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Development and Evaluation of a Rice Stripping Header System

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ABSTRACT: In rice production systems, harvesting is labour intensive and leads to grain losses. For mechanical threshing energy consumption is high because of the handling of material other than grain (MOG). A header was developed for in-situ stripping of grains and to evaluate the best combination of rotor speed, element height, element angle, MOG passing and rotor height for minimum grain losses. The header consists of flexible comb elements mounted on a rotor spinning on horizontal axis with its upper half enclosed by a movable hood. Stripped grains were collected on a removable tray. The header was attached to two wheel tractor.

The system has proved to be effective in terms of stripping ability and capacity and power requirements. Laid and weed infested fields presented no problems. Transportation and handling of straw is avoided by threshing the standing crop. The stripper head offers potential for developing a light, cheap and simple rice harvester.

INTRODUCTION

Agricultural development largely depends on the technological innovations and its successful transfer. Mechanization has been identified as a complementary input to improved farming systems with other agricultural inputs and higher levels of skills and management. It increases crop production and labour productivity. In developing countries the major food crop harvested is paddy (Table 1). However, throughout the tropics the arduous operation of harvesting is usually performed manually by women and children with the use of traditional hand tools, consuming much time and labour.

Time and labour play a very crucial role in the introduction of high yielding varieties, in the application of improved crop production technology, irrigation and multiple cropping. Because of the large quantity of crop that must be handled and harvested the time available

Table 1. Major food crops, world and developing countries ranked in order of estimated production (FAO)

WORLD			DEVELOPING COUNTRIES		
Crop	Tonnes ('000)	%	Crop	Tonnes ('000)	%
Wheat	417478	15.67	Paddy	186230	21.36
Paddy	345386	12.97	Cassava	103486	11.87
Maize	334010	12.54	Wheat	95045	10.90
Potatoes	287554	10.80	Maize	73328	8.41
Barley	189654	7.12	Banana	55199	6.33
Sw.Potatoes	135855	5.10	Coconuts	32664	3.75

between two successive crops has narrowed down. Harvesting cost forrice is much higher than for other grains and amounts to about 30% of total cost for producing rice (Burkhardt, 1975; Jacob, 1974). Investigations on the nature and magnitude of field grain losses in paddy production indicate that 20% losses do occur during harvesting.

This condition restraints the farmer from maximizing the productivity of his land and increases crop losses due to untimely harvesting. These constraints necessitates the introduction of a fast and efficient harvesting technique in which only the most valuable parts of the crop are harvested.

HISTORICAL DEVELOPMENT OF GRAIN STRIPPING

The Gllic Vallus (70 AD), as described by an ancient Roman writer Pliny, was a cart about 2ft 6in. wide, with a forward projecting comb, and pushed by bullock into the crop from the rear (Rotawator, 1966). Stripped heads were raked back into the container by an attendant. Inspired by this ancient account of collecting the grain, by 1786, a revolving cylinder with several rows of teeth was produced. In 1799 James Boyce patented a machine with revolving knife and protecting guards. Table 2 gives the details of the development of grain harvesting methods.

Study of literature on previous attempts to develop grain stripping mechanisms suggest four main reasons for failure.

1. Disturbance on entry of the stripping elements into the crop leading to unacceptable high shatter losses.

2. Incomplete detachment of the wanted plant parts.

3. Detached seeds and seed – bearing parts not being impelled consistently towards the collecting mechanism.

4. Inability to recover the wanted plant parts when condition and presentation of the crop were unfavourable.
   Although some work has been done on the stripping of rice crop the main interest and research work have been on wheat, barley, oats etc.

Table 2. Development of grain harvesting methods

Time	Inventor	Method
5000 BC		Wooden implements for stripping ears.
4000 BC		Flint knives for cutting ears.
3000 BC		Sickle - shaped saws of clay for cutting ears.
2800 BC		Sickles of copper and bronze.
700 BC		Seythes of iron, which superceded the sickle.
200 BC		"Gallie Mowing Cart" with tine comb attached to the front pushed by oxen.
50 BC	Plinius	Device for reaping ears on a two wheel cart.
1786		Mowing machine with ripped cylinder resembling a reel in England.
1799	James Boyee	Reaper with rotating ring of seythes.
1800	Meares R.	Front harvester operating on the scissors principle.
1828		German patent issued for a combine harvester.
1831	Manning	Harvester with the draught animals harnessed to its sides.
1836		Combine harvester in the USA.
1843	Ridley	Stripper Harvester in Australia.
1858	Hussey	Harvester with cutter bar whose basic design is still in use.
1860		Industrial series production of combine harvesters.
1918/28		Introduction of tractor drawn combine harvesters.
1965	Feiffer et al	The first electronic loss checking deice for automatically and continuously measuring the grain losses.

