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DEVELOPMENT OF THE GRAIN CONVEYING UNIT FOR FIAT COMBINE HARVESTER

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ABSTRACT

The main purpose of this study is to develop the grain-conveying unit to the grain tank of Fiat combine harvester. The modified grain conveying unit was proposed to avoid the continues wearing in the transmission bevel gearbox of distribution auger and grain elevator, to increase the combine field capacity and to improve overall efficiency of the combine.

The grain-conveying unit includes elevator, bevel gearbox and grain distribution auger. The grain-conveying unit of Fiat combine was developed in this study on two stages, the first stage was to change the fixing place of grain elevator and distribution auger with respect to the grain tank. While, the second stage was to change the transmission bevel gearbox between distribution auger and grain elevator by two sprocket wheels and chain. The development was carried out in a private workshop in Mansoura City. The field experiments were conducted at different farms in Dakhalia Governorate during the wheat harvesting seasons of 2002 and 2003. Harvesting of Sakha 93 wheat variety was carried out using the Fiat combine harvester before and after development taking place. The total losses, field capacity and efficiency, combine performance efficiency and criterion harvesting cost as a function of change in drum speed, grain moisture content and reel index were considered.

Development of grain conveying unit of the grain tank of Fiat combine harvester decreased the total grain losses by about 1.8-4% and the total grain damage (visible and invisible) by about 15-30% compared with its results before development. Using the developed combine improved overall performance efficiency and recorded the maximum values of effective field capacity and efficiency (3.03 fed./h and 76.4%, respectively) compared with the performance of un-developed combine (2.88 fed./h and 63.9 %, respectively) at forward speed of 4.5 km/h. The minimum value of criterion cost (120.89LE/fed.) was recorded with the developed combine at drum speed of 30.2 m/s, reel index 1:1.3 and grain moisture content of 20.2% compared with 126.87 LE/fed for the un-developed combine under the same previous conditions.

INTRODUCTION

Cereal crops are considered the most economical crops participating in the international income added to the local consumption in feeding and different aspects. So, increasing the yield by means of up-to date technology through the different agricultural processes, decreasing grain losses during the harvesting are important considerations to be challenged. Nowadays, the combine harvester became popular and more advanced and developed according to new operation concepts to satisfy different crops and conditions. The development of combine mechanisms and improving their parts are still working out to increase combine capacity and improve overall efficiency by recovering the free seeds from plant residues with minimum losses.

Kepner *et al.* (1982) stated that drum effectiveness is related to cylinder speed, cylinder concave clearance, type of crop, condition in terms of moisture content and maturity and rate at which the material is fed into the machine. Yunus (1987) stated that the factors affecting on grain losses at harvesting and threshing of paddy are the travelling speed, grain moisture content, drum speed and plant properties. Dilday (1987) studied the influence of drum speed and grain moisture content at harvest on milling yield of grains. Grain moisture content of 12-26% was threshed at drum speeds of 600 or 1000 rpm. The results showed that the percentage of broken grain virtually was doubled when the thresher drum was increased from 600 to 1000 rpm and generally decreased as grain moisture content at harvest increased. El-Berry and Ahmed (1989) found that the total lost time (machine preparation, travelling to the working site, returning, grain unloading, resting and turning time) affected by combine type and this was reflected on field capacity.

Hassan *et al.* (1994) indicated that the main effective parameters, which affect combine header performance, are combine forward speed, cuter bar speed and grain moisture content. They also added that increasing forward speed from 2.1 to 3.5 km/h, at constant cutter bar speed of 1.2 m/s and constant moisture content of 19.2 % increased total losses from 1.7 to 2.3 % using Yanmar combine. Helmy *et al.* (1995) reported that increasing the forward speed tends to increase the actual field capacity and to decrease the field efficiency. They indicated also that the effective field capacity increased by decreasing the straw moisture content. El-Haddad *et al.* (1995) stated that the combine harvesting gave the lowest cost of 229 LE/feddan in comparison with 283.4 LE/feddan for mounted mower and 300 LE/feddan for manual sickle system. Farag *(1997)* evaluated the performance of combine machines (Yanmar TC 3500, Deutz-Fahr M980 and Fortischritt E 512). He stated that increasing the forward speed and cutter bar speed caused an increase in header losses.

