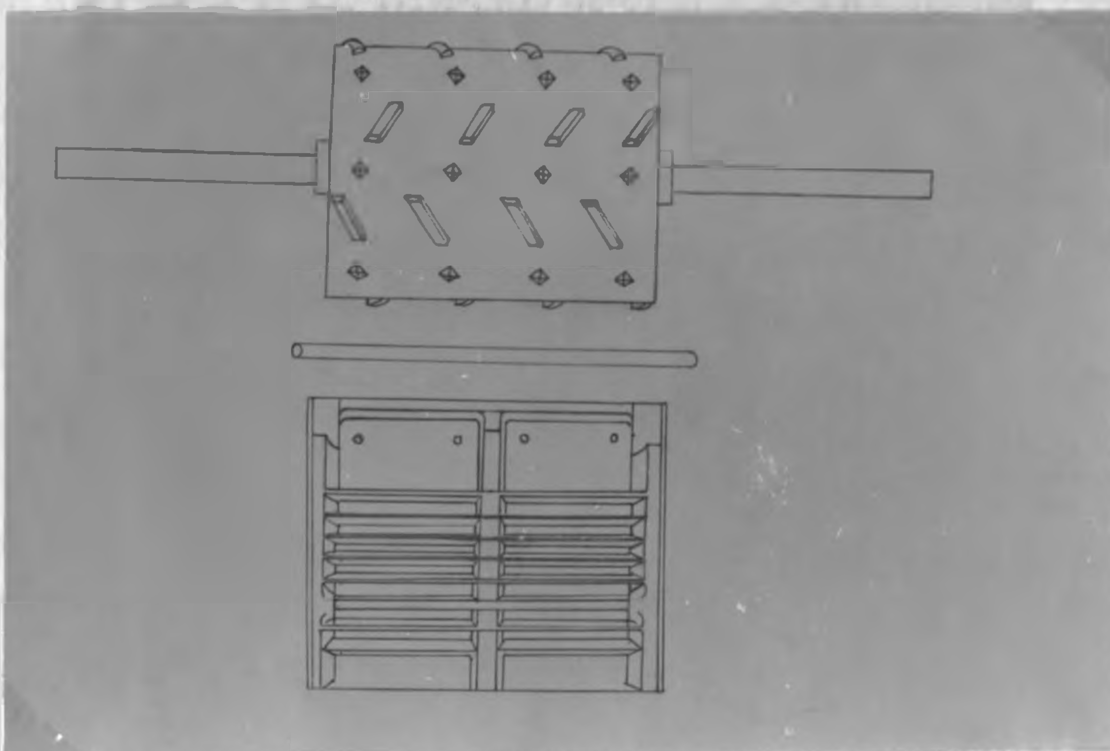


PLATE NO. 16

STAR-BAR DRUM AND CONCAVE

ping is also carried out by hand or with sticks. A simple, inexpensive, self driven stripper has been developed by Ramly (1966) in the Republic of Sudan. It is claimed that the output is ten times more, in comparison with mere hand stripping.

The stripper basically consists of a five bar revolving cage fixed between end plates on a stand at a height convenient for manual operation. Stripping is carried out by holding the plants by the haulms and striking the root ends with pods sharply against the bars, which are covered with rubber to prevent damage to the pods. A canvas deflector is fixed around the cage to guide the stripped pods into an open bag beneath the bars.

The hand-operated version of the groundnut sheller - called "KANO SHELLER" (see Plate No. 4.) is made up of a convex sector drum, the drum having on its periphery six spiked cast iron bars. A slotted screen made of 5 mm sheet metal forms the base of a hopper with two end sheet metal plates. The drum is oscillated with a handle which is fixed to the axle at the centre of the drum. Between the drum portion and the screen there is a clearance of about 6-10 mm. A thick layer of groundnuts is put between this clearance during shelling. Successive rubbing during rocking action of the drum crushes and cracks open the pods. The shells and nuts are allowed to drop through the screen. Various sizes of screens are available to prevent breaking of nuts. Winnowing is necessary to obtain clean seeds. Tests carried out by Munobwa (1968) showed that this mechanism had a capacity to decorticate 213 kg of unshelled nuts in an hour. However, this figure is very misleading as it does not include the time required for winnowing. It was estimated by Munobwa that at least 3 extra hours would be required for winnowing.

Shelling of groundnuts has also been accomplished through successive rubbing by flexible rubber beaters, on a thick layer of groundnuts, placed inbetween the concave and the rubber beater bars. This type of construction is used in the 'Richmond Groundnut Sheller' (Munobwa, 1968). (see Plate No. 17). Its output according to Munobwa is about 115 kgs/hr. of clean seed. In Russia groundnuts are threshed by feeding the crop between rubber beaters of an outer and an inner drum. The inter-action of beating and dashing propels the crop through and in the process threshes the crop (Kotovich, 1959).

2:1:1 Comparative Efficiency of Different Cylinder/ Concave Threshing Mechanisms

Very little data seems to have been collected which would make it possible to compare inherent characteristics of different types of mechanisms. Bainer et al (1965) for instance have observed.

"There is considerable difference of opinion among operators and manufacturers regarding the relative merits of the different types of cylinders, and very little published data is available to provide a basis for comparison. Until about 1930, the spike tooth cylinder was almost used exclusively. Since then the trend has been towards the other two types, (i.e. rasp bar and angle iron types) with the rasp bar construction predominating. The rasp bar and angle bar type are readily adaptable for a wide variety of crops and threshing conditions, have less tendency to break up the straw, and are more tolerant of green growth (weeds). The spike tooth cylinder has a more positive feeding action and is preferred in some areas,particularly for heavy rice crops and for windrowed beans".

Casem (1968, 1969), from the Phillipines has reported

PLATE NO. 17

SHELLING ASSEMBLY IN THE RICHMOND GROUNDNUT SHELLER. NOTE THE RUBBER BEATER BARS AND THE SLATTED CONCAVE on his comparative trials and has shown that with the "throw in" feeding method for paddy, the spike tooth cylinder exhibited the best overall performance throughout the velocity range under test. (275 m - 1400 m/min.). But with the "hold on" feeding method the rasp bar and spike tooth cylinders exhibited relatively poor performances at the slower velocities in terms of threshing efficiency. According to the same author, for the "throw in" feeding method, the peg tooth cylinder is better suited, especially if low cylinder speed velocities are desired. This may be so because of positive feeding nature of the spike tooth drum. The minimum peripheral speed for threshing rice was found to be 1200 m/min. for the spike tooth mechanism and 1300 m/min. for the rasp bar mechanism. Arnold (1959), Goss et al (1966), King et al (1960) and many others have carried out detailed work to find optimum peripheral speeds, concave clearances and optimum moisture content for threshing temperate cereal crops.

2:1:2 Threshing Effectiveness of the Cylinder Concave Type of Mechanisms

Thoroughness of threshing, with minimum seed damage, appears to be related to (a) the peripheral speed of the cylinder, (b) the cylinder concave clearance, (c) the number of rows of concave teeth, in case of the spike tooth cylinder, (d) the type of crop, (e) the conditions of the crop in terms of moisture content, maturity etc., and (f) the rate at which material is fed into the machine.

High cylinder speeds and close concave clearances favour thoroughness of threshing (Goss et al, 1966). King and associates (1962) found that the actual requirements are very much dependant on the crop and its moisture content at the time of harvest or threshing. Research and survey work carried out by Arnold (1959 and 1963) and Nyborg et al (1969) reveal that as far as temperate cereal crops like wheat, barley and oats are concerned the recommended peripheral speeds are within the range of 1300 m/min. to 2000 m/min., whereas the optimum cylinder/concave clearances should be between 6 mm and 12 mm. Grain is mostly harvested at a m.c. of 16-22% (Johnson, 1959). Use of the maximum cylinder speeds and the minimum concave clearances to obtain high threshing efficiency is limited primarily by the amount of seed damage that is acceptable for the anticipated use of the crop. For example, the malting trade, demands a product with very little mechanical damage whereas for feed barley a considerable amount of damage is acceptable.

Although seed damage can occur because of the cylinder concave clearance being too small, tests by Arnold (1963) indicated that the level of damage sustained depends only to some extent on the concave clearance of the thresher. Work carried out at the National Institute of Agricultural Engineering, Silsoe (Mitchell, 1955; Mitchell, 1955; Arnold et al, 1958; Arnold, 1959) suggests that the type of seed damage incurred and its magnitude could primarily be functions of grain moisture content, type and variety of the grain and cylinder peripheral speed. Some workers single out impact blows received during the threshing process to be the prime cause of damage to seeds (Mitchell et al, 1964).

Extensive and detailed corn harvesting cum threshing studies have been conducted in some locations of the corn belt in the United States of America by Johnson et al (1963); Byg et al (1963) and by Waelti et al (1963). These studies were undertaken with a view to minimize seed loss at harvesting and shelling. Their findings are summarized below. i) the optimum moisture content for harvesting maize was between 20-30%. In one year's test it was shown that the

kernel loss was 4% at 30% m.c. whereas when harvested at 26% the loss increased to 7%. However, elsewhere it was shown by Waelti et al (1969) that these high moisture content harvesting has a tendency to increase kernel damage. Below 25% m.c. pre-harvest ear drop loss increased rapidly.
ii) Preharvest ear drop losses were the largest single losses and amounted to over 50% of the total losses.
iii) Combined snapping roll, cylinder, separating and cleaning losses were generally one percent or less of total yield and did not vary significantly among varieties nor with moisture content.

Kolganov (1956) advocates a two stage system of threshing cereals to reduce the seed damage. According to him a high proportion of the larger, riper grains in a crop could be removed in the first cylinder operating at 600-1200 m/min. depending on the crop, variety and m.c.; the remainder passing to a second cylinder having a peripheral speed of 1200 m - 1800 m/min. During the course of his experiments, he compared the single and two stage threshing and found out that in repeated and in single stage threshing the breakage and micro-damage assumed a considerable magnitude. Moreover, in all variations of two stage threshing, the percentage of unthreshed grain was small. However, because of complications involved in modifying the present combine harvesters to two stage threshing, the system failed to receive a wide support. Since the work was carried out using test rigs on grain at 2-10% m.c. and the suitability of these speeds for field use, especially at higher m.c. was not demonstrated, the ideas were not followed up further.

However, Bainer et al (1965) from the United States of America report of the development of a related type of mechanism to thresh beans, which are known to be more susceptible to damage than cereals. They report:

"To increase the recovery of undamaged beans, especially for seed crops, especial bean threshers have been built with two spike-tooth cylinders in series. The first cylinder is operated at a peripheral speed of perhaps 300 to 400 mpm and removes most of the seeds without excessive damage. The second cylinder is operated somewhat faster to remove the beans left by the first cylinder".

The almost universal adoption of the cylinder/concave mechanism to thresh a wide range of crops demonstrates the versatility of the mechanism to adjust itself to differing threshing demands. Most of the work done to exploit its potential has largely been carried out using cereal crops and it appears that at times results have been directly related to thresh legume crops. Its shattering principle of threshing could be a little harsh on some of the soft seeded legume seeds, resulting in increased seed damage. On the other hand, chances are that if the mechanism is used skillfully, on the basis of experimental results, the magnitude of damage could be lowered or even completely eliminated.

2:2 Centrifugal Threshing Mechanisms

This system purpots to incorporate a completely new principle for threshing and cleaning grains. Buchele (Lalor, 1963) invented a threshing cone for centrifugal threshing, which in turn was originally proposed and studied by Lamp (Hamdy et al, 1967) as a non impulsive means of threshing. It was shown to reduce the impact level on grains and obtain threshing separation and cleaning in one process, unlike conventional threshing where the actual knocking out of grains from the ears and separation of the grain from the chaffe are two distinct processes. In this new thresher, however, the heads of the grains are taken into a conical cylinder in which a rubbing action in combination with a whirling movement separates the grains from the heads. The centrifugal force developed by this whirling action drives the grain to the screened cylinder wall, whence it passes through the screen, where a wind blast cleans the grain of any chaffe that managed to get through the screen. The study carried out by Hamdy et al (1967) indicated that generalized vertical rotors are theoratically capable of subjecting particles sliding inside them to centrifugal acceleration of the same order as that necessary to thresh wheat under typical harvesting conditions. Data collected from practical experiments, to thresh wheat by Lamp (Lalor, 1963) revealed that threshing efficiency was above 99% at all rotor speeds. Separation efficiency decreased from 77 to 69 per cent, as the rotor speed increased from 300 to 500 r.p.m.

However, technological problems arising from its inherent unbalance in a continuous flow, such as strength and vibration, would be very critical and could set a limit on the development of centrifugal threshers (Long, 1969).

2:3 <u>Fluted Rim and Rotating Disc Mechanism (Maize Shellers).</u> (Smith, 1948).

Essentially, the hand peeling process of shelling kernels, comprising the rubbing together of two ears has been successfully mechanized by the use of a fluted rim and a rotating tooth disc (see Plate No. 18). Three components constitute the basic design of a hand maize sheller. Maize is shelled by pressing the cobs on the fluted rim, held in the required position by pressure from springs, - or in the absence of these springs, it is necessary to hand press the cobs to prevent them jumping out during shelling. A toothed rotating disc peels off the kernels from the ears. Evaluation trials carried out by Munobwa (1968) indicated that an output of the shelled maize in the region of 350 kg/hr. is obtainable with ease. The same survey also showed that if the mechanism is motorised, the maximum output can nearly be doubled. The engine coupled machine could be a very ideal piece of machinery on co-operative farms. However, the basic design in this mechanism did not suggest any potential to consider it for grain legume thresher development work.

2:4 Rubber Rolls and Endless Belt Mechanisms

With grain legumes it is quite possible to split open the pods with a squeezing action, a rubbing action or a joint

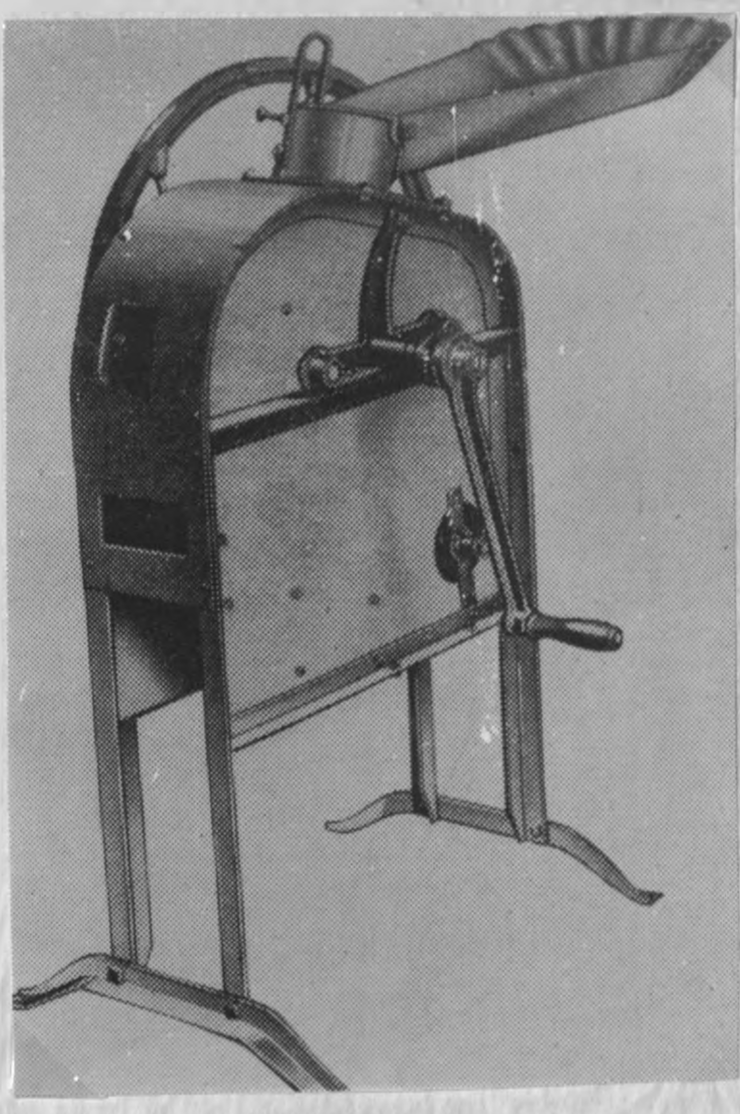


PLATE NO. 18

ONE-HOLE SPRING CORN SHELLER

OPERATED MANUALLY.

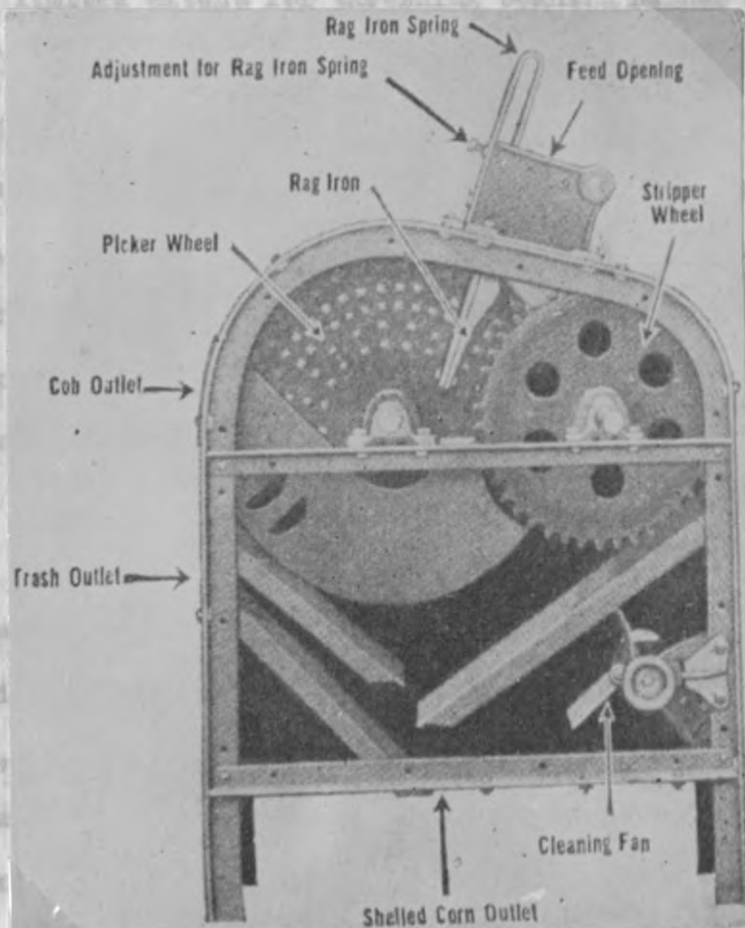


PLATE NO. 18 A

SECTIONAL VIEW OF ONE HOLE SPRING CONE-SHELLER.

action of both. Rubber covered steel rolls have been used to a limited extent for threshing beans. Bainer et al (1937) in their study developed an experimental bean combine, which had a series of three pairs of rubber covered rolls, operating at a peripheral speed of 80 m.p.m. to 90 m.p.m. instead of a conventional cylinder. Threshing in this machine was entirely due to squeezing and rubbing action of the pods. Satisfactory threshing was obtained without appreciable seed damage. (Bainer et al, 1938).

This mechanism at the outset looked to be the very one suitable for the peasant farmer since the peripheral speed required for threshing was low enough to be achieved with ease, for hand operation. But a critical look into the mechanism showed two limitations for its wide adoption as a tool for the small farmer. The cost involved in driving three rollers with gears may raise the final production cost, beyond that what a peasant could afford. Secondly, for a successful threshing the important criteria seemed to be that the pods ought to be sort of crisp dry before they would give up to this squeezing, rubbing action, and pop open.

A somewhat similar mechanism is at times installed in front of the conventional cylinders - known as flax rolls. The mechanism is made up of one rubber covered roll and one steel roll. The upper roll is spring loaded and is driven about 10% faster than the lower roll, to give a rubbing action, complimenting the squeezing effect. In addition, to their threshing action, flax rolls tend to hold the material against the pulling action of the cylinder, thus promoting more uniform feeding.

A completely new and a quite revolutionary mechanism which uses two belts, running at different surface speed to snap open podded crops has been invented by Agricultural Engineers in the United States (World farming Editorial, 1970). The mechanism is named as an 'Endless Belt Mechanism'.

In a modified version of a conventional combine harvester, the conventional threshing cylinder was replaced with two rough surfaced endless belts and the conventional oscillating flat screen was exchanged for one vertical rotating screen.

Conventional threshing cylinders, according to these engineers, operate like an old fashioned flail - literally beating the seed loose by the fast movement of the tines and knobs. In contrast, the flat endless belts run close to each other at different surface speeds, the ratio being 3:1, giving a gentle shearing action to pods, similar to the rubbing of pods between palms of hands.

From the literature reports it appears that some sort of pre-threshing assistance is a prerequisite for the mechanism to work efficiently. Silbernagel et al (1968) pointed out that depending upon a particular design either a low speed spike tooth cylinder is used to shred the plant material before it passes between the belts; or rubber covered rollers are placed which help to crush seed pods as the crop passes under them. These two devices it is claimed, help in metering out the plants, thus preventing bunches of them passing through to the threshing belts.

Shelling of maize by a squeezing action has been accomplished, using rubber belts, in Iowa (A.E. 1965) and Russia (Fanfaroni, 1958). But Marsden (1959) failed to achieve satisfactory threshing of a rice crop using the endless belt mechanism.

Advantages claimed with this mode of threshing are little or no damage and nearly cent percent threshing of beans, which are reputed for being extraordinarily susceptible to the germ damage. An obvious restriction to its wide adoptation is its inherent weakness to effectively deal with slightly green or damp pods. Moreover, its construction cost, especially use of gears for 3:1 reduction for belts, may make the whole proposition prohibitive for the small farmer to acquire it. Besides it appears very doubtful whether the mechanism would lend itself for local manufacture. Also it is claimed that the use of rubber reduces both reliability and output - as its rate of wear is excessively high (Arnold, 1966). Experiments carried out by Marsden (1959) suggested that the mechanism was not suitable for rice threshing.

2:5 Vibrational Threshing Mechanisms

The successful threshing of podded plants with a squeezing, or a rubbing action or a combination of the two, brings to one's mind the likeliness of popping open the pods by subjecting them to vibrations of extremely high magnitude. The vibrations can be imported to the pods by hitting them alternatively with revolving bars. This hitting will certainly be distinct from impact blows received during the conventional threshing, since the hits from the shafts are free and not against any surface, as is the case with the drum/concave mechanisms.

The theory of vibrational threshing was successfully tested by Okorokov and co-workers (1962) and Gudkov and co-workers (1964) for rye seed and wheat seed threshing. However, there are no records in the literature showing any work done to thresh grain legumes using the vibrational principle of threshing. From its mode of action, it is quite likely that the vibrational threshing will treat legume seeds kindly thus reducing the degree of damage incurred whilst threshing.

A mechanism called 'PERISTALTIC' has been designed in America (Muchiri pers. comm., 1969) to test its suitability as a possible threshor for the small holder. A full report on the various aspects of the mechanism appears in the next chapter.

2:6 Seed Cleaning and Sorting. (Henderson et al, 1966)

The chief reasons for cleaning and sorting seeds are:

i) To remove foreign material such as chaffe, broken straw, clods, stones and seeds of other plants.

ii) To obtain restricted size groups as an aid to precision planting.

