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## RESEARCH ARTICLE

# EFFECT OF THE USE OF ANAXIAL FLOW THRESHER-CLEANER ASI ON THRESHING-CLEANING EFFECTIVENESS AND RICE QUALITY IN BENIN

***,1,2Afolabi Romaric Igor Biaou Olaye, [3]Barnabé Zokpodo, [2]Aminou Arouna, [2]Jean Moreira and [3]Joseph Hounhouigan, D.**

[1]Faculty of Life Sciences, University of Abomey-Calavi (UAC / FAST), Benin
[2]Africa Rice Center (AfricaRice), 01 BP 2031 Cotonou, Benin, Tel: (229) 21350188
[3]Faculty of Agronomic Sciences, University of Abomey-Calavi (UAC / FSA), Benin

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**ABSTRACT**

Production activities and rice processing are done in Benin with inefficient and strenuous traditional technologies. Bad threshing operation in Benin affects the quality of rice. This study aims at evaluating the technical and technological performances of the ASI axial flow thresher-cleaner in farmer's field. The improved method with the thresher-cleaner and farmer's practice using barrel have been tested in the real conditions of rice harvesting and threshing in Benin. Indicators of technical and technological performances (Hourly capacity, impurities percentage, threshing losses)reveal that the ASI thresher-cleaner has better results compared to the farmer's practice using barrel. Results showed that the hourly capacity (kg/h) of the axial flow thresher-cleaner is 1780.5 kg/h or 445.05 kg/man/h compared to 129.14 kg/h or 32.29 kg/man/h for the farmer'spractice using barrel. The percentage of the losses at threshing is 4.13%for traditional threshing practice against 0.14% for the ASI thresher-cleaner. The germination percentage of rice grains is 79.38% for the threshing on barrel versus 89.47% for the thresher-cleaner. It emerges from this study that the ASI thresher-cleaner has a high-performance and allows producers to save time by reducing the work hardnesscompared to the traditional method. Moreover, this machine is highly appreciated by rice producers because it does not significantly alter farmer's practices, gives clean paddy and significantly reduces the broken ratewhich is a key factor affecting rice quality in Benin. This thresher-cleaner can be used in seed production.



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## INTRODUCTION

Rice is the most consumed cereal by almost half of the world's population (Khush, 2005). This illustrates the importance of this food crop (Cottyn *et al.,* 2001). In Africa, rice production in 2014 was estimated to be 30,788,497million tons (Mt) of paddy (FAO, 2014). With the revival of the rice sector, rice production keeps rising in Benin year after year. It increased from 124,974.72 tons in 2010 to 206,943.32 tons in 2013 (FAOSTAT, 2013). These efforts are more remarkable under the production aspect than the post-harvest one which has received less technical support so far (Juliana Rwelamira, 2015). Therefore, the quality of rice produced locally in Benin is poor with a high broken rate at milling, and cannot compete with imported rice (Adégbola *et al.,* 2014).

***Corresponding author:* Afolabi Romaric Igor Biaou Olaye**
Faculty of Life Sciences, University of Abomey-Calavi (UAC / FAST), Benin.