Arnaout *et al.* (1998) mentioned that increasing forward speed for wheat harvesting from 2.3 to 3.2 km/h, at average grain moisture content of 19.8% and average L/W (length/width) of 2/1, decreased total cost requirement from 199.43 to 190.37, 189.45 to 184.35 and 182.95 to 174.78 LE/feddan, under three different plot area of 0.25, 0.5 and 1.0 feddan, respectively. Kamel, (1999) proved that, all kinds of losses (header, drum, straw walker and shoe losses) increased with the increase of cutting height and harvesting speed for both tested combines and the three rice varieties Giza 178, Sakha 101 and Sakha 102. The lowest values of total loss percentage were obtained at harvesting speed of about 0.3 m/s and cutting height of about 7 cm.

Problem statement:

During harvesting cereal crops such as wheat, rice and parley by using Fait combine harvester (4.2 m width) some of operational problems were noticed in the grain-conveying unit especially in the bevel gearbox, which transmit motion between grain distribution auger and grain elevator. This problem causes excessive wear to bevel gearbox and damage it after a short periods of operation, consequently, caused wasting more time in repairing or changing bevel gearbox. This results in a decrement in field capacity and an increment in harvesting cost.

After deep study the problem could be explained as follows: The distribution auger is fixed to the half of the grain tank, after a few minutes from operation the lower half of tank is filled with grains. At this time, the driver must be discharging the tank. Otherwise, the grains will accumulate and close the distribution auger outlet, resulting in increasing the load on the distribution auger and creating more wear at the bevel gearbox, finally it will be damage. This problem is not only affecting on the wearing of bevel gearbox but also the total grain damage, number of discharging times, consequently, the combine capacity/efficiency and harvesting cost.

The main purpose of this study is to modify the grain-conveying unit of grain tank of Fiat combine harvester to avoid the high wearing in the transmission bevel gearbox between distribution auger and grain elevator. In addition to the increase in the combine field capacity and improve overall efficiency by decreasing the total grain damage and harvesting cost.

