eISBN 978-967-16145-1-8

Konvensyen Kebangsaan Kejuruteraan Pertanian Dan Makanan 2019
21 Mac 2019, Wisma Tani, Kementerian Pertanian Malaysia, Putrajaya

MSAE2019-AMA14

Comparetive Field Performances and Quality of Conventional Combine and Mid-Size Combine in Wetland Rice Cultivation in Malaysia

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Abstract
In paddy cultivation, harvesting is the most important operation, which needs suitable machinery. Thus, this study was carried out to compare and evaluate field performances, grain quality and harvesting grain losses of conventional 5 m cutting width NEW HOLLAND CLAYSON 8080, combine running on a total net area of 42.78 hectares and the new mid-size 2.7 m cutting width WORLD STAR WS7.0, combine running on a total net area of 16.95 hectares of plots for two rice (Oryza sativa L.) cultivation seasons. The conventional combine as compared to mid-size combine showed 14.4% greater mean fuel consumptions, 31.1% greater mean effective field capacity, 20.90% lesser mean operational speed and 10.8% lesser mean field efficiency. In terms of quality of harvested grain the conventional combine showed 9.48% lesser mean whole and healthy grain and 2.29 times greater mean broken grain and 85.78% greater mean foreign materials and 8.97 times greater mean empty grain than the mid-size combine. In terms of grain losses, the conventional combine showed 2.06 times greater mean total losses, 2.94 times greater mean cleaning losses, 1.03 times greater mean unthreshed losses than the mid-size combine. The results revealed that the mid-size combine is more suitable in conducting the harvesting operation in rice cultivation in Malaysia than the conventional combine.

Keywords: Wetland Rice Cultivation, Rice Combine, Field Machinery Performances, Grain Quality, Harvesting Losses.

Introduction

Maintaining working conditions and optimal performance of combine harvesters is a vital importance in agricultural and rice production due to the timeliness factor. The planning and selection of equipment for the harvest of crops can greatly impact the performance and profitability of a farm. The type and size of equipment used to affect the harvested yield and nutritive value of the crop as well as production costs (Rotz, 2001). The performance of combine harvester should work in trend for reduced grain losses in order to produce the highest quality and quantity of rice. Grain losses during harvest represent a direct loss of income for the farmer. In some countries, it is perceived that the reasonable small grain loss should reach a maximum of 3 % of the total crop yield (Wiersma and Allrich, 2005). Adam & Pebrian, (2017) reported in their survey about harvesters in Malaysia that the farmer complained about the amount of harvested grain losses and quality of harvested grain of the conventional combine harvester. Broken grain is reducing the quality of grain as it leads to a reduction in the percentage of germination (R.Bawatharani et al., 2016). Broken grain means that organisms can easily penetrate the broken grains so that breakage can lead to difficulties in the storage of the grain, a factor affecting grain quality. Rice crop is too sensitive to harvesting operation due to the high percentage of grain losses affecting total yield. Hence, efficient harvesting and its quality of work are the main concern for the farmers and first customer to reduce grain losses and increase the grain quality.

It has been for decades in Malaysia that harvesting of rice is done using a 5 m cutting width and 5 ton capacity self-propelled rice combine harvester. This combine has been used because of its good effective field capacity to justify the short time slot that is available for the farmers in the harvesting of the crop. In the most occasion, the field harvesting operations have to be completed as soon as possible to minimize the yield losses of the overripe crops due to the incoming weather storm. However, the used of these combines have been reported to give several operational problems. Among the problems includes, bogging of the combine during operation especially on soft and watery terrain, slightly high grain losses during the harvesting operations, higgh percentage of broken grain and substantial damage to the terrain surface. Thus, with mid-size combine, there might be a possibility of less destruction to the field surface terrain and perhaps to the extent of reducing the grain losses, reducing broken grain and increasing the field effeciency. The quality of work in the harvesting operations with such combine could be much easier to achieve than the currently used combine.

An initiative was taken up here to compare the field performance of conventional combine harvester NEW HOLLAND CLAYSON 8080, 82 kW@2500 rpm and the newly introduced mid-size combine harvester WORLD STAR WS7.0 PLUS WS7.0, 76 kW@2600 rpm under the actual field harvesting operation in the real field conditions for two rice

cultivation seasons in Malaysia. Specific objectives of this study to compare and evaluate working performance, grain quality and harvesting grain losses of these two combines.

