THE MODIFICATION OF A TWO-WHEELED MARKET GARDEN TRACTOR TO PROVIDE A RICE THRASHING MECHANISM

(D.PAPER II)

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My thanks are also due to members of the Farm Staff who have helped in field trials and to the Farm Carpenter and the Staff of the College Works Department who helped in constructional work.
Rice, being a crop grown predominately by peasant agriculturalists, faces most of the problems of cultivation associated with small scale peasant farming. Being the staple food of many of the peasants who grow it, rice in many ways directly effects the prosperity of these people. Whereas a good crop can give relative prosperity, a poor crop can bring near famine and a very low standard of living. Consequently anything which can lower the present hazards of rice production, will in turn increase the prosperity of the peasants themselves.

One of the main causes of crop failure in peasant farming practice, is the shortage of labour at critical periods of cultivation. This is due to the fact that most peasant farmers, where possible, take employment outside their holdings in neighbouring estates etc. Their holdings are then run in the evenings and at weekends. This means that only a small proportion of the day can be spent on their own crops. Also peak periods of labour requirements on the holdings often clash with similar peak periods on the estates and the peasants employed there may be expected to work extra hours at these times. Consequently the peasants' crops tend to be neglected, planting is done late, weeding is carried out insufficiently and the yields fall below average.

An improvement in the actual cultivation of the rice crops on these holdings could, therefore, quite feasibly be attained by mechanisation, if that mechanisation could lower the number of man hours per acre required in cultivating the crop. Also, of course, the costs of the mechanical cultivations must be comparable with the costs of present hand cultivations. The cost of hand cultivation is also hard to assess in terms of
direct costs to the peasant farmer due to the fact that most work is done by unpaid family workers. However, on holdings where most of the family labour is employed full time on the farm, mechanisation might free some of the labour and allow some members of the family to take up outside employment. Which ever may be the case, the main deterrent to mechanism is the lack of capital characteristic of peasant farmers. Their holdings are based on short term crops of low capital investment, which quickly yield a return. Also many peasant holdings are farmed at subsistence level only and yield no cash income to the farmer. In most cases, therefore, mechanisation would have to be government sponsored.

If the problem of supplying capital can be overcome, the next problem arises in the selection of suitable machinery. The holdings, small in themselves, usually provide further difficulties due to extreme fragmentation. Hence one holding may be made up of several widely scattered plots each only a fraction of an acre in size. Implements and machinery employed must therefore be suited to these special circumstances which immediately cuts out large tractors and the usual cultivating implements which are popularly used in temperate regions. The need is more for small, portable implements characteristic of farming on a market garden scale, that is, small hand controlled tractors with a range of easily detached implements and fittings which will allow the single power unit to do all necessary cultivations.

Returning specifically to the rice crop, further difficulties arise, namely those of working under waterlogged conditions. In Malaya, where much research work in this line has been done by Ashby (1949) and others, cultivation under wet conditions with small horticultural tractors has met many difficulties and in many cases trials have ended in complete failure. It appears
possible to use such implements where there is a hard pan beneath the wet surface soil, but where the lower soil is soft the small tractors tend to sink in deeply and the wheels slip. Here, the answer will most likely lie in the provision of wide wheels which will give greater floatation to the tractor, or otherwise the introduction of a small track layer may prove successful.

In this report the emphasis will be on one specific department of this problem only, namely the mechanisation of rice thrashing. However, in the design of such an implement as a thrashing unit, it must always be remembered that the design must be considered against the broad background of mechanised cultivation in general and not the provision of a single purpose, expensive powered unit which will remain idle for the greater part of the year. The aim should be to provide an attachment which will fulfil the purpose for which required and which can readily be affixed to a general purpose power unit.

Malaya presents a very good picture of the path that mechanisation of peasant rice cultivation has taken, probably due to the fact that in Malaya rice is the staple food of the peasants and therefore very much decides their welfare. As previously discussed in general terms, the peasants of Malaya work on the big estates and run their small holdings in their spare time. Consequently the Malayan Department of Agriculture has attempted to improve the rice crops by reducing the man hours required for various cultivations by means of mechanisation. In the latest trials and experiments, much emphasis has been put on mechanical harvesting and thrashing and the following paragraphs discuss briefly the progress which has been made in this field.

One of the early attempts at producing a rice thrashing unit was made at Kelantan, in Malaya, by H.K. Ashby (1949). The unit consisted of a simple 15" diameter drum with loops of wire
to form pegs. The drum was mounted on a shaft and driven by a belt from a stationary tractor. This design is basically similar to that produced by J. Taylor (1956), further trials and modifications of which are discussed in later chapters. The unit proved to be uneconomical, due primarily to the high costs which must be attributed to the running and maintenance of the tractor. However it was reported that the separation of grain from the straw due to the combing action of the pegged drum, was satisfactory and at least as good as that obtained by traditional hand thrashing.

Allen and Haynes (1953) carried out quite a large scale trial of various thrashing units including the simple drum described above. Attempts were made to use a combine harvester but little success was attained with standard types, which tended to be too big for use in small plots and also had difficulty in operating under waterlogged conditions. Such units must at present be considered rather over ambitious for introduction into peasant agriculture unless some sort of workable co-operative can be initiated.

One of the more successful units tested, was the Tullos hand driven thrashing machine. The machine was specifically designed for small holders being simple in design and relatively portable. The unit has 12" wide drum of 24" diameter and is fitted with a concave and straw shakers so that the straw passes right through the machine, unlike the simple peg-drum type where the straw is held manually while the pegs comb out the grain. This machine, although efficient and economical for the purpose of thrashing, was not popular with the peasants due to the hard work involved in turning the handle which drove the mechanism. An attempt to improve this method was made by Nansayakkara (1951) in Trinidad. The heavy hand driving was overcome by substituting
a small 1½ h.p. engine. With this motorised version he was able to thrash an acre of rice in 13½ hours using three operators. Once again, however, it is doubtful if costs of maintenance and depreciation on such a motorised unit would allow its profitable use on peasant holdings where it would lie idle most of the year, unless owned collectively by a number of neighbouring farmers. Apart from the driving of this machine it is unlikely that the engine itself could be utilised for other operations throughout the rest of the year.