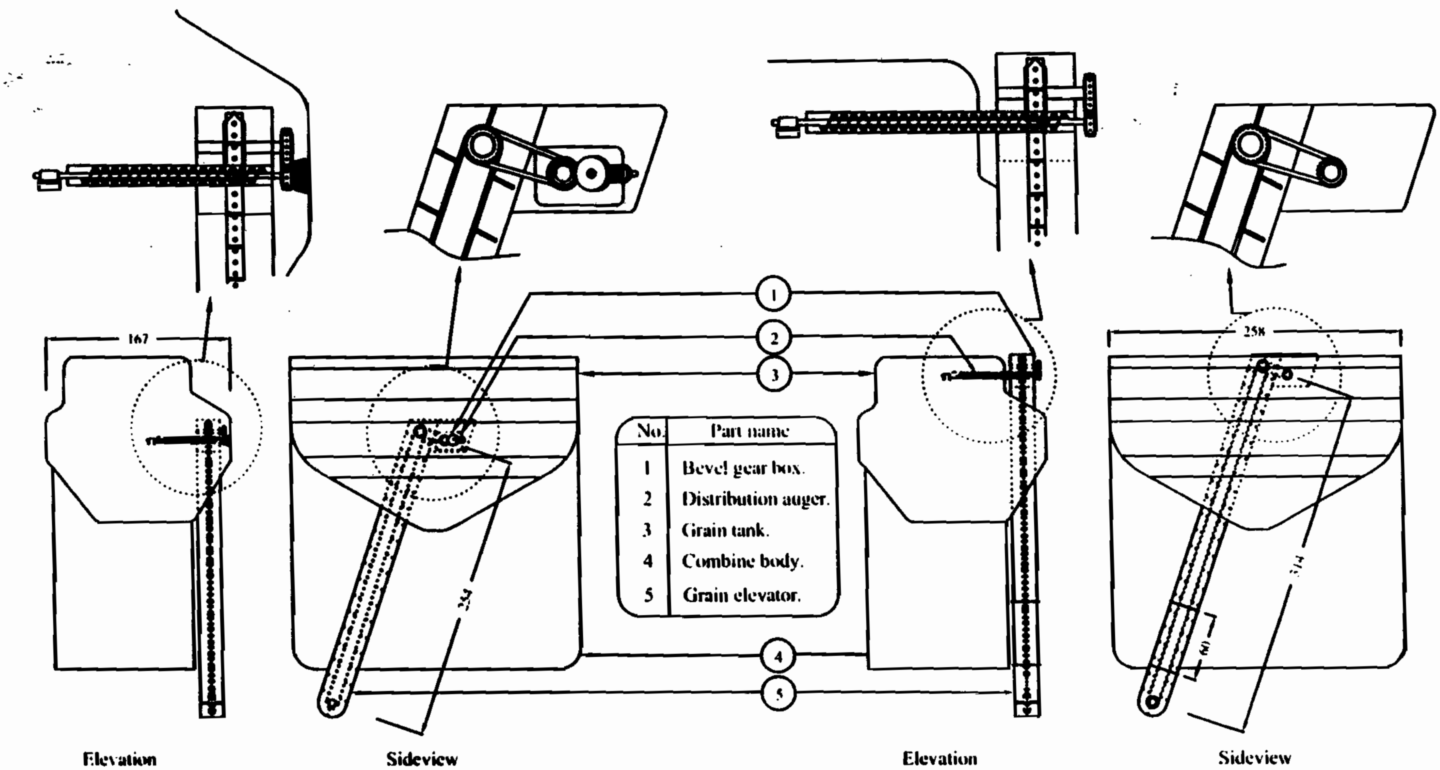
MATERIALS AND METHODS

The field experiments were conducted during the agricultural seasons of 2002 and 2003 at different private farms in Dakhlia Governorate. While, the develcpment process was carried out in a private workshop in Mansoura City. The grain-conveying unit includes elevator, grain distribution auger was developed in this study in two stages. The first stage was to change the fixing place of grain elevator and distribution auger with respect to the grain tank by increasing the length of grain elevator by 60 cm. In this condition the distribution auger fixed below the upper surface of grain tank. This procedure was done to decrease the number of discharges of the grain tank due to increasing the capacity of tank. In addition, to decrease the total grain damage due to avoiding grain accumulation in front of grain distribution augur outlet. While, the second stage was to change the transmission bevel gearbox between distribution auger and grain elevator with two sprocket wheels and chain. This procedure was supposed to decrease the variable cost of combine due to decrease the repair and maintenance costs.

The technical specifications of the Fiat combine harvester are summarized in Table 1. Moreover, the grain-conveying unit of Fait combine harvester before and after development is shown in Fig.1.

Table 1: Technical specifications of Fiat combine harvester.

Item	Specification
Source of manufacture	Italy
Model	LAVERDA 3500 R
Type	Transverse Flow
Working width, m	4.20
Engine rated power / 2500rpm	74 kW (105 hp)
Grain tank capacity before development	2.0 ton
Grain tank capacity after development	3.5 ton
Field capacity	10-15 fed./day



A - Grain conveying unit before development.

Dim. in cm.

B - Grain conveying unit after development.

Fig. 1 : Grain conveying unit of Fiat combine harvester before and after development.

Study parameters:

Field experiments were conducted to evaluate the Fiat combine harvester before and after development under the following parameters. Four different levels of drum speed (21.6, 24.5, 27.4 and 30.2 m/s), three different ratios of reel index (1:1, 1:1.3 and 1:1.5) and four different levels of grain moisture content (23.5, 20.2, 17.3 and 13.5%).

Measurements:

1- Total grain Losses:

a- Header Losses:

The main effective parameters, which affect the combine header loss, are cutter bar speed, reel speed, forward speed and grain moisture content. The header loss was determined by inserted the V-shaped trays between stand wheat plants. After passing the cutter bar over the trays, the combine harvester was stopped and the trays are backed. The grains shattered by header were collected in the trays and weighed. The percentage of header losses was calculated using the following equation:

$$Header\ loss,\% = \frac{Header\ loss,\ ton/fed}{Total\ yield,\ ton/fed} \times 100 \quad \text{.......................... (1)}$$

b- Rear Losses:

Rear losses including drum, separating and cleaning losses. Drum loss was determined by dragging two plastic sheets (10.0 m Length) behind the combine harvester one above the other. The collected material on the upper plastic sheet consists of straw; unthreshed and damaged grain (drum loss). The unthreshed ears were manually threshed and the separated grains were weighed. While, the chaff and free grains discharge from the drum w ere w eighted (separating l oss). T hese l osses w ere calculated using the following equations according to Marey (1997):

$$Drum\ loss,\% = \frac{Drum\ loss,\ ton/fed}{Total\ yield,\ ton/fed} \times 100 \quad \text{............................(2)}$$

$$Separating\ loss,\% = \frac{Separating\ loss,\ ton/fed}{Total\ yield,\ ton/fed} \times 100 \quad \text{.................(3)}$$