This is due to low performing post-harvest technologies practices by producers.Houssou *et al.* (2016), Ahoyo and Clarys (2009) showed that traditional threshing and drying techniques of paddy rice are not performing and cause fissures leading to high breakage rate over 40% at milling. Improving rice quality goes necessarily through good post-harvest activities, namely threshing and drying (Adégbola, 2010).Shelling or commonly calledthreshing is one of the main post-harvest operations of handling rice sheaves after harvesting (Ogunlade *et al.,* 2014). Several traditional rice threshing-cleaning techniques are widespread in Benin and vary from one area to another. Among these methods used, we can cite threshing on barrel, on a trunk of tree, on cans, using sticks, on mortar, on the floor rubbing or treading it (bulls or sometimes men).Traditional threshing-cleaning of rice in Benin has always been very important in preserving rice grain quality, since mechanical threshing-cleaning does not exist for technical and financial reasons (Ahouansou and Affokpon, 2012). The traditional threshing-cleaning method on barrels is cheap but is more labor demanding with loss of time and energy.Moreover, during these traditional methods, service providers sometime experience body burns due to bad drying of rice sheaves. In fact, the inner side of the straw being not well dried consumes oxygen and releases carbon dioxide, thus producing high heat intensity. To this should be added general tiredness; general body complaints; cuts; pains at the level of the joints (nerves); chest pains; hips pains; ringing ears; and worn fingers are problems service providers are faced with. Moreover, rice yield and quality obtained after milling are affected when threshing-cleaning is not properly done. Productivity and production of these traditional methods are low and it is therefore necessary to switch to the mechanical motorized threshing system (Kedar *et al.,* 2016). This farmer's practice of threshing-cleaning is not performing, and does not favor obtaining good quality rice, able to compete with imported rice, because of its high breakage rate (Houssou *et al.,*2003).The general conclusion shows that small traditional tools still dominate at the level of most rice production systems (Biaou Olaye, *et al.,* 2016). The consequence of this is work hardness, loss of time and energy and absence of competitiveness of locally produced rice (Moreira, 2015). The ASI thresher-cleanerhas been adapted in farmer's field and has proven itself in Senegal when it combines efficiency, productivity and time saving. It has been introduced in Benin recentlythrough AfricaRice's technology dissemination program. Two prototypes were manufactured during a two-week training session at Songhaï Center and tested in Benin for the first time (Songhaï, 2014). Only the engine, the rims, the belts and the tires are imported.The equipment can play an important role in the economy of the country by increasing production, which is translated by a great quantity of rice threshed but also by reducing losses during threshing-cleaning. This can lead to rice self-sufficiency and exportable surpluses. These economic factorsimpacts local artisans, service providers and users of this machine. No technical and technological studies has been carried out so far on the real performances of this machine. This study aims at verifying if the thresher-cleaner can be adapted to the real conditions of harvesting and threshing-cleaning of rice sheaves in Benin but also its impact on the quality of grains threshed and the germinative capacity of the seeds.

## MATERIAL AND METHODS

### Threshing material used

Two manualthreshing and winnowing methods and one mechanical threshing and winnowing technology using ASI thresher-cleanerwere used during our investigations. These are a farmer's threshing practice using one by one shelling of grains to be used as seeds (Picture 1); a barrel and winnowing (Picture 2 and 3) and the axial flow thresher-cleaner (Picture 4). IR 841 variety freshly harvested at 22% moisture content was used.

**One by one manual shelling Technology:** This operation used a rice sheaf and removing manually the rice grains one by one.It is used when the grains are to be used as seeds.

**Traditional threshing and winnowing Technology:** It consists in displaying a tarpaulin on the floor on which you put a barrel. Rice sheaves are put on both sides of the barrel. About 03kg of rice sheaves are held and beaten manually against the barrel in order to separate the grains from the panicles. At each contact with the barrel, rice sheaves are well shaken in order to minimize losses during threshing. After drying them, the grains mixed with impurities are separated from these impurities by hardworking women thanks to the wind.

**Picture 1. Manual shelling**

**Picture 2. Traditional threshing on barrel**

**Picture 3. Manual winnowing thanks to the win**

**Improved threshing technology using a thresher-cleaner:** It is a fabricated machine made of iron sheets, flat iron bars, and corner irons of different thicknesses. It has been fabricated by local artisans thanks to the collaboration between AfricaRice and Songhaï Center. It carries out three different operations at the same time. These are: threshing, winnowing and densimetric separation. The axial flow thresher-cleaner is operated by a 15.7 kilowatts engine and has four driving wheel to facilitate its movement from one plot to another. It is equipped with two stands and a jack on which it is mounted when being used.

conditions, then packaged in envelops. Before the harvesting operation, the moisture content of the grains was determined using the Kett Riceter (KETT C600) type of moisture meter. The general trend of the moisture content was about 22%. Afterwards, the sheaves were dried on the floor in the field for 03 to 04 days.