Another thrashing unit included in the trial by Allen and Haynes, was the Robinson Midget Thrasher. This machine has a 26" wide, peg drum and a complete range of sieve trays etc. The drive is by chains which are exposed and tend to be dangerous to the operators. Also the machine was found to be very noisy and tended to shake itself into pieces in a comparatively short time. The unit was heavy and not very portable. Although it was suggested that many of the unit's faults could be corrected by replacing the chains by V-belts, the difficulty of high costs of maintenance and depreciation once again threatened the economy of the machine. Haynes (1954) estimated that depreciation, maintenance and fuel constituted 95.2% of the running costs of the unit, even though few man hours were saved in comparison to other methods tried.

From this brief survey of research work in Malaya, emerges quite clearly the major problem presented by high maintenance and depreciation costs as a deterrent in the mechanisation of small scale agricultural holdings. Unless these costs can be reduced to an economical level, the mechanisation of peasant rice production would appear unpracticable. Other alternatives would be either for the governments concerned to take rice growing out of the hands of peasants and grow the crop on a large
scale which would lend itself to mechanisation or secondly to form co-operatives within the peasant farmers which could run bigger machines on the collective capital of many peasants.

The first case is rather impracticable mainly due to the feelings of the peasants themselves who have grown rice in their traditional manner for many generations and accept rice growing as part of their way of life. The second method of co-operative farming would appear much more satisfactory in theory but would meet many snags. Firstly the co-operative system could not use large scale machinery in the present minute plots typical of peasant rice growers. This would mean that there would have to be a re-allocation of land in larger units, or at least a collection of small plots together in an area which can be worked as one so far as machinery is concerned. Secondly would arise problems of harvesting. It would be difficult to get all the peasants to plant the same variety at the same time to ensure even ripening of a large area which would be essential for the economic use of binders or combine harvesters. Also the capital outlay to sponsor such a scheme would not be forthcoming from the peasant farmers and could only be initiated by government grants.

In places such as British Guiana where rice growing on a large scale has been adopted the advantages of extensive cultivation of the crop can be seen. Large irrigation schemes which can give water control throughout the year can be employed and also linked with adequate drainage, this facilitates the provision of dry conditions for pre-sowing cultivations, harvesting etc. In this way, cultivation and harvesting costs are similar to those already well proved as economical in other cereal crops. Thrashing can be done either by means of a normal combine harvester or the traditional thrashing machine, typical of
H.P. Baley (1955), describes the rather unusual evolution of the rice industry in British Guiana. The main influence in rice production there came from imported East Indians who worked as indentured labour on the sugar estates. These people quickly started to cultivate any spare plots of land they could procure to produce their native food, rice.

When their period of compulsory labour was over many of the Indians left the sugar estates and started growing rice on a scale which quickly lead to the production of a surplus over the country's needs and hence the export trade was born.

As early as the late 1920's, Codd and Peterkin (1933) report on the importation of machinery such as winnowing machines, reapers and thrashing machines which they considered essential to reap full benefits from the rice exports of British Guiana.

Since the 1939 - 45 World War, rice exports from the traditional exporting countries of the East, have fallen markedly for in those countries, which were ravaged by the war, it has been difficult to keep the rice supply sufficient to meet the needs of their ever increasing populations. This has given impetus to other countries in the New World to increase their rice exports to fill the world demand. Consequently, rice production has become highly mechanised in such places as British Guiana and America. The use of proper irrigation schemes has facilitated this mechanisation to a great extent, the capital being available due to the assured and unsatisfiable demand. Combine harvesters have been modified to suit wet conditions, as have other cultivating implements. Giglioli (1956) states that in British Guiana, the use of pick-up reels has been essential with combines, due to the amount of lodging typical of rice. However he states that mechanisation is in a young stage and the
next step is to select varieties more suited to the machines employed. At present they were experiencing lower yields and lower quality of rice in comparison to peasant methods of production, but this was primarily due to losses from lodging of peasant varieties and an increase in poor grains due to the less rigid selection of seed grain as compared with peasant selection on their limited scale, where individual plants can be picked out for future seed.

The chances of any large scale changes in peasant rice growing areas, where the crop is grown essentially as a food for the grower himself, are unlikely, therefore, and only in countries where the rice is grown as a cash crop, can such rapid development as seen in British Guiana and America, be expected. The subsistence level rice growers present a problem of their own which must be answered according to their needs. Hence the attempts to provide simple mechanical implements as have been described earlier concerning Malayan peasant rice growers.

The following chapters of this report describe a similar attempt to mechanise rice thrashing under the peasant conditions of Trinidad, which are similar in many ways to those found elsewhere. The work has been based on the possibility of introducing small horticultural tractors into peasant agriculture. These would be used throughout the year for the various cultivations on the holdings and be a source of driving power to such machines as a simple thrashing machine or winnowing machine. Consequently the design of thrashing units, designed and tested in these trials, has been based on using a Howard "Gem" rotavator as the power unit. It has also been attempted to combine in any thrashing unit design, the qualities of cheapness, simplicity, durability and long working life. These are all factors which will appeal to the peasant farmer.
OBJECTS OF WORK.

The basic object of the project is to provide a means of mechanically thrashing rice based on a Howard "Gem" rotavator as the power unit. The thrashing machine must be capable of producing a rice sample at least as good as that obtained by traditional hand thrashing whilst incorporating a significant saving in man hours and consequently, at a cost comparable with present manual methods.