The collected material from the lower plastic sheet was winnowed to get the free grains (cleaning loss). The percentage of cleaning loss was calculated by using the following equation:

$$Cleaning\ loss,\% = \frac{Cleaning\ loss,\ ton/fed.}{Total\ yield,\ ton/fed.} \times 100 \quad \text{.........................(4)}$$

2- Grain damage

a- Visible grain damage:

Visible grain damage was determined by separating the damaged grains by hand from a mass of 50 g sample, which was taken by a randomized method from the threshed grains. The percentage of grain damage was calculated based on the original mass of sample.

b- Invisible grain damage:

A germination test was carried out to determine the invisible damage in grains. The samples of these tests were taken from the remained portion of the visible sample after separating damaged grains. The germination test was carried out in the five petri dishes on a filter paper, covered with water and incubated at 20°C for 24 hours. The germinated grains were collected in each dish and expressed as a percentage of the original number of grains.

3- Combine performance efficiency:

The combine performance was calculated using the following equation:

$$\text{Performance efficiency, } \% = \frac{\text{Output, ton/fed.}}{(\text{output} + \text{total losses}), \text{ton/fed.}} \times 100 \quad \text{.................(5)}$$

Where:

Output = The amount of grain yield collected in the grain tank of the combine harvester, ton/fed.; and

Total losses = All losses that are actually caused by the combine (header, drum, separating and cleaning losses), ton/ fed.

4- Field capacity and efficiency:

The following procedure has been used for calculating the field capacity and efficiency *(Hunt, 1983)*.

a- The theoretical field capacity was calculated by using the following formula:

$$F.C_{th} = \frac{W \times S}{4.2}, fed./h \quad \text{..(6)}$$

Where: $F.C_{th}$ = Theoretical field capacity, fed/h;

W = Theoretical width of combine, m; and

S = Average working forward speed, Km/h.

b- The effective field capacity was calculated as follows:

$$F.C_{eff} = \frac{1}{T_{eff}}, fed./h \quad \text{..(7)}$$

Where: $F.C_{eff}$ = Effective field capacity, fed/h; and

T_{eff} = Effective total time in hours per feddan (actual harvesting time + turning time + adjusting or repair time + discharge time).

c- The Field efficiency was calculated by using the following formula:

$$\eta_{eff} = \frac{F.C_{eff}}{F.C_{th}} \times 100, \% \quad \text{..(8)}$$

Where: η_{eff} = Field efficiency, %;

$F.C_{eff}$ = Effective field capacity, fed./h; and

$F.C_{th}$ = Theoretical field capacity, fed./h.

5- Cost analysis:

The total harvesting cost was calculated by estimating both the fixed and variable costs *(Kepner et al. 1982)*.

The criterion Function cost (C_f) was calculated to determine the optimum operating parameter for the used machine. This function can be calculated as the sum of the unit cost (*Uc*, LE/ton) plus the losses cost (*Lc*, LE/ton) *(Helmy, 1988)*.

$$C_f = U_C + L_C \quad \text{...} (11)$$

Where: $L_c = (10^{-2}\, C_{pw} \times T_L) + (0.67 \times T_{GD})$, LE/ton;

C_{pw} = Current price of one ton of grain wheat (450 LE);

T_L = Total grain losses, %;

T_{GD} = Total grain damage, % and

0.67 = Current price of one ton of broken wheat grain, LE

RESULTS AND DISCUSSION

1- Total grain losses:

The total grain losses of the combine including header, drum, separating and cleaning losses were estimated and showed in Fig. 2. The results indicated that using the developed combine decreased the total grain losses by 1.8 – 4.0 % compared with it before development. However, the differences between total grain losses for un-developed and developed combine was found to be not significant. The minimum value of total grain losses (4.85%) was obtained for developed combine harvester under drum speed of 30.2 m/s, reel index of 1:1.3 and grain moisture content of 20.2% compared with 5.321% for the un-developed combine under the same pervious conditions.

