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Modification of the Longitudinal Rotor to Suit Rice Harvesting

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ABSTRACT

This research was basically carried out to modify the longitudinal axial flow rotor for threshing wheat machine to suit threshing rice crop. Three phases were done to improve and modified this machine. Firstly, adding four rasp bars on the front part of threshing zone. Secondly, replacing four straight paddles by rasp bars on the front of separating sector of rotor and finally, alternating the stable clearance zone threshing of rotor by another inclined one. Harvester forward speeds of 1.5, 1.7 and 2.0 km/h; peripheral rotor speeds of 17.0, 19.5 and 21.5 m/s; inclined concave clearances of 7:4, 6:4, 5:4 and 4:4cm under moisture contents of (32/24), (27/21) and (20/16) for (straw/grain%, d.b.) were evaluated. Number of jamming times per feddan, threshing efficiency, visible grain damage, field efficiency and power requirement were estimated. In conclusion, higher efficiency attained when threshing was done at lower moisture content and higher rotor speed. After modification, field efficiency increased to 80% under forward speed of 2.0km/h with rotor speed of 21.5m/sec, threshing efficiency reached to 98% with grain damage of 1.5% while power requirements decreased to 47.35 kW.

Keywords: Axial-flow; rotor speed; moisture content; rice damage; jamming; threshing efficiency

INTRODUCTION

Rice is an important staple food in Egypt and grown on an area of about 1.076 million feddan with a total paddy production of about 2.7 million tones. Main rice cultivated areas in the country are located in Northern provinces of Delta producing 75% of the totally production. Egypt has rice varieties map distributed by rice governorates included long and short varieties. As (Olugboji, 2004) reported IRRI developed an axial flow thresher, which has been widely manufactured. According to Agidi *et al*. (2013) threshing is the process of loosening the edible part of cereal grain (or other crop) from the scaly edible chaff that surrounds it. It is the step in grain preparation after harvesting and before winnowing. El-Sheikha and El-Beba (2006) use a long drum of 155cm and diameter of 68 cm and consists of three sections threshing, separating and throwing paddles. Separation section is more affectively by assembling an alternative helically sweepers to facilities moving the straw in direction to thrower paddles. Ismail *et al*. (2007) developed a double cone shape drum device of the Turkish thresher to increase the threshing efficiency and capacity, and improve the threshed grain quality. The results showed that the highest threshing efficiency (98.50%), and the least breakage of grain (1.0%) was observed at 1400 rpm and moisture content of 9.1 %. Also, the developing of Turkish thresher increasing from traditional outlet capacity (Mca) by about 12%. Alizadeh and Bagheri (2009) examined a thresher with an open axial flow peg tooth threshing drum; a throw-in feed opening and straw throwing pedals at the end of drum. Normally in axial-flow thresher, 80% of grains were separated in the first half of drum, whereas, only 20% of grains were removed at latter half of the rotor. Morad and Fouda (2003) developed long axial flow rice thresher to be suitable for threshing rice crop with high efficiency and low power requirement. Threshing of rice was conducted by using long axial-flow thresher before and after development taking into consideration operational efficiency, cleaning efficiency, power requirements and threshing cost as a function of change input capacity and drum speed. Chimchana *et al*. (2008) developed an unequal speed co-axial split rotor thresher for rice. The first serves mainly the threshing operation, whereas, rotating at relatively higher nine speeds, the second rotor does mainly the separation of rice grains from husk. Faster rotation of second rotor increased separation performance due to increasing centrifugal force. The optimum speed for rotor threshing considered at 25.12 m/s (600 rpm with 0.8 m diameter threshing rotor) while, the optimum grain separation found at speed of 30.2 m/s. Lotfy (1998) studied the different position for concave clearance of (20/10, 25/15, 30/20 and 35/25 mm) on threshed grain. It was noticed that decreasing the clearance from 35/25 to 20/10 mm causes a decreasing of un-threshed grain and increasing grain damage while increasing clearance from 20/10 to 30/20 causes to increases of threshing efficiency. Awady *et al*. (1982) stated that the high percentage of damaged seed resulted from high moisture content and high threshing cylinder speeds. While, Harrison (1991) indicated that grain losses were affected by rotor speed, vane angle, feed rate, and lesser extent by material moisture content and concave clearance. Srivastava *et al*. (1993) mentioned that since the separation is not only depending on gravity and also, the irregularity of ground grain surface has no effect on the separation process. Rice quality workshop (2003) stated that axial flow combine have along rotor which also turns against a fixed surface but which is set on the long axis of the combine. Axial flow combines use the rear end of the rotor to separate the straw and grain.

The original rotor designed for wheat harvesting. Such investigation should that this rotor is not qualified to deal with rice crop because of the deference between the properties of the two cops. Therefore, the main objectives of this research are modified and test axial rotor in order to increase the efficiency of the modified rotor to suit harvesting rice crop.

MATERIALS AND METHODS

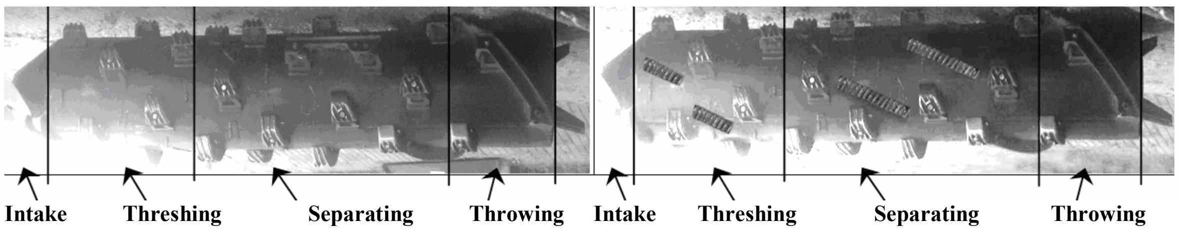
The axial-flow combine (CASE International 1620) including a long rotor with rasp bars arranged in helically paths around the thresher rotor. The rotor is driven by main shaft of harvester engine with 3000 rpm.

Specifications of the original rotor

The main specifications of the original combine harvester are shown in Table 1. Figs (1-A and 1-B) show the original rotor parts that used for threshing wheat crop with dimensions of 200cm length. The original rotor consists of: threshing zone with length of 80cm; separating sector assigned for separation has 120cm length and throwing zone to straw exit, which started at the rear end of the separation ledge. For repelling straw, two paddles with a length of 25cm are fixed over rotor body elongated by 15cm length outlet rotor body with thickness of 5cm and 50cm circumference, respectively. Rotor specifications before and after modification are presented in Table 2.

