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Design of throw-in type rice thresher for small scale farmers

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Abstract: Threshing is an integral part of postharvest activities for cereal and legume crops. In many developing countries, threshing is carried out manually by farmers that lead to low quality of paddy rice and grain loss. When the rice production increases, consequently the manual threshing becomes arduous. In order to mechanize this process, a throw-in type thresher JEP based on a prototype of a thresher made by IRRI (International Rice Research Institute) was designed and tested. The wind board was modified after testing to enhance threshing quality. Also, in place of welding the whole machine is joined by bolts, nuts and rivets for easy assembling and disassembling. Output capacity from the performance test on the machine was 316 kg/hr at a moisture content of 21%wb (wet base) for IR28 rice variety. This could attain 350-400 kg/hr when both, the speed and the feeding speed increase. The overall results are impressive and it will help improve drudgery and threshing challenges with small scale farmers.

Keywords: paddy rice, postharvest, design, thresher JEP

Introduction

Rice is a cereal cultivated mainly for the human consumption and also finds use in manufacturing of alcohol, starch, glucose, acetic acid, vinegar, acetone, oil and pharmaceutical products and diet foods. The rice ball is developed like fuel and ashes which are re-used in the form of organic manure (Pirot, 1998). More than 40% of the rice consumption in West Africa is imported, which represents ~2.75 million tons per year (Barris *et al.*, 2005). This strong quantity of imported rice constitutes a significant loss of currencies, more than one million $US per year according to WARDA'S. Also, the current blaze of the rice prices limits the imports and threatens food security in the countries as Togo whose consumption relies mainly on these imports. In order to bring a response to the current rice crisis, FAO and WARDA launched an emergency initiative on the rice in which Togo takes part in the sides of ten other member states of the WARDA. Irrational harvest and the rudimentary post-harvest operations are factors of losses of rice that can reach 35%. The inefficiency of manual threshing and winnowing, seasonal drudgeries of the women and the children in West Africa worsens its losses: damaged and broken grains sensitive to the damage of storage and commercial low value. The policies which promote the local production as well increase the workload of the producers. So manual threshing and winnowing being already arduous require more labour (WARDA, 2005). The extension of the threshing-machines ASI, manufactured in several countries of West Africa: Ghana, Mali, Senegal, Burkina Faso, Mauritania and Côte d'Ivoire, has reduced the arduousness and has increased the labour capacity (threshing output: 1-2 t/hr). These threshers which cost 2.8-2.9 million francs CFA (~5000 $US) have a rate of separation grain straw of 99%. According to the conditions of Sub-Saharan Africa where 80% of the farmers exploit small-scale farms (Bobobee, 1993; Phillip, 1993; Faure, 1994; Anonymous, 1996; 1998) and 43% of the total population live below the poverty line, less than 1.00 $US per day (Sims & Kienzle, 2006), the design of a thresher with a mean capacity output was planned. The main objectives of this research work are: to design and evaluate a throw-in type thresher using long grain variety of rice and to increase threshing efficiency while reducing losses. Crossing the specifications of the threshing-machine IRRI with Japanese techniques and specifications given by specialists from Togo, Ghana and Tajikistan, the thresher JEP, light and less expensive was designed. This paper presents the results of the designing, the technical performances and the socio-economical advantages of the thresher JEP.

Materials and methods

Socio-technical and economical context of the study

Drudgery, labour intensiveness, low grain quality and widespread use of simple farm tools which results in low productivity and high postharvest losses are the common features of many developing countries.

Togo: The demand for rice is high while the imports levels become higher than the national production output. From 2000 to 2004, the rice imports in Togo have reached 264576 tons which were in value 13.895 milliard francs CFA (ITRA, 2007). Togo has an enormous potentiality for rice production, in particular the availability of low lands and alluvial plains not yet exploited (Table 1), a favourable pluviometry (900 to 1400 mm of rain per year), the availability of a range of powerful improved rice seeds adapted to various ecologies: TGR1, TGR34, IR46, IR841, ITA212, MK53-86, NERICA. In regard to the rice crisis (weakness of the national production and rise of the import prices), Togo takes part in the emergency initiative on the rice which will make possible to reduce 17% of the imports till the end of 2009. This reduction of the imports or in otherwise the increase in 37% of the current production of paddy rice, represents a saving in currencies of about 13 million $US. In order to achieve this goal, the Ministry for Agriculture, Livestock and Fishery worked out a strategy of revival of the agricultural production (MAEP, 2008) of which one of the priority actions (Emergency plan 2008-2010) is the required food

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production and more particularly the revival of the national production of rice. This emergency plan 2008-2010, adopted in the Council of Ministers of the 30th July 2008, has to be based on the following actions: a partial support of paddy farming based on small installations, an improvement of the post-harvests operations going from threshing to the transformation by small units, the conditioning, and the trade-circuit.