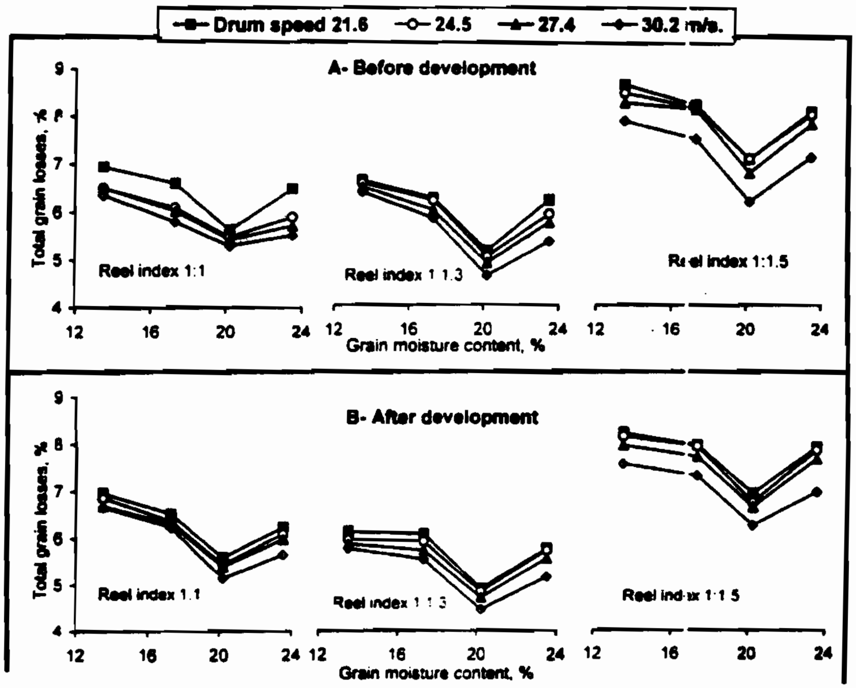


Fig. 2: Total grain losses for Fiat combine before and after development under different levels of drum speed, reel index and grain moisture content.

The best conditions (the least losses) for developed combine harvester were obtained at drum speed of 30.2 m/s, reel index of 1:1.3 and grain moisture content of 20.2 %.

It could be noticed that there was a significant effect of drum speed, reel index and grain moisture content on the total grain losses for the un-developed and developed combine. The header loss recorded the maximum values of losses in comparison to the other losses (drum, separating and shoe losses) under the different levels of reel index and grain moisture content.

2- Total grain damage:

The total percentages of wheat grain damage, which include visible and invisible damage, were greatly influenced by the development of grain conveying unit as well as by drum speed and grain moisture content as indicated in Fig. 3. The un-developed combine achieved the highest values of visible and invisible grain damage. While, the lowest values were associated with the developed combine. This trend was because the grain distribution auger in un-developed combine is fixed to the half of the grain tank, which decreases the actual capacity of grain tank and rapidly filling after a few minutes of operation in addition to the driver not discharge the grain tank on time. Therefore, the grains were accumulating and closing the distribution auger outlet results in more grain damage percentages.

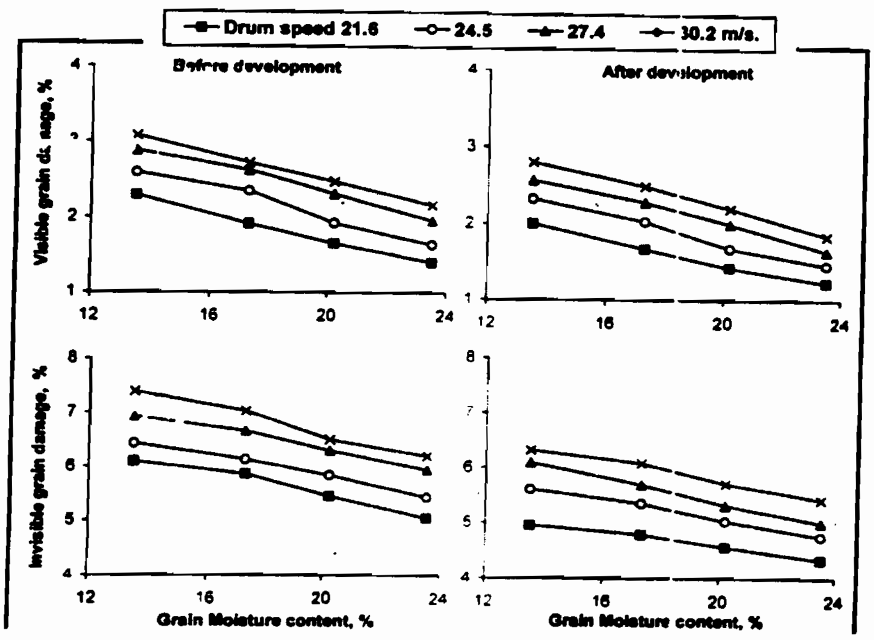


Fig. 3: Visible and invisible grain damage for the combine before and after development under different levels of drum speed and grain moisture content.