DESIGN AND DEVELOPMENT OF THE STRIPPER HEADER

The term "harvesting" normally refers to all operations carried out in the field such as cutting the stalk, laying out of stalk paddy on the stubble to dry, binding, shocking, threshing and cleaning.

Manual cutting and separate threshing has been the traditional method since ancient times. Cutting is accomplished by sickle. The method of threshing varies from region to region and also according to the economic means of the farmer. The range of methods are simply knocking the grain out over a wooden horizontal pole, "combing" the rice out using a steel comb, using a treadle, wire loop thresher, or a power operated wire loop/pin type head feeding thresher. Animal-drawn equipment is not widely used for harvesting rice, as it requires dry field conditions.

There are two types of western "through type" combines, the trailed type using a separate tractor for power and the self propelled type. However these machines take in all the straw and the grain has to be separated. This makes the "through type" combines heavy, bulky and expensive. These combines would have difficulty in entering and leaving paddy fields. Trafficability would be poor that would reduce field efficiency. Requirements for rice harvesting using different operations are given in Table 3.

The Stripper Header system described overcome many of the disadvantages of these two. Development Strategy adopted was based on the three types of machines that could be developed using a stripper head.

1. A simple stripper head that would take a sample. The collected material would require re-threshing and cleaning.

2. A stripper head incorporating a re-thresher. The sample then would only require cleaning. Typical MOG would be upto 10% by weight.

3. A stripper head which would take only the grains plus minimum MOG and provide full cleaning facility.

With the three options the possibility of longitudinal mounting versus transverse mounting were considered. From the work done on wheat

Table 3. Requirements for rice harvesting (Johnson, 1963)

Operations	Man hours/ha Min	Man hours/ha Max	Man hours/ha Range	Animal hours/ha Min	Animal hours/ha Max	Animal hours/ha Range	Rated hp-hours/ha Min	Rated hp-hours/ha Max	Rated hp-hours/ha Range
Hand harvest individual panicles with small knife	-	-	240/69*	-	-	-	-	-	-
Hand harvest with sickle, transport and stack	72	370	80-160	-	-	-	-	-	-
Tractor and binder (40hp)									
Binding	4	-	-	-	-	-	80	-	-
Shocking	8	-	-	-	-	-	-	-	
Threshing	12	30	-	-	-	-	240	-	-
Hauling	2	-	-	-	-	-	80	-	-
Combine, 2-man crew (60-80 hp)									
In USA	2.2	7.5	4.4	-	-	-	-	-	175
In tropics	3.2	21.5	6-12	-	-	-	100	600	180-360
Foot threshing by man	200/69*	-	-	-	-	-	-	-	-
Flail threshing	16*	35*	20-30*	-	-	-	-	-	-
Beating on bamboo frame, basket	16*	-	-	-	-	-	-	-	-
Pedal thresher	8-10*	25*	100/20*	-	-	-	-	-	-
Trample by ox or buffalo	60/89/6*	-	-	150/178/6*	-	-	-	-	-
Japanese power thresher (0.5-3hp)	48/20*	197/25*	100	-	-	-	15/3*	-	25/5*
Treading with standard tractor	-	-	80	-	-	-	55	150	80
Treading with 15 hp tractor and disk harrow	-	-	-	-	-	-	50*	-	80*
Stationary large thresher	12	30	12	-	-	-	90	-	180
NIAE thresher	52*	155*	80*	-	-	-	3.2*	9.7*	5*
Tossing in air	10*	-	-	-	-	-	-	-	-
Field winnowing with hand fan	-	-	6.7*	-	-	-	-	-	-
Hand operated fan mill	1.5*	7*	-	-	-	-	-	-	-
Chaff sieve	4*	8*	-	-	-	-	-	-	-

(* denotes hours per 1000 kg)

it was found that longitudinal mounting increases capacity nearly by 100% (Herbolt et Marooze, 1986). Thus this option was pursued.

Once the above had been decided upon then the considerations would have to be given to its method of propulsion. There again are three possibilities.