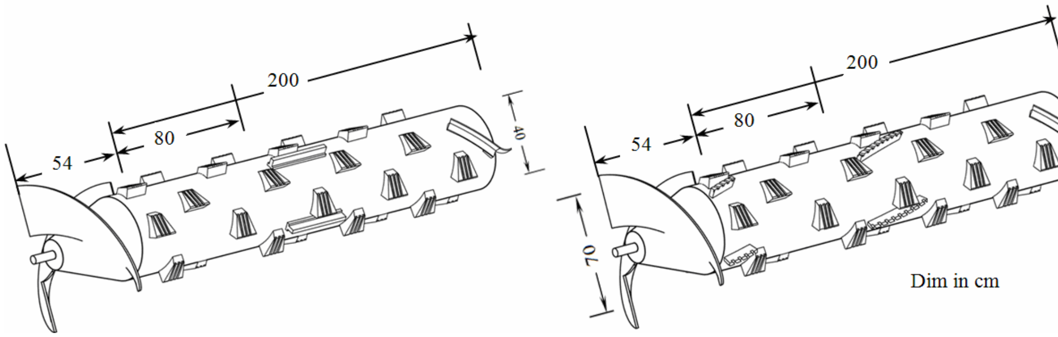
Table 1. Specifications of the original combine harvester and power source

No.	Items	Specifications
1	Harvester type Operating width, cm	CASE International 1620 400
2	Engine	6 cylinders diesel Perkins type
3	Engine power, kW(hp)	87.6 (120)
4	Drive	Hydrostatic
5	Rotor specifications:	
	- Body of rotor working width, diameter, cm	200, 40
	- Intake wing's height, cone length, cm	35, 26
	- Threshing zone length, cm	80
	- Separation sector length, cm	120
	- Outlet repel paddle length, cm	15
	- Maximum speed, rpm	1000



Original rotor Modified rotor

Fig. 1-A. The original and modified rotor



Before modified **After modified**

Fig. 1-B. A schematic diagram of rotor before and after modification

Table 2. Rotor specifications before and after modification

Before							After						
Se.	Organ	No.	Length, cm	Width, cm	Height, cm	mass, g	Se.	Organ	No.	Length, cm	Width, cm	Height, cm	mass, g
1	Hammer	32	11	7	5	2000	1	Hammer	32	11	7	5	2000
2	Straight paddle	4	30	2	5	2340	2	Helical bar	4 4	15 30	2 2	5 5	1200 2340
3	Rotor body	1	275	40	40	200,000	3	Rotor body	1	275	40	40	200,000
4	Repel arm	2	25+15	5	5	8,000	4	Repel arm	2	25+15	5	5	8,000

Principal modification points

The main idea of this modification was adding a rectangular rasp bars make impeller moves easily and at same time optimize crop flow for gentle threshing and increased through put in tough conditions. There were fixed in the poor spaces area between the four main helical paths of the original rotor as shown in Fig. (2). These impeller bars insure divide and easy to in-out the crop straw in threshing and separating parts.

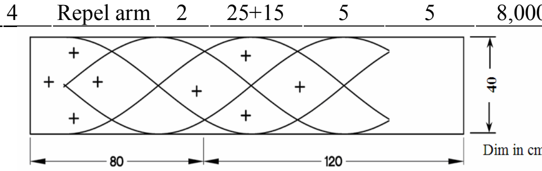


Fig. 2- A. The positioning area of impeller bars in modified rotor

The modifications of threshing and separating rotor

The modification conformed as the following steps:

1- Assembling four rasp bars with dimensions of 15×2×5 cm (Fig. 2-A) on the beginning threshing section to drive the intake straw mat).

2- Replacing four straight paddles with four rasp bars with dimensions of 30×2×5 cm (Fig. 2-B) on the front of separating section of rotor to motivate the flow of the threshed material easily.

All parts are made of steel (Figs. 2-B and 2-C). All rasp bars carefully checked and set matching for equal weight distribution on the rotor surface.

Adjusting both static and dynamic balances

1- Static balance:

a- Vertically: by hanging the rotor vertically from one end and ensure it parallel to Y axes.

b- Horizontally: by hanging the rotor horizontally from its two end and ensure it parallel to X axes.

2- Dynamic balance: by ensuring that the rotor stopped at different points by rotating it many times.

Fig. 2-B: Rasp bar of 15cm

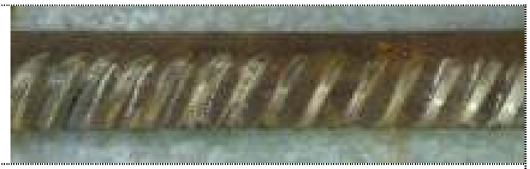


Fig. 2-C: Rasp bar of 30cm

3- Alternating the stable clearance -which is under the threshing section of rotor- by another inclined one starting from the beginning threshing point to end one of separating sector of the rotor. This inclined line will be in longitudinally with the rotor axis. Accordingly, the clearance enlarges in the front-beginning opening- and narrows in the rear-end opening. Four levels of clearance were experiment as 7, 6, 5 and 4cm at front with 4 cm clearance at rear of rotor.

Figs. 3 indicate the modification of clearance to overcome the problem of threshing cage, which represented in jamming.