Materials and methods

Study area

The chosen study area was located at (3º29´47´´N and 101º09´56´´E) in Sungei Burong, Kuala Selangor. Table 1 compares the technical specifications between the two combines. The involved field tests on the two combines were conducted in two cropping seasons; June to November 2017 for the first season and January to June 2018 for the second season. The paddy area is located within the total area that is under the management of North West Integrated Agricultural Development Authority (IADA) Rice Scheme. In the first season, 30 farms were involved in the data collection. While in the second season, 32 farms were involved, where 43 farms were harvested by using the 5 m cutting width conventional combine and 19 farms were harvested with the 2.7 m cutting width mid-size combine harvester. The farms that were harvested by the conventional combine in the two seasons involved a total area of 44.72 ha with average size area of 1.04±0.07 ha while the farms that were harvested by the mid-size combine involved a total area of 16.95 ha with average size area of 0.89±0.13 ha. Harvestings of the crop in the first season were conducted from 14 to 30 November 2017 while harvestings of the crop in the second season were conducted from 25 May to 18 June 2018. The recorded average crop yield in the first season was 6.7 ± 0.05 ton/ha and in the second season was 7.04 ± 0.05 ton/ha.

Table 1: Technical specifications of conventional combine and mid-size combine

Parameters	Conventional Combine	Mid-size Combine
Name	NEW HOLLAND combine	WORLD STAR combine
Model	CLAYSON 8080	WS7.0 PLUS
Max power	82 kW	75KW
Rated speed	2500 rpm	2600 rpm
Total weight	10000 kg	3400 kg
Tracking tire	Half-track	Full track
Fuel type	Diesel	Diesel
Fuel tank capacity	350 l	130 l
Grain tank capacity	3.5 ton	0.80 ton
Unloading discharge	8.70 kg/s	1.68 kg/s
Working width	5m	2.2m
Worker	1-2 Person	1 Person

Field performances

The measured combine field performance parameters include speed of operation, theoretical field capacity, actual field capacity, field efficiency, labor hour and fuel consumption. Field efficiency is the ratio between the harvester's productivity under actual working conditions and the theoretical maximum possible productivity and it calculated as shown in equations 1, 2 and 3 as defined by ASAE standards S495.1. (ASAE Standards, 2005 & Amponsah et al., 2017a)

$$\text{Field efficiency } \% = \frac{Effective\ field\ capacity}{Theoretical\ field\ capacity} \times 100 \quad (1)$$

$$\text{Effective field capacity, ha/h} = \frac{Total\ area,\ ha}{Total\ operation\ time,\ h} \quad (2)$$

$$\text{Theoretical field capacity} = \frac{Total\ area\ harvested, ha}{Effective\ operation\ time, h} \quad (3)$$

The fuel consumed by the conventional combine was determined by refilling the combine fuel tank back to its full capacity after the harvesting operation using a measuring cylinder as defined by ASABE standards D497.7, 2011 (ASABE Standards, 2011 & Amponsah et al., 2017b). While the fuel consumed by the mid-size combine was determined by directly reading of the difference in the fuel level gauge of the combine fuel tank after the harvesting operation.

Harvesting losses

Pre-harvest losses were determined by placing the wooden frame of 0.5m×0.5m mentioned above, randomly through standing crop in twelves different locations in each farm before the combine harvester entered the plots. Loose grains and panicles fell on the ground were collected within the quadrate and weighed as in (Bawatharani, 2013), and the percentage of pre-harvest losses was calculated by using the following equation,

$$\text{Preharvest losses } \% = \frac{Mass\ of\ collected\ grains, kg}{Total\ mass\ of\ grains, kg} \quad (4)$$

The harvesting losses (threshing and cleaning losses) were determined, at twelve different places randomly selected within the harvested area.
The area from where the sample was collected was 0.5 m in the direction of combine travel using metal frame 0.5m×0.5m. threshed and unthreshed grain

Grain qualty

To determine percentage the of whole healthy grain, broken, cracked, husked grains, and the impurities, randomly ten samples of 100g rice was taken from the tank of rice combine harvester from each farm and then broken and husked grains and any material other than grain were collected and separated manually and weighted, then the whole healthy grains were determined (Srivastava et al., 1998; Alizadeh & Allameh, 2013). The broken grains, husked grains were determined for quality losses, weed seed, straw or any other material were taken out manually and weighed employing an electric digital balance.