1. Modification of an existing Tiller chassis and transmission.

2. A tractor mounted machine.

3. Self propelled machine.

A critical appraisal of the above approaches lead to the conclusion that in many respects the first approach offers advantages: the machine would be cheap, of high output and simple to operate and maintain.

Other consideration affecting stripping includes the moisture content in the grain and the energy requirements for threshing. The moisture content of the paddy grain is the best index for determining the optimum time for harvesting, irrespective of varieties and dates of heading. As a general rule of thumb, the optimum moisture content for harvesting paddy is about 20% (wet basis). This moisture level should be adjusted according to the rice variety and the crop handling system used. Figure 1 presents the results of measurements made at the IRRI (Khan *et al.*, 1973). The correlation between moisture content and field yield established (Bhole *et al.*, 1970) shows that the minimum field losses occurred when the harvesting moisture content was between 21 and 24 percent (Figure 2).

In threshing, the rice kernels are separated from the panicles by applying forces that exceed the retention forces. Panicle retention forces vary with the size, form and structure of the plant tissue holding the kernels. Other critical variables are grain weight, degree of ripeness, kernel moisture content, and possibly of most important, the rice variety. Casem and Khan (1968) studied the separation of rice grain from the panicle by centrifugal force. This force was determined to be

$$F = 3.9943\ W_g R N_c^2$$

where, F = threshing force, kg R = average radius of panicle, m
N_c = revolutions per second W_g = grain weight, kg

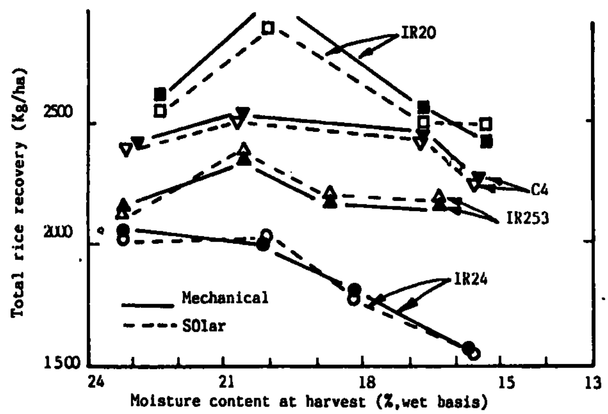

Fig.1. Total rice recovery versus moisture content at harvest of 4 varieties of irrigated rice using two drying methods. Gapan, Nueva Ecija, 1973 dry season.

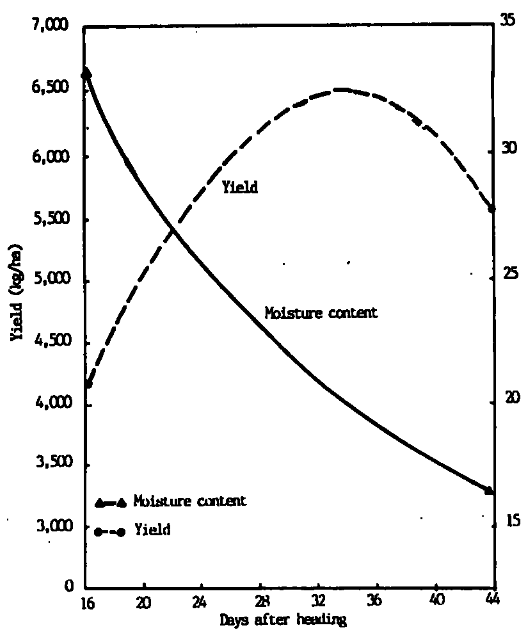

Fig. 2. Effect of time of harvest on grain moisture content and field yield. IR-8, 1968 dry season. (From Rice Production Manual 1970).

The relationship between the threshing force and the percentage threshing for the IR-8 variety at 7 different stages of maturity and moisture level is shown in Figure 3. The relationship between cylinder speed and kernel cracking as well as loss of grains is shown in Figure 4.

MATERIALS AND METHODS

Prototype No.1

A prototype stripper harvester was made to determine the best combination of rotor speed, loop height and loop angle. The threshing drum was made out of GI pipe. Wire loops were made out of 3 mm dia. iron wire (Figure 5). This threshing drum was mounted on a 2 wheel tractor frame. The drum was propelled by a 1/3 hp single phase 1425 rpm electric motor. Drum speed was varied by changing the driving belt tension and changing the driving pulley. Test runs were carried out altering the rotor speed, rotor height, loop height and loop angle. A collection pan was attached to the bottom of the rotor. Visual assessment was made of the materials collected, un-threshed losses and grain damage. Also the overall effect of forward speed on different rotor height as evaluated.