In pursuit of this basic object two main lines will be followed:-

(1) The continuation of work started by Taylor (1956) in the year 1955-56. This entails giving a full scale trial to the thrashing unit designed by Taylor and determining its capabilities both as a means of thrashing rice and as an economic proposition. The trial will consist of thrashing about an acre of rice on the Imperial College New Farm. As far as possible, peasant conditions will be replicated and the various operations involved accurately timed. The efficiency of the unit will be judged on the following factors:-

(a) The efficiency of removal of the grain from the straw.
(b) The cleanliness of the rice sample produced.
(c) The costs incurred in man hours, fuel, and maintenance and depreciation of the machine.

These will be compared with corresponding factors for traditional hand thrashing methods.

(2) Further developmental work. This will be decided largely by the results of the trial described above, and may take either of two alternative courses.

(a) If the thrashing unit in its present form proves both economical and efficient in performance, the future work will
consist of making slight modifications to the prototype with the idea of making a more polished unit which could then be put into production if this was thought feasible. These modifications would include the replacement of the present rather crude, hand made drum, by a properly balanced, welded drum. Also an attempt would be made to render the thrashing unit easily detachable from the "Gem" rotavator, when the tractor is being used for purposes other than thrashing. A third modification which has been contemplated, is the introduction of some kind of winnowing device to the existing unit in an attempt to produce a cleaner sample of thrashed rice. This would, of course, be followed by further trials to establish its practicability or otherwise.

(b) If the present unit is proved uneconomical in the thrashing trial, however, more drastic modifications or even a totally new design will have to be considered. The aim would be to either increase the output of the machine or reduce its labour requirements, which ever offered the best solution to the problem. Since most failures in producing an economic unit in Malaya have been attributed to the high costs of maintenance and depreciation of the machine power unit, it is likely that getting the maximum possible output from the machine will prove the answer to the problem. At present it is known that the engine of the "Gem" rotavator is under loaded and so there is scope for improvement along these lines.
MODIFICATIONS.

Although it had been decided to give the rice thrashing machine as designed by J. Taylor (1956), a full field trial before any further basic modifications were made, it was thought prudent to make certain slight changes in the construction of the machine for the purpose of both strengthening the unit and making it safer to operate. These minor modifications were suggested by J. Taylor himself after preliminary trials during the year 1955 - 1956. These modifications in no way altered the actual thrashing mechanism or mode of thrashing. The changes in structure were basically three in number, as follows:

(a) In preliminary trials it had been noticed that when the machine was in motion it was difficult to see the point at which the steel pegs of the rotor emerged through the slatted table on which the rice was held. This, therefore, was a potential danger to the hands of the operator of the machine. For this reason a cross piece of 1" x 1" angle iron was bolted onto the slatted table along the line of emergence of the pegs. The angle iron was bolted to the slats by means of 3/4" nuts and bolts. As well as marking the point of emergence of the pegs, the angle iron acts as a prevention against the operators hands being drawn into the rotor, should the straw become wound round the thrashing drum.

(b) The second modification was the substitution of 5/16" steel pegs in the rotor, for the 1/4" pegs previously used. This was thought necessary due to the fact that many of the 1/4" pegs had become bent during thrashing in preliminary trials. Also these pegs were locked more securely in position by tapping threads for them through the cross beams of the skeleton drum. This acted as a locking device when the nut was applied on the underside. The pegs were made from 3" bolts with the
heads sawn off. The result was a more sturdy drum which would more readily withstand the considerable vibrations experienced whilst the machine is in motion.

(c) The metal shield over the top of the rotor was extended backwards and downwards to limit further the spread of rice after thrashing and so localise the rice on the tarpaulin and prevent any spray off the tarpaulin. Similar galvanised sheeting to that used previously was again employed and some more rigid stays were added.

These modifications were completed on November 10th, 1956. The machine was tested by running the rotor empty to ensure that all pegs ran truly through the slatted table and then declared ready for a full scale trial.
The first complete trial of the rice thrashing unit was started on November 13th, 1956. The trial consisted of two main parts. The first trial consisted of thrashing four 1/8th acre units using different numbers of operators, the object being to establish the optimum number of operators for the thrashing unit. Secondly a trial was carried out on an accurately measured 1/2 acre of rice on a task-work basis to give an accurate assessment of the machine's capabilities under normal working conditions.

In both cases the rice was cut on the day prior to thrashing and stacked on the trace at the side of the field. These stacks comprised about 1/8th acre of rice each in the first trial and exactly 1/2 acre each in the second. The operators employed were normal farm staff who were without special training or previous experience with the machine.

The thrashing process consisted of laying out a medium sized tarpaulin sheet on the trace by the side of the stacked rice, and setting up the Gem rotavator with the thrashing unit in the centre of the sheet. Thrashing continued until the accumulation of rice under the machine hindered the efficient action of the rotor, at which stage the engine was stopped and the thrashed rice hand winnowed and bagged. The hand winnowing consisted of removing any large pieces of straw contaminating the thrashed rice.

The thrashing process was timed throughout to establish the actual running time of the machine, the total man hours, and the time spent winnowing and bagging. Throughout the trial allowances were made for any breakdowns due to mechanical failure of the unit. A check was also kept on the fuel consumption as this was required for costing purposes.

Before reporting fully the results of the trial, it is of
interest to note some of the general features of the trial concerning the general reaction of the machine itself and also the plot of rice used for the experiment.

In the early stages of the trial difficulties were encountered due to the pegs on the rotor and also the nuts and bolts holding the drum skeleton together, coming loose. These had to be tightened at quite short intervals in the early stages but after the first 1/8th acre had been thrashed, the nuts and bolts appeared to become bedded in and little further trouble was encountered although two of the drum pegs were lost during the trial. These in no way hindered the unit's thrashing ability. Some time was spent removing straw from round the main drive shaft but this could be prevented by the introduction of a metal guard at this point.