Statistical analysis

Data were subjected to analysis of variance T test using the statistical software of MINITAB. Variable means found to be significant were compared using 5% level of probability.

fallen in the metal frame after the machine has run over it was picked up manually, all grains and panicles inside it gathered and weighted (Alizadeh & Allameh, 2013).

Results and discussion

Field performances

Table 2 and Figure 2 indicate that conventional combine shows 31.1% greater mean effective field capacity (0.69 versus 0.53 ha/h), 10.8% lesser mean field efficiency (0.64 versus 0.72), 14.4% greater mean fuel consumptions (21.13 versus 18.46 l/ha), 1.43 times greater mean effective working width (4.40 versus 1.81 m) and 20.9% lesser mean operation
speed (3.24 versus 4.1 km/h) than the mid-size combine. The operating speed of conventional and mid-size was within the recommended operating speed of 3 to 6.5 km/h range for harvesting operation with a self-propelled combine by ASABE (ASAE, 2000). The advantage of having large working width makes the conventional combine to have greater field capacity even though with a field operating speed that is much lower than the mid-size combine. Alizadeh et al. (2013) found that the theoretical and effective field capacities of whole-crop and head-feed combines were 0.495 and 0.361 ha/h, respectively.

Table 2: Comparison of field performances between conventional and mid-size combines

Performance	Conventional	Mid-size	p value	Difference
Operating Speed, km/h	3.24±0.19§	4.10±0.28	2.26E-08***	-20.9%
Effective Field Capacity, ha/h	0.69±0.05	0.53±0.071	0.00262**	+31.1%
Field efficiency	0.64±0.04	0.72±0.12	0.00431**	-10.8%
Fuel Consumption, l/ha	21.13±0.95	18.46±0.91	0.0035**	+14.4%
Effective cutting width, m	4.40±0.08	1.81±0.05	1.91E-23***	+1.43

***Significant at α = 0.001 and **Significant at α = 0.01
§ At 95% confidence interval

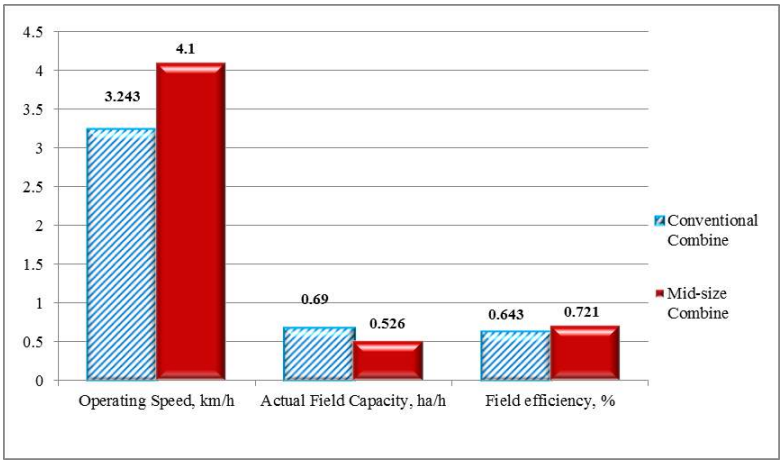

Figure 2: Comparison of field performances between Conventional and mid-size combines

Harvesting quality

The conventional combine harvester showed 9.48% lesser mean whole and healthy grain (87.32% versus 96.47%), 2.29 times greater mean visible broken grain (2.37% versus 0.72%), 85.78% greater mean empty grain of rice (4.05% versus 2.18%) and 8.97 times greater mean foreign materials (dockage and rubbish) (6.28% versus 0.63%) than the mid-size combine harvester (Table 3, Figure 3 & Figure 4).