From the first trials it was found that rotor speed of 600 to 800 rpm, loop height of 40 mm and 26^0 loop angle give the best performance.

Prototype No.2

Second prototype threshing drum was made of 960 mm long 165 mm dia., 10 mm thick PVC pipe (Figure 6). It was mounted in front of a ISEKI KS 600 two wheel tractor chassis powered by Robine-KY20 engine. However, it did not produce any satisfactory results compared to prototype No. 1.

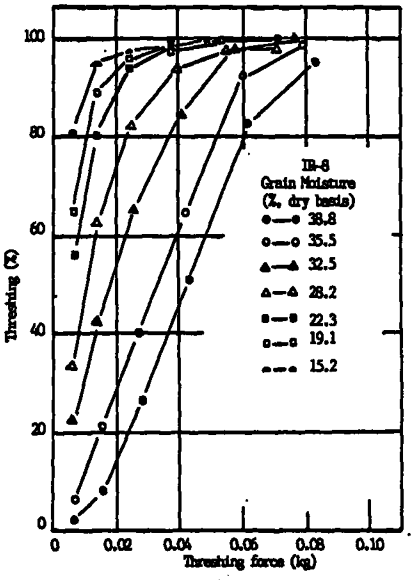

Fig. 3. Relation between threshing force and threshing percentage. IR-8 at seven grain-moisture levels.

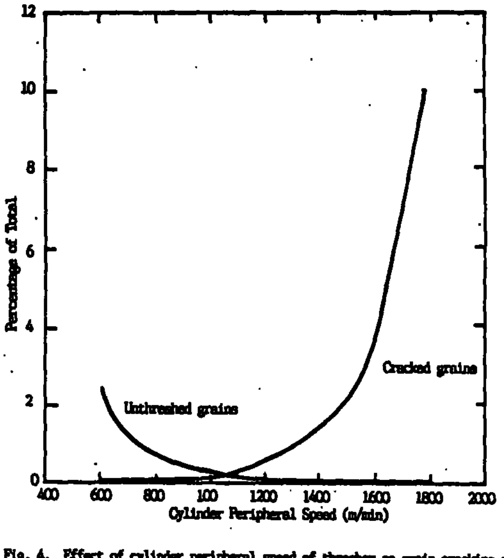

Fig. 4. Effect of cylinder peripheral speed of thresher on grain cracking and degree of threshing. IR-8 at 16 percent moisture content, wet basis. (From Harrington 1970).

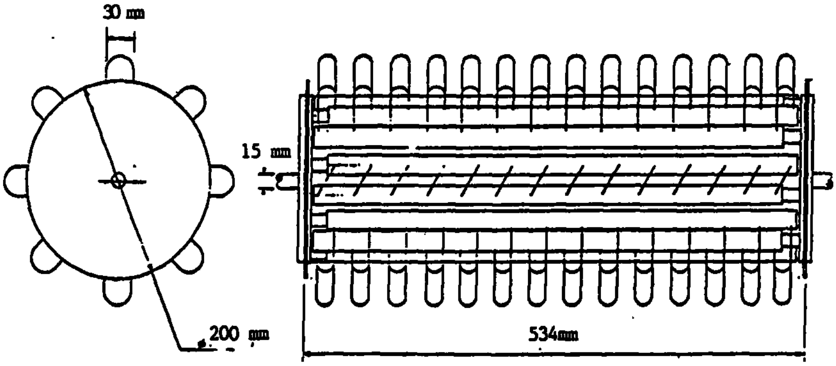

Fig. 5. First prototype stripper header

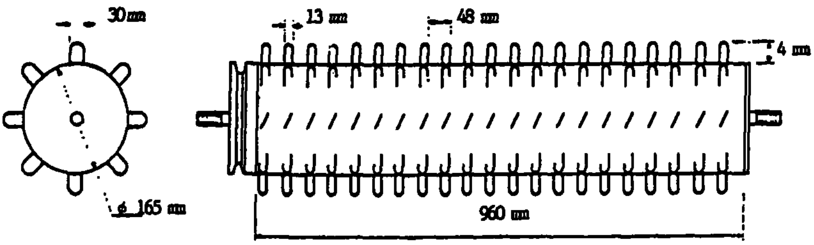

Fig. 6. Second prototype (P.V.C. drum rotor)

Prototype No.3

Third prototype threshing drum was made out of iron pipes. To avoid forward bending of plants, this was equipped with adjustable reel in front of the threshing drum (Figure 7). This was mounted on the same ISEKI tractor. From the first three prototypes, it was found that although the threshing was satisfactory grain damage and losses were unacceptable.