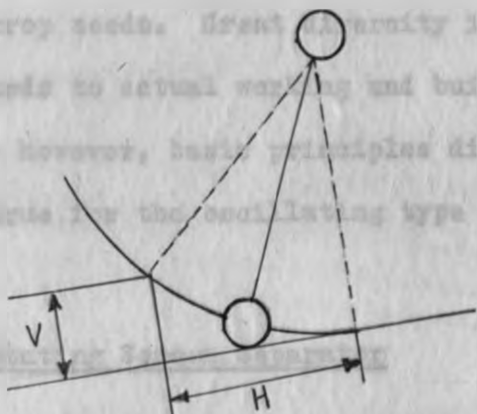
Physical differences existing between the seeds and the foreign material or between different grades of seeds chiefly assist in the process of separation. The principal characteristics utilized in making separation are size, shape, specific gravity, surface characteristics and colour. Separation on the basis of colour are highly specialised, usually involving electronic equipment and therefore does not fall within the scope of the present project.

The operation of a mechanical separator often depends upon more than one type of characteristic difference. Separations made on the basis of size, shape and specific gravity predominate. Machines utilising size and shape characteristics for sorting seeds, or separating them from foreign material may have screens or sieves, moving pockets, spiral cones, angle sieves or inclined belts. Specific gravity separations ordinarily involve an air blast, often in conjunction with some other mechanisms.

2:6:1 <u>Screen and Pneumatic Cleaning</u>

Screens (Sometimes referred to as sieves) are used more widely than any other type of device for sorting granular products. Air-separation can be employed in seed cleaning to separate inert material, weeds and other contaminants from crop seed provided these components possess different terminal velocities. Terminal velocity represents the maximum velocity a seed will attain in a free fall through still air. Terminal velocity enters harvesting picture, too, where it helps to determine best air openings for the combine fan. Harmond et al (1966) and Garret et al (1966) have separately in the course of their work determined terminal velocities for different crops. Soyabeans are shown to have a terminal velocity of 13.5 mps., the highest among the crop tested. This sieve/pneumatic combination is put together in a fanning mill. (see Plate No. 18). A similar combination is found in the cleaning shoe of a thresher or a combine. The screens in a fanning mill consists of framed, perforated metal sheets or wire cloth and have non-adjustable openings that are generally round, square, oblong or triangular in shape. Sieves with adjustable openings are common in combines. The screens are supported by hangers and oscillated by means of an eccentric, a crank, or a reaction drive, generally in the direction of the material flow, or sometimes crosswise (Known as side shake - present in the

Bobbin windmill). The hanger mounting is such that the screens have a horizontal oscillating motion and a smaller vertical motion (see below).



The combination of motion thoroughly agitates the material and gradually tosses it towards the point of discharge. The slope of the screen is usually adjustable for controlling the rate of flow.

Under normal operating conditions, a large portion of the threshed seeds (along with some chaffe) is separated from the straw at the threshing unit, falling through the concave extension grate. In the absence of such an arrangement, the whole lot passes over on to the straw rake. The upper sieve of the rake is of the louvered type with serrated adjustable louvres. The oscillating motion by the straw rake, propels straws to the discharge end. Seeds fall through depending upon a particular design, either straight to the grain pan or to the shoe cleaner for cleaning. Air draft during this fall blows out foreign material lighter than the crop seeds. Great diversity is likely to be found with regards to actual working and build up of the cleaning unit, however, basic principles discussed above still hold true for the oscillating type of screens.

2:6:2 Vertical Rotating Screen Separator

Though the oscillating screen appears to have gained an unrivaled popularity for the cleaning purposes, doubts are expressed regarding its efficiency in utilizing the huge amount of energy it requires for its operation. It is felt that, the large part of this energy is not in fact, required for driving the screen, but it appears to be wasted in the momentarily stopping of the rack and for the res-torting of its journey in the opposite direction. To over-come this waste of energy, a vertical rotor screen having a unidirectional movement has been proposed. Park and Harmond (1967) disclose that whilst this vertical rotary screen separator performs the same functions as the flat screen separators, it offers a number of advantages in-

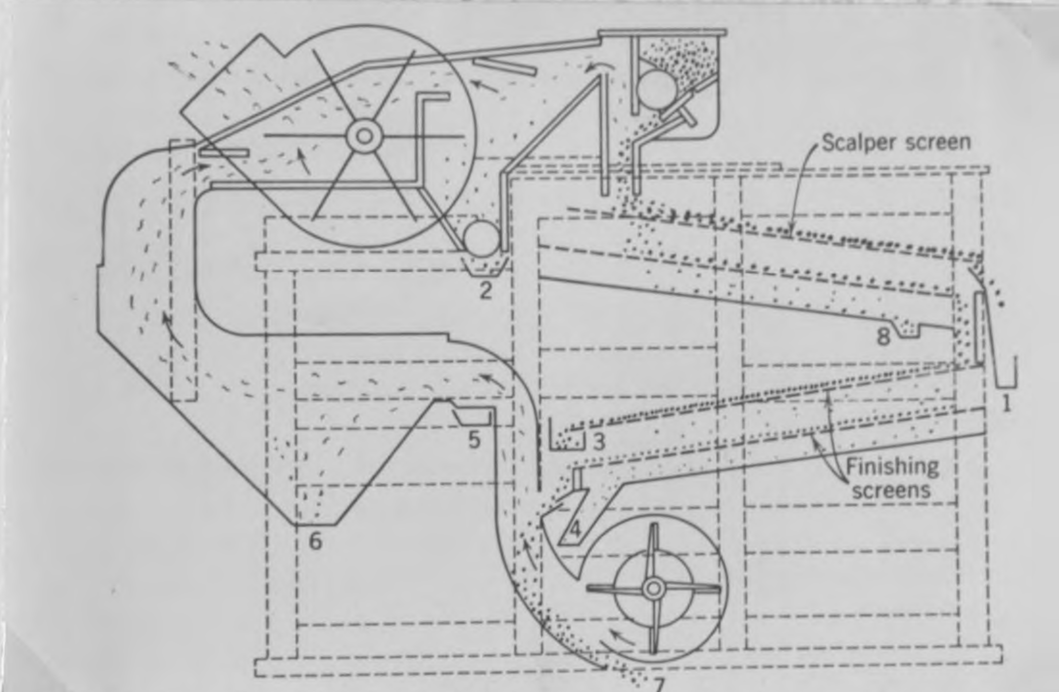


PLATE NO. 19

SECTIONAL VIEW OF A FANNING MILL. MIXTURES TO BE SEPARATED ARE FED TO THE TOP SCREEN THROUGH AN ASPIRATING AIR COLUMN. THE BULK OF THE COARSE MATERIAL IS COLLECTED AT 1. ADDITIONAL MATERIAL LARGER THAN THE SEED AT 3. THE DESIRABLE SEED AT 7, AND THE FINE MATERIAL AT 4 AND 8. LIGHT SEEDS MAY BE COLLECTED AT 2, 5 AND 6.

cluding a higher capacity per unit of screen area. It can separate any seeds or granular material that a flat screen can. A typical rotary cleaner designed by Khan (1969) uses two rotating concentratic cylindrical screens, with a 7.6 cm clearance. The inner screen has perforations large enough for the grains to pass through and the outer screen has perforations small enough to permit the passing of only dust and other finer impurities. Air is blown through the 7.6 cm clearance only in the lower half portion, where the grain is tumbled. The grain to be cleaned is delivered into the inner cylindrical screen. Special sheet metal baffles mounted on the inside of the inner cylinder move the straw and larger impurities while the grain falls through the inner screen perforations into the outer cylinder. The grain is tumbled inside the outer cylinder and is moved axially in the direction opposite to the air movement, by spiral baffles. The air blows the empty grain and other light impurities from the tumbling grain while it is moving in the outer cylinder towards the discharge spout. In a single pass a clean sample of seed is obtained.

2:7 Conclusions (On literature review)

The literature review suggested considerable vari in approach to threshing and cleaning of various crops. The potential of these mechanisms were critically assessed in order to establish whether any possible mechanism could be either wholly, or in a partly modified form be developed for grain legume threshing and cleaning in Uganda.

The performance of the endless belt and rubber roller mechanisms would appear to offer considerable promise, but their inevitably complicated design ruled them out as a prime objective of the current investigations was to develop simple machinery which could be locally manufactured.

The more novel mechanisms, requiring little energy for operation such as (vibrational threshing by pairs of rollers) proposed by Okorokov (1962) and Gudkov (1965) would seem a fruitful line for further investigations. The propositions were followed up in the designing of the so-called 'Peristalti mechanism, to investigate the possibilities of threshing grain legumes by this novel mechanism.

Whilst the rasp bar, toothpeg and angle iron are known to be rather severe in action and thus likely to damage the sensitive grain legume seeds, it was considered desirable to nevertheless examine these mechanisms further in these particular investigations.

As far as the information on cleaning mechanisms is concerned, though mechanisms involving a rotary screen seemed to be an obvious choice for development work, the oscillating mechanism was chosen for development. The reasons for this being that an oscillating mechanism is simple to construct and secondly, it was envisaged that once designed its use could be extended to form the basis for establishing the design parameters for a variety of crops.

With the above approach in mind, development and evaluation work was thus initiated.

DEVELOPMENT WORK AND OBSERVATIONS ON THRESHING MECHANISMS

CHAPTER 3

From the literature review, it was quite evident that despite their certain inherent drawbacks, for example, high power requirements for driving them, or the harsh treatment of the crop being threshed, the cylinder and concave mechanisms are by far the most popular mechanisms used for threshing. Their inherent ability to thresh a wide range of crops, simplicity in operation and high general level of efficiency have resulted in their almost universal adoption for threshing. In view of the advantages offered by these mechanisms, it was thought quite logical to concentrate efforts on the mechanisms based on this conventional mode of threshing, and in addition to examine a novel mechanism which may appear to be more suitable for threshing the grain legumes. For the former, the rasp bar and toothpeg were chosen and for the latter a mechanism based on the principle of vibrational threshing and called the 'peristaltic' was chosen. The toothpeg type besides being versatile in its use, offers an added advantage of being able to strip off groundnut shells from their haulms - a process reputed to be labour demanding when done manually. For the peristaltic it was claimed that as the components involved in threshing were light the power requirement for driving them was likely to be low - hence offering a great potential for hand operation.

The members of the leguminosae family, as a rule have a pod as a fruit which when mature splits open along both dorsal and ventral sutures. Most of the members possess a tendency to have a profuse lateral branching (Cobley,1963) (see Plate No.20) which makes them very bulky for transporting and threshing purposes at times. Moreover, the tendency of shattering among certain varieties makes it very necessary to harvest them much earlier, at moisture contents not suitable for threshing. If combined they need further treatment to dry them to safe moisture content for storage or if stationery threshing is practiced then they need sundrying before they are threshed. The number of pods produced on each flowering axis is quite variable (Cobley, 1963) and so is the size of the pods. The members like Green Mung (Phaseolus aureus) and Soyabeans (Glycine soja) produce the pods in groups from three to fifteen (Cobley,1963). Since the members of the leguminosae family have a tendency for profuse branching the pods are produced at times throughout the entire length of the main stalk unlike the cereals, where the seeds are confined to the top part. (see plate No.21). As a result for threshing, the whole plant has to be passed through the threshing mechanism. Therefore, the "hold on" method of threshing is not practicable with the legumes, though widely practiced for threshing rice and wheat on a small scale.

Work on the project was carried in phases to avoid congestion of work at any one time. The first part of the work was devoted to carrying out investigations to establish the suitability of the peristaltic and the rasp bar for threshing grain legumes. Output potential, threshing efficiency and grain damage were assessed at varying revolving speed of the mechanisms, crop moisture content, drum/concave clearance (rasp bar) and feeder roller/table clearance. The second part of the project consisted of establishing operational parameters for the toothpeg type of mechanism. Though this mechanism has been in use for centuries now, especially for threshing cereals, the investigations to work out the importance of variations in design within the spike-tooth drum concept have been largely left unpublished, particularly in relation to grain legumes. Certain amount of work has been carried out on

PLATE No.20

FRENCH BEANS. (PHASEOLUS VULGARIS). NOTE THE TENDENCY FOR BRANCHING.

PLATE No.21.

ON THE LEFT : RICE PLANTS (ORYZA SATIVA)

ON THE RIGHT: SOYABEAN PLANT (GLYCINE SOJA)

THE SEEDS OF RICE PLANTS ARE CONFINED IN THE TOP AREA. IN CONTRAST THE SEEDS ON SOYABEAN PLANT ARE PRODUCED ON LATERAL BRANCHES AS WELL.

the rasp bar mechanism on the same line at the National Institute of Agricultural Engineering, Silsoe, England (Arnold, 1964). These investigations were confined to the temperate cereals only. The absence of such basic data in the case of tooth-peg mechanism provided stimulation to undertake some basic work on its design parameters.

On the assumption that the operational parameters of the mechanism needed some attention, a series of observations were carried out to ascertain effects of variations in the dimensional parameters and design on threshing efficiency and output. Methods of crop presentation, length of the spike teeth both on the drum and the concave, effect of drum peripheral speed and its relation to other parameters and variations in design within the general framework of the mechanism were investigated. Attempts were made to establish the optimum moisture content for threshing soya-beans by hand-operated threshers.

The main object of the latter study in design was to ascertain that the dimensional parameters used in the construction of a prototype were based on the data collected from recorded observations with a particular crop rather than straightforward adopted from some existing mechanism.

It was envisaged that the use of correct dimensional parameters in the design, could very much improve the performance of the machine.

PART A - PERISTALTIC AND RASP BAR

3A : 1 Description of the Peristaltic Mechanism

The idea for this mechanism was suggested by Muchiri (*pers. commn.* 1969). On his suggestions and guidance, an experimental model for this noval mechanism was designed and fabricated at Kabanyolo (see Plate No. 22).

In actual fact, 'peristaltic' is a medical term meaning involuntary muscular action of the alimentary canal or other organ by which it forces its contents forward. A similar action imparted to the plants during threshing by the revolving shafts of the mechanism, gives it the name of 'Peristaltic'.

Essentially, threshing is done by two scutchers which revolve at right angles, in opposite direction to each other. Each scutcher in turn is composed of two shafts, welded at both ends to a steel plate (see Plate No. 23). The plants stripped by the feed roller are directed into this space between the scutchers, which are arranged to have an overlap at right angles. The beater bars of the lower and upper scutchers alternatively strike the crop causing transverse vibration of the stalks, leading to threshing of the grains. Also as a result of these alternate hits the plant material is propelled forward in a wave like motion. Some threshing is likely to occur as a result of this impact but its contribution to the overall threshing action does not appear to be significant, since the hits are not directed against any sort of surface but are free in the air. (see Plate Nos. 23-26 for a pictorial explanation).

In the test model, each scutcher was made from two alloy steel shafts 2 cm in diameter and two mild steel plates 2.5cm wide, 1cm thick and 15cm long. The shafts were welded at each end to these two plates. These shafts were welded at a distance of 14cm from each other. In order to avoid occurrence of any collision between the two scutchers whilst they were revolving it was found necessary to keep a clearance of 2.3cm between them. The scutchers were supported in self-aligning ball races bearings, with provision for adjustment to alter the clearance between the scutchers.

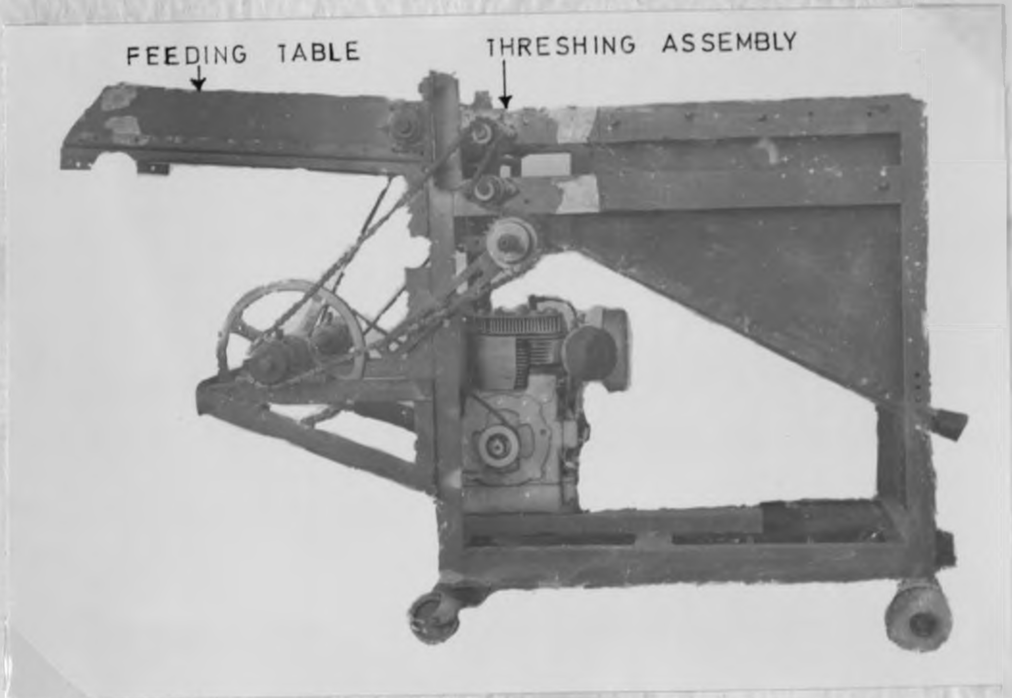


PLATE No. 22

EXPERIMENTAL PERISTALTIC THRESHING UNIT.

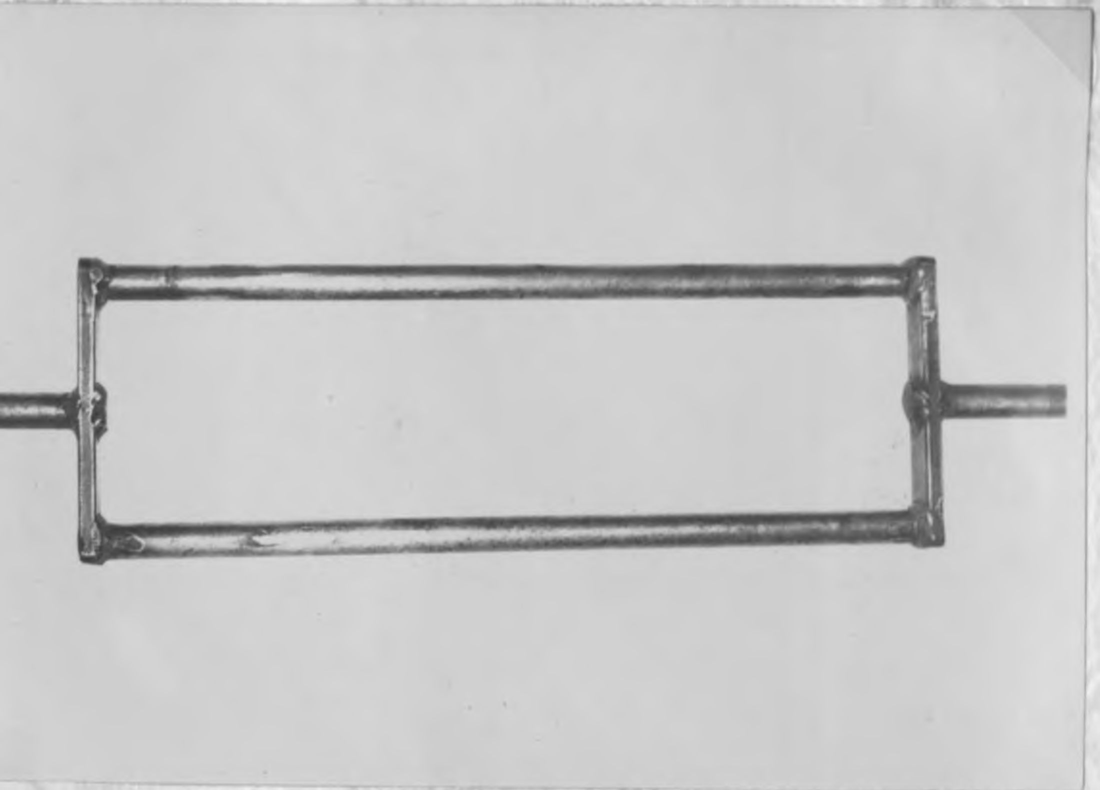
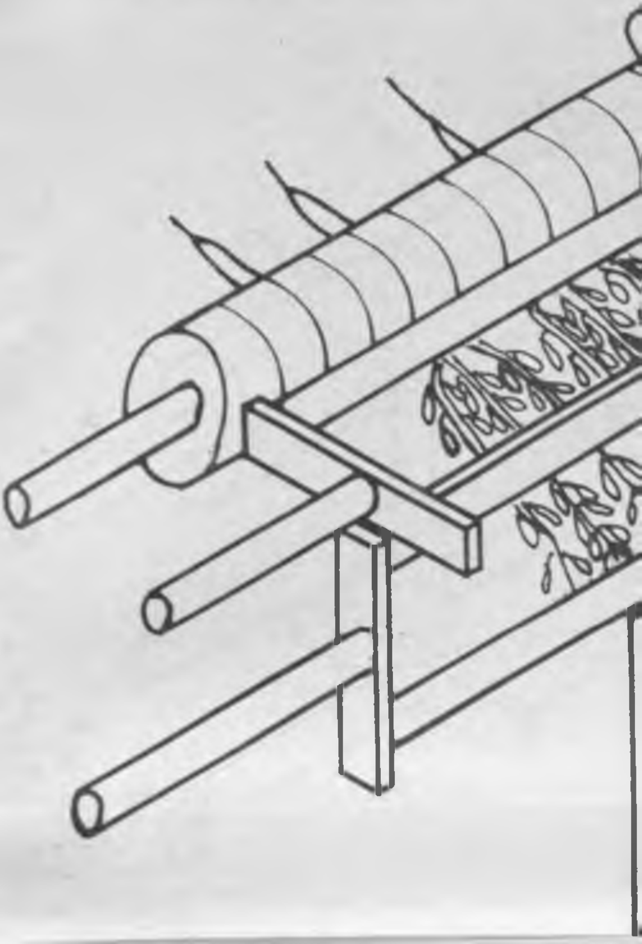


PLATE NO. 23

SCUTCHER.

PLATE NO.24A

SCHEMATIC DRAWING ILLUSTRATING THE FUNCTIONS OF DIFFERENT COMPONENTS AND THE PRINCIPLE OF THRESHING BY THE PERISTALTIC THRESHER.