The plot of rice used for the trial comprised two experimental plots of about 1/4 acre each. The significant feature of the plots was that the rice had been broadcast and not hand planted in the traditional Trinidad peasant method. Consequently the stand of rice was much thicker than would be expected under conditions of hand planting and also there was a higher straw to grain ratio than normal. The yield of rice, especially on half the area which had been broadcast on a dry seedbed, was higher than average peasant yields. The straw was also badly lodged in many places which lead to difficulties in getting all the heads at the same level when held in the thrashing unit. No undue setback was suffered on this account however, and the quality of thrashing as judged by the amount of rice left in the straw was exceptionally good throughout.

As the rice was harvested the day prior to thrashing, the stacks were rather at the mercy of the weather and it was obvious throughout that the drier the straw could be kept, the speedier was the thrashing and the cleaner the rice sample obtained.
RESULTS.

Trial A. (To find the optimum number of operators.)

(1) One Operator.

A plot of about 1/8th. acre was used for this trial. The operator had to carry the cut rice from the stack to the machine, separate it into convenient bundles and knock the butts to get all the heads together, thrash the in the machine, and finally winnow and bag the thrashed rice.

It soon became evident that this was both a slow and expensive method. This was due to the time spent by the operator walking backwards and forwards from the stacked rice to the thrashing machine. This meant that the machine, the most expensive item in the costings, was running idle for much of the time. As fuel and depreciation costs for the machine are major items in the overall cost of the operation, idle running of the machine cannot be tolerated. The following table shows the exact details of this trial.

Table No. 1.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>HOURS/ACRE</th>
<th>FUEL GALS.</th>
<th>DEP. @ 71¢ PER HOUR</th>
<th>TOTAL COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine</td>
<td>40 4/10</td>
<td>20</td>
<td>9.00</td>
<td>28.90</td>
</tr>
<tr>
<td></td>
<td>THRASHING</td>
<td>WINNOWING</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HOURS/ACRE</td>
<td>HOURS/ACRE</td>
<td>TOTAL MAN HOURS/ACRE</td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td>40 4/10</td>
<td>12 4/10</td>
<td>53 4/10</td>
<td>17.70</td>
</tr>
</tbody>
</table>

TOTAL COST PER ACRE

$55.60
Two Operators.

As this was the method suggested as optimum by J. Taylor (1956) in his preliminary trials last year, a ½ acre plot was used for this trial. The system employed was that one man actually thrashed the rice in the machine, whilst the second operator carried the rice from the stack and handed it to the man operating the thrashing machine, in convenient bundles. The second operation of carrying the rice could quite readily be done by a woman or child but for the purpose of this trial both operators were costed as adult workers.

This method proved to be much more economical than with a single operator as the machine could be kept running fully loaded apart from the periods of winnowing and bagging when the engine was shut off. It was found to be possible to run the machine for a period of about ½ hour before stopping to bag up the thrashed rice. Both men worked together whilst winnowing and bagging which doubled the speed of this operation over the single operator method although the total man hours were about the same.

Provided the stack is near to the thrashing unit, the worker carrying rice from the stack has no difficulty in keeping the thrasher operator supplied and there is no need for more than one operator thus employed.

Table No. 2.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>HOURS/ACRE</th>
<th>FUEL</th>
<th>DEP.@ 7½/PER HOUR</th>
<th>TOTAL COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine</td>
<td>18</td>
<td>9</td>
<td>4.00</td>
<td>12.50</td>
</tr>
<tr>
<td>Labour</td>
<td>36</td>
<td>11½</td>
<td>47½</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$ 32.25</td>
</tr>
</tbody>
</table>
Three Operators.

The results of this trial showed that although thrashing time could be reduced and output per hour be significantly increased by the use of three operators, the actual cost per acre was higher than when only two operators were used. However the costs were significantly lower than when only one operator was employed.

The system was to have the third operator constantly employed winnowing and bagging the thrashed rice. This meant that the thrashing unit could be kept running non-stop for long periods. The thrasher operator commented that standing in the one position for long periods became very tiring and he thought he could work longer and faster if he were allowed the change offered by winnowing and bagging.

Again these costs have been given for three adult workers but the task could have been done using one adult and two children or women and this method would very probably appeal to a peasant farmer thrashing his own rice and using family labour.

The results are contained in the following table:

<table>
<thead>
<tr>
<th>ITEM</th>
<th>HOURS/ACRE</th>
<th>FUEL GALS.</th>
<th>DEP.@ 7½ PER HOUR</th>
<th>TOTAL COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine</td>
<td>20</td>
<td>10</td>
<td>4.50</td>
<td>14.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18.70</td>
</tr>
<tr>
<td>Labour</td>
<td>40</td>
<td>20</td>
<td>60</td>
<td>19.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>38.60</td>
</tr>
</tbody>
</table>

TOTAL COST PER ACRE $38.60
Trial. B. (Two operators on task-work basis.)

In this experiment, $\frac{1}{4}$ acre of rice was thrashed by two operators on a task-work basis. The task set was to thrash $\frac{1}{4}$ acre of rice per day, an amount which appeared very reasonable from the previous trial. The $\frac{1}{4}$ acre plots were accurately measured out and harvested the day prior to thrashing and stacked on the trace as in the previous set of experiments.

The crop was not as heavy as that used in the first trial but the results gave a good reflection of the rate of working which could be expected from peasant farmers using the machine on their own crops. Hence these figures could be used to compare with costings collected for hand thrashing by peasants and hence give a picture of the machine's efficiency and probability as a commercial proposition.

The figures below refer to the costs per acre of thrashing a crop of rice which yielded about 2,900 lbs. of uncleaned grain.

First day's task.