This result agreed with the findings of Ahuja, (2016); Masek et al. (2016) and Sinha et al. (2014) they found that the grain breakage in axial flow cylinder was lesser than tangential threshing system cylinder. Bansal & Lahan, (2009) reported that the axial flow machines result in minimum seed damage with higher output and threshing efficiency. They found that the lesser grain damage in using the axial thresher than in using the conventional thresher.

Table 3. Quality of collected grains in grain tank of combines

Parameter	Conventional Combine		Mid-size Combine		p-value	Differences
	Weight, gm	% Total	Weight, gm	% Total		
Whole grain	87.32±1.168§	87.32	96.470±0.771	96.47	1.22E-19***	-9.48%
Broken grain	2.37±0.358	2.37	0.720±0.168	0.72	3.38E-11***	+2.29
Empty grain	4.05±0.569	4.05	2.183±0.542	2.18	1.08E-06***	+85.78%
Foreign materials	6.28±0.619	6.28	0.631±0.110	0.63	1.01E-20***	+8.97

***Significant at α = 0.001
§ At 95% confidence interval

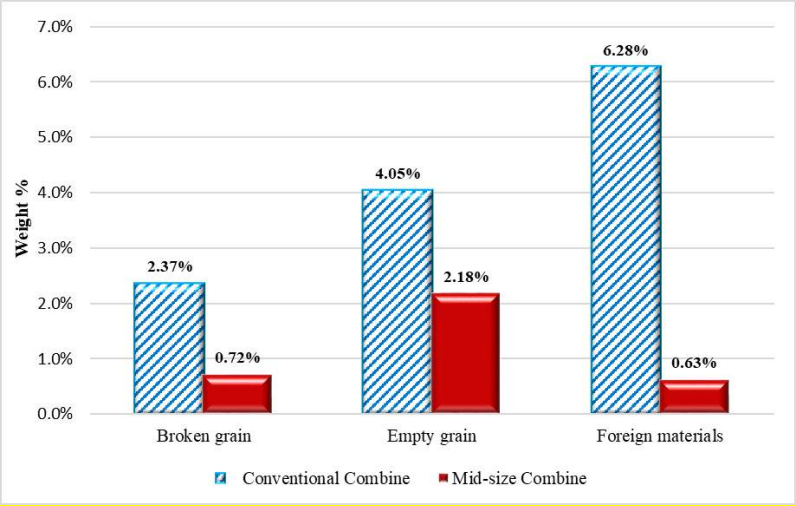

Figure 3. Quality of output grain for conventional and mid-size combine harvesters

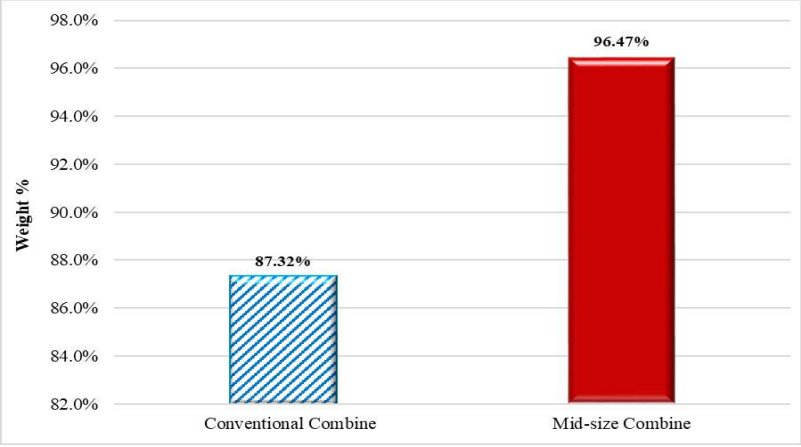

Figure 4. Whole and healthy grain of the conventional and mid-size combine harvesters