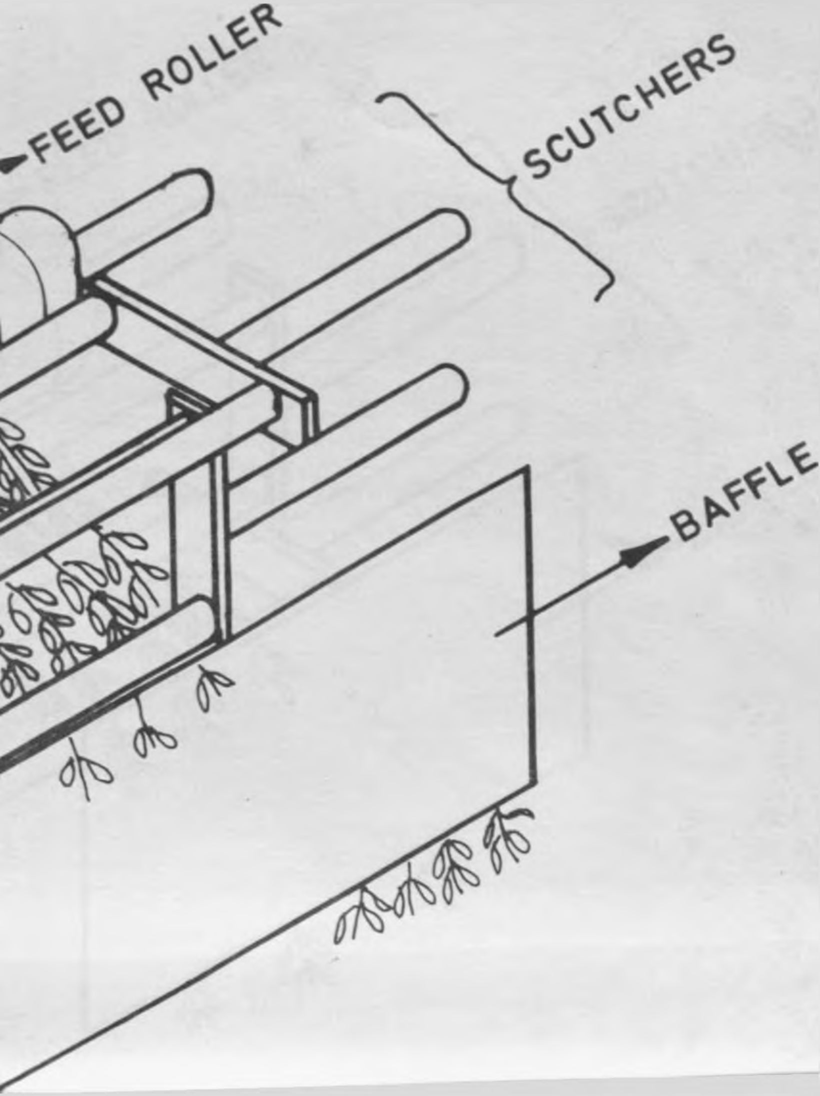
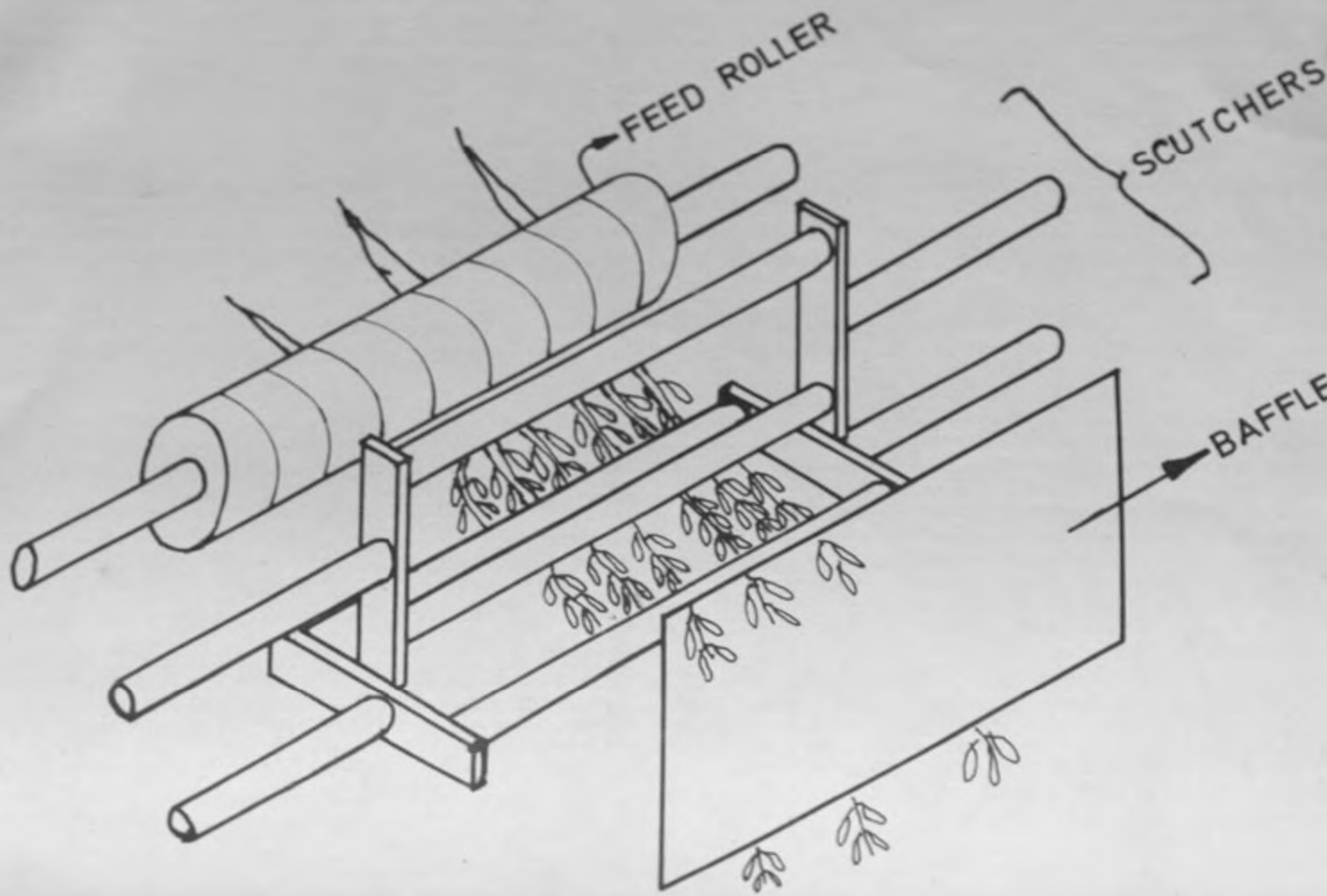

FEED ROLLER
SCUTCHERS
BAFFLE

PLATE No.24B

SAME AS PLATE No.24A EXCEPT THAT
SCUTCHERS HAVE MOVED THROUGH 90 DEGREES.



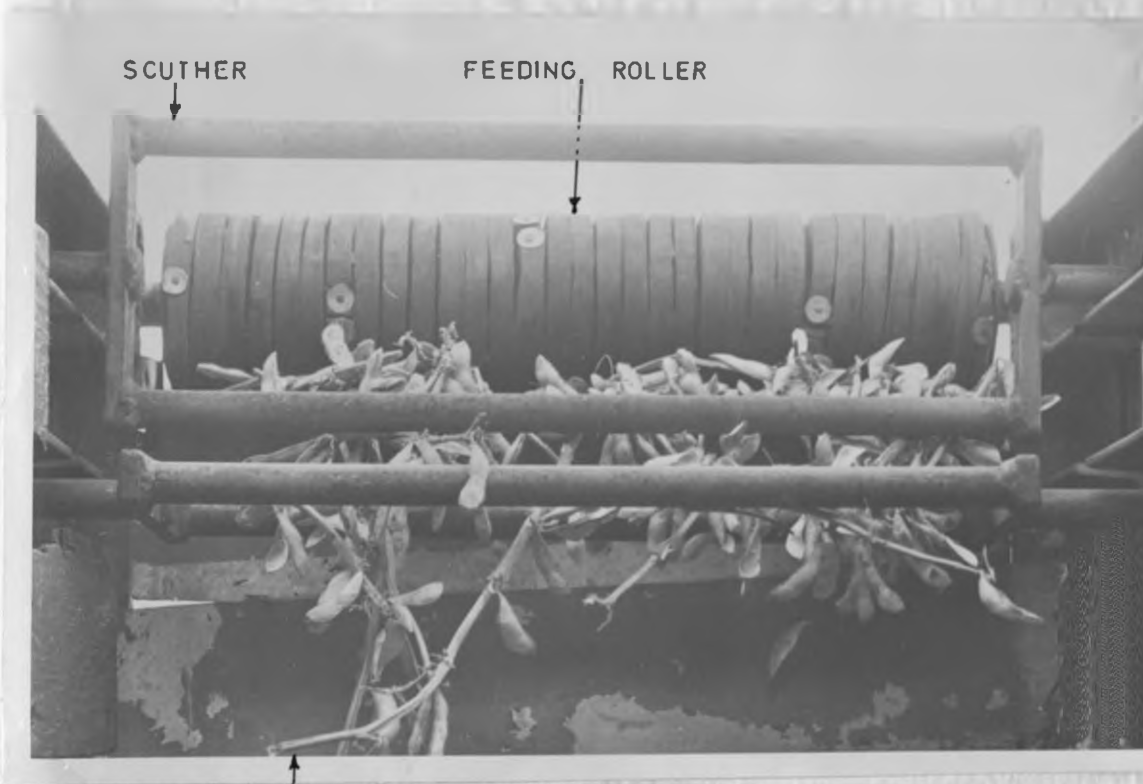


PLATE No. 25A

SHOWING RELATIVE POSITIONS OF THE SCUTCHERS, FEEDING ROLLER AND CONCAVE (BAFFLE MISSING).NOTE ENTRANCE OF PLANTS INBETWEEN THE SCUTCHERS. (PHOTO TAKEN DURING THRESHING OBSERVATIONS).

PLATE No. 25B

SAME AS 24A EXCEPT THAT THE SCUTCHERS HAVE MOVED THROUGH 90 DEGREES.

An adjustable baffle made of 22 gauge galvanised iron was fitted in front of the scutchers on the side away from the feeding roller (see Plate No.24). The assistance rendered by the baffle in threshing was found to be of tremendous value. The first test model built from a dexion frame did not have any provision for the baffle in its earlier stages. As a result threshing efficiency was very low. The pods at the terminal end escaped the effects of hits from the shafts. Attempts were made to improve the efficiency by decreasing the peripheral speed of the roller, but improvement was not significant. Therefore a baffle was put in front of the scutchers so that the plants could be rounded off and sent back to the scutchers for rethreshing. Though the provision of the baffle helped in improving the threshing efficiency, it also brought in some problems of its own. Some restriction had to be exercised in the feeding rate in order to allow for the time for rethreshing. It also increased laceration in the threshed straws. As a result there was an increase in the broken straw and in the amount of chaffe. Whereas without the baffle, a very high quality straw was obtained with very little chaffe. The latter very much decreased the time required for cleaning the threshed product. All that was required was to cream off the straws, shake off the split pods, and the product was nearly ready for bagging.

The lower portion of the scutchers was surrounded by 22 guage galvanised iron sheet, curved in a fashion of a concave from the inlet end to the baffle and from there on sloping downwards for moving threshed material to the discharge end. The sides were enclosed with hard card-board pieces fixed on the main frame. Precautions were taken to seal off the little spaces around the scutchers left out during the construction work. The top was covered with a hard cardboard piece fitted to a dexion frame.

The base frame, housing the mechanism and other accessories, was constructed from channel iron of 7.5cm x 4.0cm x 0.5cm size and angle iron of 5cm x 5cm x 0.5cm size.

Power to drive the scutchers was obtained from a 10 h.p Koeler petrol engine. The drive was first transmitted to a countershaft using taper bush lock in pulleys and a vee belt of A section. From the countershaft, the drive was transmitted to the scutchers via sprokets having a ratio of 2:1 and driven by a motor cycle roller chain. The sproket/chain transmission was specifically used in order to avoid any slippage in transmission, which was likely to bring the scutchers out of alignment hence causing their collision. The drive to the feed roller from the countershaft was transmitted using aluminium pulleys having a ratio of 1:4 and a vee belt of A section. The peripheral speed of the feeding roller was based on the data collected from the first experimental model, where the roller was hand driven to find out the correct peripheral speed. Transmission of the power from the engine to the scutchers and the feeding roller via a common countershaft presented one difficulty. The speed of the feeding roller varied with the variation in the speed of the scutchers, controlled through the engine governor. It was felt that such a variation in the speed of the feeding roller was not a very desirable feature. Therefore, it was found necessary from time to time to change the pulley ratios on the feeding roller transmission to achieve a constant speed of the feeding roller.

The feeding mechanism consisted of a feeding roller and a feeding table. (see Plate No.25). The core of the roller was made out of hard timber enveloped by a rubber layer 6mm thick, fixed with evostick. Two flanges made out of mild steel plate were screwed to the wooden core at both the ends. The shafts supporting the roller in plummer block bearings were welded to these phlanges. The feeding table was cut of galvanised iron sheet of 22 guage.

PLATE NO.26

TOP VIEW OF THE PERISTALTIC
EXPERIMENTAL MACHING SHOWING
THE FEEDING TABLE AND ROLLER.

Its height in relation to the feeding roller was adjustable, thus making it possible to obtain variable clearance between the roller and the table.

3A : 2 Description of the Rasp Bar Mechanism

As the machine, incorporating this mechanism was already present at the testing site, it was found quite appropriate to use it for the testing purposes, instead of constructing a new assembly. The machine was built by the Landmaster Co. of England, and is designed to be operated by the Landmaster walking type of tractor, which is especially manufactured for small scale cultivation. (see Plate No.27).

A rasp bar type of closed drum and an open slatted concave constituted the threshing assembly. (see Plate No.28). The threshing drum was constructed from two mild steel spoke type discs welded to a control shaft, which ran in selfaligning ball races fixed onto the main housing body. There were four rasp bars fitted transversely across the face of the drum at an interval of ninety degrees. Each rasp bar was 4cm wide having serration at 10cm pitch. The drum was 33cm long and 30cm in diameter to the tips

PLATE NO.27

THE LANDMASTER THRESHING UNIT.

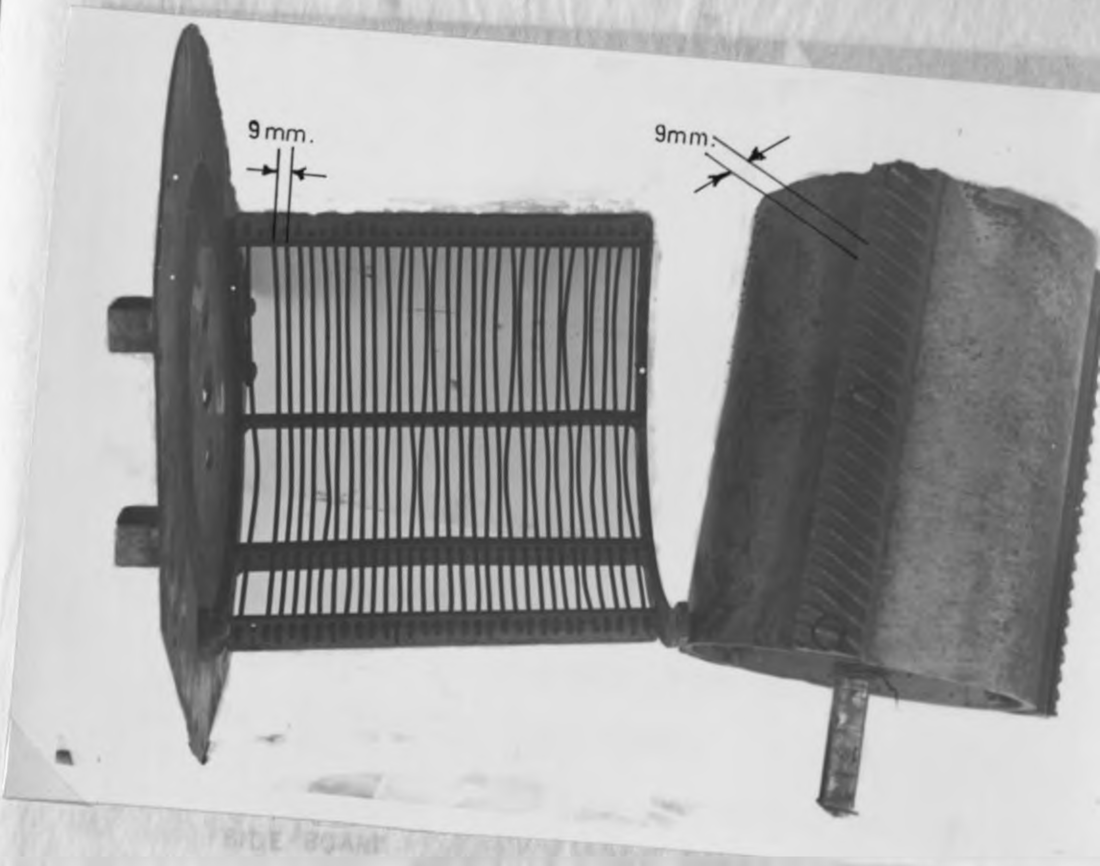


PLATE NO. 28

LANDMASTER DRUM AND CONCAVE. NOTE SERRATIONS ON BOTH ARE 9mm APART.

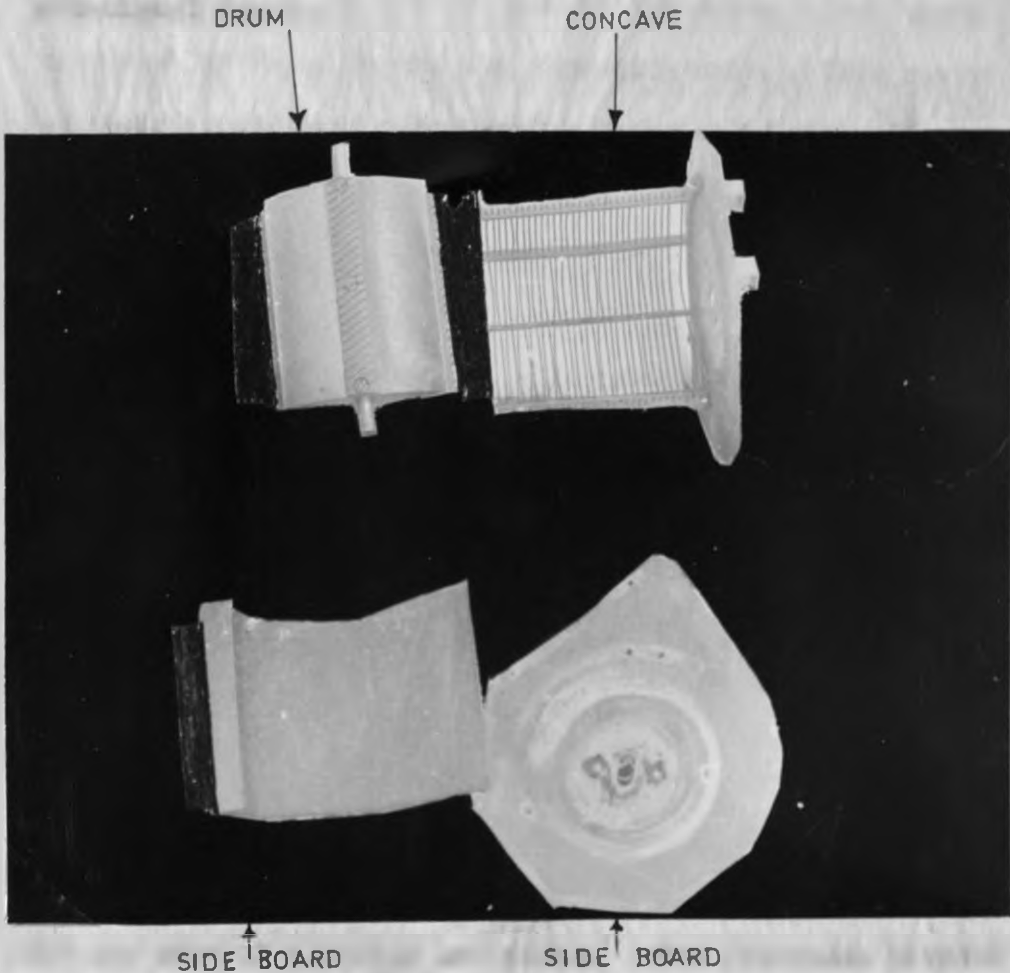


PLATE No.29

DISASSEMBLED PARTS OF THE LANDMASTER THRESHING UNIT. (FEEDING TABLE MISSING).

of the rasps. The non-driven end of the shaft was drilled to take in a hand tachometer for measuring the drum rotational speed.

The concave was of open construction (split concave), 43cm in circumference and consisting of slatted rods 10 cm in diameter and which had a single row pitch of 10 cm. It was fixed at the lower end of the drum. Usually open concaves are incorporated in order to advance the separation of the seeds from the rest of the undesirable material as the threshing progresses. This instant removal of the seeds reduces repeated impact blows from the beater bars, hence minimises the degree of seed damage. This arrangement in addition hastens up the cleaning process, as the seeds can directly be moved to the cleaning shoe. However, in this particular machine, the threshed material got collected in one lot beneath the threshing drum as there was no provision for any sort of cleaning mechanism. The clearance between the drum and the concave was controlled by moving the bearings, housing the central shaft, vertically up and down. The position of the concave remained static.

The feeding table made of mild steel plate was broader at the farther end and narrowed down to the same width as the drum near the throat end. It was 62 cm long. A detachable three sided cloth cover fixed on a wooden frame was attached on the outlet side of the drum. Its length extended by 60 cm beyond the threshing unit. This cover very much assisted in preventing haphazard flying off of the seeds in all directions. A collecting tray was placed underneath the threshing assembly to prevent the contamination of the threshed material by the dirt on the bare ground.

The threshing unit was housed in metal shrouds and was supported on an angle iron chassis. Being chiefly designed for a small farmer it was light in weight.

For the purpose of operation, it was attached to the Landmaster single axle tractor, having a two stroke engine of 4.5 h.p. Besides supplying power to the threshing unit, the tractor assisted in supporting the unit. Power from the engine crankshaft was directly transmitted to the drum using a pully ratio of 1:2 and a vee belt of A section.

3A : 3 Evaluation Procedures for the Peristaltic and the Rasp Mechanisms.

The crop for testing was obtained from the Kabanyolo

Farm where it was grown for commercial purposes. With such an arrangement, a large quantity of the material was easily available, since they were grown on quite a big scale. They were machine planted and 2 cwts/acre of superphosphate was applied at the time of planting. Only one variety, Bukalasa 4 was grown on a commercial scale, hence the observations were confined to this variety only. Owing to wide variation in the soil fertility, maturity period was quite uneven, as a result the earlier harvesting was usually done in patches. Though being a high yielding variety Bukalasa 4, is notorious for its shattering characteristics, hence has to be harvested when the pods are still little wet. In the absence of any mechanised threshing equipment, crops grown on the farm are usually harvested and threshed by the manual labour.

As the crop neared maturity, they were kept under observation so as not to miss the boat for a particular moisture range. When the required ripeness had been reached the moisture content of the grain was determined using a capacitance type of electric moisture meter. On the day of the harvest, the plants were pulled out manually and transported on the same day to the threshing site, where they were stored in a shade to await treatment. Storing this way gave them a partial protection against the changes in the weather. To avoid complications caused by the presence of moisture owing to the high humidity at night, experiments were delayed till later part of the morning, and then also only undertaken if the weather was ideal for threshing i.e. bright and sunny. By following this procedure, it was hoped that uniformity was maintained throughout the trial period.

In an attempt to complete the experiments while the ideal conditions were present, it was felt that a conflict existed between the need to obtain results speedily while the favourable conditions prevailed and the demands of orthodox statistical methods. Very often randomisation was passed over in favour of timeliness. Whether this had a cumulative effect in increasing the experimental error cannot be ascertained. However, where possible no efforts were spared to feed in as typical and uniform sample as possible.

3A : 3:1. Training of Labourers.

Efforts were also directed to reduce the element of the human experimental error, adversely affecting the results. Foremost among them being that adequate practice was given, to all involved in the evaluation work, specialising them in their particular tasks - for example, if a labourer was trained to feed in the crop, it remained his domain throughout the season. In all five labourers were employed to assist during the trial period. One for feeding the crop, second for maintaining a continuous stream of the plant material from the adjoining table, third looked after the adjoining table, fourth was kept at the outlet end to carry away threshed stalks and fifth was extra but instructed to lend his hand where work seemed to be getting a bit out of control at any station. Some mock runs were made to enable the labour force to develop a tempo, style and sharpness required for the testing work.

Earlier experience had indicated that if feeding is carried out manually, the threshing components receive the material for threshing only about half of the time. The other half is utilised in gathering the material which is then fed in bunches. This method though widely practiced only keeps the drum loaded for part of the time. What effect this part loading has on the performance of a particular mechanism is not yet assessed, but for certain the output figures are likely to have an adverse effect. To rectify this error, a long table of the same height as the feeding table of the mechanism was placed adjoining to the feeding table. The feeding then was in a continuous uniform stream, since the feeder did not have to bend down any more to collect the material from an adjoining heap, but his table was kept fully supplied by his colleague.

3A : 3 : 2. Trial Runs, Number of Replications, Cleaning, Winnowing and Weighing.