Table No. 4.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>HOURS/ACRE</th>
<th>FUEL GALS.</th>
<th>DEP. @ 71¢ PER HOUR</th>
<th>TOTAL COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine</td>
<td>10$\frac{1}{2}$</td>
<td>5$\frac{1}{2}$</td>
<td>2.50</td>
<td>7.60</td>
</tr>
<tr>
<td>THRASHING</td>
<td></td>
<td>WINNOWING</td>
<td>TOTAL MAN</td>
<td></td>
</tr>
<tr>
<td>MAN/HOURS</td>
<td>2$\frac{1}{2}$</td>
<td>8</td>
<td>HOURS/ACRE</td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td>21$\frac{1}{2}$</td>
<td>8</td>
<td>29$\frac{1}{2}$</td>
<td></td>
</tr>
<tr>
<td>TOTAL COST PER ACRE</td>
<td></td>
<td></td>
<td></td>
<td>$19.70</td>
</tr>
</tbody>
</table>
Second day's task.

Table No. 5.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>HOURS/ACRE</th>
<th>FUEL GALS.</th>
<th>DEP.@ 71¢ PER HOUR</th>
<th>TOTAL COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine</td>
<td>11 1/2</td>
<td>6</td>
<td>2.70</td>
<td>8.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>THRASHING</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WINNOWING</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL MAN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HOURS/ACRE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td>23</td>
<td>8</td>
<td>31</td>
<td></td>
</tr>
<tr>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL COST PER ACRE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes.

The following rates have been used in costings:

- Fuel 45¢ per gallon.
- Labour 33¢ per gallon.

The depreciation figure used is based on figures supplied by Nansayakkare (1951) and is split up as follows:

- Depreciation (life 2625 hours, cost $ 1,250.00) 47¢
- Repairs and maintenance (10% cost per year) 17¢
- Housing (3% cost per year) 5¢
- Interest in Capital (2% of 1/3 initial cost per year) 2¢

Total cost per hour 71¢

For trial A, the costings given refer to a yield of unclean grain of 4,100 lbs. per acre whereas the average yield for peasant rice is 2,500 lbs. or less of clean grain. In the case of trial B, the yield was not greatly over the average for peasant crops, being in the region of 2,700 lbs. per acre.
DISCUSSION.

Having established the ability of the Gem rotavator and thrashing unit to successfully thrash a crop of rice, and having found the optimum number of workers required to operate it, we must look now to the main point at issue, namely the economics of using such a unit. This is not an easy assessment to make when considering a machine to be used by peasant farmers whose main source of labour is from within the family and therefore difficult to cost. It is also difficult to decide whether a saving in man hours will have any real meaning when dealing with such family units, although with the present trend of peasant farmers and their families to take up additional outside employment this may well become an important factor. For the present, however, perhaps the best solution will be to establish some figure for costing the present hand methods of rice harvesting and thrashing, based on man hours per acre, against which the costs established for the mechanical thrashing unit can be compared.

Such figures are available in a publication of the Trinidad and Tobago Economics Department (1953), which reports on the findings of a survey of rice production on peasant holdings in Trinidad. In this survey an attempt was made to estimate the total time, in man hours per acre, spent in the cultivation of the rice crop, and also to split this overall figure down into its respective parts for planting, weeding, harvesting, thrashing, winnowing etc. The following table is an extract from these figures, concerning the operations of thrashing and winnowing.
Table No. 6.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Caroni</th>
<th>Chagoupe</th>
<th>Pishing Pond</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrashing</td>
<td>43.2</td>
<td>46.7</td>
<td>67.4</td>
<td>47.5</td>
</tr>
<tr>
<td>Winnowing</td>
<td>15.4</td>
<td>26.5</td>
<td>27.5</td>
<td>21.8</td>
</tr>
<tr>
<td>Yield per acre (lbs.)</td>
<td>2,800</td>
<td>2,100</td>
<td>2,700</td>
<td>2,500</td>
</tr>
</tbody>
</table>

From these figures we see that the average man hours for hand thrashing an acre of rice is 47.5 for a yield of 2,500 lbs. of rice grain. There is however, considerable variation around this figure. Costing this figure at the same rate of 33¢ per hour as in the figures given for the trial of the Gem and thrashing unit, we arrive at an average cost for hand thrashing of $15.80 per acre.

In comparison with this figure it is intended to use only the costings from the second trial which was done on a task-work basis and will therefore most nearly approximate to the conditions of peasant farmers working on their own crops. The higher figures obtained from the first trial can be accounted for partly due to a much slower rate of work due to the operator being comparatively inexperienced with the unit, the fact that quality of thrashing and not speed was the main aim and also the yield of the crop in that trial was very high, being far above the average crop yield, and quite naturally the rate of working the unit in primarily effected by the amount of straw and grain which has to pass through it.

The comparable figure for machine thrashing, therefore is $20.40 for a yield of approximately 2,700 lbs. of clean rice. Although this represents a higher cost of $4.60 per acre it does however represent a saving in man hours per acre of 25. As discussed earlier, however, the value of this saving in man...
hours in peasant agriculture is still rather doubtful, but if these man hours were utilised in alternative employment, the saving would be considerable. As this assumption cannot be made, it becomes necessary to look for other factors which can be modified or altered to bring about a reduction in the costs of operating the machine.

A study of the figures in tables 4 and 5, brings out one point very clearly. That is the comparatively high figure of 71\(\frac{1}{2}\) per hour which has to be attributed to the depreciation of the Howard "Gem" rotavator. However, the engine under the present system, is by no means fully loaded and, therefore, it is feasible to expect that the load could be increased, giving a corresponding increase in output without increasing either the fuel costs or the costs attributed to depreciation. It was decided therefore, that although the thrashing machine may, in its present form, be an economical proposition under some circumstances, to attempt further modifications based on this idea.

To this end, two methods of increasing the load were considered. The first of these was to build a much broader thrashing drum which would facilitate two operators actually working at the machine and so almost double the throughput of rice. However, difficulties were foreseen in the smoothness of keeping the two operators supplied with unthrashed rice, probably leading to a much smaller output than expected. This method will, however, be borne in mind and may be tried some time in the future.