Also, it could be concluded that the visible damage ranged from 1.232 to 2.798% while, the invisible grain damage ranged from 3.832 to 5.817% for the developed combine under different levels of drum speed and grain moisture content. However, the corresponding values for the un-developed combine were 1.407 to 3.075 % visible damage and 4.553 to 6.884 % invisible grain damage. This data indicated that the development of grain conveying unit decreased the total grain damage (visible and invisible) by 15-30% compared with undeveloped combine under different levels of the parameters.

3- Combine performance efficiency:

The values of combine performance efficiency (%) for the Fiat combine before development as affected by the different levels drum speed, reel index and grain moisture content are illustrated in Fig. 4. The performance efficiency of the developed combine was found to be higher than that obtained for the un-developed combine for all parameters.

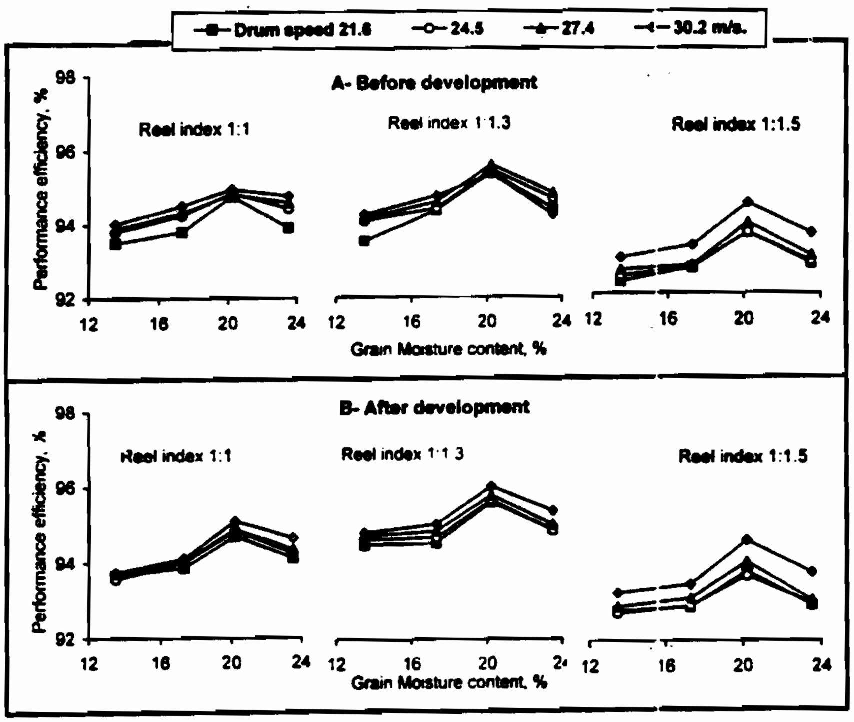


Fig. 4: Combine performance efficiency before and after development under different levels of drum speed, reel index and grain moisture content.

The maximum values of combine performance efficiency (95.76 and 95.14%) were recorded with the reel index of 1:1.3 and grain moisture content of 20.2% in comparison to the other levels for the combine after and before development respectively. The results also observed that the drum speed had a slight effect on the combine performance efficiency for any given reel index and grain moisture content.

4- Effective field capacity and efficiency:

Figure 5 shows the effect of forward speed and grain moisture content on the effective field capacity and field efficiency for the Fiat combine harvester before and after development. It could be observed that the values of effective field capacity and field efficiency of the developed combine were higher than that obtained for un-developed one. The effective field capacity increased by 11.4 % while, the field efficiency increased by 12.3 % as the result of modifying the grain conveying unit of the combine due to increasing tank capacity (from 2.0 ton to 3.5 ton) and avoiding the excessive wear in bevel gearbox consequently, decreasing the lost time in discharging the grain tank, repairs and maintenance.