Each treatment had an actual run of ten minutes. A photographer's timer was used for timing. Each run had a non experimental feeding period of three minutes, during which time it was hoped that the feeder had acquired uniformity in feeding, essential from the testing view point. At the lapse of this warming up period, a black polythelene sheet was quickly put over the threshed material to separate out the material threshed during the actual testing time. Each treatment had three replications, which were found to be adequate, since the conditions, apart from the ones which were deliberately altered remained more or less uniform.

As none of the machines had a cleaning mechanism attached to it, at the end of each run the threshed material was collected for cleaning. An assortment of sieves and a winnowing basket were used to clean the threshed grains. The cleaned grain was stored in the paper bags, for weighing later on. The weighing was done with the Taledo (U.S.A.) platform laboratory model scale, which weighed in one gram increments. Doubts can be expressed questioning the validity of the output figures based on the cleaned material, where-as the time spent on the cleaning was not taken into account. Very valid arguement if a particular model was under test. Whereas this was not the objective of the study. The interests were mainly directed to find out the inherent potential of a mechanism and not a particular model. Later on, if the mechanism proved to be suitable, the cleaning mechanism could be incorporated into its framework.

3A : 3 : 3. <u>Efficiency Indicators</u>.

According to Mark and associates (1963) output performance could be assessed and compared relative to 'straw and chaffe feed rates". Whereas, the farmers interest is in the high grain capacity per hour, who in fact is the ultimate decision maker as to the acceptability of thresher performance. He must decide if a new thresher will provide greater economic returns than other optionals available to him. In Africa, for most of the crops, he will be comparing the performance with the traditional threshing methods. However, again according to Mark et al (1963) for the development work, the farmer's approach can help to assess the performance, if the runs are replicated and a proper record is kept of the whole procedure. The latter approach makes it possible to present the assessment in the farmers language.

Test runs lasting for ten minutes were made to assess out the potential output/hr of the mechanism at different moisture contents and peripheral speeds.

At the end of each run, manual and visual selection was made to separate out the unthreshed grains and these then were threshed manually. The weight of the grain thus obtained, was added to the weight of the grain threshed by the machine. As a result the maximum grain content of the fed in plant material was obtained. The threshing efficiency was then expressed as a percentage of the maximum threshable grain. For example:

Weight of the threshed grain - a kg.

" " " unthreshed " - b kg.

$$\therefore \text{Threshing efficiency} = \frac{a}{a+b} \times 100$$

The assessment of seed damage was simple, consisting of expressing the percentage by weight of the broken grains in a representative sample, selected at random, during the course of the trial run. The assessment was restricted to the visual and physical injury counts only and no attempt was made to evaluate the internal damage, since the facilities were not adequate to carry out such an elaborate exercise at the testing site.

3A : 3 : 4. Variables.

On the whole, the variables were studied independantly, since the main objective was to establish the optimum working settings for the different variables. As a result at no time interest was shown to work out the interaction between any two variables.

The variation in the peripheral speed was controlled through the engine power. First, the speed of rotation of the threshing mechanism under load was taken using a hand tachometer. These speeds were subsequently converted to peripheral speeds in order to permit direct comparison between machines of different cylinder diameters.

Three distinct catagories of moisture contents were specifically studied. They were wet, moderately wet and moderately dry - the last category representing a typical moisture content when the farmer would wish to thresh his crops. At the end of every run, irrespective of the treatment, grains were taken for the moisture content determination. The oven method was adopted for determining the moisture contents. Whole grain samples of 25 gms were weighed on an electronic balance and kept in an oven at 103^0 for 24 hours. This time temperature combination, as it was worked out, avoided the evaporation of the volatile oils present in the seeds. Three samples were taken out for measuring the moisture content and the final figure was expressed as an average of these three samples. The m.c. was worked out on a wet basis. The straw m.c. was not measured.

Only observational runs were made to find out the most optimum concave/drum clearance for the rasp bar mechanism. The aim was to find out the setting which will allow the maximum feed rate, and still obtain satisfactory threshing. This was followed keeping in mind that the narrow clearances result in more break up of the straw, thus decreasing the effectiveness of the separation and cleaning units. The interdependance of the concave with the drum in deciding the performance was not investigated, as it did not fall within the aspirations of this study.

For the peristaltic, similar runs were made to find out the optimum clearance between the feed table and the feedroller, and also at the same time, watch was kept to detect the effect of this clearance as a prethreshing aid to the main mechanism. For the latter purpose, the drive to the scutchers was disconnected, in order to fully measure the effect of the clearance on pre-threshing.

Certain parameters were kept constant throughout the trial period. The foremost among them being the method of feeding. In order to obtain a maximum output, the "throw in" method was adopted in preference to the "hold on" method, as the former method permits continuity in the feeding pattern. No special care was taken to feed the material in a particular direction, however, the presentation of plants parallel to the drum axis was avoided. The angle of presentation to the drum varied between 30° to 50° to the horizontal. Overall grain/straw chaffe ratio came to 0.78 : 1.

Before any treatment was tested as much of the apparatus as possible was assembled before the start. For each treatment sheaves were taken at random and kept on the extended feeding table. Before the start of each run, desired settings were adjusted, the cylinder run to the required speed and rechecked after two minutes to ensure that the speed had not changed either way. When the time for a particular treatment was over, feeding of the material was halted, but the machine was kept in motion for further two or three minutes to ensure that the material already fed was completely threshed, - thus leaving no residues for the next run.

3A: 4 Observations on the Rasp Bar and the Peristaltic Mechanisms.

3A : 4 : 1. Moisture Content.

On the whole, wetter grain is associated with wetter straw. Usually a change in the m.c. of either is invariably accompanied by a similar effect on the other, though not necessarily of the same magnitude, largely because of the difference in their wetting and drying rates. The difference in magnitude is likely to be quite pronounced if the environmental conditions exhibit a speed change. Arnold (1964)

When the plants having a high m.c. (25–27%) were fed to the peristaltic, first when without a baffle in the front of the scutchers, most of the plants came out at the discharge end unprocessed. After the baffle was put in a little improvement was observed in threshing because of the back feeding of plants to the scutchers. But on the other hand, this backfeeding tended to choke up the mechanism, as the beater bars (shafts) could not manage to break down or tear apart the wet straw, which as a result got wrapped around the scutchers. When the accumulation of such straws reached a certain point, they put a cumulative resistance to the movement of the scutchers, which at first slowed down and then completely stopped revolving.

working on wheat and barley concluded that the grain condition or damage depended on the seed m.c. whereas the threshing efficiency was affected by the straw m.c.

The test result showed that the peristaltic mechanism had its performance very much decided by the moisture content of the crop. Whereas the rasp bar mechanism appeared to be capable of threshing soyabeans over a wide range of m.c. (15-27%) the peristaltic in contrast could only thresh soyabeans within a narrow m.c. range.

The tendency of choking by the wet straw was also observed at the high scutcher peripheral speed of 1400m/min. A marked improvement in the threshing quality was observed when a dry crop was fed. Though the choking could not be completely eliminated, its effect was drastically reduced by exercising a control on the feeding rate.

3A : 4 : 2. Grain Condition or Grain Damage.

The maximum amount of broken grains visually during the runs both with the rasp bar and peristaltic never reached any significant level. However, this does not in any way indicate the extent of internal damage, which unfortunately could not be assessed owing to the lack of facilities at the testing site.

3A : 4 : 3. Concave Clearance - Rasp Bar Mechanism.

Lack of uniformity in the size of the soyabeans plants did not allow any critical studies on this parameter. The thickness of plants varied from 2 mm to 6 mm (see Plate No.30). This variation was largely present because of the soil fertility gradient in the field. However, some observational runs were undertaken to find out the optimum

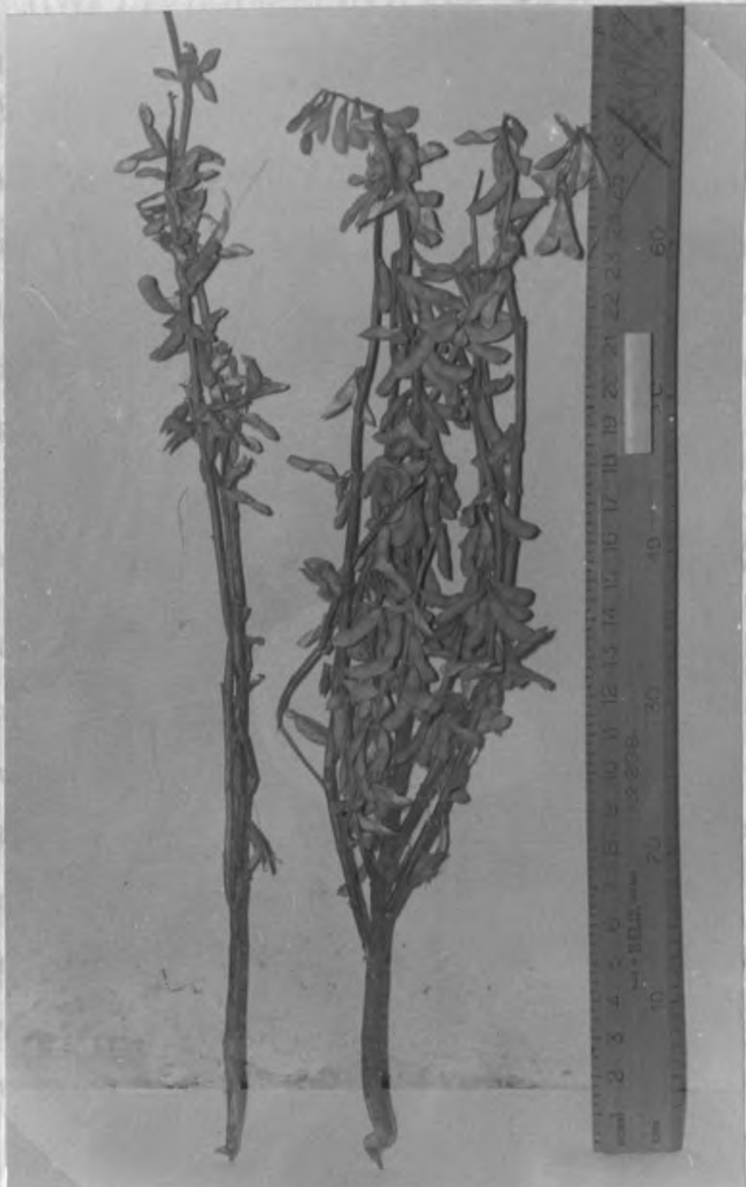


PLATE NO.30

SHOWING TWO SOYABEAN PLANTS. NOTE THE DIFFERENCE IN THEIR STEM THICKNESS AND BRANCHING.

clearance. As a result it was found that complete threshing with negligible damage was obtained at the maximum clearance of 2.75 cm in the centre. Since this setting gave a satisfactory threshing at all grain moisture contents, and in addition allowed the maximum feed rate, it was adopted as a standard setting for threshing soyabeans for the rest of the runs.

3A : 4 : 4 : Roller Feed Table Clearance - Peristaltic.

Hopes of having pre-threshing treatment between the roller and the feeding table whilst the crop passed between them were not fully realised. To have any degree of pre-threshing treatment it was found that a very narrow clearance was necessary. Moreover, even at this narrow clearance the pre-threshing treatment was only confined to the pods coming in direct contact with the revolving roller. This was so largely because the pods beneath the top layer had a cushioning effect from the heavy plant vegetation, hence escaped the shearing or pressing action from the roller. In addition the narrowing down of the clearance had an adverse effect on the output as the feeding rate was cut down. In view of these findings, it was found logical to keep the clearance at the maximum to achieve a high feeding rate. Some improvement in the pre-threshing treatment might have been achieved if the plants had been passed through two revolving surfaces rather than one. However, owing to the complications involved in installing such a mechanism in the existing model the idea was not followed.

3A : 4 : 5. Threshing Efficiency.

Threshing efficiency was earlier defined as being the amount of threshed seeds expressed as a percentage of the maximum grain content of the crop being threshed.

From the recorded observations (see Table No.1 and 2), threshing efficiency appears to be a function of moisture content and peripheral speed of the mechanism. A rise in the threshing efficiency with an increase in the drum peripheral speed was exhibited throughout the m.c. range, but near perfection in threshing was only achieved with the rasp bar mechanism and that also when a dry crop (m.c. 15-17%) was fed at a drum peripheral speed of 1400m/min. (maximum possible).

Both with the rasp bar and the peristaltic, the influence of the moisture content on the drum loss or threshing efficiency seemed to be quite pronounced (see Graph No. 1 and 2). Whereas the raspbar mechanism showed an ability to thresh soyabeans on a wider range of moisture content (27% and below) the peristaltic on the other hand appeared totally unsuitable for threshing a high moisture content crop. It managed to thresh the crop having a m.c. of 23 percent at the scutcher speed of 700m/min. but the efficiency was below 50 percent. The pods were knocked off the plants but did not get shelled. Prolonged running was, moreover, difficult at this m.c. when lower peripheral speeds were tried, as the scutchers failed to breakdown the plants into the size that would not wrap around the scutchers.

Though the peristaltic was able to thresh the crop at a m.c. of 21-23% its threshing efficiency at the highest possible scutcher speed was below 95 percent. Comparatively the rasp bar mechanism achieved this performance at a lower drum speed of 1000m/min.

Both showed improvement in threshing efficiency when a little drier crop (m.c. 15.17%) was fed into them. However, the extent or rise in the improvement did not follow a common pattern. At the highest possible peripheral speed of 1400m/min, the peristaltic had a threshing efficiency of 98 percent, in comparison at the same peripheral speed, the rasp bar reached near perfection in its efficiency.

A common feature with the rasp bar type of mechanism was the rise in the threshing efficiency at all m.c. when the drum speed was raised to 1000m/min.- though this rise was in varying intensity. The improvement in the threshing efficiency when the drum speed was raised above 1000m/min was quite gradual and very unlike the earlier improvement when the speed was raised to 1000m/min. (See Graph No.1).

With the peristaltic thresher, at a m.c. of 21-23 percent a marked increase in the threshing efficiency was observed, when the scutcher speed was raised from 1000 to 1200m/min. Moreover, at this m.c., improvement in the threshing efficiency was observed with the increase in the scutcher peripheral speed throughout the entire range. At a bit lower crop m.c. of 15-17 percent, the improvement in the threshing efficiency was only abnormally high when the scutcher speed was raised from 700 to 860m/min.

DRUM PERIPHERAL SPEED IN METERS PER MINUTE	MOISTURE CONTENT (W.B.)		
	25-27%	21-23%	15-17%
	THRESHING EFFICIENCY EXPRESSED IN PERCENTAGE. AVG. OF THREE REPLICATES.		
700	87.27	93.98	98.28
860	87.46	93.58	98.67
1000	88.84	97.95	99.60
1200	89.41	99.00	99.76
1400	91.22	99.43	99.78

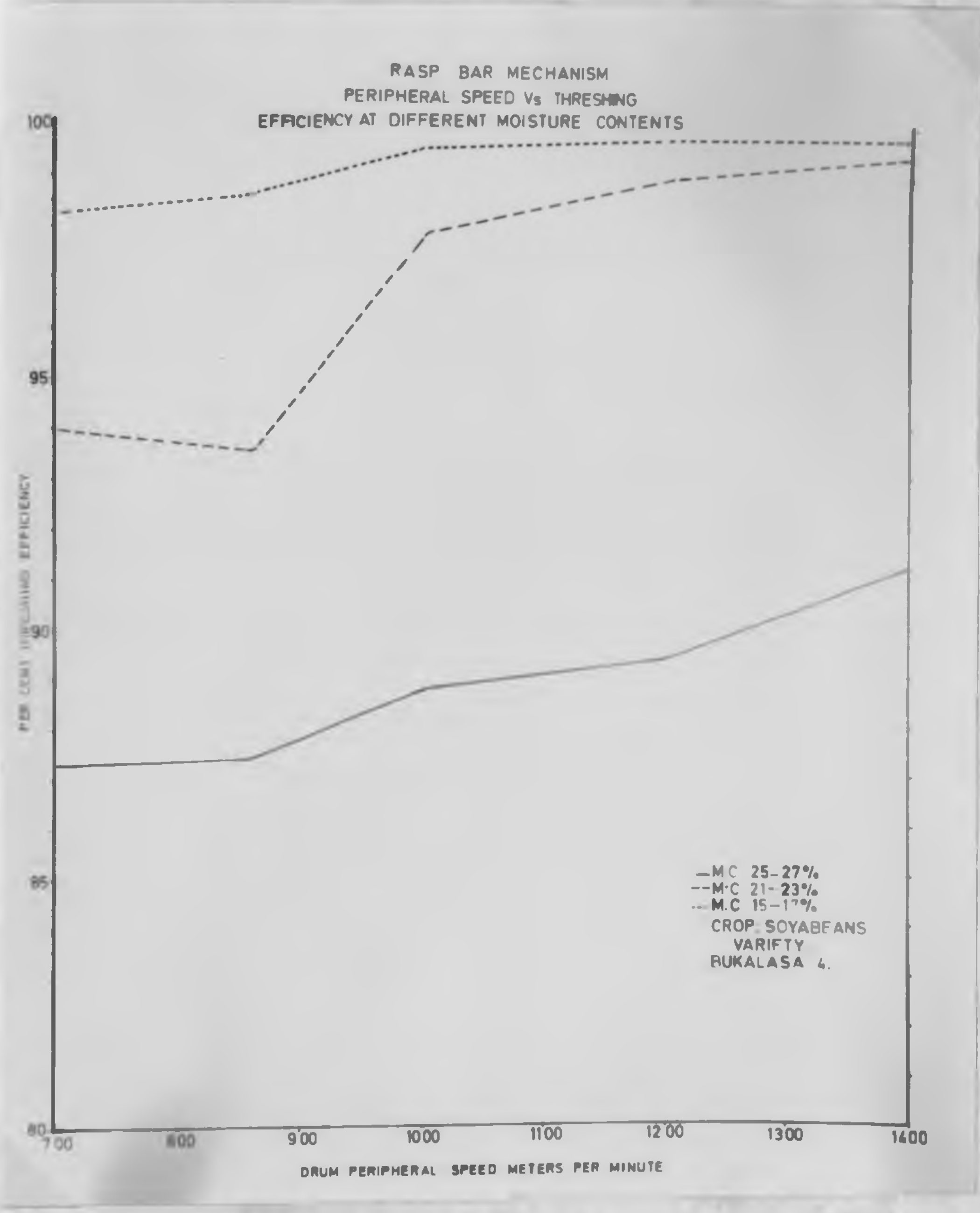
TABLE No. 1 - RASP BAR MECHANISM.

Showing the relationship between threshing efficiency and drum peripheral speed at different moisture contents.

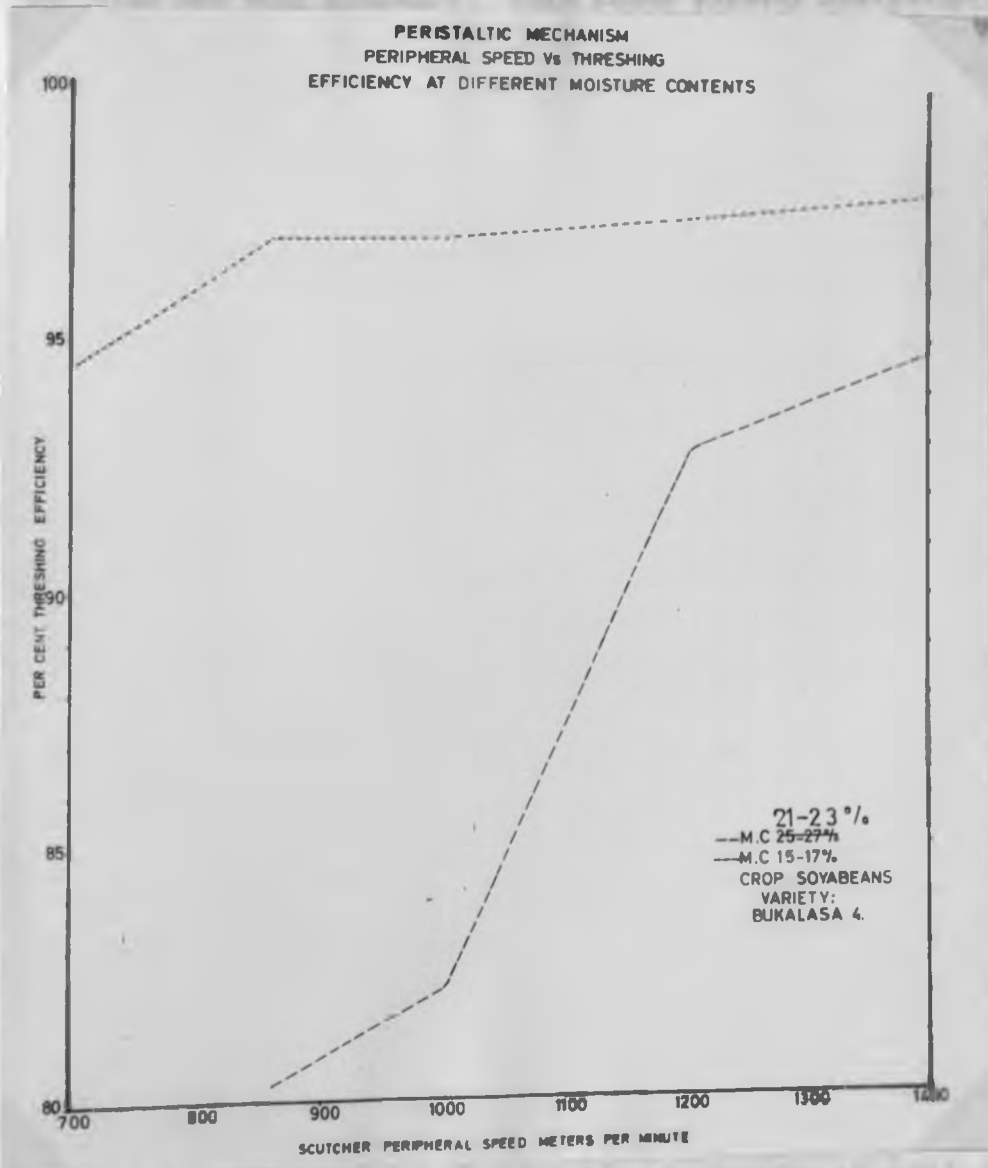
DRUM PERIPHERAL SPEED IN METERS PER MINUTE.	MOISTURE CONTENT (W.B.)		
	25-27%	21-23%	15-17%
	THRESHING EFFICIENCY EXPRESSED IN PERCENTAGE. AVG. OF THREE REPLICATES.		
700	Threshing not Possible.	-	94.40
860		80.33	96.86
1000		82.22	97.01
1200		92.81	97.42
1400		94.73	97.86

TABLE No.2. - PERISTALTIC MECHANISM

Showing the relationship between threshing efficiency and scutcher peripheral speed at different moisture contents.


RASP BAR MECHANISM
PERIPHERAL SPEED Vs THRESHING
EFFICIENCY AT DIFFERENT MOISTURE CONTENTS
100
95
90
85
80
700
800
900
1000
1100
1200
1300
1400
DRUM PERIPHERAL SPEED METERS PER MINUTE
—M.C 25-27%
--M.C 21-23%
CROP. SOYABEANS
BUKALASA 4.

GRAPH No. 1


PERISTALTIC MECHANISM
PERIPHERAL SPEED Vs THRESHING
EFFICIENCY AT DIFFERENT MOISTURE CONTENTS
PER CENT THRESHING EFFICIENCY
100
95
90
85
80
700
800
900
1000
1100
1200
1300
1400
SCUTCHER PERIPHERAL SPEED METERS PER MINUTE
21-23 %
M.C 25-27%
M.C 15-17%
CROP SOYABEANS
VARIETY:
BUKALASA 4.