**Picture4. Rice mechanical threshing cycle using an axial thresher-cleaner**

**Table 1. Principal components of the tested threshing-cleaning methods**

| Threshing method | Specifications | | | | | |
|---|---|---|---|---|---|---|
| | Threshing methods | Length of the drum | Diameter of the drum | Power used | Rotation speed | Winnowing method |
| Manual Shelling | - | - | - | Human force | - | - |
| Manual threshing and winnowing | Barrel | 875 mm | 550 mm | Human force | - | Depending on the win |
| Thresher-cleaner ASI | Jagged threshing drum | 1100 mm | 300 mm | 15.5 kW diesel engine | 800 revolutions/min | Integrated centrifugal winnowing system |

## Methods

Figures 1, 2and3show the general process of shelling, threshing and winnowing using the three methods. A part the shelling method, the difference between both methods of threshing is at the level of threshing and winnowing principle. One with straw held takes place on a barrel and the other one along the principal axis equipped with erected teeth without holding the straw. The product obtained using the traditional threshing method is not clean and therefore requires winnowing depending on the wind and some sorting. However, the grains obtained with the thresher-cleaner are clean, well calibrated since integrated in a winnowing system.Unlike these two threshing-cleaning methods, manual shelling (Figure 1) is a constant referential to remove the grains manually.Figures 1, 2 and 3 show the process of obtaining paddy rice using the three methods of threshing and winnowing.

## Methodological approach used

A completely random design with three (03) replications at a factor « threshing-cleaning » and two (02) treatments: farmer's threshing-cleaning practice with a barrel and axial flow thresher-cleaner were used. The trials were carried out with the participation of 12 active producers. Manual shelling was used as a reference in the frame ofour study and was used on 03 kg of rice sheaves for each producer. After this operation, the quantity of paddy obtained was weighted using a mechanical scale (Quaye, 2016). The samples were dried in the same

The moisture content after drying went down to 18%. Using a mechanical scale, the sheaves were weighted by lots of 50 kg. Each trial was repeated (03) times on 50 kg of rice sheaves. Each of the two rice threshing-cleaning methods was tested at the level of each producer. Thus, a total of 108 samples were made. After threshing-cleaning, the samples were dried up in the same conditions on the drying area of Gbaglo in the commune of Zagnanado schemeuntil obtaining the required moisture content between about 12 and 14% (Buggenhout *et al.,* 2013; Rickman *et al.,* 2013; Siebenmorgen *et al.,* 2005).

## Determining the technical parameters and the technological indicators

## Technical parameters

During the tests, the efficiency of each technology was determined based on the following technical parameters: threshing duration (h), hourly capacity (kg/h), threshing rate (%), machine operating capacity, cleaning efficiency (%), fuel consumption (l/h) (Mehta *et al.,* 1995).

**Threshing duration (d)**: is the time needed to thresh a quantity of sheaves. It is determined by the following formula:

$$Threshingduration(d) = Tf - Ti \quad (1)$$

With $Tf$the final time and $Ti$ the initial time.

**The hourly capacity (Ch)**: is the quantity of rice sheaves threshed in one hour time. It is determined by the following formula (Adejumo *et al.,* 2015; Radwan *et al.,* 2009):

$$Hourlycapacity(Ch)(\%) = \frac{Mb}{d} \times 60 \qquad \textbf{(2)}$$

With (*Mb*) the quantity of sheaves threshed (kg) and *d* the duration of the work (min).