In the rice farming zones, threshing is often carried out manually with sticks and rammers (output capacity ≤1 ton per day), or is mechanized, carried out with pedal threshers whose output capacity is around 100 to 150 kg/hr (Gret *et al*., 1993; Akintayo *et al*., 2008). The motorized threshing-machines are practically non-existent on the sites of rice production. From the rice farming under irrigation in the valley of Zio (Fig. 1), we describe the harvest and postharvest systems in Togo.

When rice paddy becomes ripe, harvest occurs after 30-35 days of hunting of birds to reduce the losses of output. Harvest is carried out in general by the women using sickles and knives. The producers carry out harvest when maturity of the rice plant is very well attained that causes spontaneous losses by shelling. Mechanical threshing is carried out with Chinese pedal threshers handled by 2 persons + 3-4 women who deal with the collect and the transport of paddy grain to the area of drying. The farmers carry out sorting using traditional sieve then apply mechanized winnowing (Fig. 2). Thresher JEP combines both, threshing and winnowing.

Ghana: Food sufficiency rate for cereals and legumes in Ghana is 51% while rice is 41%. This low rate is largely attributed to high postharvest losses at 30% rate and low level of mechanization adoption in the country. To reduce all these challenges, government brought a policy to promote the use and acquisition of farm machinery and other agro-processing equipment like threshers. Use of this threshing machine will drastically reduce drudgery, losses and improve upon the quality of threshed crops and this if widely adopted will not only improve farmers life but the country's economy as well.

Tajikistan: Tajikistan is an agrarian Country and its agriculture's contribution to the gross domestic product is 22%. More than 70% of the population of the country which is estimated at 7 million people lives in a countryside and agriculture is their mainstay. The main farm power used for hard works such as plowing, planting is mechanical power while harvesting and weeding is done by hand. Majority of farmers harvest their crops manually with the use of handmade simple tools. Threshing is also carried out manually where there are loss and crushing of grains that reduces quality and amount of production. Therefore the use of thresher could reduce grain losses, increase the production and improve the working conditions.

Design (IRRI, 1981).

The wind board was modified and the whole unit is joined by bolts, nuts and rivets for easy assembling and disassembling.

Performance test

Before the final test, preliminary functional test was carried out to assess the performance of every part, both at the workshop and at the field which was all successful.

Table 1. Potential small rice farms in Togo for the use of the thresher JEP

Region	Type of paddy farming	Site	Observations
MARITIME	Under Irrigation	Mission Tové, Kovié	Project PARTAM for the rehabilitation of 360 ha and the arrangement of 300 ha
		Agoméglozou	Project for the rehabilitation of 90 ha and the arrangement of 496.5 ha
	Under Rain fed	Assahoun* Agbatamé*	Not documented
PLATEAUX	Under Irrigation	Amou Oblo, Kpélé-Toutou, Sodo*	Not documented
	Under Rain fed	Kpélé Akata*, Ablevé	Not documented
CENTRALE	Under Rain fed	Tchakaoude	Potential of 100 ha
		Tchévé	Potential of 20 ha
		Kadjoworou*	10 ha exploited out of 30 ha
KARA	Under Irrigation	Agbang, Tchamoro Kabou	Potential of 50 ha including 6.5 ha used Potential of 150 ha
	Under Rain fed	Djabakou*	Potential of 100 ha
		Possao	Potential of 1000 ha including 100 ha cleared and 30 ha ploughed since 1997
		Tchitchira	Potential of 300 ha cleared
		Bidjande	Potential of 30 ha including 10 ha have ploughed since 1979
		M'Boratchika	Potential of 300 ha including 30 ha ploughed since 1996. Clearing and ploughing carried out by the Northern project Togo (300 ha)
SAVANES	Under Irrigation	Tantiégou, Kombeloti*	Potential of 200 ha extensible to 300 ha
	Under Rain fed	Simtoti*	40 ha exploited
		Nawakasso	Potential of 120 ha including 75 ha cleared by the Project Namiélé