GRAPH No.2.

Above that speed, though some improvement was observed, the rise was very gradual. This trend clearly indicated the perstaltic's inherent ability to thresh a high moisture content crop.

3A:4:6. Grain Output.

In general, the output potential of a mechanism appeared to be once again a function of the mechanism's peripheral speed and the crop moisture content.(see Graph No.3 and 4). In all cases, a linear relationship seem to exist between the mechanisms peripheral speed and its output. Though, the linear slopes were different for the rasp bar and the peristaltic, however, for each mechanism it could not statistically be shown that the slopes were different at different moisture contents (see Appendix A_2 and B_2). In other words, the rate of increase of output, though was shown to depend on the type of mechanism and its peripheral speed, the rate was however not shown to be very much dependant on the moisture content of the crop. In the case of the peristaltic mechanism it was discovered that for every increase of 100m/min in the scutcher's peripheral speed, there was a corresponding increase of 2.22kg/hr in the output independant of the m.c.

The corresponding figures for the rasp bar mechanism were calculated to be 6.52 kg/hr per every increase of 100m/min in the drum peripheral speed. It follows therefore that there are more chances of obtaining a better output with the rasp bar mechanism than there are with the peristaltic mechanism.

At a lower crop m.c. of 15-17 percent, it was also noticed that slightly better separation of straw and seeds was achieved in both mechanisms. In addition the regression lines appear to suggest that it is possible to obtain some output at this low m.c. if the mechanism's peripheral speed is below 700m/min.

In case of the peristaltic, the crops moisture content appeared to have more influence on the mechanism's performance. This is illustrated by a wide gap in the output of the peristaltic mechanism at two different moisture levels. (see Graph No.4). The data collected for the peristaltic are not complete because it was found that at a high m.c. of 25-27 percent, threshing efficiency was very poor. For the same reason, output at a m.c. of 21-23 percent at the scutcher speed of 700m/min could not be measured.

3A:4:7 Wrapping.

The tendency of material to wrap, or continue around revolving members of mechanisms, was found to depend primarily on the design features of a mechanism. This was demonstrated by the high rate of wrapping in the peristaltic mechanism and the virtual absence of wrapping in the rasp bar mechanism except in isolated incidences when a wet crop was fed into the mechanism.

The occurrence of wrapping in the peristaltic was primarily because of the presence of the baffle in front of the scutchers. In trying to carry out its function of feeding back the plants for rethreshing, it also slowed down the exit speed of the plants and thereby encouraged wrap promoting tendencies. With a damp straw the situation was so much exaggerated that wrapping completely blocked the movement of the scutchers. Wrapping occurred less frequently with a dry straw. To a certain extent the wrapping tendency was lowered by putting the baffle at a correct spacing from the scutchers and also by angling it towards the exit end, so that the plant material came out in a stream. However, it was difficult to completely eliminate wrapping in the peristaltic, unless the baffle was completely done away with, but this on the other hand

DRUM PERIPHERAL SPEED IN METERS PER MINUTE	MOISTURE CONTENT		
	25-27%	21-23%	15-17%
	OUTPUT IN KG. PER HOUR/30cm WIDE THROAT. AVERAGE OF 3 REPLICATES.		
700	13.60	22.52	30.70
860	18.04	23.11	42.77
1000	28.04	37.13	63.76
1200	51.06	53.10	69.12
1400	56.57	59.45	72.90

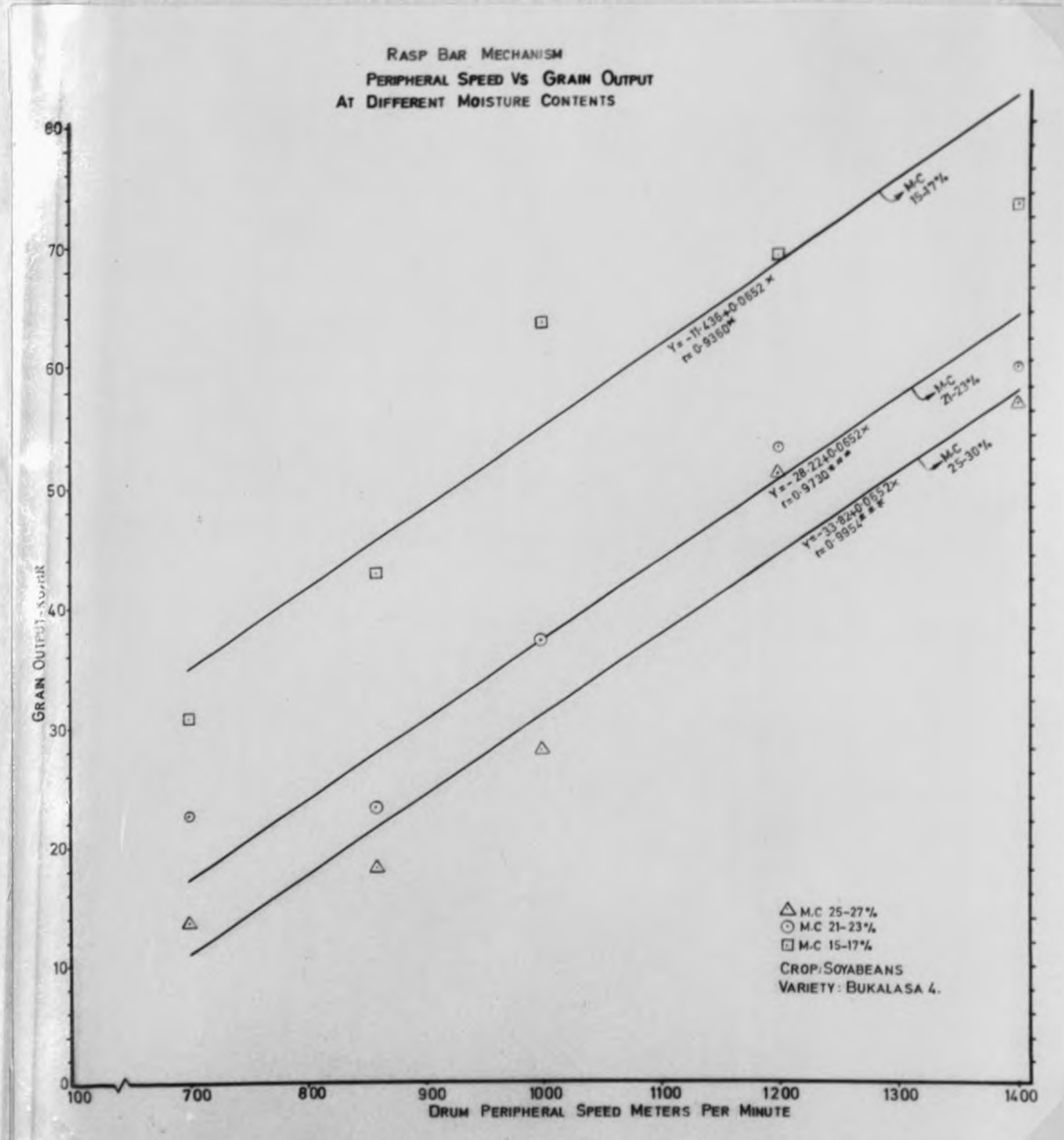
TABLE No.3. - RASP BAR MECHANISM

Showing the relationship between output and drum peripheral speed at different moisture contents.

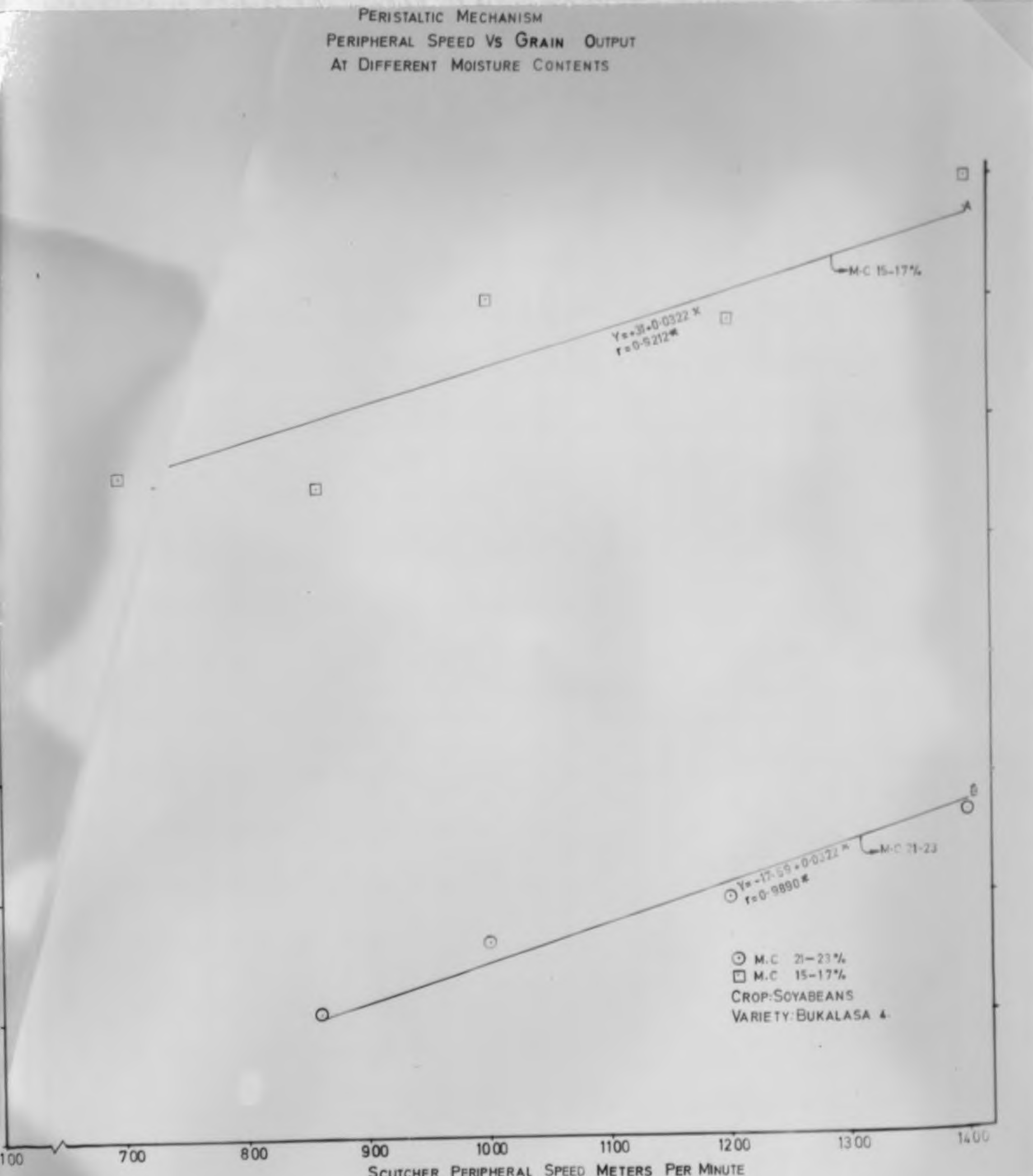
SCUTCHER PERIPHERAL SPEED IN METERS PER MINUTE	MOISTURE CONTENT		
	25-27%	21-23%	15-17%
	OUTPUT IN KG. PER HOUR/45cm WIDE THROAT. AVERAGE OF 3 REPLICATES.		
700	-	-	54.82
860	-	10.51	54.00
1000	-	16.32	69.54
1200	-	19.77	67.85
1400	-	26.63	79.62

TABLE No.4. - PERISTALTIC MECHANISM

Showing the relationship between output and scutcher peripheral speed at different moisture contents. (For missing figures see Text).


RASP BAR MECHANISM
PERIPHERAL SPEED VS GRAIN OUTPUT
AT DIFFERENT MOISTURE CONTENTS
Y= -11·436+0·0652 x
r= 0·9360*
M.C 15-17%
Y= -28·224+0·0652x
r=0·9730***
M.C 21-23%
Y= -33·824+0·0652x
r= 0·9954***
M.C 25-30%
M.C 25-27%
M.C 21-23%
M.C 15-17%
CROP: SOYABEANS
VARIETY: BUKALASA 4.
GRAIN OUTPUT
0
10
20
30
40
50
60
70
80
100
700
800
900
1000
1100
1200
1300
1400
DRUM PERIPHERAL SPEED METERS PER MINUTE

GRAPH No. 3


PERISTALTIC MECHANISM
PERIPHERAL SPEED VS GRAIN OUTPUT
AT DIFFERENT MOISTURE CONTENTS
M.C 15-17%
M.C 21-23
M.C 21-23%
M.C 15-17%
CROP: SOYABEANS
VARIETY: BUKALASA 4
700
800
900
1000
1100
1200
1300
1400
SCUTCHER PERIPHERAL SPEED METERS PER MINUTE

GRAPH No.4.

would have adversely affected the threshing quality.

3A:4:8 Broken Straw.

Slightly more broken straw was observed in the crop threshed with the rasp bar mechanism, than in the crop threshed with the peristaltic. This was probably due to the shearing action by the rasp bars, as the plants passed between them. In case of the peristaltic, a very high quality end product was obtained, if the baffle was completely removed. This would have been at the expense of threshing efficiency.

3A:5 Discussion on Observations - Rasp Bar and Peristaltic Mechanisms.

3A : 5 : 1. Threshing Efficiency.

From the observation records it is evident that two factors namely, the crops moisture content and the mechanisms peripheral speed, play a key role in determining the level of threshing efficiency. This appears to be more pronounced with the peristaltic mechanism, where if a high threshing efficiency is desired then the crop must be threshed when its moisture content is below 15 percent and at high scutcher speeds. With the rasp bar mechanism a wet crop can be threshed at a desired efficiency if correct peripheral speeds are employed. The vibrational mode of threshing used by the peristaltic, appears to be a little mild hence not harsh enough to thresh a wet crop. On the other hand, the impact mode of threshing used by the rasp bar mechanism appears to be quite severe enough to thresh a wet crop. The soyabean crop having a m.c. of 23 percent can be threshed near to perfection if a drum peripheral speed of 1400m/min is used. This is not the case with the peristaltic. Moreover, the rasp bar mechanism appears quite capable of threshing a wet crop (m.c. 25-27 percent), though the level of threshing efficiency is not high (see Graph No.1). The peristaltic is completely unable to thresh soyabeans at a m.c. of 27 percent and above. With a dry crop (m.c. 15-17 percent) the rasp bar mechanism demonstrated ability to achieve a threshing efficiency of 99 percent at a lower drum peripheral speed of 700m/min - whereas the peristalties threshing efficiency was 95 percent with a similar set of conditions. This indicates that even if the crop is dry high scutcher speeds are necessary to thresh the crop, if a high threshing efficiency is desired.

3A : 5 : 2 Grain Output.

The great care which must be taken to thresh a soyabeans crop at the right moisture content to obtain a high output has been demonstrated. Even so more with the peristaltic where the output is nearly more than doubled if the crop m.c. is reduced from 21 percent to 15 percent (see Graph No.4). The explanation for a high output at a low m.c. appears to be the higher rate at which the crop is able to pass through the mechanism thus making it possible to increase the feeding rate.

Once again the rasp bar mechanism demonstrated its superiority over the peristaltic. A reasonable output of 60kg/hr was obtained at a crop m.c. of 21 percent and at the maximum peripheral speed of 1400m/min. The peristaltic under a similar set of conditions had an output of 30kg/hr.

The likely cause for such a big difference in the output at the above m.c. appears to be the mode of action of a threshing mechanism. The feeding rate must be matched with the mechanism's ability to thresh the crop. On the relative basis, the peristaltic demands more time to thresh a wet crop than the rasp bar mechanism. Two possible reasons account for this extra time. The first being that a large proportion of the crop is fed back by the baffle to the scutchers for rethreshing. As a result, the crop spends more time inside the threshing mechanism. This in turn means that the feeding rate has to be controlled. Secondly, a wetter crop requires more hits per cm of travel to get threshed, which means that the passage of a wet crop through the scutchers is slowed down. As the crop gets drier, the amount of rethreshing proportionally decreases, together with a proportionate decrease in the number of hits required for threshing. In addition, the exit speed of the threshed material is higher when a dry crop is fed, therefore the rate of feeding can be stepped up.

3A : 5 : 3. Peristaltic's Performance and its Chances for Further Development.

The development work on the peristaltic mechanism was initiated to assess the potential as a possible mechanism for threshing grain legumes. The present study has served to bring into light certain facts concerning its operation together with its performance standards when compared with a conventional threshing mechanism like the rasp bar.

Most of the facts appear to suggest that the peristaltic mechanism shows very few promises for further development as a small scale threshing mechanism.

The lightness of the components involved in threshing was the main feature of attraction. It was thought that this feature would decrease the energy requirements needed for driving the mechanism hence would be very suitable for hand operation. During the course of the study it was discovered that very high peripheral speeds were necessary to achieve a high threshing efficiency and a reasonable amount of grain output. These high scutcher speeds meant that the energy requirements for operating the mechanism would be quite high thus contradicting the earlier expectations of low energy demands.

Its mild form of vibrational threshing completely failed to thresh a wet crop having a m.c. above 23 percent. In addition though it exhibited abilities to thresh a dry crop,a certain amount of rethreshing was required to achieve an acceptable standard of threshing. This requirement necessitated the presence of a baffle in front of the scutchers for rounding back the plants for a second round threshing. The baffle though helped to inprove the mechanisms performance on the other hand it tended to promote wrapping tendencies among the plants.

Wrapping occurred frequently when a wet crop was threshed. As the baffle sent the plants for rethreshing they began to revolve around with the scutchers. The scutchers could not breakdown the wetter straw into pieces to speed up their exit. As a result, extreme caution had to be exercised in the feeding rate to avoid choking up of the mechanism. With a dry crop, the situation was not so exaggerated as the scutchers were able to break-down the straw into small pieces thereby speeding up their exit. Moreover, factors like the thickness and the length of the plants tended to exaggerate wrap promoting tendencies.

Perhaps, the need for the presence of a baffle could be eliminated by adopting a multiple threshing principle - i.e. having two sets of scutchers for threshing. In this instance the length of the plants could be an added advantage, since they would very well suit for the multiple threshing principle.

The maximum output of 80kg/hr. did not appear to be very encouraging in view of the wideness of its throat (45 cm). In comparison, the rasp bar mechanism had a maximum output of 72kg/hr. per 30cm wide throat.

Apart from the above mentioned inherent weaknesses, it did not prove to be a simple mechanism to operate and fabricate locally. A slight deviation in the aligning of the scutchers usually resulted in the scutchers entangling each other after a short run.

In short, the peristaltic did not appear to be a good suggestion for developing a small scale thresher for grain legumes. The basic principle of operations needs to be studied first. In view of this it was thought best to abandon the development work on it.

3A : 3 : 4. Use of Regression Methods.

Where it was found appropriate straight line regressions were fitted (Graph No.3 and 4). These regression lines were then in each case compared to see if there was any significant difference in their relationships. As a result for each mechanism, these lines have been drawn with a common slope since it could not be shown that the slopes for different lines for a particular mechanism were different (see Appendix A_2 and B_2).

In some cases the trend of results appeared to be quite indicative by itself, hence linear regressions or other statistical analysis were not attempted. It appeared that the latter would be of very little help. Such results were then presented diagramatically (see Graphs 1 and 2).

PART B - SPIKE TOOTH THRESHER

3B : 6. Description of the Experimental Spike Tooth Thresher

An experimental testing thresher was locally designed and fabricated at the testing site (see Plate 31 and 32).

The threshing assembly had a big drum, 1m in diameter an 45cm wide. The former specification was adopted to give a reasonable drum peripheral speed at moderate revolutio of the drum, and the latter was arbitrarly thought to be the maximum drum width a single operator could comfortably feed. The drum was made from mild steel plate 3mm thick. The concave was cut out from the same plate and was strengthened along its periphery with a flat bar measuring 3cm x 0.5cm (see Plate 33). It was also found necessary to strengthen the interior of the drum, which was done by fixing on each side six spokes, made from 2cm galvanised

PLATE NO.31.

SIDE VIEW OF THE EXPERIMENTAL

SPIKE TOOTH THRESHER.

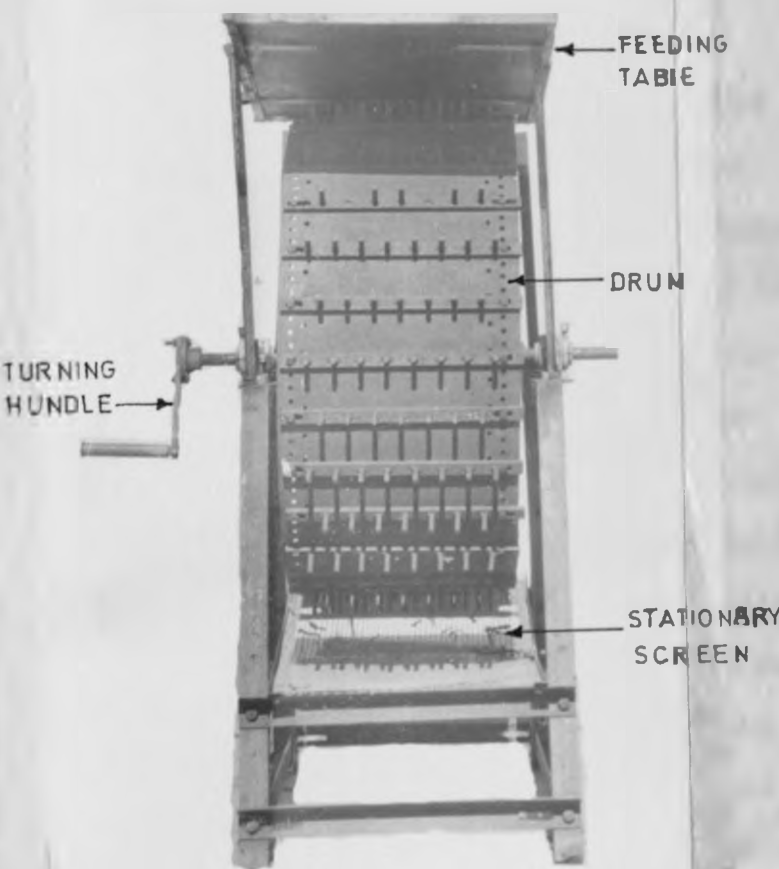


PLATE No.32

FRONT VIEW OF THE EXPERIMENTAL SPIKE TOOTH THRESHER.