The second, and most promising method at first sight, was the construction of a combined thrashing and winnowing machine. With the present machine, the rice bagged up requires almost the same degree of winnowing as is practiced with normal hand thrashing. If this winnowing could be done by the machine simultaneously with the thrashing process, both the loading of
the machine would be increased and the man hours at present spent in winnowing could be eliminated. From the previous table (6), it can be seen that man hours for hand winnowing vary from about 15 to 27 per acre with an average of about 22 man hours per acre. This would represent an average saving of about $7.00 per acre with no extra running costs.

It was decided, therefore, that an attempt should be made to design such a machine and as previously, the accent should be on cheapness and simplicity to suit the needs of peasant farmers.
As is stated in the previous chapter, the new design is based on the principle of combining the processes of thrashing and winnowing in one unit with the object of producing a sample of padi equivalent to that obtained by traditional hand thrashing and winnowing, in a single operation. By so doing it is hoped to reduce further the man hours required for the two processes without increasing the mechanical costs per acre. As with the previous thrashing unit, the combined thrashing and winnowing unit is designed so that the Howard 'Gem' rotavator can be used as the power unit.

Because the existing thrashing unit, which is actually built on the 'Gem' rotavator was so low, with little clearance between the drum and the ground, it did not seem feasible to attempt to build a winnowing unit on to it. Consequently it was decided that a completely new unit should be built and this unit should not be attached directly to the 'Gem', as with the previous model, but should be a separate unit capable of taking a belt drive from the 'Gem' rotavator. This meant that the drum could be placed at a higher level than in the first model which would not only facilitate the incorporation of a winnowing unit beneath it, but would also make the working height of the machine more comfortable to the operator. Previously the slatted table had stood at only 20" above the ground and the operator had had to work with his back constantly bent which lead to considerable discomfort and loss of efficiency when the machine was used for long periods. It was proposed, therefore, to raise the height of the slatted table to 40" which was considered the maximum height for convenient operation for the machine.
A further factor considered in the design of the unit was cheapness and simplicity of construction. Cheapness is essential if mechanisation is to be introduced into the peasant areas where capital is available for investment in machinery. Simplicity ensures both trouble free running and easy maintenance by the farmer and also has the advantage that the machine besides the possibility of being put into production, could easily be built locally by semi-skilled craftsmen. Hence the basic structure was made of wood and could readily be built by a local carpenter and the metal fitting, so designed that they could be produced by a local blacksmith. The only parts likely to be unavailable locally are bearings and belts and pulleys. The only modification to the 'Gem' rotavator necessary to provide the power for the machine, is the extension of the main drive shaft so that a pulley can be incorporated outside the main drive sprocket already present.

The actual design of the machine is shown in Diagrams I to V. These diagrams show the basic design of the unit but are subject to modifications which may be deemed necessary when preliminary trials have been carried out. The following is a description of the construction of the machine and the materials used.

(1) **MAIN FRAMEWORK**

The basic framework of the machine consists of a skeleton of 2" x 3" Pitch Pine of dimensions 40" x 30" x 24" forming a box-like structure onto the end of which is built the fan. Cross members are present to take the drive shafts and the bearings are let onto these members. The corner joints are all tenon and mortise and these are secured by wooden pegs. The cross members have 'half and half' joints at their points.
of intersection and these are secured by means of screws. The top frame supporting the slatted table is $1\frac{1}{2}'' \times 1\frac{1}{2}''$ Pitch Pine and is fastened to the lower frame by tenon and mortise pegged joints.

The outer surface of the framework is covered with galvanised metal sheeting, apart from the inlets of the fan and a portion running the width of the opposite end and $12\frac{1}{2}''$ in depth through which the draught from the fan blows. Also the sheet below this gap is fitted in slots and is removable to facilitate the removal of thrashed padi and also facilitates oiling of the shafts and adjustment of the sieve trays. This outer covering could equally well be of ply-wood or other hard board, the deciding factor being availability and relative costs of these materials.

(2) THRASHING UNIT

The thrashing mechanism of the unit is basically the same type of peg drum as that designed by Taylor (1956) for the original thrashing unit. As the this type of drum proved quite efficient in removal of padi from the straw, in previous trials, there seemed little advantage to be obtained by making basic modifications at this point. The only differences are that the drum is now based on a wooden skeleton instead of the metal frame of the original and the effective width has been increased from 12'' to 16''.

The drum was built in two halves with semi-circular end pieces of 1'' x 6'' planking with a diameter of 12''. Each half has four cross members of 1'' x 1'' Pitch Pine through which are bolted 5/16'' pegs at 4'' intervals with a 1'' staggering on successive cross members. Hence in one complete revolution, two pegs pass through any one orbit, the orbits being 1'' apart.
This is demonstrated in Diagram V. The pegs, as previously, are made from 4" x 5/16" bolts with their heads sawn off. The two halves of the drum are secured rigidly to the shaft by being bolted to steel plates which are welded onto the shaft. Each half of the drum is held at each end by three ½" bolts. The shaft itself is of 3/8" polished steel, machined at each end to take 5/8" bearings. The shaft is mounted at both ends which is a further improvement over the original and should give better balance, and less wear on the bearings.

The slatted table consists of ½" metal strips running the length of the top of the frame at 2" intervals and secured by means of screws. At the point of emergence of the pegs through the slats, is a guard of 1" angle iron which serves as a protection to the hands of the operator.

The drum is covered by a galvanized metal shield to prevent rice being thrown over the back of the machine. The shield is continued down to the slatted table on the right hand side to prevent straw falling down onto the drive shaft. The shield is secured by a 1" x 1/8" steel support with ½" steel strips down the edges to give rigidity.

(3) WINNOWING UNIT

The whole of the winnowing unit is situated below the thrashing drum and consists of a fan directing a flow of air over two sieve trays, one situated below the other. The draught from the fan blows along the line of the trays and out through the opening on the opposite end of the unit.