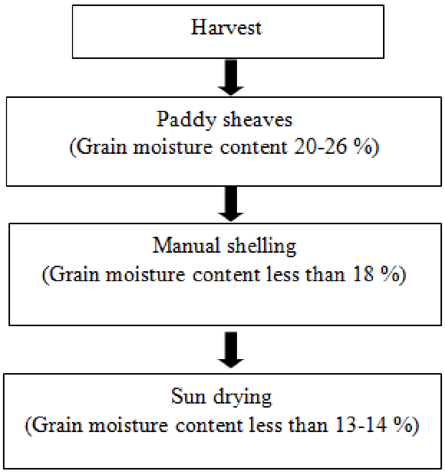



**Figure 1. Manual shelling cycle**

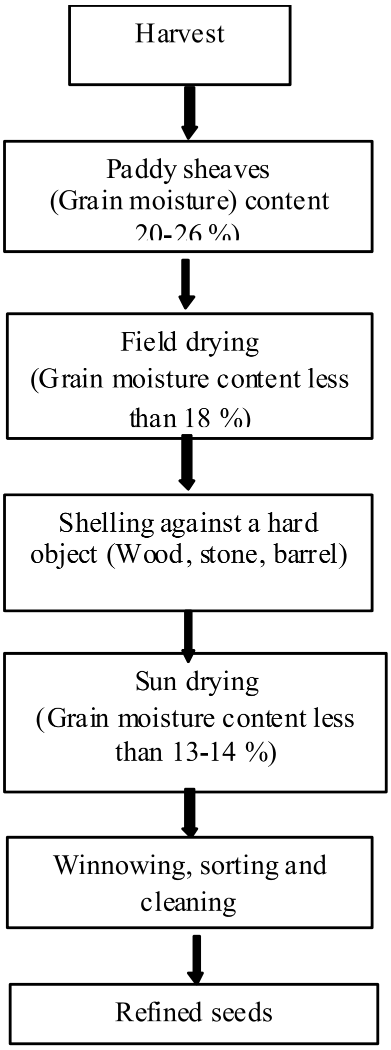
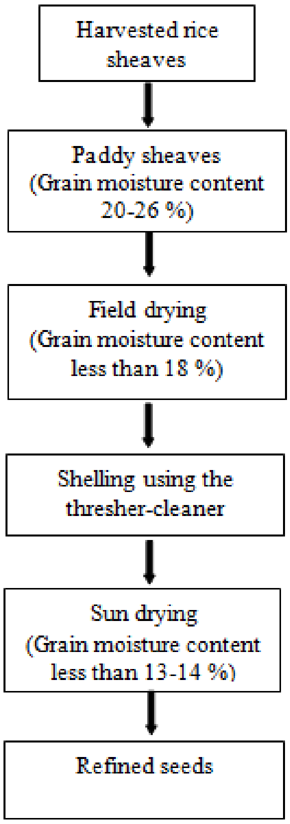



**Figure 2. Traditional threshing-winnowing cycle**




**Source**: (Azouma, 2009);(Benrajesh & Rajan, 2016).

**Figure 3. Mechanical threshing cycle using a thresher-cleaner**

**The percentage of non-threshed grains (Gnb):** is theratio between the quantity of grains not threshed over the total quantity of the rice sheaves to be threshed in percentage (Mehta *et al.,* 1995; NSTCGT, 1998).

$$Percentageofnonthreshedgrains(Gnb) = \frac{MGnb}{Mtge} \times 100 \qquad (3)$$

Where, *MGnb* = Quantity of non-threshed grains and*MTge* = Total quantity of rice sheaves to be threshed.

**Threshing efficiency (T)**: is calculated by doing 100 minus the percentage of non-threshed grains (Adejumo *et al.,* 2015; Agidi *et al.,* 2013; Mishram and Desta, 1990; Walied *et al.,* 2014; Zakaria, 2006). It varies depending on the technique used and the quality of raw material to be treated.

$$Treshingefficiency(T)(\%) = 100 - GnB(4)$$

**Cleaning efficiency:** Itis the ratio between the quantity of impurities separated over the quantity of non-separated impurities of paddy expressed in percentage (Agidi *et al.,* 2013; NSTCGT, 1998) and is given as follows:

$$Cleaningefficiency(E)(\%) = \frac{Mpn}{Mp} \times 100 \qquad (5)$$

With *Mpn*the quantity of paddy separated from impurities and*Mp*the quantity of non-separated impurities.