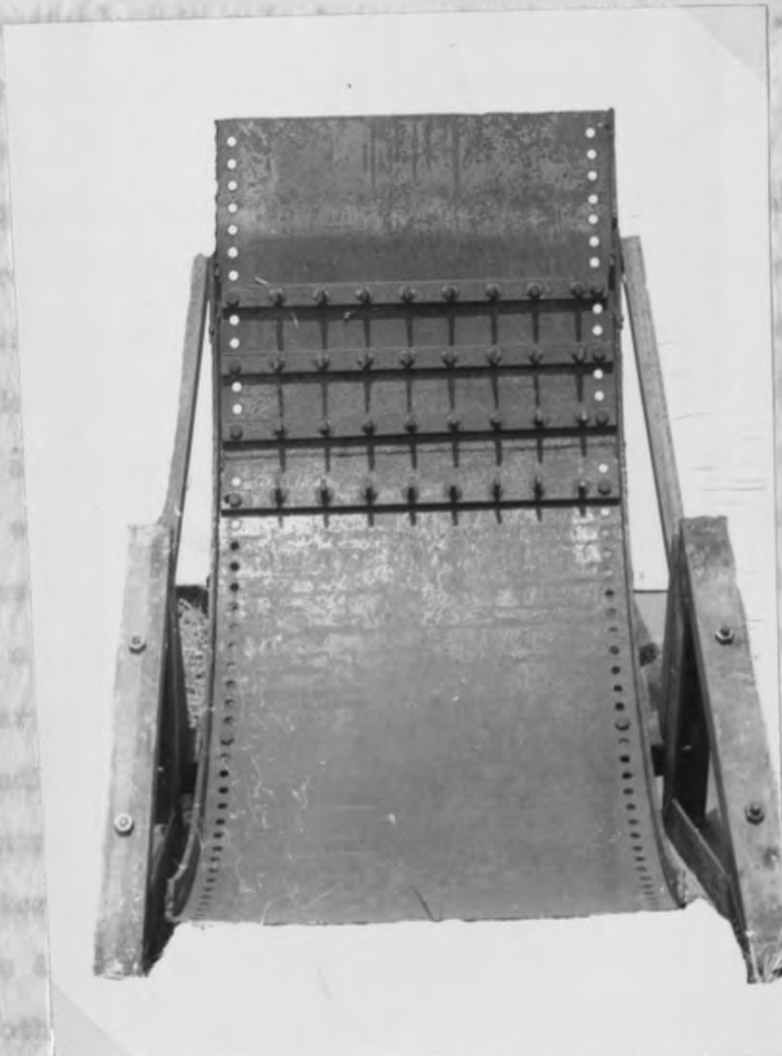


PLATE NO.33

CONCAVE FOR THE EXPERIMENTAL SPIKE TOOTH THRESHER.

water pipe. These spokes were then welded, at the other end, to a hollow central shaft (5cm outside diameter) again made from a galvanised water pipe. A steel alloy shaft (2.5cm diameter was passed through this hollow pipe and was attached to the central shaft by welding it to washers which in turn were welded to the hollow shaft. This alloy steel shaft ran in two plummer block bearings fixed on either side of the drum. In passing it may be mentioned that an attempt was made to run the hollow shaft directly in wooden bearings but unfortunately the resistance encountered in driving the shaft was excessively high, as a result the wooden bearings were replaced by ball bearings. The longer end of the shaft was fixed with a handle for driving the drum. The non driving end was centrally drilled to take a tachometer for measuring rotor speeds. Holes were drilled on both the edges of the drum at an interval of 2.5cm for fixing bars carrying toothpegs. The toothpegs in turn were welded on to the bars (2.5cm x 1cm) in a single row (see Plate 34). The bars were bolted on the drum, to give a staggering pattern to the pegs.

Similar holes as on the periphery of the drum were

PLATE No.34

TWO BARS CARRYING WELDED PEGS. ALSO SHOWING THE CLEARANCE RELATIONSHIP BETWEEN THE TEETH IN THE SPIKE-TOOTH CYLINDER AND THOSE IN THE CONCAVE.

drilled on the concave to bolt the bars carrying the pegs. The concave was supported on an angle iron frame (same size as the main frame) and bolted to the main structural frame. The design work included the provision for varying the drum/concave clearance and the amount of overlap of teeth on the drum and concave. The concave was made 17cm to radius greater than the drum and its length extended along almost half the circumference of the drum (see Plate 33). The flat iron strips carrying welded spike teeth (7.6cm long and tappered at the free end) were bolted to the inside of the concave. Originally it had been planned to stagger the teeth on the concave as well, but this idea was dropped because of the difficulty experienced in clearing them through the staggered teeth on the drum. The clearance relationship between the teeth of the drum and the concave is shown in plate 34.

The feeding pan was placed on the top side of the drum and this end of the concave was raised by 5cm to provide a throat at the entrance. Partial cleaning of the threshed material was secured by placing a stationery 1cm mesh screen at the exit end (see Plate 35). This screen separated the plant straws and part of the split

PLATE NO.35

STATIONERY SCREEN OF THE EXPERIMENTAL SPIKE TOOTH THRESHER.

haulms from the rest of the material i.e. seeds, chaffe and split haulms which managed to pass through the screen openings.

Being a test model, where appropriate and possible, emphasis was placed on the ease of trying out wide variations in the dimensional parameters. This kind of flexibility, made it extremely easy to collect facts regarding roles played by the different parameters and also helped to find out their optimum settings. The provision of such a flexibility in the use of the parameters was partly responsible for increasing the drum weight.

3B : 7. Evaluation Procedures for the Spike Tooth Thresher.

Once again the crop for testing was obtained from the farm where it was planted for commercial purposes. The details concerning its growth etc., are the same as those mentioned earlier under section 3A : 3. All the necessary precautions, mentioned in the same section (3A:3) were strictly observed to avoid the element of human error affecting the results.

Most of the trials were run on purely observational basis with the purpose of visually detecting the effect of a change in a particular parameter. The threshed material was usually not collected for weighing or for calculating the drum loss, except when the optimum settings were finally worked out and then a few runs were made to collect such information. The effect of a new setting was judged by the change in the magnitude of threshing efficiency. Throughout the trial period, an endeavour was made to maintain a visual threshing efficiency of nearly 95 to 100 percent. It was felt that the adoption of this method very much speeded up the work, besides avoiding cumbersome statistical analysis. Any setting which appeared to show a threshing efficiency below 95 percent was outright rejected. Therefore, doubts questioning the validity of the observational results, it is hoped, do not arise.

Each new setting had an actual observational run of five minutes. A photographer's timer was once again used for timing the runs. Three replications for each new setting were conducted. When the threshed material was to be collected for weighing the drum was revolved without any load for two minutes. During this period, the required peripheral speed and the uniformity in driving the drum were achieved.

As the cleaning by the stationery screen was not a hundered percent, it was found necessary to follow this partial cleaning with some sort of manual cleaning and winnowing to get a clean end product. This was carried out immediately at the end of every run. Where weights were taken of the threshed crop, the same procedure as mentioned in section 3A:3 was followed.

The tests to find out output and threshing efficiency of the mechanism at different settings were of five minutes duration and were run on the same lines as those adopted for the peristaltic and the rasp bar.

Neither visible nor invisible seed damage count was made owing to the fact that the peripherical speeds employed during the trials were quite low, hence most unlikely to cause any appreciable amount of damage.

In each treatment only one variable was studied, the remaining factors were kept constant at approximately, the middle of the range, if the optimum for such factors were not yet studied. Again in very few cases, co-relation between any two parameters was given some serious thought. Throughout the study the parameters were carefully watched and processed one by one, the order of study decided by the weight of a particular parameter on the overall performance of the thresher. Once an optimum setting was established, it was left undisturbed in most instances. However, if any change was carried out, it was of a very minor nature but of a quite large benefit in the optimum establishment of some other parameters.

For the purpose of continuity in the presentation of the facts revealed during the course of the study, methods and observations for an individual variable are reported under a common heading.

3B : 8. Observations - Spike Tooth Experimental Thresher.

Only moderately dry material (m.c. below 14 percent) could be threshed to the required level of efficiency. This was so because there was a limitation to the maximum drum speed which could be obtained and maintained comfortably, whilst the drum was hand operated. Crop having a higher moisture content than 14 percent could be threshed but the efficiency was not to the required level and in addition was inconsistent. As a result the rest of the trials were carried out with a crop having a m.c. of 12-14 percent (W.b). The moisture content was determined by the oven method, following the same procedure as mentioned under 3A:3.

3B : 8 : 1. Minimum Peripheral Speed Required for Threshing.

The drum peripheral speed was indirectly measured with a hand tachometer, which in first instance recorded drum rotor speed, this rotor speed was subsequently converted to peripheral speed. Before any material was fed into the machine, the drum was run to the required speed. During the course of observations the tachometer was held on at its station to keep a check on the drum speed. By this it was ensured that a constant drum speed was maintained when the drum was loaded with the crop. For the purpose of measuring the drum peripheral speed, drum diameter was measured to the middle of the pegs.

The trials run to find the maximum possible drum rotational speed showed that when hand operated a maximum rotation speed of 50-60 revolutions per minute (r.p.m.) could be achieved. At this rotational speed the desired level of threshing was obtained. This speed was then dropped in steps of 5 or 10 r.p.m. to observe the effect of lowering drum speeds. Some degree of inconsistency was observed, in threshing efficiency, within a replication but its overall effect was likely to be of very little significance.

The optimum peripheral speed was shown to be much dependant on the moisture content of the crop. To a certain extent, the size of the plants and relative humidity at the time of threshing also seemed to be having an effect in determining the correct peripheral speed. It was observed that the runs made during the late afternoon (R.H. 45-50 percent) definitely re-quired lower drum peripheral speeds than the runs made during the early morning (R.H. 90 percent). It is believed this happened because of the hygrascopic nature of the material.

In general, tests undertaken to find the optimum peripheral speed indicated that this appeared to be within the range of 130-150m/min. for threshing soyabeans having a m.c. of 12-14 percent. This meant that the drum had to be revolved at 40-50 r.p.m. which proved to be a little tiring if continued for more than 10 minutes. However, this peripheral speed (130-150m/min.) was adopted for the rest of trials.

3B:8:2. Spacing of Spike Tooth Rows on the Drum.

The experiment was begun with the minimum possible distance between the rows of the pegs, and then was increased by 5cm at a time to observe the effect of the change.

The starting spacing was 5cm between the rows of the pegs on the drum. This setting it was felt was almost approaching somewhere near to a solid drum. Three other spacings were tried viz 10cm, 15 cm and 20cm. In each case the effect of the change was noted on the threshing efficiency. Among the last three settings tried, a distance of 10cm between the rows appeared to work best. The threshing efficiency was upto the required level and it was easy to feed the plants at this spacing.

3B:8:3. Length of the Pegs on the Drum and Concave.

The aim was to find out the optimum peg length which would give the highest output.

Three replicated runs were made, first when the peg length was 8cm followed by similar runs when the peg length was reduced to 4cm. Simultaneously identical changes were carried out on the concave pegs.

The effect of a change in the length appeared to be on the output and the ease of feeding. There appeared to be no significant difference in the threshing efficiency. The output by **using** the longer pegs (8cm) was higher and the difference was significant at 1 percent level with the shorter pegs (4cm - see Table 5). Within limits the longer the pegs, the higher the output seemed to be. The probable reason being that larger amount of crop could be thrown in the threshing compartment, if the longer pegs were used. Moreover, it was observed that with the reduced size of the pegs, the crops at times seemed to be experiencing difficulty in passing through the pegs.

For construction purposes, a length of over 8cm was considered impracticable, therefore 8cm was adopted as the optimum.

Length of Pegs	Drum Peripheral Speed Meters/Min.	Output/Hr in Kg. Avg.of 3 Repl.	Threshing Efficiency
8 cm	150	29.46	92%
4 cm	150	19.09	91%
Mean Difference		10.37	1.0 N.S.

TABLE No.5.

Showing output and threshing efficiency of soyabeans at two different lengths of pegs.

3B : 8 : 4 Spacing of Spike Tooth Rows on Concave.

Similar trial runs as mentioned under 3B : 8 : 2 were undertaken to find the optimum spacing of rows on the surface of the concave. Among the various combinations that were tried, a spacing of 6cm between the rows seemed to be the best as a closer spacing than this ended up in plants getting plugged up between the pegs. Beyond the spacing of 6cm the threshing efficiency was lowered. The probable reason being that above this spacing, the plants did not encounter enough resistance at the right moment to decelerate their forward movemen[t]. Hence they gained momentum and were shot out with their pods unthreshed.

The observations seem to indicate that besides the number of beats or repetition of combing action, probably the actual distance between bars may play a part in deciding the quality of threshing, in that it influences the way in which ears are presented to the spaces between the pegs. It seems that a point is reached when bar spacing is reduced, at which the opportunities for pegs to act are so low that threshing efficiency may even begin to fall off.

3B : 8 : 5. <u>Minumum Arc of Contact on Concave Necessary for Threshing and its Relationship with Drum Peripheral Speed</u>.

The aim was to establish the duration of crop exposure to combing action necessary for threshing, and to find out if any co-relation existed between the drum peripheral speed and the concave length. The reason for the latter being that if such a co-relation was found to exist then it was believed that the decrease in drum speed could be compensated by increase in the length of concave. This would have allowed the rotational speed of the drum to be lowered for the ease of operating by manual labour. This was in line with the generally held belief that the duration of combing on the crop can be increased by using more bars, or by increasing the length of time for which the crop is exposed to the combing action e.g. by increasing the length of the concave.

The minimum exposure duration was determined by the number of strips carrying pegs necessary on the concave for threshing. The observation was started with the maximum possible number of strips which could be accommodated on the concave. At each successive set of run, one row of pegs was removed, starting from the exit end. To begin with, there were 14 such strips, 5cm apart - that means the reduction in the arc of contact was carried out in steps of 5cm, till it was found that threshing efficiency was lowered below the acceptable standard, by the removal of the last strip.

Once again during the course of the observations it was shown that the moisture content of the crop appeared to be the deciding criteria as far as the duration of exposure was concerned. Soyabeans having a m.c. of

12-14 percent required a minimum of 4 strips, whereas crop below 12 percent was effectively threshed with only one row of pegs on the concave.

The observations undertaken to establish the presence of any relationship between the drum speed and the effective length of the concave showed negative results at the crop m.c. of 12 percent i.e. no relationship could be established. This particular finding was rather disappointing since the absence of any relationship meant that the drum peripheral speed could not be lowered below 130-150m/min. This finding appears to indicate that it's the magnitude of impact during the combing action which is the deciding factor rather than the number of impacts which finally determine the level of threshing efficiency.

However, with a very dry crop (m.c. below 10 percent) some sort of negative co-relation appeared to be present between the drum speed and the length of contact. With a reduced concave length, higher peripheral speeds were necessary to obtain a high level of threshing. Further exploitation of this relationship was not carried out, as it only seemed to work in the lower range of the concave length - i.e. within 1 to 4 strips of pegs.

In addition, it was observed that the distance of the first strip on the concave from the inlet played a vital roll in deciding the number of strips necessary for threshing. On this particular thresher, placing of the first strip 20cm from the inlet end appeared to work best. Advancing of the strip towards the inlet, resulted in plants getting blocked in the beginning, thus slowing down their passage. If the strip was placed beyond 20cm from the inlet, the passage of the plants was accelerated, resulting in a rise of unthreshed pods. The placing of the first strip had also effect on deciding the number of strips necessary for threshing, for example, if the strip was placed at 40cm from the inlet, five strips were necessary, whereas at 20cm four were necessary for threshing.

This shows the importance of the combing action of the pegs at the entrance to the drum. Thereafter, the action of the pegs appears to be at random and less effective because the stream of crop is much thinner.

3B : 8 : 6 <u>Drum/Concave Clearance</u>.

The sections carrying the pegs were so arranged on the drum and concave, that the net clearance between them came out to 1.2cm. This parameter was not varied as it was proved that a wider gap than 1.25cm was likely to be detrimental to threshing and a narrower gap likely to encourage plugging of plants between the pegs.

3B : 9. Observations on a Prototype Spike Tooth Thresher.

After collecting the data pertaining to operational parameters involved in the operation of spike tooth thresher for grain legumes, it was felt that these could be used to design and construct a prototype hand operated thresher. Most of the dimensions used in its design were directly taken from the last series of observations. However, in order to reduce the cost and speed up the work, a discarded drum from the Landmaster threshing unit was utilised for constructing the drum. As a result the drum's specifications were altered as follows:

Drum width : 33cm

Drum Diameter : 30.5cm to the middle of pegs.

Two closed types of concaves were made from flat iron bars (1cm thick and 2.5cm wide) and galvanised iron sheets of 26 guage. The aim was to try out two different positions of fixing the concave. One below the drum, the other above it. The central drum shaft was supported in two selfaligning ball races which were fixed on the main housing. The mechanism was housed in two 22 guage galvanised iron sheets (see Plate 36) which were strengthened at various places with 2.5cm square hollow channel iron. A stationery screen of 1cm mesh was placed below the concave to separate out seeds from haulms and straws. One end of the shaft had a handle fixed on it for revolving the drum. The other end was made to take a hand tachometer for measuring the drum revolutions. A feeding table was fixed at the throat end. A wooden table was attached to this feeding table, in order to increase the length of the feeding table. This arrangement as mentioned earlier (3A:3) made it possible to have a continuous and uniform feeding of the crop to the threshing unit.

Observational methods and crop conditions were same as those mentioned for the experimental toothpeg thresher.

The observations undertaken to find out the suitable positioning of the concave suggested that a better threshing was obtained with the concave below the drum than above it. Moreover, with the latter arrangement, a certain amount of plugging of straw was observed when the concave was below the drum, straws were carried away due to gravitational pull hence the frequency of plugging was low.

PLATE NO.36

PROTOTYPE SPIKETOOTH THRESHER.

The earlier runs were directly made with a handle attached on the drum shaft. As the drum diameter was small, it had to be revolved at a very high speed to achieve the required peripheral speed. However, even at the maximum possible drum revolutions of 120 per minute, the output and threshing efficiency were not very striking. Average of three runs gave the following results:

Threshing efficiency : 72 percent.

Output/hr. : 20 kg of seeds/33cm wide drum.

In addition, some difficulty was encountered with the direction of presentation of the crop. The feeding had to be done with a butts first direction to avoid plants having thick stems or profuse branching getting plugged between the pegs. It appeared this was done at the expense of threshing efficiency. When plants were fed with the butt end first, it appeared that there was a marked absence of any sort of means to arrest their acceleration through the pegs, as a result they were shot out instead of being combed through the pegs, hence remained unthreshed. The passage of plants is to some extent analogus to sewing needle eye and splitted strands of a thread. If an attempt is made to pass the splitted end (heads first in the case of plants) resistance is encountered. However, on the other hand if the clean and neat end (butt first in the case of plants) is presented to the eye, it slides through easily, pulling along the split end as well.

Foremost among the possible reasons for such a disheartening performance, appeared to be the lack of right magnitude of impact to thresh open the pods or to shear apart the plants caught between the pegs. The magnitude of impact is known to be a function of weight and velocity of a body. In this instance the weight could not be altered, without some major modifications in the design, e.g. heavier pegs, therefore an increase in the velocity of the drum was necessary. The required increase in the drum speed was obtained by incorporating in the design a temporary countershaft carrying a pulley of 23cm diameter to drive a 7.5cm pulley on the drum shaft via a vee belt of A section. With this modification, a maximum peripheral speed of 305m/min. was reached. To maintain this speed, the pulley on the countershaft had to be revolved at 100 r.p.m. which proved to be a difficult task to continue for any length of time. It was observed that approximately 16 Kcal/min. were demanded from an operator. On an hourly basis the figure comes to 960 k cal/min. Whereas the maximum number of Kcal that can be made available per day of eight hours are 1400 (Boshoff, 1970).

The encouraging features of these modifications were a marked increase in the output and threshing efficiency. At 305m/min the average results of three runs were as follows:

Threshing efficiency : 85 percent.

Output/hr : 30 kg of seed/33cm wide dr

Comparing the results of the last two exercises, it was evident that a drum's peripheral speed and also likely its width probably play a key role in deciding the machines output and its threshing efficiency.

Some work was undertaken to find out if the presence of a pulley or/and some added weight would ease out the task of driving the drum. On one side of the drum shaft a flywheel weighing 12kg, and on the other side a cast iron block weighing 27kg were attached to induce some extra momentum. There was plenty of advantage from this extra momentum, when the drum was running free, but as soon as some load was put on it, the advantage of induced momentum seemed to fade out in proportion to the increase in load.

With the same assembly, some runs were made to verify its potential as a suitable mechanism for groundnut stripping. The few runs made to test this potential, clearly indicated that the toothpeg type of mechanism could be successfully utilised to strip groundnuts off their haulms (see Plates 37 and 38).

The last series of observations brought out into light the possibilities of threshing soyabeans and stripping groundnut with the toothpeg type of mechanism. The initial goal of running the mechanism manually were not materialised as the energy demands for driving the drum were excessively high. Tests carried out in Ethiopia (CADU,1969) also appear to suggest that there is very little advantage gained from hand operated threshers. In view of these findings, it is proposed that it would be extremely useful to incorporate some sort of power source, preferably an engine, for motivating the drum. This machine could be then an ideal tool for co-operatives or for contract work. Using such a machine to thresh crops on different farms should be quite possible in view of the nature of its job, i.e. threshing can be spread over a long period. With such an arrangement (i.e. using the thresher on a commercial basis) adequate

PLATE NO. 37

GROUNDNUT PLANTS BEFORE STRIPPING

PLATE NO.38

SHOWING THE SUCCESSFUL STRIPPING OF GROUNDNUT SHELLS BY THE TOOTHPEG MECHANISM.

amount of work per season could be anticipated to economically justify its purchase.

DEVELOPMENT WORK AND OBSERVATIONS ON CLEANING MECHANISMS

CHAPTER 4

Hand cleaning by shaking sieves, tossing the mixture into the air, or pouring it above the ground in the wind is a time consuming and tedious task. Winnowing could be greatly speeded up by making artificial winds combined with mechanical agitation of sieves. Whilst in the Eastern countries, farmer's have developed their own indigenous fanning devices, farmer's in the tropical Africa still to a large extent rely on slow hand cleaning. (Kline et al, 1969). Furthermore, on the whole little appears to have been done for developing a small scale separate winnower, having provision for attaching a suitable threshing mechanism if desired so, thus combining these two operations into a single unit. Studies of various nature encompassing different aspects of travelling and cleaning characteristics of an oscillating sieve have been carried out independantly by Garvie (1966), German et al (1969), Lee et al (1969) and Batel (1960). But these studies have been undertaken with a view to improve the quality of output from a combine harvester. It may not be appropriate, therefore, to directly use their findings in the designing a small scale cleaner/ sorter.

Small threshing units very rarely have cleaning mechanisms incorporated in their design. Using such a threshing unit, the problem of separating the straw when threshing crops like soyabeans is simplified by just shaking and lifting straws off as the threshed crop comes out at the exit end. Further cleaning in such a form of threshing is confined to removal of foreign material like stones, debris and chaffe. This task appears to be within the capacity of a fanning mill. Difficulties are encountered, when attempts are made to simultaneously carry out threshing and cleaning in one operation. For example, with crops like soyabeans, straw separation problem is somewhat aggravated because of its bulkiness in relation to seed/pod volume. Experience indicates that usually high reciprocating speeds of the straw walker are necessary to make straw travel to the discharge end. There are two distinct disadvantages of these high speeds. Firstly, if it is to be hand operated, it is doubtful if the required frequency of oscillation can be sustained for any length of time. Secondly, high reciprocating speeds are likely to induce stresses on the frame structures, thus shortening their life span.

The present study was therefore undertaken with a view to reduce the oscillating frequency of the straw walker to the minimum, without affecting its walking efficiency and at the same time collect some basic design data for local manufacturing of the machine.

The intensity of grain separation by a shaker screen depends on a number of factors. (Deutsche Agrartechnik,1964).

1. Shape and size of screen surface.
2. Size, number and angle of slots.
3. Length of the stroke.
4. Number of oscillations to which the mass of grain and straw is subjected.
5. Straw moisture content.
6. Quantity of material to be passed over the shaker in any given time.
7. Air volume i.e. air velocity.
8. Entrance conditions i.e. drop or no drop.

Of these, factors like shape and size of the screen surface, straw moisture content, input rates, straw, chaffe:

grain ratio, air velocity, having some influence on the efficiency of travel of straw and separation of seeds were held constant. Length of the stroke, frequency of oscillation, size, number and angling of slats were studied. Ease of travel of straw, time taken to reach the discharge end and quality of seeds coming out at the discharge spout were used as a measure to establish the optimum settings.

4:1 Description of the Experimental Cleaner

In view of the practical importance of certain factors affecting the efficiency of a cleaner, an experimental cleaner based on the reciprocating principle was designed by Muchiri (*pers. comm.* 1969) for local fabrication. The machine was called 'The Universal Cleaner' since its designing incorporated features to extend its use to clean a wide variety of crops. With each parameter under study, provision was made to operate it on a wide range of settings, so that the optimum for each parameter could be established.