The fan consists of a four bladed paddle rotating within a cylinder consisting of end pieces of 1" planking and covered with galvanized metal sheeting. The end pieces each have a 4" square air inlet which are adjustable by means of sliding shutters. The blades of the paddle are made of ½" planking and are 4½" x 17" in size. The blades are secured, each by four ½" bolts to metal supports, two to each blade,
welded to the drive shaft. The shaft is again of 7/8" polished steel, machined at each end to take 5/8" bearings. The trays consist of a frame of 1" x 1" Pitch Pine and covered by wire mesh, the lower one having a finer mesh than the upper. The exact size of the mesh will be decided after preliminary trials, but initially 3/8" mesh is used on the upper tray and 1/2" mesh on the lower. The arrangement of the trays is also uncertain until the optimum slope and position can be determined by experimentation. It is proposed finally to have the lower tray reciprocating by means of an eccentric shaft as shown in Diagram 4. The trays will be hung by means of flexible straps which will tend to give some reciprocation due to the vibrations of the machine.

(4) DRIVE

The main drive from the Howard 'Gem' rotavator is to the drum shaft. The drive for the fan shaft is in turn taken from the drum shaft. Power transmission is by V-belts and pulleys.

From previous experience with a similar drum, it is known that a drum speed equal to the normal engine speed of the 'Gem' is quite satisfactory for efficient rice thrashing. However little evidence is available to suggest what fan speed will give optimum results. Consequently, for experimental purposes during preliminary trials, both the drum shaft and the fan shaft have been fitted with three-in-one pulleys which will be able to give a wide range of fan speeds between them and the optimum will be selected by trial and error.

Work on the construction of the machine started on 26th February 1957. The main framework was built by the College Farm carpenter and the shafts were made at the College Works Dept. The machine was ready for preliminary tests by 30th.
March 1957.

It must be remembered that the machine described above is essentially an experimental prototype and mechanically is lacking in several finer details. The bearings, for instance are not supplied with grease nipples which necessitates constant oiling during operation. Also old bearings have been used to keep the initial costs of the prototype as low as possible.

Finally handles will be fitted to the unit which will facilitate the machine to be easily carried by two men or lifted onto a cart or trailer for transport.
DIAGRAM I
SIDE VIEW OF THRASHING MACHINE.
(Scale: 1/5th. full size)
DIAGRAM II.
SECTION THROUGH SIDE VIEW OF MACHINE.
(Scale: 1/5th full size)
DIAGRAM III.
END VIEW OF THRASHING MACHINE.

(Scale: 1/5th. full size)
DIAGRAM IV
SECTION OF END VIEW OF MACHINE.

(Scale: 1/5 full size)
DIAGRAM V.
TOP VIEW OF MACHINE SHOWING EMERGENCE OF PEGS THROUGH SLATTED TABLE.

(Scale: 1/5th. full size)
COSTINGS OF THE MACHINE

The following figures refer to retail prices of materials prevalent in Trinidad at the time of purchase. The costs for labour are based on the standard rates of the Imperial College Farm and Works Department. No costs are included for work carried out by the author of this report. The itemised costs were as follows:-

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Main Framework:</td>
<td>Timber</td>
<td>7.00</td>
</tr>
<tr>
<td></td>
<td>Galvanized Sheeting</td>
<td>16.20</td>
</tr>
<tr>
<td></td>
<td>Labour</td>
<td>11.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>34.70</strong></td>
</tr>
<tr>
<td>(b) Drum:</td>
<td>Timber</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>Pegs</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td>Shaft</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td>Bearings (estimate)</td>
<td>6.00</td>
</tr>
<tr>
<td></td>
<td>Labour</td>
<td>2.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>12.70</strong></td>
</tr>
<tr>
<td>(c) Slatted Table:</td>
<td>Timber</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>1.75</strong></td>
</tr>
<tr>
<td>(d) Fan:</td>
<td>Timber</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Shaft</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td>Bearings (estimate)</td>
<td>6.00</td>
</tr>
<tr>
<td></td>
<td>Labour</td>
<td>2.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>11.00</strong></td>
</tr>
<tr>
<td>(e) Sieve Trays:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(f) Pulleys:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 'three-in-one'</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>6.50</strong></td>
</tr>
<tr>
<td>(g) V-Belts:</td>
<td>2 75&quot; circumference</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>4.25</strong></td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL</strong></td>
<td><strong>75.40</strong></td>
</tr>
</tbody>
</table>

Consideration of these figures leads to the assumption that these costs could be considerably lowered by reducing the cost.
of the main frame. This could be done by substituting local timber for the expensive imported timber actually used and by the use of some less expensive covering material than the galvanised sheeting, which stands out as the dearest single item. A further reduction would be possible if the materials were available at wholesale rather than retail prices.

Otherwise, if the machine proves an economic proposition so far as a rice thrashing and winnowing machine is concerned, the price is not high in relation to the expected low depreciation of the unit, for there are few wearing parts.

This set up was rather unsatisfactory as it meant that the machine could not be tested under true field conditions. Also the Villiers engine had considerably less power than that of the 'Gem' and also had no direct clutch mechanism which made it difficult to start the thrashing machine turning. However it did serve as a means to test such factors as fan speed required, setting of the sile trays, and the size of mesh required on the sieve trays, the knowledge of which was of prime importance before a full scale field trial could be contemplated.

Another handicap was that the only rice available was the discard left over from a previously harvested rice experiment and this had been subjected to three days heavy rain before it could be brought from the field to the Machinery shed at the Old Farm where one trials were carried out. By that time the rice was very wet and much of the rice had sprouted. It was possible however to pick out a small dry sample which sufficed for the purposes of the trial.