**Parameters related to the thresher-cleaner**

**Machine operating capacity**:This efficiency was obtained by making the ratio between the real efficiency obtained in the standard conditions of rice harvest and threshing in Benin over the efficiency obtained in the conditions in Senegal multiplied by 100. It is the ratio between the current capacity and the potential capacity of the machine expressed in percentage (Adisa *et al.,* 2016).

$$\text{Operatingcapacity} = \frac{\text{Currentcapacity}}{\text{Potentialcapacity}} \times 100 \quad (6)$$

**The peripheral threshing speed (revolutions/min):** it measures the number of revolutions/min by using a laser tachymeter and is expressed as follows:

$$Peripheralspeed = \frac{\pi N D}{60} \quad (7)$$

With *D* the diameter of the thresher in meter and*N*the number of revolutions/min.

**Technological parameters**

**The percentage of losses after threshing:** It is the sum of losses registered during the threshing process. It is the ratio between the quantities of losses obtained after threshing over the total quantity of grains collected expressed in percentage. On the contrary, the percentage of non-threshed grains is the quantity of grains not removed from the straw.

$$Percentageoflossesafterthreshing = \frac{Mpe}{Mg} \times 100 \quad (8)$$

Where (*Mpe*) is the quantity of losses after threshing and (*Mg*) the quantity of threshed grains.

**The percentage of impurities after threshing:** It is the ratio between the quantities of impurities obtained after threshing over the total quantity of grains collected expressed in percentage.

$$Percentageofimpuritiesafterthreshing = \frac{Mi}{Mg} \times 100 \quad (9)$$

Where (*Mi*) the quantity of impurities obtained after threshing and (*Mtb*) the quantity of threshed grains.

**Germination test**

The same quantity (20g) of seed samples was collected on each set of the test. The grains were planted and submitted to the same conditions for germination. The number of germinated grains for each sample was taken. The germination percentage was calculated as follows (ISTA, 1999; Sony *et al.,* 2013; Mollah *et al.,* 2016):

$$\text{Percentageofgermination}(\%) = \frac{\text{Numberofgrainsgerminated}}{\text{Totalnumberofgrainsplanted}} \times 100 \quad (10)$$

**Statistical analysis**

The analysis of variance (ANOVA) at one factor was done to determine the possible significant differences at the threshold of 5% between the means of the data collected for each type of shelling. The software SPSS version 16.0 was used.

## RESULTS AND DISCUSSION

**Evaluatingthe technical performances of the two threshing-cleaning methods**

Table 2 shows the results of the analysis of variance (ANOVA) indicating the technical parameters of the different threshing methods tested (hourly capacity, fuel consumption, threshing efficiency, cleaning efficiency).

**Table 2. Evaluatingthe technical performances of the different threshing-cleaning methods tested**

| Threshing-cleaning types | Hourly capacity (kg/h) | Threshing efficiency (%) | Cleaning efficiency (%) |
|---|---|---|---|
| Manual threshing on barrel | 129.14a | 92.54b | 73.41b |
| Threshing using ASI thresher-cleaner | 1780.5b | 99.03a | 95.92a |

*Figures of a column with the same letter are not significantly different at the threshold of 5%.*

The hourly capacity of the traditional manual threshing-cleaning method on barrel is 129.14 kg/h against 1,780.5 kg/h for the threshing using the axial flow ASI thresher-cleaner. The comparative analysis of the results show that there is a significant difference between the two threshing-cleaning methods tested (P <0.05) for the assessed parameters. The results show that using the axial flow ASI thresher-cleaner gives an hourly production equivalent to almost 14 times that of the hourly production of the traditional threshing-cleaning method on barrel. This is a 13-hour time saving. It confirms the efficiency of the axial flow thresher-cleaner that reduces not only the broken paddy grain but also the working time by increasing the production. The action of the erected teeth fixed on the drum in rotation causes an impact on the sheaves and separates more easily the grains from the panicles. However, the hourly capacity of ASI 1,780.5 kg/h in Benin was lower than that written in the technical specification (2500 kg/h) in Senegal.