Conventional combine principles of cleaning by mechanical agitation assisted by an air blast were used to design the cleaner (see Plate No. 39).

PLATE NO. 39

UNIVERSAL CLEANER

The main chasis was constructed from channel iron measuring 7.5 cm x 4 cm x 0.5 cm and angle iron of 5 cm x 5 cm x 0.5 cm. At the feeding end a triangular frame with an adjustable stand was attached to carry the engine. Pitch of the cleaner was largely controlled by this adjustable stand. The whole framework was supported on two rubber pneumatic wheels.

The straw walker's exterior frame was made from 3 mm thick mild steel plate. Screens of varying square mesh were first fixed on the dexion frames and then were slid inside the straw rake and were bolted on to the clamps. Only one such screen was supposed to be in use at a time, depending on the size of the seed. A second smaller mesh size screen was permanently fixed about 5 cm above the grain pan to receive grains registering through from the top screen, and also receiving chaffe which was not blown away by the air draft. The idea was to filter through chaffe and allow grains to move towards the collecting spout made of mesh screen and having the same hole opening as the second screen. Further cleaning of the threshed seeds took place here. (see Plate No. 40). The straw walker was suspended from the frame by two pairs of parallel links, 25 cm in length,

PLATE NO. 40

SHOWING STRAW-WALKER AND DISCHARGE
SPOUT OF THE UNIVERSAL CLEANER

which were running in rubber bushes. These links were set to give an inclining slope towards the discharge end. This arrangement was found to assist the forward movement of the straws. Oscillating of the straw walker was done by means of an eccentric crank, in the direction of the travel of the straw.

Power to crank the straw walker was provided by a 10 h.p. Clinton petrol engine. The drive was first linked to a countershaft via pulleys and a vee A section belt. This countershaft was running in taper lock self-aligning ball race bearings. From the countershaft drive to the cranking mechanism was transmitted via sprokets having a ratio of 1:3 and a roller motorcycle type chain.

A radial type of fan was installed to provide an air blast for pneumatic cleaning. It was positioned at the front end of the straw walker. The air draft was directed on to the grain, registering through the upper sieve, to blow away chaffe and any other light material. To a certain extent, the blast also assisted the forward movement of the grain/straw mass on the upper sieve. The fanshaft ran in a self aligning ball races,receiving its drive from the countershaft via a 3:1 pulley ratio and a vee A Section belt.

4:2 Evaluation Procedure

Test material was obtained by threshing soyabeans crop, originally collected for the threshing trials. Threshing was done with the peristaltic thresher. The grain: straw/chaffe ratio of 0.75:1 almost remained constant. The samples for measuring the grain and the straw moisture contents were taken separately. The grain m.c. was in the range of 12-14% (w.b) and the straw/chaffe m.c.was between 14-17% (w.b.). These were thoroughly mixed before they were dropped on the straw walker from a height of 6 cm. The input rate was maintained constant at 1 kg per every drop. Three replications of each setting were conducted, but were not statistically designed. Fresh material was used for each replication.

Preliminary tests were run to find out the optimum air blast, that will blow chaffe away, but not seeds. By this means, it was ensured that the loss of seeds occurring at the discharge end was kept to the minimum. A hand tachometer was used to record the oscillation frequency of the straw walker. A photographer's timer was again used to measure the time taken for the mass to travel 1.8 m long straw walker. Time was measured till the last straw fell down. Certain parameters were not timed, as visual and practical observations were found to be more helpful. The oscillation frequency was controlled through the engine speed. Before the start of each run, the shaker frequency was brought up to the required level, and run at that level for 3 min. to avoid unwarranted changes in the engine revolution affecting the shaker frequency.

It was pointed out earlier that the aim of the exercise was to establish the optimum settings for various parameters through visual and practical observations rather than relying on statistically designed experiments. Hence, it has been found more appropriate to present the working procedure, and observations on an individual parameter under a common heading.

In each treatment only one variable was studied at a time, the remaining factors were kept constant at either approximately middle of the range or if already studied, kept at their optimum settings.

4:3 Observations

4:3:1 Length of the Stroke

In theory, within limits, the longer the stroke the faster will be the walking speed of the straw. However, in practice, there is a limit to which one can exploit this parameter to increase the rate of travel of the straw. The obvious reason being that beyond a certain length, the whole cleaner begins to jump from the ground at each forward stroke. Such a form of jumping, apart from being queer and unconventional, may shorten the life span of the structural members, by introducing stresses in the members which may be beyond their stress limit.

The length of the stroke was measured from the centre of the shaft driving the eccentric box to the beginning of the link driving the straw walker and connected to the eccentric box. Provision was made to slide the straw walker link within the box to vary the stroke length.

At the start of the study, the stroke length was kept at 2 cm. being the minimum possible. From then it was increased by 0.5 cm. each time, till the straws showed some signs of mechanical agitation and showed a tendency to have gained some momentum for the forward travel. The satisfactory movement of the straw was observed when the stroke length reached 3.5 cm. When the stroke length was increased beyond 4 cm, unacceptable intensity of shaking was produced in the cleaner. From these two observations, the optimum stroke length was established to be somewhere between 3.5 to 4 cm.

4:3:2 Slat Size, Spacing and the Angle of the Slating Face and its Interaction with Oscillation Frequency.

Slats are small triangular shaped wooden pieces which assist the straws in their forward movement, by tossing up the straws. (see Plate No. 41). For soyabeans crop, they were fitted on a screen of 10 mm mesh. The interaction of this parameter with the oscillation frequency was also studied. The results of the study of various aspects of this parameter are given below.

i) Slat pitch - and upper edge sharpness. On the whole, the pitch of the slat appeared to have a very meagre effect on the walking rate of the straws, but had a marked effect on the forward movement of the threshed pods. If the

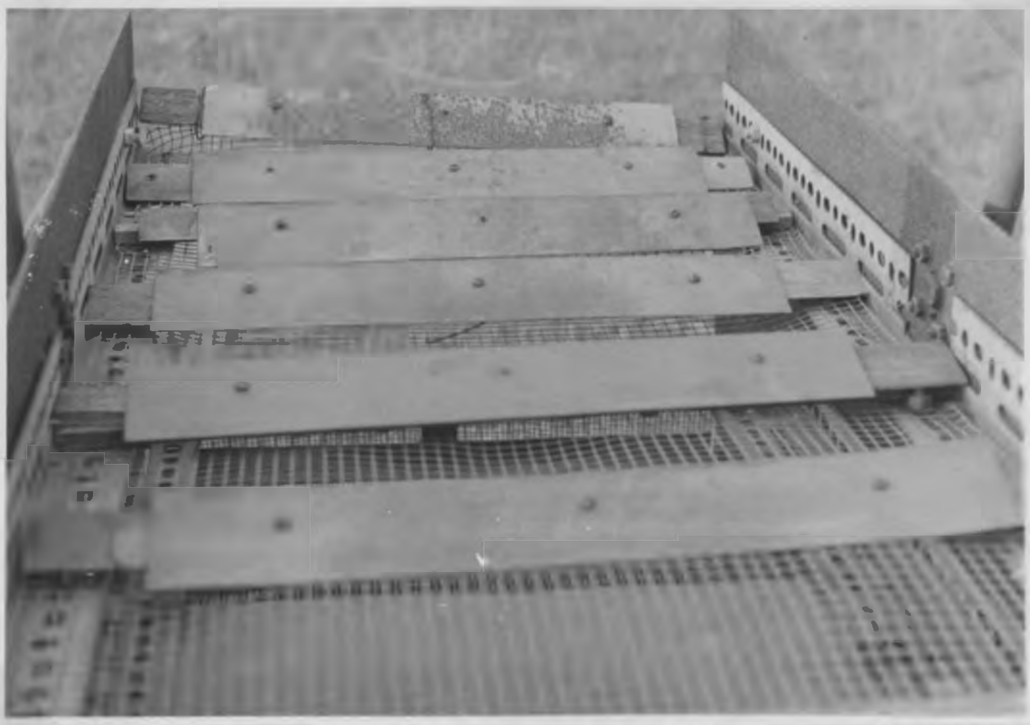


PLATE NO. 41

SHOWING SLATS WITH METAL STRIPS ON

THE STRAW WALKING DECK OF THE

UNIVERSAL CLEANER

vertical rise was kept too steep, the inertia present in the pods was not high enough to enable them to jump over the slats. As a result the pods were locked in their movement between two slats. The gradient was slowly reduced in steps till it was found that the pods could easily jump over the slats. The final optimum pitch was found to be 10° - measured from the bottom line of the slats.

As the tossing induced by the bare slats was not adequate enough for the forward movement of the straws, metal strips were attached on to the slats, which then very much improved the tossing quality of the slats. These metal strips were attached so that they protruded 2.5 cm above the height of the slats. Some serrated edged metal strips were also tried but their performance was not any better than the plain edged metal strips.

ii) Distance between slats in collaboration with oscillation frequency.

This exercise was undertaken to find out the optimum distance between the slats on the walking deck and its relationship to the frequnncy of oscillation of the straw walker.

The trials were commenced by keeping a distance of 10 cm between the slats and at the same time an attempt was made to work out the correct oscillation frequency. It was observed that the plants just began to move when the straw walker's oscillation frequency was approaching 185 strokes/min. At 190 strokes/min.,the straws began to move freely. But when the frequency speed was raised to 195 strokes/min.,a significant amount of seed loss was observed at the discharge end, presumably because the energised seeds did not have enough time to register themselves through the screen openings. Of course, at this oscillation frequency there was a marked increase in the travelling rate of the straws and the difference was significant at 5 percent level (c.f. with 185 strokes/min.). Apart from this bouncing disadvantage, it was also evident that at such a high oscillation frequency unnecessary stresses were put on the frame structures, which was not very desirable. On the average it took 14.5 sec. for the straws to finish their 1.9 m long journey. There was no significant difference at 190 strokes/min.

Next, the distance between the slats was reduced to 5 cm. This reduction had an adverse effect on the passing of seeds through the screen openings, largely because the arrangement reduced the area available for seeds to pass through hence most of them bounced out. This tendency of seeds to jump out faded when the distance between slats was increased to 7.5 cm. By this change the threshold for the movement of the straw was brought down to 165 strokes/min. But at this frequency, the straw journey took a little longer and lasted for 25 sec. Three more oscillation frequency rates were tried to decrease the time of travel. Recorded observations are shown in Table No. 6. When the frequency rate was increased beyond 180 strokes/min. some grain loss at the discharge end was observed, as such the maximum limit was established at 180 strokes/min.

The time taken by the straws to complete their journey at 180 strokes/min. was significantly less at 1 percent level over the other two treatments (175 and 170 strokes/min.). In turn the difference between 170 strokes/min. and 175 strokes/min. was significant at 5 per cent level.

Further work on cleaning mechanisms was abandoned at this stage for the following reasons.

Firstly, it became evident that the investigations into threshing mechanisms were claiming a considerable effort leaving little time to cover other aspects of the problem.

Secondly, it became evident that cleaning rather than grading was the first requirement as far as soyabeans was concerned. Furthermore, the development of a simple hand winnower (see Plate No. 42) at the National Institute of Agricultural Engineering in the United Kingdom (Wilcocks, *pers. comm.* 1970) which proved to be perfectly adequate for this operation, suggested that the available research time could best be concentrated on the problem of actual threshing.

DISTANCE BETWEEN SLATS	OSCILLATION FREQUENCY RATE	TIME TAKEN TO TRAVEL 1.9m LONG STRAW WALKER. AVG.OF 3 REPLICATES	
7.5 cm	170	20 sec.	A
"	175	14.8 sec.	B
"	180	8.7 sec.	C

TABLE NO. 6.

Showing time taken by soyabeans straw to travel 1.8 m long straw deck at different frequency levels.

PLATE NO. 42

THE N.I.A.E. HAND SEED CLEANER

SUMMARY AND CONCLUSIONS

CHAPTER 5

The study was undertaken with an objective to look for an appropriate mechanism and to establish operational parameters for the threshing of grain legumes in Uganda. It was also aimed at the same time to establish possible design parameters for a cleaning mechanism for the crop. A basic objective was that the equipment should preferably be hand-operated (low power requirement) and be able to lend itself to local manufacture (simple in design). The machine in short must be tailored to suite the precise farming conditions.

The literature on threshing and cleaning mechanisms indicated that the conventional drum and concave mechanism was the most universally used for grain legumes and for that matter any other crop. Two versions of this mechanism were therefore chosen for investigations. These were the rasp bar drum/concave and toothpeg drum/concave.

Of the less commonly used threshing mechanisms, several appear to have considerable potential for grain legumes notably the rubber rolls, the endless belt mechanism and the centrifugal threshing mechanism. As these are all of rather complicated design, and thus likely to conflict with the objective of simplicity in design, none were tried in the course of these investigations.

However, one novel mechanism, the so called peristaltic, was examined and experimented upon in some detail. It offered potential for low power requirement as well as simplicity in design and had as such not yet been tried for the threshing of grain legumes. In this mechanism, threshing is done by two scutchers which revolve at right angles, in opposite direction to each other. Each scutcher in turn is made of two shafts, welded at both ends to a steel plate. These shafts hit the plants and in doing so impart vibrational waves to the pods and thus pop them open. It is reputed to be a very mild form of threshing with a low degree of damage.

The study programme was divided into two phases. During the first phase, the peristaltic mechanism was constructed locally and then its performance was assessed in comparison with the rasp bar mechanism. Most of the second phase was devoted to a critical study of the tooth peg type of mechanism.

The investigations undertaken to assess the performance of the peristaltic mechanism suggested that this mechanism was unsuitable for the purpose envisaged. Irrespective of the speed employed to run the scutchers, the mechanism appeared to show an overall inability to thresh high moisture content soyabeans. It was observed that when a wet crop was fed, the wrapping tendencies were promoted by the presence of the baffle. As a result, after a short run, under these circumstances the mechanism was choked up and therefore came to a temporary halt. Though it showed some ability to thresh a dry crop (m.c. below 17 percent) with the assistance of a baffle, the overall scutcher speeds required for efficient threshing and good output were excessively high, for manual operation of the mechanism. In addition, it did not prove to be a simple mechanism for local construction. A lot of care was required in aligning and spacing of the scutchers. However, considerable basic data on its mode of operation was obtained. With a dry crop (m.c. below 17 percent) it was able to thresh 80 kg/hr. of seed per 45 cm wide throat at the scutcher peripheral speed of 1400 m/min. and at the same time had a threshing efficiency of 98 percent. This mechanism may still offer possibilities, but its fundamental study would appear to demand sophisticated laboratory testing equipment, which was outside the means available locally and further study of this mechanism was therefore discontinued.

The rasp bar mechanism, on the other hand, appeared to be capable of threshing the crop at practically any moisture content though the efficiency of threshing at high moisture contents was not to the required standards. The comparative output figures for the rasp bar mechanism were as follows:

M.C. of the crop	Drum peripheral speed	Threshing efficiency	Output/hr. of seed per 33cm wide throat
25-27%	1400 m/min.	89%	56 kg.
15-17%	1400 m/min.	Nearly 100%	73 kg.

The critical observations undertaken during the second phase with the toothpeg type of drum showed that the mechanism was capable of threshing soyabeans and stripping groundnuts as well. During the course of experiments some useful data were collected concerning the main operational parameters, which in fact was the principal involvment in this phase. As a result of this study, some recommendations for constructing a small scale tooth peg type of thresher can be suggested as follows:

(a) Range of peripheral speed: 1000 m/min - 2000 m/min.

Though during the course of trials threshing was accomplished at lower peripheral speeds, than recommended here, it may be recalled that the crop threshed was almost crisp dry. The range given here is with a view to extend machines used to thresh a high moisture content crop and to increase its output.

(b) Spacing of the rows on the circumference of the drum: 10 cm.

(c) Spacing of the rows on the concave-along its circumference: 6 cm.

(d) Minimum number of strips on concave necessary for threshing: 4

(e) Placing of first strip on
the concave circumference: 20 cm from the inlet

(f) Size and spacing of the
pegs. - Both on the drum
and concave: 8 cm long and 1 cm wide
To be fixed 5 cm apart.

In the course of trials it was revealed that manual operation was not likely to be feasible over long hours, and it is therefore suggested that the machine should be motivated by an engine of approximately 5 h.p. The incorporation of an engine in the machine will allow some flexibility in the design of the drum. The drum size could be then made bigger to increase the machines output. The likely specifications for the drum could be suggested as follows:

Drum diameter: 30 cm to the middle of pegs.

Drum width: 45 cm.

The likely output of the machine fabricated on the above specifications could be envisaged to be in the range of 90-120 kg/hr. of seed at the drum peripheral speed of 1200-1500 m/min. and also depending upon the condition of the crop at the time of actual threshing.

In as far as the cleaning aspects of the project were concerned, a cleaning mechanism called 'The Universal Cleaner' was designed and locally fabricated. It was designed to be a versatile piece of machinery, having accessories attached to it, which could be changed to clean different types of crops. Once again, the focal point of the study was to collect basic design data embracing various operational parameters. The initial phase of the study brought into light some basic requirements of a cleaner and on the basis of this, following recommendations for constructing a small scale cleaner can be suggested.

Length of the stroke of the straw walker:	3.5-4 cm.
Slat pitch:	10° measured from bottom line of the slats.
Slat interval:	7.5 cm.
Upper edge of the slat to be sharp	
Oscillation frequency of the straw walker:	170-180 strokes/minute

This aspect of the study, perhaps, was not pursued in great depth as it was soon realised that a table or stationery screen attached to the thresher and relative simple operations of picking the haulms, would on the whole be adequate, provided that a suitable winnower could be made available. It was suggested in the last chapter that the winnower designed at the National Institute of Agricultural Engineering in the United Kingdom, was reputed to be excellent for this purpose, there appeared to be no point in stressing further this aspect of the study.

In regards to threshing of grain legumes with particular reference to soyabeans, these investigations suggest quite conclusively that the peg drum and concave mechanism would be more suitable for threshing of grain legumes being more effective in managing high moisture content material and at the same time the mechanism could conceivably be adopted also for the strippings of groundnuts - a crop not uncommonly grown in the same environment as soyabeans and other grain legumes.

As far as possibilities for developing a hand operated threshing machine is concerned, these investigations would seem to confirm that mechanical power would be highly desirable for operating rotating threshing mechanisms, in view of the high energy demanded by them for rotating. The incorporation of an engine is likely to raise the final construction cost of the assembly, but on the other hand if the machine is made mobile, it could be an ideal piece of equipment for communal use. It could be then shared either through a private contractor or a co-operative venture to make it an economically viable proposition.

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APPENDIX NO. A_1

RECORD OF OBSERVATIONS ON THRESHING

THRESHING UNIT: RASP BAR MECHANISM

SEASON: JULY/AUGUST, 1970

CROP: SOYABEANS VARIETY BUKALASA 4

M.C.: 25-27% WET BASIS

DRUM PERIPHERAL SPEED IN M/MIN. AND REPL. NO.		WT. OF THRESHED SEEDS IN TEN MIN. IN KG. (a)	WT. UNTHRESHED SEEDS IN TEN MIN. IN KG. (b)	DAMAGE EXTERNAL	THRESHING EFFICIENCY PERCENTAGE $\frac{a}{a+b} \times 100$	OUTPUT PER HOUR IN KG.
700	A	2.424	0.158	Negl.	93.88	14.544
	B	2.116	0.138	1 gm.	93.88	12.696
	C	2.260	0.140	Negl.	94.17	13.560
TREATMENT MEAN		2.267			93.98	13.600
860	A	3.486	0.162	Negl.	95.56	20.916
	B	2.988	0.266	Negl.	91.82	17.928
	C	2.550	0.226	Negl.	91.86	15.300

DRUM PERIPHERAL SPEED IN M/MIN. AND REPL. NO.		WT. OF THRESHED SEEDS IN TEN MIN. IN KG. (a)	WT. UNTHRESHED SEEDS IN TEN MIN. IN KG. (b)	DAMAGE EXTERNAL	THRESHING EFFICIENCY PERCENTAGE $\frac{a}{a+b} \times 100$	OUTPUT PER HOUR IN KG.
1000	A	5.704	0.096	Negl.	98.34	34.224
	B	4.084	0.114	Negl.	97.28	24.504
	C	4.232	0.086	Negl.	98.23	25.392
TREATMENT MEAN		4.673			97.95	28.040
1200	A	7.368	0.088	Negl.	98.82	44.208
	B	9.518	0.070	Negl.	99.27	57.108
	C	8.644	0.095	Negl.	98.91	51.864
TREATMENT MEAN		8.510			99.00	51.060
1400	A	9.298	0.045	Negl.	99.52	55.788
	B	9.064	0.066	Negl.	99.28	54.384
	C	9.925	0.052	Negl.	99.48	59.550
TREATMENT MEAN		9.429			99.43	56.574

THRESHING UNIT: RASP BAR MECHANISM

SEASON: JULY/AUGUST, 1970

CROP: SOYABEANS. VARIETY BUKALASA 4

M.C.: 21-23% WET BASIS

DRUM PERIPHERAL SPEED IN M/MIN. AND REPL. NO.		WT. OF THRESHED SEEDS IN TEN MIN. IN KG. (a)	WT. UNTHRESHED SEEDS IN TEN MIN. IN KG. (b)	DAMAGE EXTERNAL	THRESHING EFFICIENCY PERCENTAGE $\frac{a}{a+b} \times 100$	OUTPUT PER HOUR IN KG.
730	A	3.684	0.640	Negl.	85.20	22.104
	B	3.924	0.440	Negl.	90.33	23.544
	C	3.650	0.580	Negl.	86.29	21.900
TREATMENT MEAN		3.753			87.27	22.516
860	A	4.000	0.650	Negl.	86.02	24.000
	B	3.648	0.612	Negl.	85.63	21.888
	C	3.910	0.400	Negl.	90.72	23.460
TREATMENT MEAN		3.853				23.116

DRUM PERIPHERAL SPEED IN M/MIN AND REPL. NO.		WT. OF THRESHING SEEDS IN TEN MIN. IN KG. (a)	WT. UNTHRESHED SEEDS IN TEN MIN. IN KG. (b)	DAMAGE EXTERNAL	THRESHING EFFICIENCY PERCENTAGE $\frac{a}{a+b} \times 100$	OUTPUT PER HOUR IN KG.
1000	A	5.925	0.623	Negl.	90.48	35.550
	B	6.434	0.785	Negl.	89.13	38.604
	C	6.206	0.835	Negl.	86.91	37.236
TREATMENT MEAN		6.188			88.84	37.130
1400	A	9.940	1.213	Negl.	89.12	59.640
	B	9.148	0.730	Negl.	92.61	54.888
	C	10.636	0.935	Negl.	91.92	63.816
TREATMENT MEAN		9.908			91.22	59.448

THRESHING UNIT: RASP BAR MECHANISM

SEASON: JULY/AUGUST, 1970

CROP: SOYABEANS VARIETY BUKALASA 4

M.C.: 15-17% WET BASIS

DRUM PERIPHERAL SPEED IN M/MIN. AND REPL. NO.		WT. OF THRESHED SEEDS IN TEN MIN. IN KG. (a)	WT. UNTHRESHED SEEDS IN TEN MIN. IN KG. (b)	DAMAGE EXTERNAL	THRESHING EFFICIENCY PERCENTAGE $\frac{a}{a+b} \times 100$	OUTPUT PER HOUR IN KG.
700	A	5.050	0.066	Negl.	98.71	30.300
	B	5.094	0.078	Negl.	98.49	30.564
	C	5.204	0.125	Negl.	97.65	31.224
TREATMENT MEAN		5.116			98.283	30.696
860	A	6.666	0.064	Negl.	99.049	39.996
	B	7.098	0.129	Negl.	98.215	42.588
	C	7.623	0.095	Negl.	98.769	45.738
TREATMENT MEAN		7.129			98.677	42.774

DRUM PERIPHERAL SPEED IN M/MIN. AND REPL. NO.		WT. OF THRESHED SEEDS IN TEN MIN. IN KG. (a)	WT. UNTHRESTED SEEDS IN TEN MIN. IN KG. (b)	DAMAGE EXTERNAL	THRESHING EFFICIENCY PERCENTAGE $\frac{a}{a+b} \times 100$	OUTPUT PER HOUR IN KG.
1000	A	9.088	0.032	Negl.	99.649	54.528
	B	11.534	0.055	Negl.	99.525	69.204
	C	11.256	0.040	Negl.	99.646	67.536
TREATMENT MEAN		10.626			99.606	63.756
1200	A	10.995	0.022	Negl.	99.800	65.970
	B	11.738	0.022	Negl.	99.812	70.428
	C	11.825	0.038	Negl.	99.680	70.950
TREATMENT MEAN		11.519			99.764	69.119
1400	A	11.856	0.022		99.814	71.136
	B	12.304	0.018		99.853	73.824
	C	12.289	0.040		99.675	73.734
TREATMENT MEAN		12.250			99.780	72.898

APPENDIX A_2

CALCULATION OF REGRESSION EQUATIONS

OUTPUT - A DEPENDENT VARIABLE (Y)

PERIPHERAL SPEED - AN INDEPENDENT VARIABLE (X)

MECHANISM - RASP BAR

REGRESSION EQUATION - Y = a + bx.