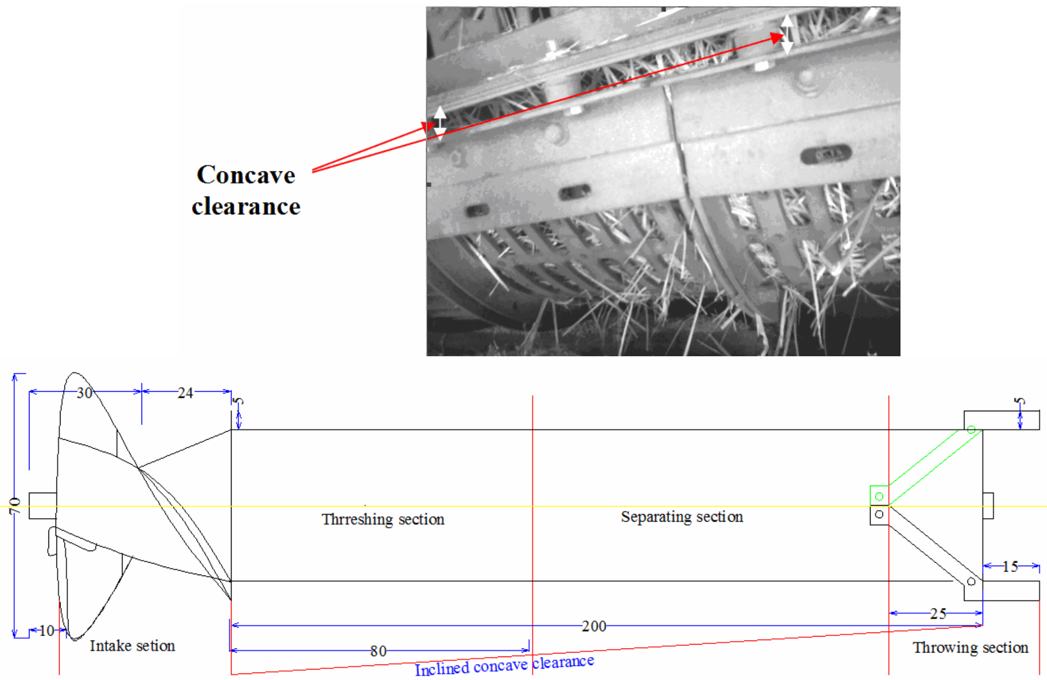


Fig. 3. The inclined clearance after modification

Rice characteristics and conditions

The main physical characteristics of rice crop variety (Giza 178) were moisture content of 20/16% grain/straw, d.b., average of plant length was 100cm, 1000 weight was 26 g and grain straw ratio of 1/1.13.

Pre-trials were applied to eliminate the ranges of the experimental factors whereas:

- Increasing forward speed up to 1.5 km/h before modification caused many times of jamming and combine failed to continue operating; and so what happened up to 2km/h after modification;
- Increasing rotor speed up to 820 rpm (21.5 m/s) caused high damaged and husked grains and
- Normal clearance increases jamming.

A rectangular area was divided into 108 plots, with width of each plot was about 4 m and length of 100 m for running. This distance was enough to take three reading. Field experiments were conducted at El-Serow Agricultural Research Station – Domiatta Governorate.

The experimental factors

- Harvester forward speeds of 1.5, 1.7 and 2km/h
- Rotor speeds of 650, 745 and 820 rpm represent as 17.0, 19.5 and 21.5m/s,
- Front to rear clearance were 7:4, 6:4, 5:4 and 4:4 cm.
- Moisture contents of (32/24), (27/21) and (20/16) for (straw/grain%, d.b)

Measurements:

1- Number of jamming times/feddan:

The times number which; threshing rotor has stopped working per feddan.

2- Threshing efficiency:

$$Threshing\ eff = 100 - percentage\ of\ the\ unthreshed\ grain \quad .....(1)$$

The value of un-threshed grains for the modified combine was evaluated according to Singh and Joshi (1980) as follows:

$$Unthreshed\ grain\ percentage = \frac{weight\ of\ unthreshed\ grain}{weight\ of\ total\ grain} x\,100 \quad ....(2)$$

3- Grain damage:

The grain damage values were classified into visible damaged and husked damage in rice crop. Both type of damage were estimated by taking sample of 1.0kg from the grain tank. The visible damaged grains were separated and weighed then the percentage of the damaged grain was calculated.

4- Field efficiency, %:

The field efficiency (η_f) was calculated by using the following formula:

$$\eta_f = \frac{Af_c}{Tf_c} x100 \quad .... \quad ....(3)$$

Where:

Af_c = the actual field capacity, fed/h.

Tf_c = the theoretical field capacity, fed/h

- The theoretical field capacity:

The theoretical field capacity (Tf_c) was calculated by using the following formula (Kepner *et al*., 1982)

$$Tf_c = \frac{w * s}{4.2} \quad .... \quad .... \quad .(4)$$

Where:

w = the working width of the combine, m.

s = average local combine forward speed, km/h.

Actual field capacity was calculated by using the following formula:

$$Actual\ field\ capacity = \frac{1}{Te/60} \quad (fed/h) \quad ....(5)$$

Te = To – (Nt + Tt + Pt), h/fed

Where:

Te : is the effective harvesting time per fed, min/fed;

To: is the total harvesting time per fed., min/fed;

Nt: is the time of maintenance and lubrication, min/fed;

Tt: is the turning time [Time of turn per min * No. of turns per fed], min/fed and

Pt: is the parasitic time, min/fed.

5- Straw length:

It was taken in ranges between <10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-80, 80-100cm and every rang was calculated as ratio of totally weighed on area of 1m^2.

6- Power requirement:

The power requirement was calculated using the following equation**:**

$$P = \left(\frac{F_u \times \rho_f \times C.V}{3600} \right) \times \left(\frac{427 \times \eta_{th} \times \eta_m}{75 \times 1.36} \right)$$

It simplified by (by Ahmed, 1990) as the following formula:-

Power required = 3.163 x F_u …………. (kW)

Where:

P : power requirement, (kW);

F_u : fuel consumption rate, (L/h);

ρ_f : density of fuel, kg/L, (for diesel = 0.85 kg/L);

C.V : calorific value of fuel, (Kcal/kg);

427 : thermal-mechanical equivalent, (kg.m/Kcal);

η_{th} : thermal efficiency of the engine, assumed 40 % for diesel engine;

η_m : mechanical efficiency to engine, assumed 80 % for diesel engine.

RESULTS AND DISCUSSION

Jamming times per feddan

The original rotor causes jamming times as shown in Figs. 4-A and 4-B with rice crop (Giza 178) whereas, un-threshed rice grains increased because of the higher cohesion force in rice crop. Increasing the rice moisture content led to gathering straw in bales. High energy was required by using original rotor.

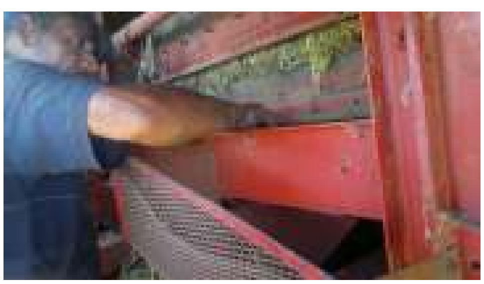


Fig. 4-A. Threshing chamber before modification

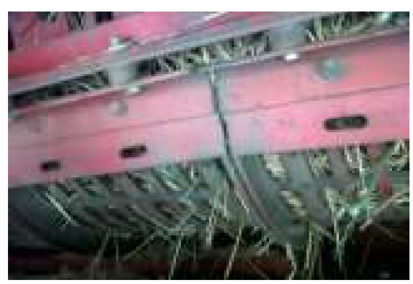


Fig. 4-B. Modified threshing chamber

Fig. 4. Jamming in threshing chamber before and after rotor modification

Fig. 5 shows the effect of peripheral rotor speeds (17.0, 19.5 and 21.5m/s) at different inlet concave clearance. Before modification, 18 jamming times/fed was recorded with rotor speed of 17.0. But after modification, the least value of jamming was 1 time/4 fed recorded by rotor speed of 21.5m/s at travel speed of 2km/h. That reduction may be due to the assembling parts on rotor surface which gave the ability for rotor to sweep the threshed material with more facility in direction to throw out threshing chamber. It was observed that rice stalks have fiber structures which cause more cohesion force on rotor surface that need more force to oblige sweeping of the threshed material in direction outside of threshing chamber.