Prototype No.4

This consisted of a stripping rotor of 540 mm tip diameter with 8 rows of flexible arrow head elements and rotating at 600 to 800 rpm giving a peripheral speed of 17 to 22.7 m/sec. The length of the rotor was 900 mm. The stripping element shape combines comb-like projections to penetrate the crop with a wide gap, and a relief aperture between each individual element projection to ensure that stripped straw is released. The profile of principal stripping elements evaluated are shown in Figure 8. Type A was used in this machine. The elements were made from impact and aberration -resistant flexible rubber of A90 hardness. The flexibility and smoothness of the elements resulted in a gentle action which reduced straw intake. A full-width curved wood made of two overlapping, sliding sections was positioned over most of the front and top of the rotor, so that the lower section could be raised or lowered. Covering the top of the header behind the hood was a flexible sheet to prevent grain splash outward, yet allow air and lighter debris to escape. A cross section of the principle components of the stripping head is shown in Figure 9. The header system was powered through a set of pulleys and belts via a cable clutch. The prime mover being a petrol/kerosine Robine KY20 engine of 5 hp at 4000 rpm mounted on a ISEKI KS600 two wheel tractor chassis. The wheels were powered by the same engine through a clutch and a gear box. The general arrangement is shown in Figure 10. In order to obtain required maneuverability the front was supported by a spring loaded pivoted skid.

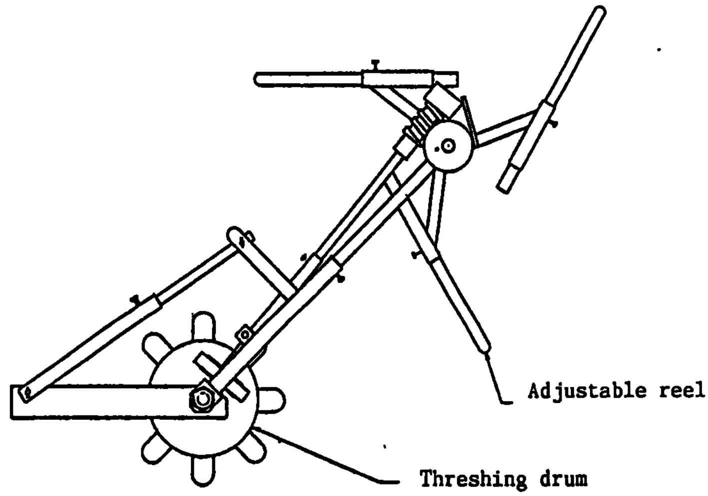

Fig. 7. Schematic diagram of the third prototype.

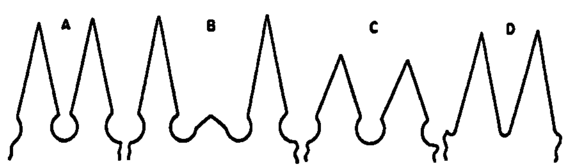

Figure 8.. Profiles of principal stripping elements evaluated: A, slender arrow head B, spaced slender arrow head; C, stubby arrow head D, plain serrated tooth.