1. A TWO WAY TABLE FOR SUMS OF SQUARES

	PERIPHERAL SPEED	OUTPUT 25-27% M.C.	21-23% M.C.	15-17% M.C.
Sx	5160.00			
Sx^2	5629600.00			
Sy		167.31	195.31	279.25
Sy^2		7103.932	8773.772	16929.085
Sxy		193544.40	219718.60	307036.20
$SSx(Sx^2-\frac{(Sx)^2}{N})$	304480.00			
$SSy(Sy^2-\frac{(Sy)^2}{N})$		1505.405	1144.573	1332.973
$SPxy(Sxy-\frac{(Sx)(Sy)}{N})$		20880.48	18158.68	18850.20
Regression SS$(\frac{(SPxy)^2}{SSx})$		1431.931	1082.954	1167.006

2. REGRESSION EQUATIONS

$$b = \frac{SPxy}{SSx} \qquad a = \frac{Sy-bSx}{N}$$

25-27% m.c.

$$b = \frac{20880.48}{304480.0} = 0.0685 \qquad a = \frac{167.31-0.0685 \times 5160.0}{5} = -\frac{186.15}{5} = -37.230$$

21-23% m.c.

$$b = \frac{18158.68}{304480.0} = 0.0596 \qquad a = \frac{195.31-0.0596 \times 5160.0}{5} = -\frac{112.23}{5} = -22.446$$

15-17% m.c.

$$b = \frac{18850.20}{304480.0} = 0.0619 \qquad a = \frac{279.25-0.0619 \times 5160.0}{5} = \frac{40.15}{5} = 8.03$$

Thus

$$Y_{25-27\%} = -37.230 + 0.0685\ X$$

$$Y_{21-25\%} = -22.446 + 0.0596\ X$$

$$Y_{15-17\%} = 8.03 + 0.0619\ X$$

3. TEST FOR GOODNESS OF FIT OF THE REGRESSION EQUATIONS

ANALYSIS OF VARIANCE

REGRESSION VARIANCE IS TESTED AGAINST

THE REMAINING(RESIDUAL) VARIANCE

25-27% m.c.

SOURCE	D.F	S. OF S.	VARIANCE	VARIANCE RATIO
TOTAL	4	1505.405	-	
REGRESSION	1	1431.931	1431.931	58.467 ***
RESIDUAL	3	73.474	24.491	

21-23% m.c.

TOTAL	4	1144.573	-	
REGRESSION	1	1082.954	1082.954	52.72 ***
RESIDUAL	3	61.619	205.540	

15-17% m.c.

TOTAL	4	1332.973		
REGRESSION	1	1167.006	1167.006	21.094 *
RESIDUAL	3	165.967	55.322	

∴ Each relationship may be validly regarded as a linear one

Are these relationships statistically different.

4. TEST FOR JOINT REGRESSION

(i) The initial squares and products may be obtained simply by adding the corresponding values for the individual regressions. (e.g. Joint Sx = $Sx_{25-27\%} + Sx_{23-21\%}$)

	25-27% and 23-21% m.c.	25-27% and 15-17% m.c.	21-23% and 15-17 m.c.
Sx	10320.00	10320.00	10320.00
Sy	362.62	446.56	474.56
Sx^2	11259200.00	11259200.00	11259200.00
Sy^2	15877.704	24033.017	25702.857
Sxy	413263.00	50580.60	526754.80

(ii) The sums of squares of deviations and sums of products of deviations are given below:

SSx	608960.00	608960.00	608960.00
SSy	2728.378	4091.434	3182.138
SPxy	39039.160	39730.68	37008.08
Regression SS	2502.719	2592.168	2249.077
Residual SS (SSy-Reg. SS)	225.659	1499.266	933.061

(iii) Comparison of the joint residual variation with the sum of the individual residuals:

25-27% and 23-21% m.c.

	D.F.	S.S.	Variance	V.R
Joint Residual	8	225.659		
Sums of Individual Residuals	6	135.093	22.515	
Difference	2	90.566	45.283	2.011 N.S.

The F test has not shown a significant improvement.in the overall goodness of fit brought about by fitting two separate regressions rather than one joint one. Therefore the two regressions may not be validly regarded as having different relationships.

25-27% and 15-17% m.c.

	D.F.	S.S.	Variance	V.R.
Joint Residual	8	1499.266		
Sum of Individual Residuals	6	239.441	39.906	
Difference	2	1259.825	629.912	157.849 ***

In this case, the F test indietes a significant improvement in the overall goodness of fit, so the two regressions may be validly regarded as different relationships.

21-23½ and 15-17½ m.c.

	D.F.	S.S.	Variance	V.R.
Joint Residual	8	933.061		
Sum of Individual Residuals	6	227.586	37.931	
Difference	2	705.475	352.737	9.294 *

In this case again, the F test indicates a significant improvement in the overall goodness of fit, so the two regressions may be validly regarded as different relationships.

5. IN WHAT WAY ARE THESE RELATIONSHIPS DIFFERENT ?

There are two possible sources of difference between linear relationships (i) the slopes ('b' coefficients) may be different and (ii) the intercepts or "elevations" ('a' coefficient) may be different. The possible source can be found out by testing whether the slopes (b values) are different.

The test is again made on residual variation to find out whether the two individually calculated regressions account for a significantly greater part of the total variation in the data compared with two parallel or "common slope" regressions. The 'common slope' calculations for SSx, SSy, SPxy and total D.F. are made by simply adding the values for the individual regressions.

	TOTAL D.F.	SSx	SSy	SPxy
Regression 25-27% m.c.	4	304480.0	1505.405	20990.48
" 15-17% m.c.	4	304480.0	1332.973	18850.20
Common Slope Regressions	8	608960.0	2838.378	39730.68
Regression 21-23% m.c.	4	304480.0	1144.573	18158.68
" 15-17% m.c.	4	304480.0	1332.973	18850.20
Common Slope Regressions	8	608960.0	2477.546	37008.88

Calculation of Common Slope Regression SS and Residual SS.

	25-27% and 15-17% m.c.	21-23% and 15-17% m.c.
Common Slope Regression SS	$\frac{(39730.68)^2}{608960}$	$\frac{(37008.88)^2}{608960}$
	= 2592.168	= 2249.174
Common Slope Residual SS	2838.378-2592.168	2477.546-2249.174
	= 246.210	= 228.372

An analysis of variance test may be made.

	25-27% and 15-17% m.c.				21-23% and 15-17% m.c.		
	D.F.	SS	Var.	V.R.	SS	Var.	V.R.
Common Slope	7	246.10			228.372		
Residual							
Sums of Individual	6	239.441	39.906		227.586	37.931	
Residuals							
Difference	1	6.659	6.659	0.166	0.786	0.786	0.002
				N.S			N.S

Since the F test is non-significant this means that there is no significant improvement in the overall goodness of fit when two individual regressions are fitted rather than two regressions with the same slope i.e. the slopes of the two individual regressions cannot be declared significantly different.

Further calculations for testing for the difference in 'elevations' is meaningless since if the slopes are not different then an overall difference between regressions means that elevations must differ.

6. FINAL REGRESSION EQUATIONS

If slopes are not significantly different regression lines should be presented with a common slope. This can be calculated from the common slope regression.

$$b = \frac{SPxy}{SSx} \qquad a = \frac{Sy - bSx}{N}$$

25-27% m.c. $= \frac{39730.68}{608960.00} \qquad = \frac{167.31 - 0.0652 \times 5160}{5}$

$= 0.0652 \qquad = -33.824$

15-17% m.c. $= \frac{279.25 - 0.0652 \times 5160.0}{5}$

$= -11.436$

Thus common slope equation

$$Y_{25-27\%} = -33.824 + 0.0652\ X$$

$$Y_{15-17\%} = -11.436 + 0.0652\ X$$

Similarly other common slope equation are:

$$Y_{21-23\%} = -23.58 + 0.0607\ X$$

$$Y_{15-17\%} = -6.79 + 0.0607\ X$$

Earlier it was shown that the regression lines representing 25-27% m.c. and 21-23% m.c. as not having different relationship therefore no attempt was made to find a common slope, however there appears to be no harm in drawing one since the results of calculations then obtained may be due to erratic observations

Thus

$$Y_{21-23\%} = -28.22 + 0.0652\,X$$

The final conclusions of this particular analysis are that rates of <u>increase</u> in the output at three different moisture contents did not differ during the period of the observations but the differences in the rate of output were already established when the crop was threshed at different moisture contents.

7. REGRESSION COEFFICIENT CALCULATION (r)

	25-27% m.c.	21-23% m.c.	15-17% m.c.
$r^2 = \frac{Reg.SS}{SSy}$	$\frac{1491.931}{1505.405}$	$\frac{1082.954}{1144.573}$	$\frac{1167.006}{1332.973}$
	= 0.9910	= 0.9461	= 0.8755
	r = 0.9954	r = 0.9730	r = 0.9360

APPENDIX B_1

RECORD OF OBSERVATIONS ON THRESHING

THRESHING UNIT: PERISTALTIC THRESHER

SEASON: JULY/AUGUST, 1970.

CROP: SOYABEANS VARIETY BUKALASA 4

M.C.: 21-23%

SCUTCHER PERIPHERAL SPEED IN M/MIN. AND REPL. NO.		WT. OF THRESHED SEED IN TEN MIN. IN KG. (a)	WT. UNTHRESHED SEEDS IN TEN MIN. IN KG. (b)	DAMAGE EXTERNAL	THRESHING EFFICIENCY PERCENTAGE $\frac{a}{a+b} \times 100$	OUTPUT PER HOUR IN KG.
700	A	Threshing efficiency at this scutcher speed was below 50 percent				
	B	(Visual observation) and therefore the treatment was discarded.				
	C	The pods were knocked off the plants but not threshed. Incidence of wrapping was high.				

SCUTCHER PERIPHERAL SPEED IN M/MIN. AND REPL. NO.		WT. OF THRESHED SEED IN TEN MIN. IN KG. (a)	WT. UNTHRESHED SEEDS IN TEN MIN. IN KG. (b)	DAMAGE EXTERNAL	THRESHING EFFICIENCY PERCENTAGE $\frac{a}{a+b} \times 100$	OUTPUT PER HOUR IN KG.
860	A	1.812	0.400	Nil	81.92	10.872
	B	1.730	0.462	Nil	78.92	10.380
	C	1.714	0.385	Nil	81.66	10.284
TREATMENT MEAN		1.752			80.33	10.512
1000	A	2.468	0.462	Nil	84.52	14.808
	B	2.675	0.596	Nil	81.78	16.050
	C	3.015	0.636	Nil	80.37	18.090
TREATMENT MEAN		2.719			82.22	16.316
1200	A	2.597	0.195	Nil	93.01	15.582
	B	3.036	0.215	Nil	93.39	18.216
	C	4.253	0.368	Nil	92.04	25.518
TREATMENT MEAN		3.295			92.81	19.772

SCUTCHER PERIPHERAL SPEED IN M/MIN. AND REPL. NO.		WT. OF THRESHED SEED IN TEN MIN. IN KG. (a)	WT. UNTHRESHED SEEDS IN TEN MIN. IN KG. (b)	DAMAGE EXTERNAL	THRESHING EFFICIENCY PERCENTAGE $\frac{a}{a+b} \times 100$	OUTPUT PER HOUR IN KG.
1400	A	4.164	0.279	Nil	93.72	24.984
	B	3.744	0.265	Nil	93.34	22.464
	C	5.408	0.160	Nil	97.13	32.448
TREATMENT MEAN		4.439			94.73	26.632

CROP above 23% m.c. by all means cannot be threshed with the peristaltic mechanism. The vibrations imparted to the pods fail to pop them open and in addition wrapping tendencies are promoted with increase in m.c.

M.C.: 15-17%

SCUTCHER PERIPHERAL SPEED IN M/MIN. AND REPL. NO.		WT. OF THRESHED SEED IN TEN MIN. IN KG (a)	WT. UNTHRESHED SEEDS IN TEN MIN. IN KG. (b)	DAMAGE EXTERNAL	THRESHING EFFICIENCY PERCENTAGE $\frac{a}{a+b} \times 100$	OUTPUT PER HOUR IN KG.
700	A	0.532	0.522	Nil	94.81	57.192

SCUTCHER PERIPHERAL SPEED IN M/MIN. AND	REPL. NO.	WT. OF THRESHED SEED IN TEN MIN. IN KG. (a)	UNTHRESHED SEEDS IN TEN MIN. IN KG. (b)	DAMAGE EXTERNAL	THRESHING EFFICIENCY PERCENTAGE $\frac{a}{a+b} \times 100$	OUTPUT PER HOUR IN KG
	B	10.426	0.638	Nil	94.23	62.556
	C	7.454	0.463	Nil	94.15	44.724
TREATMENT MEAN		9.137			94.40	54.824
860	A	9.816	0.319	Nil	96.85	58.896
	B	8.936	0.299	Nil	96.76	53.616
	C	8.246	0.257	Nil	96.98	49.476
TREATMENT MEAN		8.999			96.86	53.996
1000	A	10.744	0.244	Nil	97.98	64.464
	B	10.968	0.389	Nil	96.57	65.808
	C	13.058	0.449	Nil	96.67	78.342
TREATMENT MEAN		11.590			97.01	69.538
1200	A	11.650	0.305	Nil	97.45	69.900
	B	11.414	0.320	Nil	97.27	68.484
	C	10.862	0.275	Nil	97.53	65.172
TREATMENT MEAN		11.309			97.42	67.852

SCUTCHER PERIPHERAL SPEED IN M/MIN. AND REPL. NO.		WT. OF THRESHED SEED IN TEN MIN. IN KG. (a)	UNTHRESHED SEEDS IN TEN MIN. IN KG. (b)	DAMAGE EXTERNAL	THRESHING EFFICIENCY PERCENTAGE $\frac{a}{a+b} \times 100$	OUTPUT PER HOUR IN KG.
1400	A	13.320	0.254	Nil	98.13	79.920
	B	13.680	0.309	Nil	97.79	82.080
	C	12.810	0.305	Nil	97.67	76.860
TREATMENT MEAN		13.270			97.86	79.620

At 700 and 860 m/m n scutcher speed the mechanism appeared to be having a little trouble in clearing plant straws. Hence feeding rate had to be restricted.

APPENDIX B_2

CALCULATION OF REGRESSION EQUATIONS

OUTPUT - A DEPENDENT VARIABLE (Y)

PERIPHERAL SPEED - AN INDEPENDENT VARIABLE (X)

MECHANISM - PERISTALTIC

REGRESSION EQUATION - Y = a+bx.

1. A TWO WAY TABLE FOR SUMS OF SQUARES

	PERIPHERAL SPEED	OUTPUT 21-23% m.c.	15-17% m.c.
Sx	4460.00 (21-23% m.c.		
	5160.00 (15-17% m.c.		
Sx^2	5139600.00 (21-23%)		
	5629600.00 (15-17%)		
Sy		73.23	325.83
Sy^2		1476.812	21700.011
Sxy		86364.60	347242.00
SSx	166700.0 (21-23%)		
	304480.0 (15-17%)		
SSy		136.154	466.974
SPxy		4713.15	10985.44
Regression SS		133.256	396.347

2. REGRESSION EQUATIONS

$b = \frac{SPxy}{SSx}$ $a = \frac{Sy-bSx}{N}$

21-23% m.c. $= \frac{4713.15}{166700.0}$ $= \frac{73.23-0.0283 \times 4460.0}{4}$

$=0.0283$ $= -13.249$

$b = \frac{SPxy}{SSx}$ $\qquad a = \frac{(Sy - bSx)}{N}$

15-17% m.c. $\quad = \frac{10985.44}{304480.0} \qquad = \frac{325.83 - 0.0361 \times 5160}{5}$

$= 0.0361 \qquad = 27.910$

Thus

$Y_{21-23\%} = -13.249 + 0.0283\ X$

$Y_{15-17\%} = 27.910 + 0.036\ X$

3. TEST FOR GOODNESS OF FIT OF THE REGRESSION EQUATIONS

ANALYSIS OF VARIANCE

REGRESSION VARIANCE IS TESTED AGAINST

THE REMAINING (RESIDUAL) VARIANCE

21-23% m.c.

SOURCE	D.F.	S.OF S.	VARIANCE	VARIANCE RATIO (V.R.)
TOTAL	3	136.154	-	
REGRESSION	1	133.256	133.256	91.96 *
RESIDUAL	2	2.898	1.449	

15-17% m.c.

SOURCE	D.F.	S.OF S.	VARIANCE	VARIANCE RATIO (V.R.)
TOTAL	4	466.974	-	
REGRESSION	1	396.347	396.347	16.835 *
RESIDUAL	3	70.627	23.542	

∴ Each relationship may be validly regarded as a linear one.

Are these relationships statistically different.

4. TEST FOR JOINT REGRESSION

(i) The initial squares and products may be obtained simply by adding the corresponding values for the individual regressions (e.g. Joint $Sx = Sx_{21-23\%} + Sx_{15-17\%}$)

	21-23% and 15-17% m.c.
Sx	9620,00
Sy	399.06
Sx^2	10769200.00
Sy^2	23176.823
Sxy	433606.60

(ii) The sums of squares of deviations and sums of products of deviations are given below.

SSx	486488.90
SSy	5482.503
SPxy	7055.800
Regression SS	1023.339
Residual SS (SSy-Reg.SS)	4459.164

(iii) Comparison of the joint residual variation with the sum of the individual residuals :-

	D.F.	S.S.	VARIANCE	V.R.
JOINT RESIDUAL	7	4459.164		
SUMS OF INDIVIDUAL RESIDUALS	5	73.525	14.705	
DIFFERENCE	2	4385.639	2192.819	149.120 ***

In this case, the F test indicates a significant improvement in the overall goodness of fit, so the two regressions may be validly regarded as different relationships.

5. IN WHAT WAY ARE THESE RELATIONSHIPS DIFFERENT?*

See for explanation Appendix $A_2 5$.

	D.F.	TOTAL	SSx	
Regression 21-23% m.c.	3	166700.00	136.154	4713.15
" 15-17% m.c.	4	304480.00	466.974	10985.44
Common Slope Regressions	7	471180.00	603.128	15698.59

$$\text{Common Slope Regression SS} = \frac{(15698.59)^2}{471180.0}$$

$$= 523.039$$

$$\text{Common Slope Residual} = 603.128 - 523.039$$

$$= 80.89$$

An analysis of variance test may be made.

	D.F	SS	VARIANCE	V.R.
Common Slope Residual	6	80.89		
Sums of Individual Residual	5	73.525	14.70	
Difference	1	7.37	7.37	0.50 N.S.

Since the F test is non-significant this means that there is no significant improvement in the overall goodness of fit when two individual regressions are fitted rather then two regressions with the same slope i.e. the slopes of the two individual regrssions cannot be declared significantly different.

Therefore, there is an overall difference between the elevations (a).

6. FINAL REGRESSION EQUATIONS

If slopes are not significantly different regressions lines should be presented with a common slope. This can be calculated from the common slope regression.

$$b = \frac{SPxy}{SSx} \qquad a = \frac{Sy - bSx}{N}$$

21-23% m.c. $= \frac{15698.59}{486488.9} \qquad = \frac{73.23 - 0.0322 \times 4460.0}{4}$

$b = \frac{SPxy}{SSx}$ $\qquad$ $a = \frac{Sy - bSx}{N}$

$= 0.0322$ $\qquad$ $= -17.59$

15-17% m.c. $= 0.0322$ $\qquad$ $= \frac{325.83 \times 0.0322 \times 5160.0}{5}$

$= 31.93$

Thus common slope equation

$$Y_{21-23\%} = 17.59 + 0.0322\ X$$

$$Y_{15-17\%} = +\ 31.93 + 0.0322\ X$$

7. REGRESSION COEFFICIENT CALCULATIONS (r)

	21-23% m.c.	15-17% m.c.
$r = \frac{Reg.\ SS}{SSy}$	$\frac{133.256}{136.154}$	$\frac{396.347}{466.974}$
	$= 0.9787$	$= 0.8487$
	$r = 0.9890$	$r = 0.9212$

APPENDIX C.

Observation Records And The 't' Test For Stroke Frequency Using The Universal Cleaner.

1. A Table showing the time taken by the straws to complete their + 1m long journey on the straw deck.

STROKES/MIN	TIME TAKEN 1st REPL.	TIME TAKEN 2ND REPL.	TIME TAKEN 3RD REPL.	TOTAL
170(A)	20 Secs.	22 secs.	18 secs.	60 secs.
175(B)	15 secs.	15 secs.	14 secs.	44 secs.
180(C)	8 secs.	10 secs	8 secs	26 secs.

2. Sum and mean of each sample.

	A	B	C
X	60.0	44.0	26.0
$\bar{X}$	20.0	14.66	8.66

3. Sum of squares of deviation for each sample.

	A	B	C
$SX^2 - \frac{(SX)^2}{N}$	$1208 - \frac{3600}{3}$	$646-\frac{1936}{3}$	$228-\frac{676}{3}$
	$= 8.0$	0.67	2.67

4. Calculation of Variance

$$\frac{SX^2 - \frac{(SX)^2}{N}}{N-1}$$

A	B	C
$\frac{8}{2}$	$\frac{0.67}{2}$	$\frac{2.67}{2}$
$= 4$	$= 0.385$	1.335

5. Calculation of the S.E. of the difference between the two means.

A V_s B	A V_s C	B V_s C
$= \sqrt{\frac{\text{Variance A}}{N} + \frac{\text{Variance B}}{N}}$	$\sqrt{\frac{\text{Variance A}}{N} + \frac{\text{Variance C}}{N}}$	$\sqrt{\frac{\text{Variance B}}{N} + \frac{\text{Varian}}{N}}$
$= \sqrt{\frac{4}{3} + \frac{0.385}{3}}$	$\sqrt{\frac{4}{3} + \frac{2.67}{3}}$	$\sqrt{\frac{0.385}{3} + \frac{2.67}{3}}$
$= \sqrt{1.461}$	$\sqrt{2.223}$	$\sqrt{1.018}$
= 1.209	1.491	1.009

6. Calculation of the value of 't'

$$t = \frac{\text{Actual difference between means}}{\text{S.E. of difference between means.}}$$

A V_s B	A V_s C	B V_s C
$= \frac{20.0 - 14.66}{1.209}$	$\frac{20.0 - 8.66}{1.491}$	$\frac{14.66 - 8.66}{1.009}$
= 4.41*	= 7.60 **	= 5.94 **