Grain losses

From Table 4 the conventional combine showed 2.06 times greater mean total grain losses (52.29 and 17.10 g/m^2), 31.04% greater mean pre-harvesting loss (3.25 and 2.48 g/m^2), 1.03 times greater mean threshing loss (16.15 and 7.94 g/m^2) and 2.94 times greater mean cleaning grain losses (36.14 versus 9.08 g/m^2) than the mid-size combine harvester (Figure 5). This result was similar to (Ahmad et al., 2005; Sinha et al., 2014) Our result revealed that the mid-size combine harvester has a lower percentage of grain losses

which supported with the finding of Khan, (1986) he reported that use of axial-flow threshers in tropical producing countries have substantially reduced crop losses an estimated 2 to 5% grain has been saved. Miu, (2014) reported that in his study that the axial units have lower grain losses than the tangential threshing units. He reported that the conventional combine harvester has lower separation efficiency than the mid-size combine (92.79 and 97.72%) this led to limit grain separation and throughput of straw walkers in conventional combines and this one of the main reasons that led to the integral transfer of their function to the axial threshing units.

Table 4. Harvesting losses of combine harvesters

Parameter	Conventional Combine		Mid-size Combine		P value	Differences
	Weight, g/m^2	% total	Weight, g/m^2	% total		
Pre-harvesting loss	3.25±0.38	0.44	2.48±0.06	0.34	0.002**	+31.04%
Threshing loss	16.15±0.68	2.40	7.94±0.77	1.08	1.49E-29***	+1.03
Cleaning loss	36.14±0.94	5.38	9.16±0.22	1.25	1.26E-40***	+2.94
Total loss	52.29±1.18	7.78	17.10±0.81	2.37	3.49E-49***	+2.06

***Significant at α = 0.001 and **Significant at α = 0.01
§ At 95% confidence interval

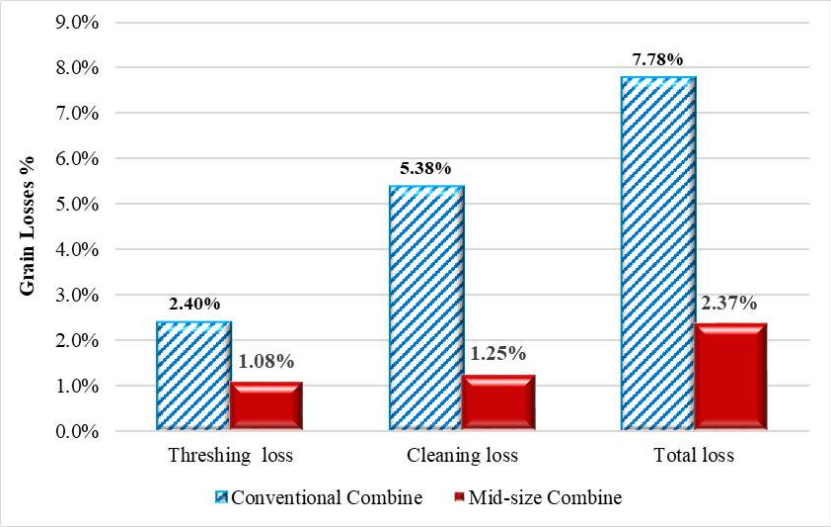

Figure 5. Total, threshing and cleaning losses of the conventional and mid-size combine harvesters

Conclusions

This study presents a comparison of the working performance, the grain qualty and harvesting losses of two combines (one conventional combine and one newly introduced mid-size combine harvester) under the actual field harvesting operation in the real field conditions for two rice cultivation seasons in wetland rice cultivation in Malaysia. From the results of the study the following conclusions are drawn:

- Although, the effective working width of the conventional combine was 1.43 times greater than the working width of mid-size combine but the conventional combine shows 10.8% lesser mean field efficiency than the mid-size-combine harvester (64% versus 72%).
- Based on the results, we can see that the mid-size combine separation devices doing better compared to the conventional combine harvester. The highest average content of whole grain weight was recorded in the harvested mass of mid-size combines.
- In contrast to conventional combine, the mid-size combine has the ideal threshing unit which produces a perfect threshing of maximum crop throughput, with optimum grain separation and preserving the natural shape and quality of grains and minimizing grain loss.
- Based on these results, we concluded that the mid-size combine harvester worked better than the conventional combine harvester, with lesser losses of rice grain, greater whole grain with a significantly lower share of impurities and less damage to the grain in relation to conventional combine harvester. It is concluded that the mid-size combine harvester is more suitable for rice harvesting than the conventional combine harvester.

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