**Sites which will be arranged or rehabilitated within the framework of the emergency plan 2008-2009 of the Ministry for Agriculture, Livestock and Fishery (MAEP) in Togo*

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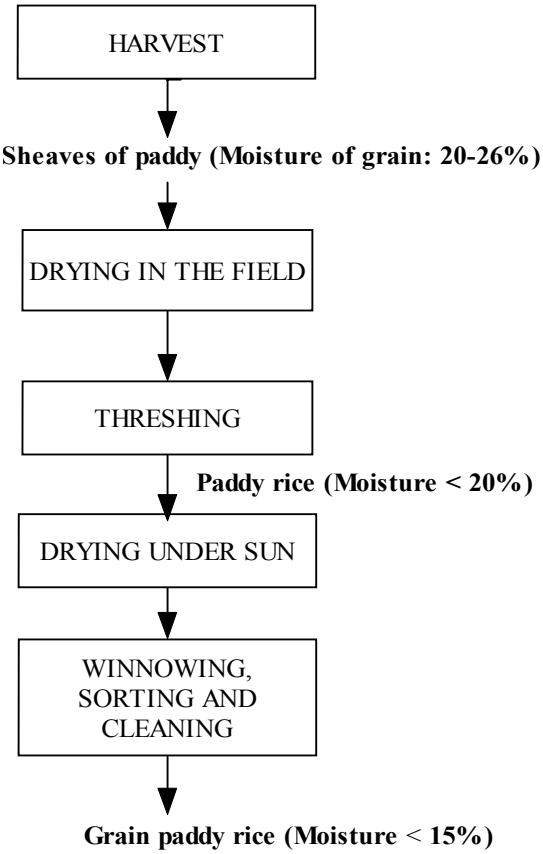
The thresher (Fig. 3), called JEP type was developed based on the existing thresher designed by IRRI (Table 2)

Procedure: After the test in the field, samples of paddy were collected and analyzed in the laboratory to determine the threshing capacity and accuracy. Three (3) drum speeds were used with an air speed of 4 m/s. A ten (10) kg of the reaped paddy was weighed for each test, and for each speed, three tests were conducted. Grain from the grain outlet was collected during the threshing operation for five (5) seconds as well as chaff from the chaff straw outlet and the oscillating screen was also collected (National Test Code of BRAIN).

Conditions: a) Prime mover condition: The prime mover used for the performance test was the Yanmar engine with characteristics shown in the Table 3. b) Crop conditions: The paddy used for the performance test was wet paddy reaped from the field with a moisture content of 21% and 76% for straw of IR28 rice variety (Table 4). The length of reaped paddy is 90 cm and the grain shattered force measured by the TR II is 1.4 N. c) Machine conditions: As explained in the procedure, the drum speed was set at 870 rpm, 970 rpm and 1050 rpm as shown in Table 5. After several search for a suitable air speed, 4 m/s was set by opening and closing of the blower window.

Fig. 1. Traditional post-harvest process in West Africa



Results and discussion

The Fig. 4 shows that the output capacity of the thresher JEP decreased as well as the speed increased to 21 m/s. This could be due to low experience of the operator. At 23 m/s the output capacity attained 350 kg/hr. This will be more if we improve the speed of the feeding and reduce the moisture of the paddy rice.

Fig. 2.Manual winnowing-machine in Togo

The distribution of grain shown in the Table 6 indicates that at 19 m/s, whole grain from the grain outlet was high (80%) but decreased when the speed was increased to 23 m/s at 70%. For the upper outlet for chaff, grain losses were minimal and nearly same for each of the speed. At the lower outlet for chaff, losses went up as speed increased. The percentage of scattered grain was nearly the same (18%) for all the speed set. The grains collected from the grain outlet contained nearly 99% of the whole grain for all speed set (Table 7).