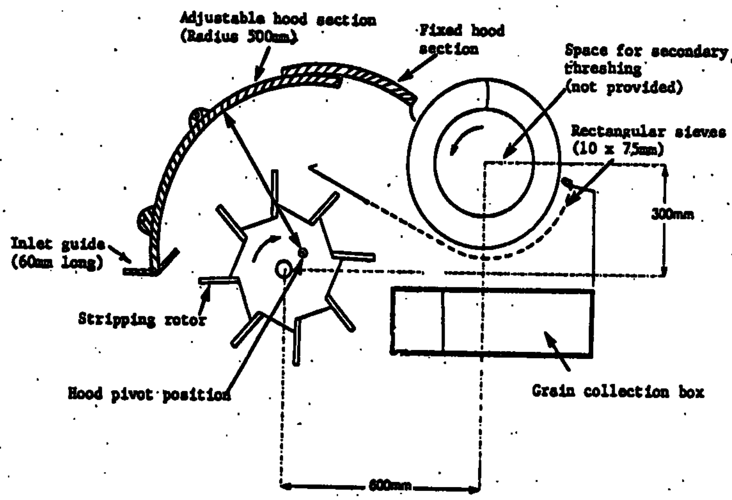

Fig. 9. Stripper header system prototype No.4

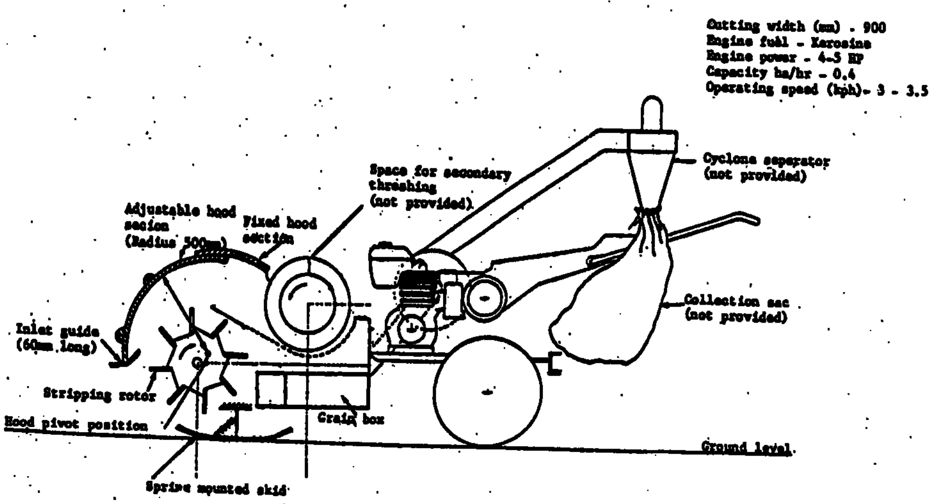

Fig. 10. General arrangement of rice stripper harvester.

FIELD TESTING AND EVALUATION

The machine was evaluated under the following test conditions:

1. Condition of crop: variety and characteristics of crop susceptibility to shattering, moisture content of stem and grain at harvesting and yield per ha.

2. Conditions of field: area and shape of field, type and characteristics of soil, degree of weed infestation and pre-harvest grain loss.

3. Condition of Machine Operation and Operator: adjustments of working parts, machine movement pattern in field, RPM of prime mover, stripping head and power, transmission pulley system, power transmission system, safety arrangements, operating speed and skill of operator.

A performance test was carried out under controlled conditions to obtain data on over-all machine performance, operating accuracy, work capacity and adoptability to varying harvesting conditions.
The items measured and observed are:

1. Performance and accuracy covering harvesting width, adjustments for different crop heights and lodged plants, percentage of misharvesting, slippage and sinking of machine, header loss on field, quality of grain out put capacity of machine, clogging and ease of its reduction, safety arrangements, power requirement, operating cost of machine and ease of operation.

2. Work rate and labour requirements which included operational speed, time spent for turning at headland, adjustment of machine and machine trouble, working capacity, fuel consumption pr hour and the number of workers and man-hours required.

RESULTS AND DISCUSSION

Removing grain from the stem proved to be a relatively easy process. Gaining control of the panicles and feeding them into the stripper was more of a challenge. However, the most difficult challenge was collecting the detached grain before it landed on the ground. The arrow–head elements with round relief was most effective in this challenge and had two advantages: reduced straw intake and reduced risk of breakage.

Vertical hood height was shown to be the principle machine setting affecting the grain loss. Lower edge of the hood 100 to 150 mm below the crop height gave minimum grain loss.

Forward speed had no effect on grain loss however, the rotor speed has a significant effect on performance. At low speeds some grains remained unstripped while very high speeds increased MOG intake. In most cases a speed of 700 rpm was satisfactory. Rotor height did not have a major effect on grain losses. Lodged rice plants pose a tough challenge for any harvester. However, severely lodged crop with the rotor height set at normal height gave good performance.

The entire crop is threshed (100%) at the point of stripping. Unthreshed panicles were rarely to be seen. There was no significant grain damage, only few dehusked full rice grains were noticed. The output for its size was very high. A one meter wide header, would, travelling at 3 kph cover one ha in 3.3 hrs. Assuming a field efficiency of 75% this would be one ha harvested in 4.5 hrs.