This is a difference of 719.5 kg. Comparing with the hourly capacity of the machine in Senegal conditions, we find that the efficiency use of the machine in Benin is 71.22%. This can be explained by the fact that in Senegal, producers use the sickle to harvest rice, while in Benin, machete is more frequently usedby cutting the straw lower because of the manual threshing methods. Manual threshing requires long straws so that the sheaves can be held easily and beaten against the barrel to separate the grains from the panicle (Rickman *et al.,*2013). The cutting height of the straw in farmer's field in Benin seems to be a handicap to a better performance of the thresher-cleaner ASI. By reducing the cutting height, the capacity of the machine could increase (less straw to be treated during threshing). In addition to the cutting height, parameters like variety, degree of rice maturity, grains moisture content, density of rice plants, rotation speed of the drum, ratio grain-straw can have an effect on the performance of the thresher-cleaner.The threshing efficiency is estimated to be 99.03% for the axial flow thresher-cleaner against 92.54% for the traditional method using a barrel. This shows that more grains escaped the manual threshing. This is part of the losses registered and which is a shortfall for producers but is also one of the drawbacks of this traditional method. Therefore, when we compare these two methods with the efficiency of the manual shelling which is 100%, we can see that each method left some grains not shelled. According to Chukwu (2008) and Afify *et al*. (2007), the threshing efficiency can also be affected by the speed of the drum, the inclination of the thresher concave, the feeding speed of the threshing chamber, the number of rows of the erected teeth fixed on the drum and the type of crop. (Sudajan *et al.,* 2002) demonstrated in a study carried out on threshing sunflower that the effect of the type of cylinder, the rotation speed and the feeding rate have an effect on the shelling efficiency.

They found in this study that the threshing efficiency obtained is higher than 99%, which is close to the value obtained for the ASI thresher-cleaner in Benin.The cleaning efficiency is 73.41% for the traditional threshing-cleaning method on barrel and 95.92% for the axial flow thresher-cleaner. This rate is closer to the cleaning efficiency value (99%) for the benchmark manual shelling method. The axial flow thresher-cleaner gives cleaner paddy at the end of the threshing-cleaning process. This is an important parameter because it limits the additional costs related to the winnowing operation. According to Afify *et al.* (2007), the cleaning efficiency can be increased by increasing the speed of the drum. The speed of the operator who introduces the sheaves into the equipment and the moisture content of the grains to be treated can also contribute to increasing or decreasing cleaning efficiency. In fact, the higher the speed of the drum, the better the threshing and cleaning efficiency are. For these tests, the speed of the drum measured using a laser tachymeter TA 110 was programmed at800 revolutions/minute. This is aperipheral speed of 12.56 m/s.

## Evaluatingrice quality technological indicators depending on the threshing-cleaning methods used

The comparative analysis of the results shows that there is a significant difference at the threshold of 5% between the different rice threshing-cleaning methods for the percentage parameters of unthreshed grains, percentage of losses after threshing and percentage of impurities after threshing (Table 3).

**Table 3. Results of the comparative testsof the technological performances of the different rice threshing-cleaning methods**

| Threshing-cleaning types | Unthreshed grains (%) | Losses after threshing (%) | Impurities after threshing (%) |
|---|---|---|---|
| Manual threshing on barrel | 0.55a | 4.13a | 2.76a |
| Threshing using ASI thresher-cleaner | 0.006b | 0.14b | 0.17b |

*Figures of a column with the same letter are not significantly different at the threshold of 5%.*

For the different parameters, higher values are registered atthe level of the use of the traditional threshing method on barrel. This confirms trends observed at the level of the threshing efficiency. During the threshing-cleaning process using the traditional method on barrel, some grains escaped the threshing-cleaning operation. Some grains were thrown away due to the use of this traditional method and this shows the high rate of losses obtained representing 4.13% of the total weight. The great quantity of impurities at threshing confirms the physical state of the paddy after threshing. This is 2.76% for the traditional threshing method on barrel against 0.17% for the axial thresher-cleaner. This obliges producers to wind the paddy after threshing, an additional task for them.