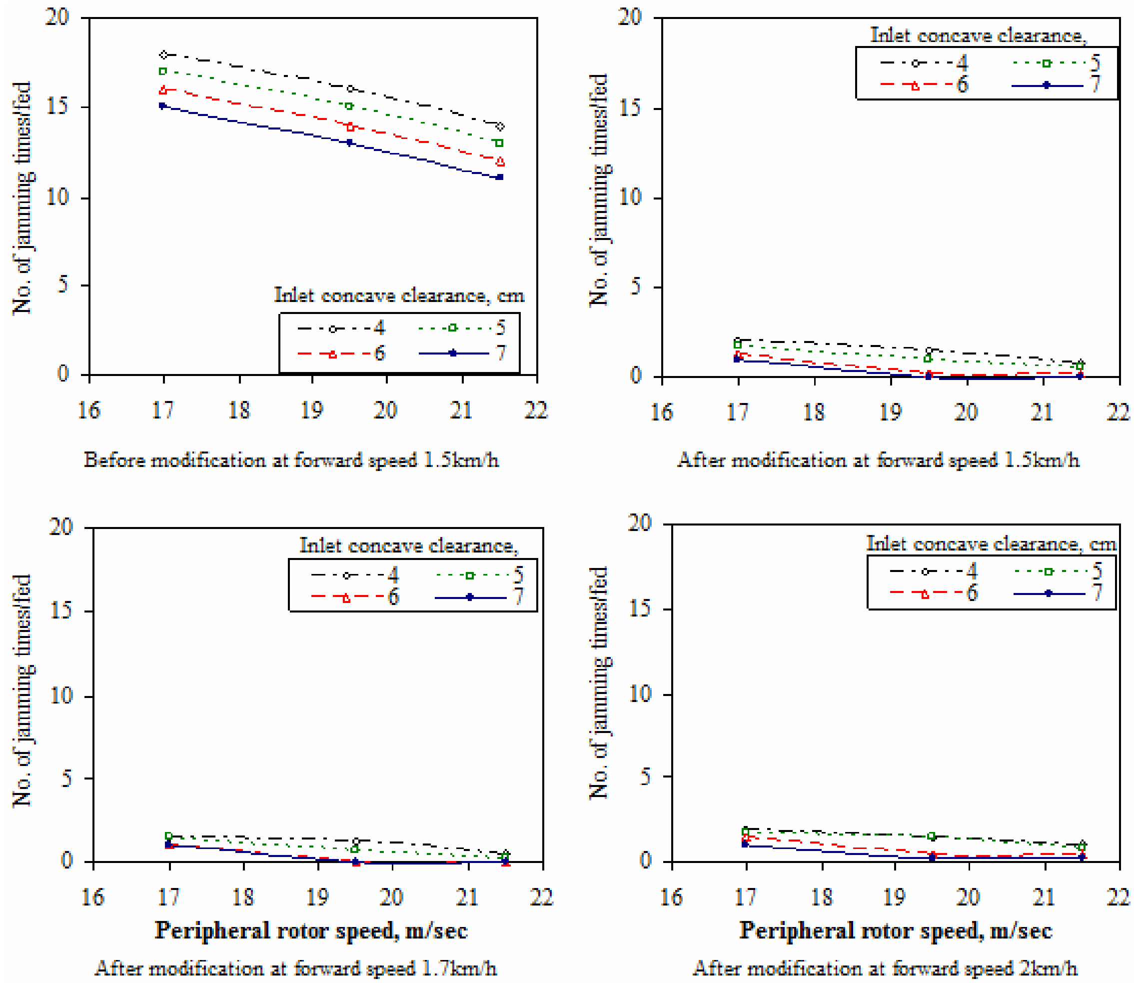


Fig. 5. Effect of peripheral rotor speed on No of jamming per feddan

Furthermore, Fig. 5 explained the effect of normal position, inclined concave clearances 7, 6, 5 and 4cm and rotor speed (17, 19.5 and 21.5m/s) as travel speed of 2km/h at moisture content (20/16 for straw/grain, %) on jamming for rice. Before modification, least value achieved at clearance of 7cm and rotor speed of 21.5m/s was 11times/feddan. Then, maximum value was 18times/feddan at 4 cm clearance, rotor speed of 17m/s and forward speed of 2km/h. While the corresponding values after modification, was zero time/feddan at least value and maximum value was 2times/ feddan with clearance. That may be due to enlarging clearance in inclining path from inside to outside in parallel path to rotor axle between rotor and concave can allow threshed material path easier from enlarging to narrowing one for the same rate of this material specially, the threshed crop material loss parts represented in grains and parts of straw gradually.

Fig. 6 shows the effect of rice moisture content (20/16, 27/21 and 20/16 for straw/grain, %) with normal position and inclined concave clearances 7, 6, 5 and 4cm and rotor speed (17, 19.5 and 21.5m/s) as travel speed of 2km/h on jamming times for rice. Before modification, minimum value achieved was with least moisture 20/16%, clearance of 7cm and rotor speed of 21.5m/s, it was (11) times/feddan and maximum value, (18) times with moisture of 32/24%, clearance of 4cm and rotor speed 17 at forward speed of 2km/h that could be due to higher moisture of material caused difficult movement over rotor surface in spiral path because of the higher cohesion force between material and peripheral chamber surfaces.

After modification, least value achieved by least moisture 20/16%, inclined clearance 7cm and rotor speed of 21.5m/s, it was zero time/feddan and maximum value, (2) times with moisture 32/24%, clearance, 4cm and rotor speed 17 at forward speed of 2km/h that may be due to reducing moisture gave material capability move easier around rotor or inside the chamber because of reduction of cohesion force.