The average grain loss was 12%. However, a modification was made in the final run to reduce the loss by providing a collecting tray at the bottom of the machine, thus reducing this loss further by 2.5%. The total thrash taken by the harvester was 6%. After the grain had passed through the separator the thrash content was 4%. It is possible to improve on this by providing a intermediate sieve with round holes.

The cost of harvesting one ha based on the trials done is 5l of kerosene and 0.5l of Petrol, the wages of operator and a helper for 4 hrs(Approx.). Based on the current prices this amounts to less than Rs. 200/= per ha. (Depreciation of the machine and cost of cleaning to remove thrash content < 4% not included).

CONCLUSIONS

The resistance of rice crop to uprooting is sufficient to permit removal of seed by in-situ stripping, provided the speed and setting of the header system are matched to crop and conditions.

The total time for harvesting could be drastically reduced using the stripper header system for rice harvesting. An even greater grain through out could be achieved and with less interruptions by employing a suitable separation system that is appropriate for stripped material. The total cost of harvesting is considerably lowered by the use of this header system.

The system has proved to be effective in terms of stripping capacity and power requirements of dry rice stripping. Laid and weed infested fields present no major problems. By threshing the standing crop transportation and treatment of the straw is avoided. The uncut straw could be used as a soil conditioner/fertilizer. No straw was found to be wrapping around the stripper head/or the end bearings. Cleaning and collection could be carried out at the farmstead itself minimizing the cost of handling and transport. The trials show that the stripper head type harvester has a good potential for development as a relatively cheap, simple rice harvester, particularly in developing countries where small plot cultivation is practiced.

RECOMMENDATIONS FOR FUTURE IMPROVEMENTS

Research and development on stripping header system should continue to further refine and improve the technology. Further work is necessary to determine resistance to wear and tear and for the evaluation of endurance. An intermediate sieve with round holes could be provided to reduce the thrash content. Further testing with smaller rotor (reduced tip diameter) and adjustable pivoting position to reduce the ground loss is necessary. A cyclone separator or a similar air activated separating system should be designed to minimise the MOG content. The material for fabrication can be suitably selected to minimise the cost of the stripping unit and also to reduce the overall weight. Improvements to power transmission system can increase the efficiency of the system thereby making it possible to increase the stripping width further using the same 5 hp engine thus increasing the overall output of the machine.

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REFERENCES

Amaratunge, K.S.P. (1989). Preliminary investigation and prototype testing of a paddy stripper harvester. Dept. of Agricultural Engineering, University of Peradeniya, Peradeniya.

Burkhardt, T.H. (1975). Stripper harvesting of rice. American Society of Agricultural Engineers. Paper No. 75 – 1537.

CAB FAO (1981) Crop Loss Assessment Method – Supplement 3. FAO Commonwealth Agricultural Bureaux – U.K.

Far Eastern Agriculture (1989). Advances in the field.

Herblot, G. et Marooze, C. (1986). Recolte Du Riz et Autres cereales par egrenage sur pied.

Klinner, W.E. (1987). Innovation in harvesting equipment. Agricultural Engineer. Autumn 1987. 85-91.

Klinner, W.E., Neale M.F., Arnold, R.E., Geikie, A.A. and Hobson, R.N. (1987). A new concept in Combine Harvester Headers. J. Agricultural Engineering Res (1987) 38, 37-45

Klinner, W.E. (1987). A new approach to seed stripping.

Lindley, P.B. (1983). Engineering design with natural rubber. NR Technical Bulletin. The Malaysian Rubber Research Association, Herts, U.K.

NAS (1981). Post-harvest Food Losses in Developing Countries. National Academy of Sciences, Washington DC, USA.

Peter, F. and Rosemarie, F. (1968). The combine-harvester and its operating conditions. Edition. leipzig. G.D.R.

Price, J.S. (1987). Evaluation and development of the Grain Stripping System -1986.

Price, J.S. (1989). An experiment rig to investigate the pre- separation of grain threshed at the point of stripping and grain losses from the stripping rotor.

Price, J.S. (1989). Future development on stripper harvesting. RNAM (1983). Testing, Evaluation and modification of Cereal Harvesters.

RNAM (1983). Test codes and Procedures for Farm Machinery. Rotawator, H. (1966). Digging stick to rotary hoe.

Sukra, A.B. (1977). Stripper harvesting in lodged rice crop. MS 74/75.