## Evaluating the viability of the seeds

At the level of the test of viability of the seeds, the germination percentage was 79.38% for manual threshing-cleaning on barrel against 89.47% for the method using the thresher-cleaner ASI (Table 4). The difference observed between the threshing-cleaning methods can be explained by the fact the operating mode is not the same. The choc received by the paddy during threshingof the rice sheaves on the barrels could have caused fissures along the embryo (Ragasa *et al.,* 2013), which could damage the embryonic axis and therefore affect the germinating power of the seeds (Jahufer and Borloo, 1992). This impact due to the choc on the paddy could modify the grains metabolism. On the contrary, threshing using the axial flow thresher-cleaner, because of its minimal strength on the grains has induced a higher germination and therefore did notaffect much the paddy grains. This system of rotating drum separates easily the grains from the panicles without damaging them. This removing take place along the axis of the rotating drum. This has a positive effect on the quality of the seed and explains the high viability rate registered for the grain from the axial flow thresher-cleaner at a peripheral speed of 12.56 m/s. When we compare the value of the germination percentage of the seeds obtained with the benchmark method (90.89%) to the percentage obtained with ASI, there is no significant difference at the threshold of 5%. Dubbern *et al.,* (2001) showed that damaged seeds usually have a reduced germinative power.Likewise, Simic *et al.* (2007) showed that several factors such as grains production phase, pests and diseases, storage duration, mechanical damages on seeds during threshing, moisture fluctuations (including drought), packages, pesticides, bad handling and biochemical injuries of grains tissue can affect the germinative powerof the grains.However, Christopher (2015) demonstrated that the improved threshing method using a rotary threshing drum can cause fissures and breakages on the grain with the possibility of causing damages to the embryo at an excessive speed of the threshing drum (1100 revolutions/min).Certain researchers like Grass and Tourkmani (1999) revealed that the main effect of mechanical damages is germination andyield reduction.Krzyzanowski (1998) affirmed that the development of more resistant varieties to the mechanical effect of equipment will improve grains quality by reducing cracks. According to the classification of the Genetic Resources Unit (GRU) of AfricaRice, a grain with germination higher than 85% can be used as certified foundation seed. However, a grain with germination rate between 51-85% is less germinative. Shelling using ASI thresher-cleaner gave grains with higher germination rates unlike the traditional manual threshing method. These results tally with those standardized (ISTA, 1999) concerning rice grains germination. Thus, the germination percentages were above the minimal standards of seeds proposed by ISTA, (1999). In a study carried out by (Benrajesh and Rajan, 2016)on evaluating the performances of the Okra thresher, it was revealed that the concave clearance, the drum rotating speed, and the moisture content of the grains have a significant effect on the germinating power.Moreover, (Sinha *et al.,*2009) showed that the machine parameters during post-harvest treatments affect the quality of chickpea seeds.Generally, the germination rate of the grains threshed is high using the three rice threshing-cleaning methods. This rate is higher when using the powered threshing-cleaning method, implying that the thresher-cleaner did not cause much internal damage to rice grain(Ajav and Adejumo, 2005).

**Conclusion and suggestion**

Threshing-cleaningis one of the post-harvest operations that influence the yield and quality of milled rice. Among the three threshing-cleaning methods evaluated with producers, the axial flow thresher-cleaner proved to be efficient in farmer's field rice harvest and threshing-cleaning in Benin because not only it preserves the grains, but also increases the threshing yield. It reduces notably the breakage rate which is a key factor influencing rice quality. Using the axial flow thresher-cleaner saves time and reduces the broken during threshing. The production cost is also reduced and the quality of rice produced is improved. This thresher-cleaner can be used in seeds production. For this reason, the axial flow thresher-cleaner can be disseminated in farmer's fields to optimize the hourly capacity, reduce losses during threshing and increase producer's revenue. However, the hourly capacity at threshing-cleaning (1,780.5 kg/h) may be affected by factors like the cutting height of the straw, therice variety, the degree of rice maturity, the moisture content of the grains, the density of the rice plants, the rotation speed of the drum, the straw-grain ratio. This first characterization of the axial flow thresher-cleaner leads us towards research paths relating to the maximum or minimum performance by playing on other criteria (grains moisture content, cutting height, rice variety and rotation speed). Let us point out that in addition to the above-mentioned parameters, the variety is one ofthe parameters which are not sufficiently tackled by researchers. Therefore, we are planning to do some tests with other varieties commonly used.

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