Threshing efficiency

Fig. 7 shows the effect of peripheral rotor speeds (17, 19.5 and 21.5m/s) for rice under moisture content of 20/16% straw/grain on threshing efficiency, %. Before modification, rotor speed of 17m/sec gave the least threshing efficiency, 80% and maximum value, 95% was achieved with rotor speed of 21.5m/s at forward speed of 1.5km/h. After modification, rotor speed of 17m/s gave least value, 85% and maximum value, 98% was achieved with rotor speed of 21.5m/s while travel speed was 2km/h that could be due to higher rotor speed increasing higher friction force which reducing un-threshed grain percent and in otherwise less rotor speed means less feed rate inside threshing chamber due to small thickness threshing material by sequence, friction action effect increased.

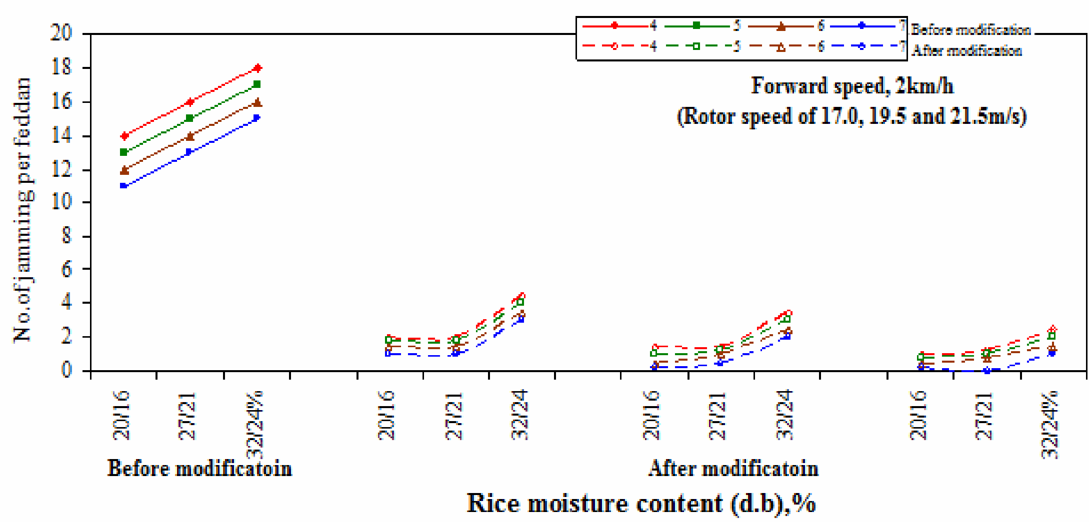


Fig. 6. Effect of rice crop moisture content on No of jamming per feddan

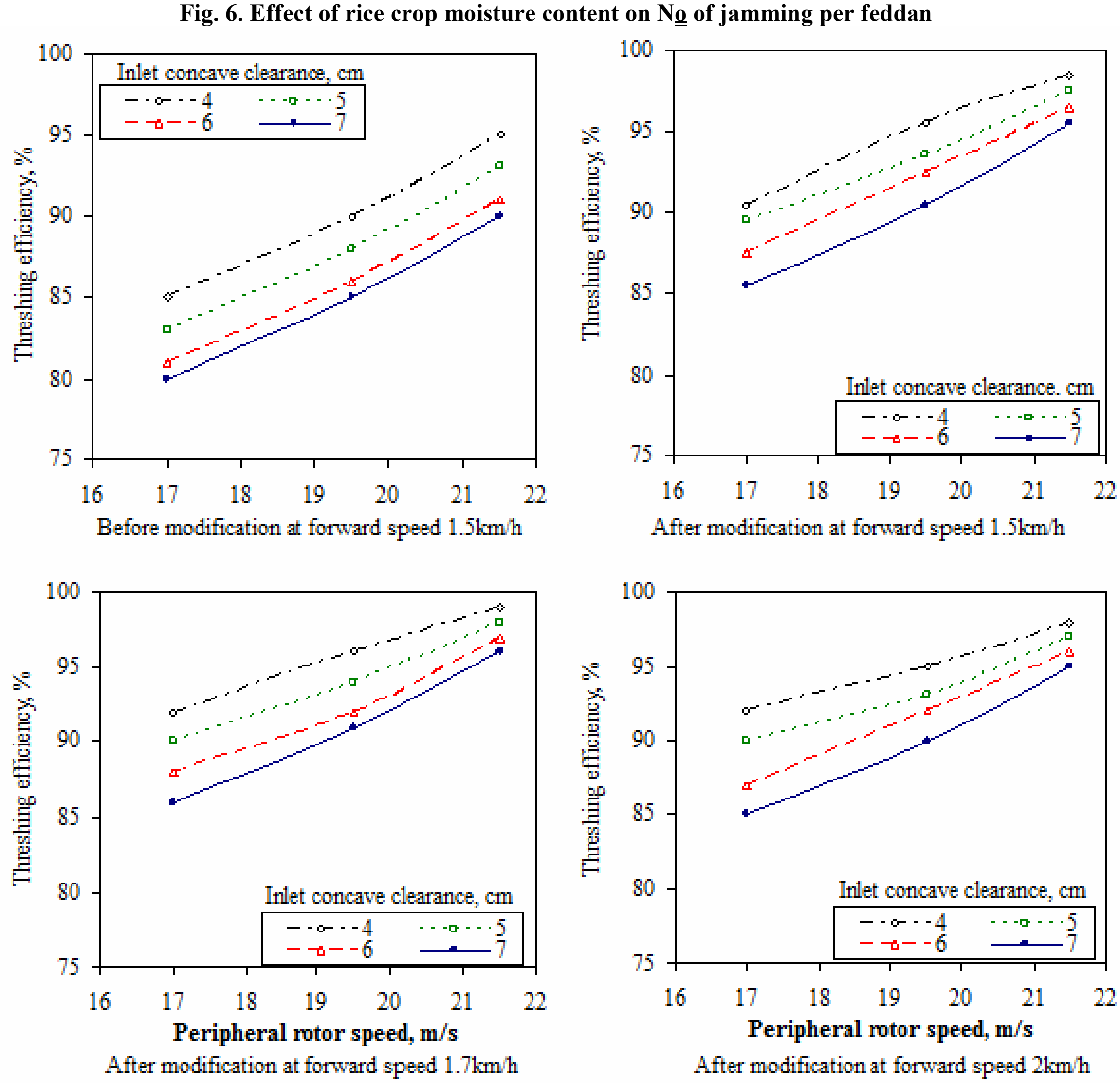


Fig. 7. Effect of peripheral rotor speed on threshing efficiency

Visible grain damage

Fig. 8 shows the effect of rotor speed (17.0, 19.5 and 21.5m/s) at rice moisture content (20/16 for straw/grain, %) visible grain damage, %. Before modification, rotor speed 17 gave minimum value, 1.45% and maximum value, of 2 % achieved with rotor speed 21.5m/s at forward speed of 1.5km/h. After modification, rotor speed 17m/s achieved least value, 1.5% and maximum value, 2.1% with rotor speed 21.5m/s while travel speed was 2km/h. these results could be explain whereas higher rotor speed resulted in increasing higher friction force which increased damaged grain percent and on other side higher rotor speed means higher feed rate inside threshing chamber due to large thickness of threshing material by sequence, friction action effect decreased.