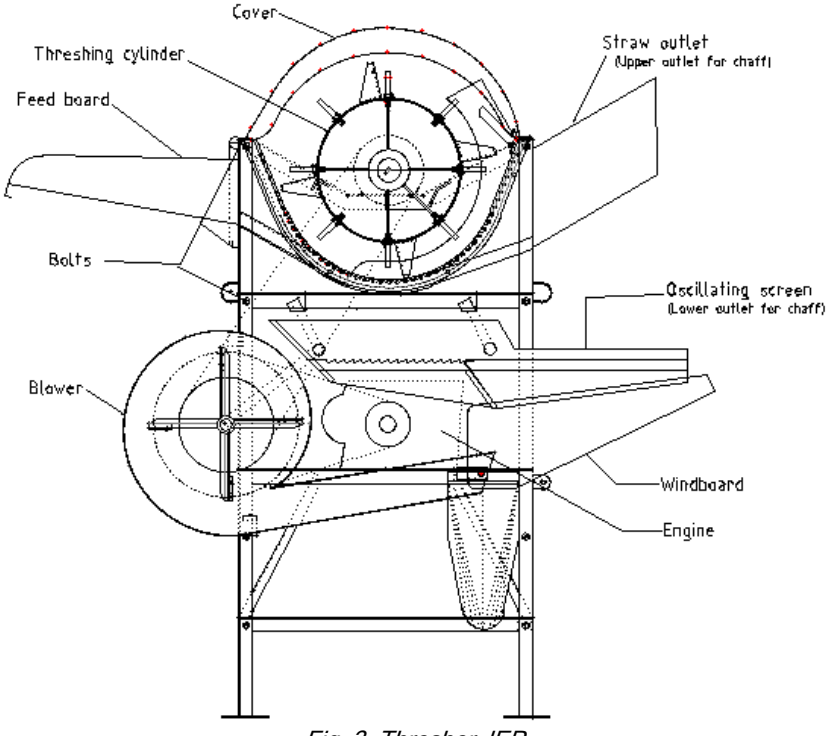


Fig. 3. Thresher JEP

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Table 2. Thresher JEP specifications

Main parts of the threshing machine				Dimension
Main frame		Length	mm	782
		Width	mm	634
		Height	mm	1.255
Drum		Length	mm	705
	Diameter (including teeth)		mm	430
Concave	Half circular		mm	890
		Length	mm	550
	Rod diameter		mm	560
Top cover	Half circular		mm	820
		Length	mm	730
		Width	mm	630
Feed pan		Length	mm	725
		Width	mm	510
Oscillating screen		Length	mm	870
		Width	mm	528
		Stroke	mm	4.8
Blower	Diameter		mm	440
		Length	mm	540
Weight of threshing machine			kg	146

Observations and comments

During the test, we noticed the followings:

- the chaff and the grain on the oscillating screen were moving towards one side;
- there were some losses from the chaff outlet lower when the drum speed was high;
- the oscillating spring got broken during the test;
- also at 21 m/s, the threshing output capacity decreased, this could be due to reasons mentioned in the results and discussions.

Modifications

The wind board was modified to enhance easy collection of grains from the screen into the grain outlet chute by increasing the length of the board with an additional metal sheet (Fig. 5). Bolts and rivets were also used in place of welding for easy assembling and disassembling (Table 8).

Comparison of the threshers used in West Africa with the thresher JEP

More than 250 threshing-machines ASI are exploited in the valley of the river Senegal (30 000-35 000 ha of rice farming). This threshing-machine also designed on the basis of the thresher IRRI, has an output capacity of 6 tons paddy rice per day and the rate of separation grain straw is 99% (WARDA, 2005). Operating requires 5 persons: 2 persons for control (who will be replaced after 4 hours), 2 persons ensures the uninterrupted feeding of the machine, and 1 person releases paddy and the chute of the obstruction caused by the straw. The machine equipped with a system of tire fixed on the frame moves using the animal draught. Two standards models of threshing-machine ASI are sold. Its output capacity varies from 1.2 to 1.4 t/hr. The output capacity attained 2 t/hr on the improved version of thresher ASI (Fall, 2005).

For operating the thresher JEP, 4 persons are needed: 1 person for control and another one for the uninterrupted feeding of the machine with sheaves of paddy + 2 substitutes who altogether (4 persons) can manually move the equipment from one field to another. Threshing-machine JEP with mean output capacity, is light and provides a very low rate of crack (Table 9). It can be started with the engine of a hand tractor. This reduces the purchase cost of the thresher for the producers or groups of producers who have a hand tractor. The cost of the materials and of the manpower and the experience of the local manufacturer in Togo allow us to predict that the purchase price of the thresher JEP with the engine will not exceed 3000 $US.