The trial was carried out essentially as a preliminary to a full scale field trial with the object of finding by experiment the optimum setting of the machine for thrashing rice in the field. No measurements of output or man hours involved were recorded and no attempt was made to estimate the economy of the
PRELIMINARY TRIALS

At the time of completion of the new machine, the Howard 'Gem' Rotavator, which had previously been used in the trials described in this report, was in an unserviceable condition and therefore an alternative power unit had to be found for preliminary experiments with the new design. The only engine available was a Villiers engine which was powering a lawn mower. This engine was removed from the mower and bolted to a bench from where a belt drive could be taken to the thrashing machine. This set up was rather unsatisfactory as it meant that the machine could not be tested under true field conditions. Also the Villiers engine had considerably less power than that of the 'Gem' and also had no direct clutch mechanism which made it difficult to start the thrashing machine turning. However it did serve as a means to test such factors as fan speed required, setting of the sieve trays, and the size of mesh required on the sieve trays, the knowledge of which was of prime importance before a full scale field trial could be contemplated.

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The trial was carried out essentially as a preliminary to a full scale field trial with the object of finding by experiment the optimum setting of the machine for thrashing rice in the field. No measurements of output or man hours involved were recorded and no attempt was made to estimate the economy of the
machine at this stage. The prime factors under consideration in this trial may be discussed under the two headings:

(a) Fan Speed.

(b) Sieve Tray Setting and Size of Mesh.

(a) Fan Speed

At the time of designing the new unit, little direct evidence of air velocities required and size of fan could be found in the literature and so the optimum fan speed had to be found by trial and error. The aim was to get the maximum draught which would remove straw and chaff off the sieve trays without blowing rice out through the back of the unit. An early difficulty was experienced in that the effect of the drum rotating above the outlet tended to deflect the draught from the fan and much of the air flow was blown straight up behind the rotating drum instead of along the line of the sieve trays. This was overcome by erecting a shield of galvanised sheeting over the top of the fan outlet and extending some six inches into the body of the unit. This shield cut down this deflecting affect to a great extent and allowed sufficient draught for winnowing purposes to be directed over the trays and out of the back of the unit.

It is stated in an earlier chapter that 'three-in-one' pulleys (3", 2" and 1\(\frac{1}{2}\)"") were used on the drive shafts of the drum and the fan and various combinations of these different sized pulleys were tried. It soon became evident that it was unlikely that draughts of air sufficient to blow rice out of the unit could be produced with the fan incorporated in the unit with the pulley ratios available. Therefore the maximum step up in drive from the drum to the fan was used and although it appeared that this may be quite satisfactory, it is possible that a higher gear ratio still may be feasible. The actual gear ratio used being 2 : 1.
Sieve Tray Setting and Mesh Size

For the purpose of these initial trials, two rigid trays were used, the upper having a 3/8" chicken wire mesh and the lower one, a 1/4" mesh. The upper tray was placed at an angle, sloping back to the fan and the lower one was horizontal, the idea being to have the draught blowing as near as possible along the surface of the trays.

The first point arising from the trial was the need for some system of reciprocation or agitation of the sieve trays. At first it appeared that the draught from the fan was insufficient to blow the bits of straw and chaff off the trays but when the trays were agitated by hand, the straw which tended to become stuck in the mesh, was freed and then easily blown out of the back of the unit. In the original design of this unit it was proposed that the lower tray should be reciprocating, but from the evidence of this trial, it would seem that this agitation should be given to both trays.

As far as the setting of the trays was concerned, there seemed to be little difference between having the upper tray sloping or horizontal.

The mesh of the upper tray was sufficient to sort out the larger pieces of straw but it was found that the lower mesh was rather too wide and tended to allow small pieces of chaff and straw to pass through. However the sample of rice produced was infinitely better than that produced by the original thrashing unit designed by Taylor (1956) and a slightly finer mesh should produce a sample which needs no hand winnowing.
RECOMMENDATIONS FOR FUTURE WORK

The main demand now that the basic construction of the unit has been completed is for a full scale field trial. However before this can be contemplated various modifications resulting from the preliminary trials are suggested:

1. The incorporation of some reciprocating or agitating mechanism for the sieve trays. Once this has been done further trials with the fan will be able to decide more accurately whether the present gear ratio of drum to fan is sufficient.

2. A finer mesh is required on the lower riddle to ensure that no small straw and chaff particles pollute the rice sample produced.

3. The provision of handles on the machine to facilitate easy handling and carrying by two men.

4. It may be necessary to construct detachable supports between the thrashing unit and the 'Gem' rotavator which will give rigidity and so prevent belt slip.

5. The unit was given preliminary trials and subjected to a few modifications listed in the report, promises to provide an efficient and economic means of thrashing and winnowing rice.

6. As the new design needs no extra operators, no more power and has the same rate of output, there should be a reduction in costs of thrashing and winnowing, over the original thrashing unit, equivalent to the total and hours previously spent on hand winnowing.

7. The low cost, simplicity and easy maintenance of the new design would enable it to fit in well with needs of peasant agriculturists and thereby the unit would serve the success for which it was designed.
(1) The original thrashing unit built by Taylor (1956) was given a full scale field trial.

(2) The trial showed a substantial reduction in man hours per acre but was only on the border line of being an economic proposition due to the high mechanical costs.

(3) It was decided that if the man hours per acre could be further reduced by eliminating hand winnowing without increasing mechanical costs, the chances of the machine being an economic proposition would be greatly enhanced.

(4) A new, combined thrashing and winnowing unit was designed and constructed. The details of the construction along with diagrams are given in the report. The new unit differs from the original in that it is not built directly onto the 'Gem' rotavator but takes a belt drive from it.

(5) The unit was given preliminary trials and subject to a few modifications listed in the report, promises to provide an efficient and economic means of thrashing and winnowing rice.

(6) As the new design needs no extra operators, no more power and has the same rate of output, there should be a reduction in costs of thrashing and winnowing over the original thrashing unit, equivalent to the total man hours previously spent on hand winnowing.

(7) The low costs, simplicity and easy maintenance of the new design would seem to fit in well with needs of peasant agriculturalists and therefore the unit should serve the purpose for which it was designed.
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