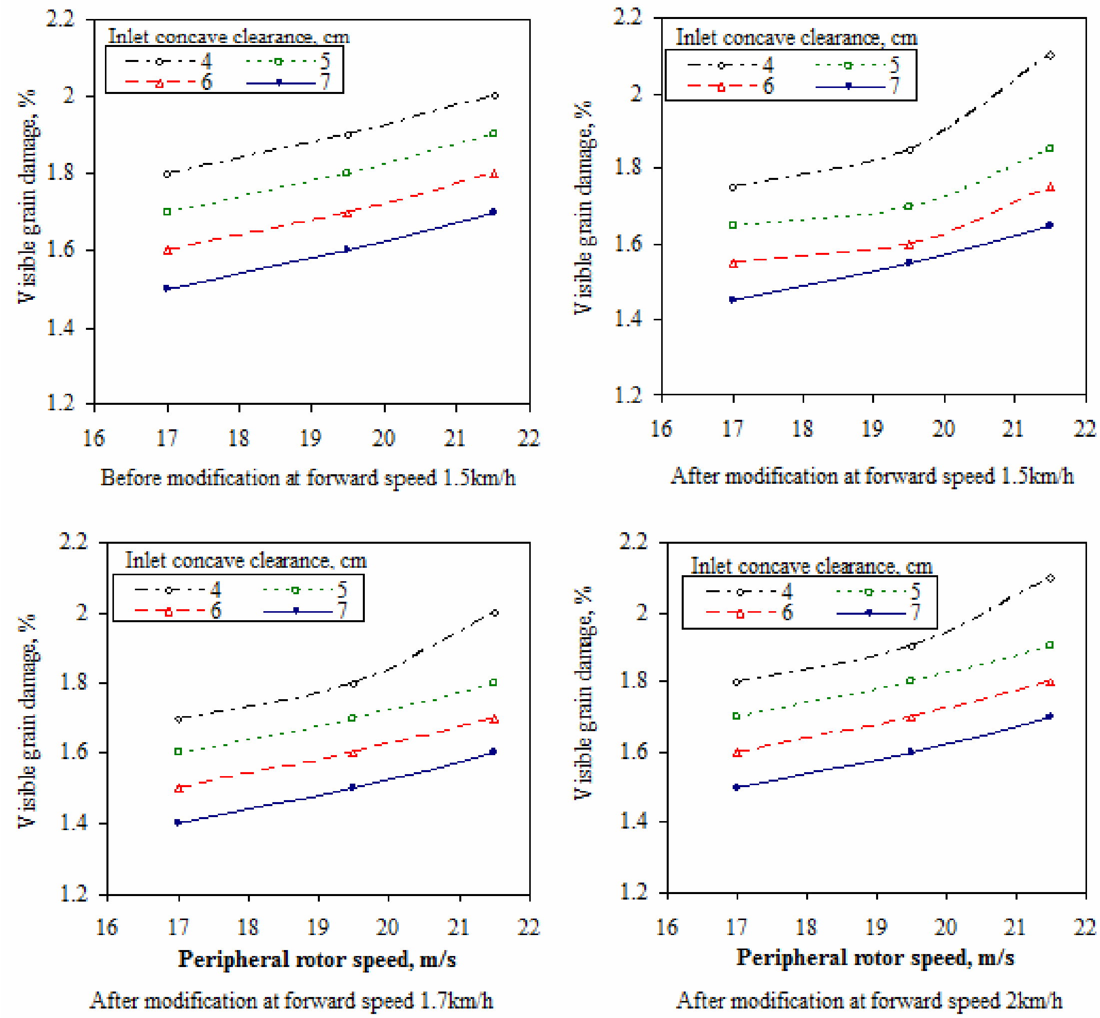


Fig. 8. Effect of peripheral rotor speed on visible grain damage

Field efficiency

Fig. 9 represents the effect of rotor speed 17, 19.5 and 21.5m/s at moisture content (20/16 for straw/grain, %) on field efficiency, % for rice. Before modification, rotor speed 17m/s gave minimum value, 12% and maximum value, 30% achieved with rotor speed 21.5m/sec at forward speed of 1.5km/h. while after modification, rotor speed 17m/s gave least value, 45% and maximum value, 80% with rotor speed 21.5 m/s while travel speed was 2km/h. Harvester can achieve one feddan at 39.37 min. by field efficiency of 80% with rotor speed of 21.5m/s.

Percentage of straw length, %

Figs. 10-A and 10-B showed the shape of rice straw after and before modifications. From the figure it can shows the shortage of straw length using the threshing rotor before modification than the straw length after modifications. Furthermore Figs. 11 indicated that the percentage of straw length, % for rice crop before and after modifications at normal position and inclined concave clearances 7, rotor speed 21.5m/s as travel speed of 2km/h and moisture content of 20/16 for straw/grain, %. Before modification, rotor causes minimum percentage of straw length, 5% in range of 80-100cm because of increasing the force required for shredding straw but after modification minimum shredded force was required because facilitating action conducting by slipping the rice straw. Lengths between 50-10cm was 55% from total straw weight.

Power requirements

Figs. 12 indicates the power required for rice crop before and after modifications at normal position and inclined concave clearances of 7, 6, 5 and 4cm and rotor speed (17.0, 19.5 and 21.5m/s) during forward speed of 2km/h. Before modification, the minimum power value achieved with clearance of 7cm and rotor speed of 17 was 53 kW but after modification minimum power value was 47.35kW at rotor speed 17 m/s with clearance 7cm and 2km/h forward speed at rice moisture content (20/16 for straw/grain, %). The increase of power required for shredded rice straw may be due to the more force needed for shearing straw.