Table 3. Prime mover characteristics

Engine	*Model*	*Weight*
4.0ps/2400 rpm	*MA4B Yanmar*	*55 kg*

Table 4. Average values of the rice IR28 crop conditions

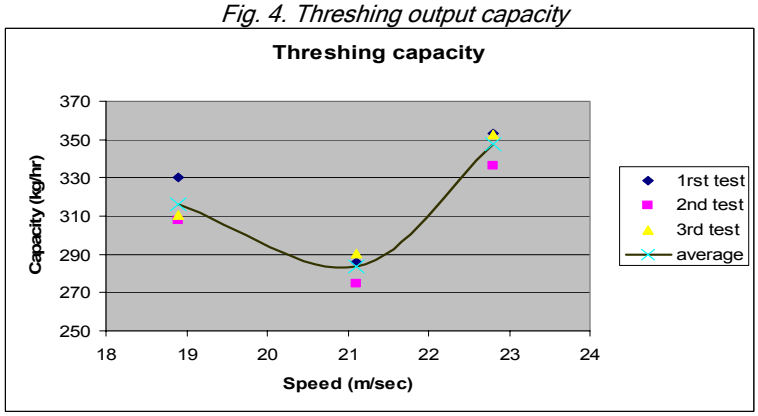
Items	Values	
Moisture (%)	Grain	21.2 (0.39)*
	Straw	76.1 (2.09)
Length of reaped paddy (cm)		90.30 (11.027)
Grain shattered force (N)		1.35 (0.448)

** Parenthesis stands for ±SD*

Table 5. Threshing drum speed

Speed without load	m/s	19	21	23
	RPM	870	970	1050
Speed with load	m/s	18	20.6	21.7
	RPM	835	950	1000

Fig. 4. Threshing output capacity



Conclusion and recommendations

The results of the research work are impressive. In order to achieve the extension of the thresher JEP in West Africa, a participatory research project is undertaken. This project involved the researchers of Université de Lomé in Togo and the local equipment manufacturer, "UPROMAH". Regarding the small scale farmers' conditions and the results of the design and the technical test of the thresher JEP, we recommend that the side edge cover of the sieve/grain pan should be raised to avoid falling of grain and chaff into the grain outlet; more tests should be conducted to ascertain why there was a decrease in threshing capacity as speed went up; the screen spring should be doubled to avoid future breakages; very wet paddy, moisture up to 21% should not be used as it stuck and does not allow

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free exit of chaff; more different rice varieties under different conditions should be used for future test; the research team should focused on designing a low-cost thresher.

Table 6. Distribution of grain per percentage

Speed (m/s)	Grain outlet (%)	Upper outlet for chaff (%)	Lower outlet for chaff (%)	Scattered grain (%)
19	80.05	0.23	1.2	18.52
21	72.89	0.21	9.32	17.58
23	70.28	0.29	10.95	18.48

NB: Both upper and lower outlets for chaff represent losses

Table 7. Grain outlet composition

Speed (m/s)	Whole grain (%)	Damage grain (%)	Empty grain (%)	Chaff (%)
19	98.6	0.01	0.34	0.85
21	98.8	0.00	0.17	0.92
23	98.7	0.03	0.20	0.98

Table 8.Differences between threshers JEP & IRRI

Thresher JEP	Thresher IRRI
Longer wind board	Shorter wind board
Used bolts, nuts and rivets	Welded joints
Drum can be removed with cover intact	Cover is off when removing the drum

Table 9. Comparison of technical performances of thresher JEP and thresher IRRI

Specification of the machine	Thresher IRRI[1]	Thresher JEP[2]
Engine	7 CV	4 CV
Output capacity	400-500 kg/hr	300-400 kg/hr
Weight	190 kg	146 kg
Rate of crack	Less than 4%	Less than 1%
Rate of separation grain straw	98 %	nearly 99%

[1]Thresher made by International Rice Research Institute (IRRI): [2]Thresher JEP which will be manufactured and tested in Togo and vulgarized in West Africa

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Fig. 5. Modified wind board: a) outside and b) inside