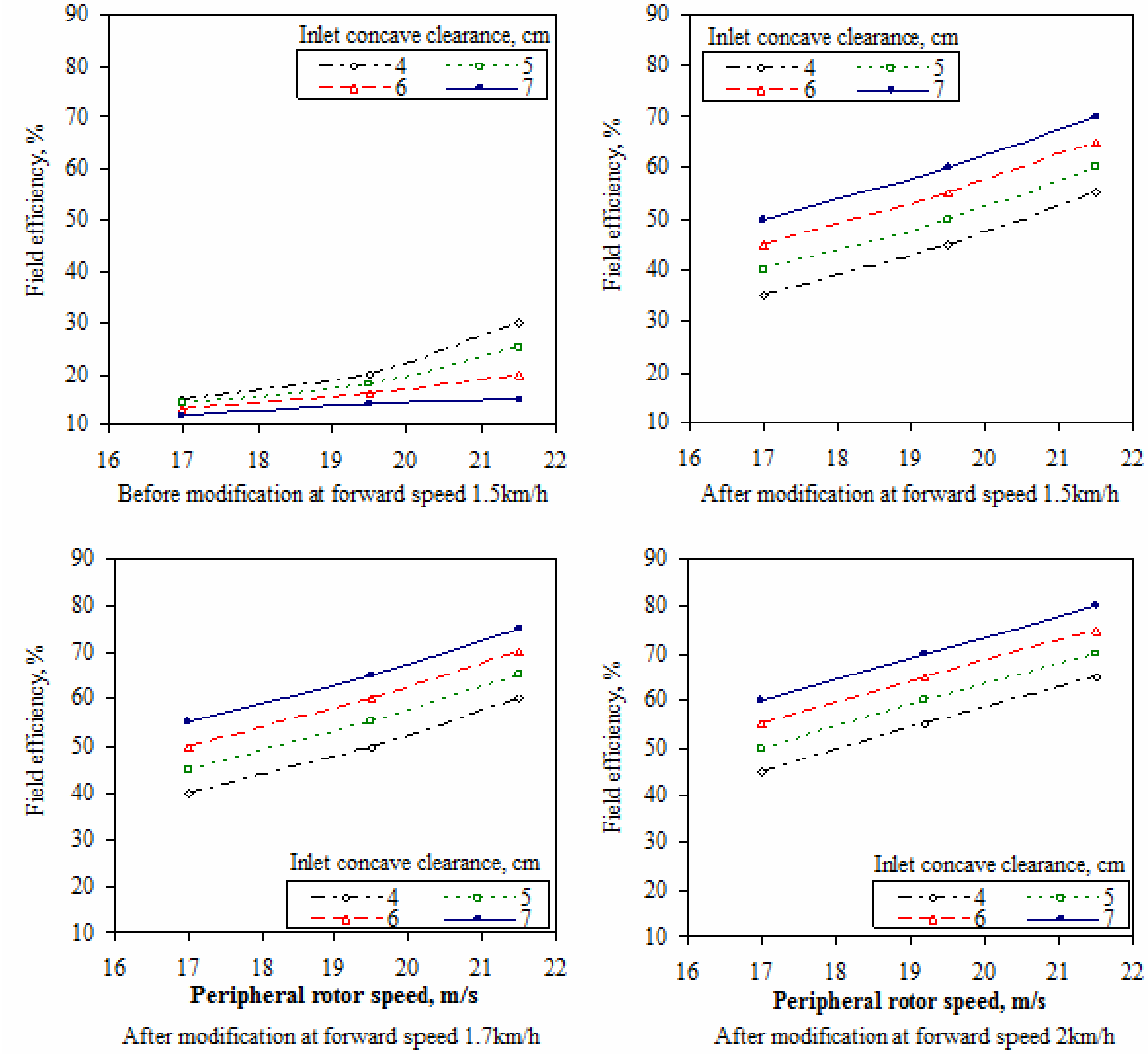


Fig. 9. Effect of peripheral rotor speed on field efficiency

Fig. 10-A. Short lengths of straw before modification

Fig. 10-B. Long lengths of straw after modification

Fig. 10. Straw shapes before and after threshing modification.

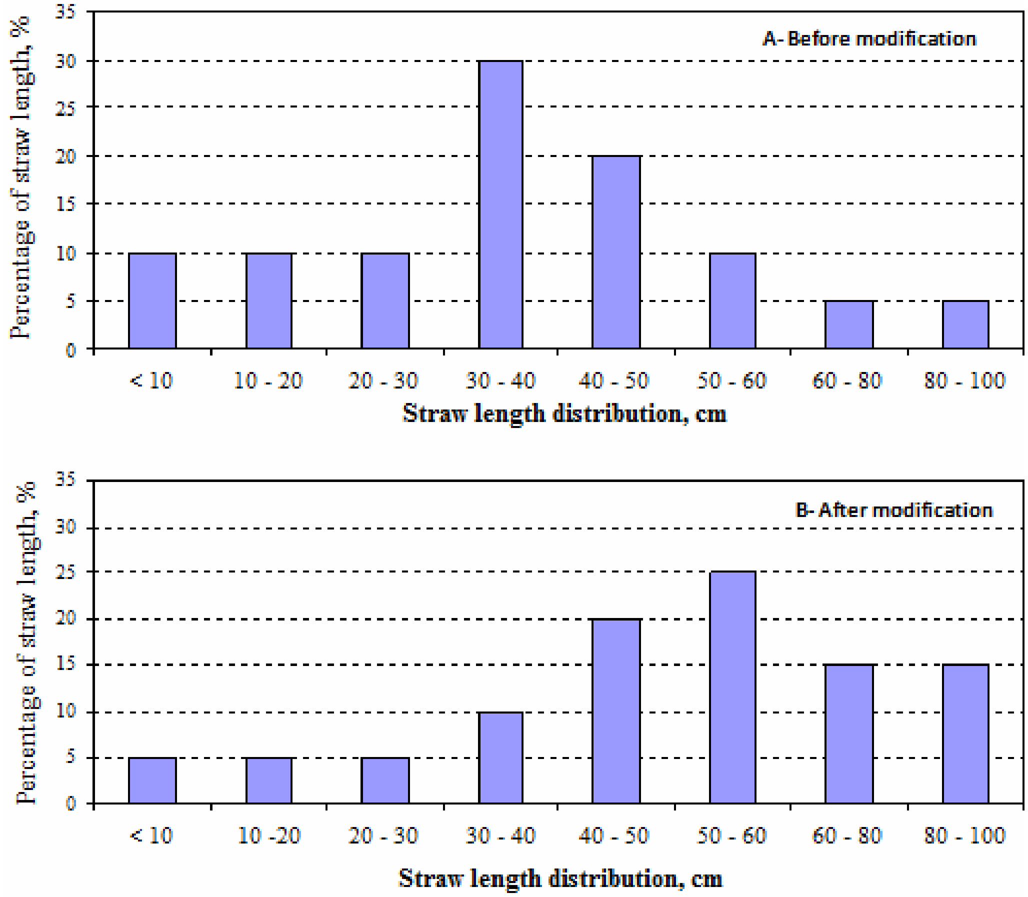


Fig. 11. The percentage of straw length

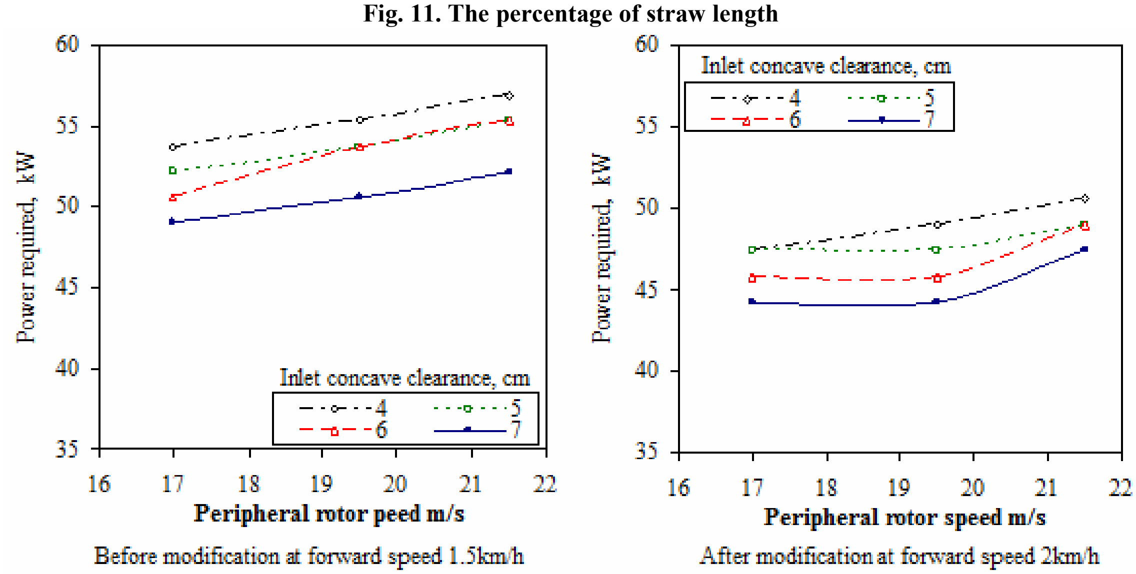


Fig. 12. Effect of rotor speed on power requirement

CONCLUSION

The results, can be concluded that, the rotor modification manages the harvester to achieve harvest one feddan in 39.37 min with jamming of one times per four feddan, visible grain damage of 1.45 %, threshing efficiency 98 %, field capacity 80% and power requirements of 47.35kW at 820 rpm (21.5m/s) peripheral rotor speed, 2km forward speed, inclined concave clearance of 7cm and rice moisture content of 20/16%.

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تعديل الدرفيل الطولي ليناسب حصاد الأرز

يوسف يوسف رمضان ، أيمن موسي البيبه و أسامه أحمد علي فوده
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يتم حصاد الأرز في مصر آلياً باستخدام الكمباين الياباني أو الريبر وهى وسائل ذات سعة حقلية منخفضة من 5-8 فدان/يوم. ونظراً لتوافر الحاصدات العملاقة ذات السعة الحقلية الكبيرة في المزارع الحكومية ولدي القطاع الخاص بالمزارع الكبيرة من النوع ذو التغذية الطولية Axial flow-type وتستخدم بشكل عام للمحاصيل في ظروف رطوبة محصولية منخفضة مثل القمح. فقد أجريت محاولات لاستخدام هذه الحاصدات فى حصاد الأرز، ونظراً لارتفاع المحتوى الرطوبي لقش الأرز (32%) مما يشكل صعوبة كبيرة في سريان وانتقال مادة الدراس على طول محور الدراس وإعاقة كبيرة لدوران درفيل الدراس أو في كثير من الأحيان توقف تام لدرفيل الدراس ومن ثم المحرك. وبناء عليه أجريت هذه التجربة في محطة البحوث الزراعية بالسرو– محافظة دمياط ، بهدف إدخال بعض التعديلات على درفيل الدراس لتمكين الحاصدة CASE International 1620 من حصاد محصول الأرز صنف جيزة 178 والذي يستوجب عند حصاده ظروف رطوبة عالية قبل فرط الحبوب طبيعياً بانحفاض درجة رطوبة المحصول. وكانت التعديلات علي النحو التالي:- إضافة أربعة قضبان مشرشرة rasp bars مع بداية جزء الدرس علي الدرفيل بطول 15سم وفى مسار حلزوني. مع استبدال الأربعة ريش المستقيمة straight paddles بـقضبان مشرشرة rasp bars مع بداية جزء الفصل علي الدرفيل بطول 30سم . مع عمل خلوص متدرج علي خط مستقيم مائل و متوازي مع المحور الطولي للدرفيل 7، 6، 5 ، 4سم؛ بديلا عن الثابت يبدأ من أول جزء الدراس وينتهي عند آخر جزء الفصل. وذلك للرفع من كفاءة انتقال (سريان) مادة الدراس الرطبة للأرز على المحور الطولي للدرفيل. وتم اختبار التعديلات عند ثلاث سرعات تقدم للحاصدة 1.5 و 1.7 و 2كم/ساعة وثلاث سرعات دورانية لدرفيل الدراس 650، 745، 820 لفة/دقيقة (17؛ 19.5و 21.5م/ثانية) وكذلك الخلوص المتدرج 7، 6، 5، 4سم، عند رطوبة المحصول (قش/حبوب %) , (21/27) ,(24/32) (16/20) علي أساس الوزن الجاف للأرز. وتم قياس عدد مرات الزوران/الفدان وكفاءة الدراس ونسبة الكسر – الكفاءة الحقلية – القدرة المطلوبة. أوضحت النتائج بعد التعديل ما يلي:- انخفض عدد مرات الزوران إلى مرة واحدة لكل 4 أفدنة ، كما ارتفعت كفاءة الدراس إلى 98% وانخفضت نسبة كسر الحبوب إلى 1.45% عند كفاءة حقلية 80% بينما استغرق حصاد فدان واحد 39.37 دقيقة وكانت القدرة المطلوبة 47.35 كيلووات وذلك عند سرعة دورانية للدرفيل 820 لفة/دقيقة، وسرعة تقدم 2 كم/ساعة، (21.5 سرعة درفيل)، ونسبة رطوبة 16/20% (قش/حبوب) وخلوص متدرج 7سم. وعليه يوصى باستخدام الكمباين بعد تعديل درفيل الدراس لحصاد محصول الأرز.