The lost time in repairs, maintenance and discharging the grain tank represented was about 36.8% in proportional to the total harvesting time for un-developed combine. However the corresponding value for developed combine was 29.3%. In general, the discharge time was decreased by 27.9% due to development the grain-conveying unit. The developed combine recorded the maximum values of the effective field capacity and efficiency (3.03 fed/h and 67.40%, respectively) compared with the un-developed combine (2.88 fed./h and 63.9 %, respectively) at forward speeds of 4.5 km/h.

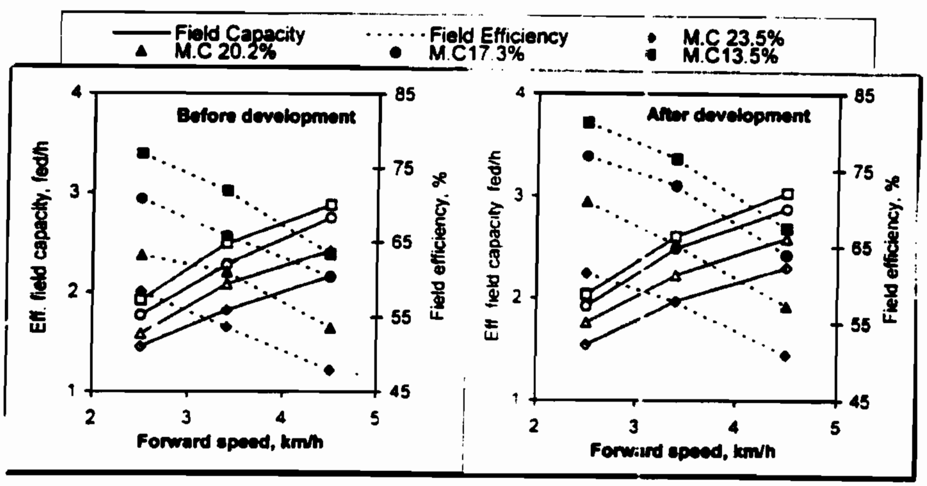


Fig. 5: Combine field capacity and efficiency before and after development under different levels of drum speed, forward speed and grain moisture content.

5- Criterion cost

The total cost was ranged from 31.57 to 59.36 LE/fed. when using the developed combine compared with 33.09 to 62.83 LE/fed. for un-developed. The values of criterion cost are summarized in Table 3. It could be concluded that the criterion cost for harvesting the wheat grain by the developed combine were less than that obtained by the un-developed combine under the different levels of drum speed, forward speed and grain moisture content. The minimum value of criterion cost (120.89 LE/fed.) was recorded with the developed combined at drum speed of 30.2 m/s, reel index of 1:1.3 and grain moisture content of 20.2%. But, the maximum value of criterion cost (183.03LE/fed.) was recorded with the un-developed combine at the drum speed of 21.6 m/s, grain moisture content of 23.5% and reel index of 1:1.5.

Table 3: Criterion cost for un-developed and developed combine under different levels of grain moisture content, reel index and drum speed.

Fiat combine	Reel index	Drum speed, m/s	Grain moisture content, %			
			23.50	20.20	17.30	13.50
Before development	1:1	21.6	178.950	158.770	169.990	172.060
		24.5	168.640	156.330	161.030	164.280
		27.4	165.460	155.460	159.860	164.380
		30.2	162.190	153.220	156.000	161.850
	1:1.3	21.6	159.910	135.330	150.490	153.390
		24.5	155.060	133.600	149.830	152.500
		27.4	152.220	130.770	146.360	151.210
		30.2	145.490	126.870	143.500	149.420
	1:1.5	21.6	182.170	162.120	175.240	178.820
		24.5	178.940	157.210	174.770	175.520
		27.4	178.940	157.210	174.770	175.520
		30.2	167.470	147.160	164.360	169.070
After development	1:1	21.6	171.250	152.100	164.450	169.620
		24.5	168.820	149.570	161.870	168.010
		27.4	166.860	148.910	160.980	165.050
		30.2	161.060	144.520	159.740	164.710
	1:1.3	21.6	148.190	128.400	143.910	142.890
		24.5	147.740	127.300	141.280	140.280
		27.4	144.860	125.110	138.230	138.590
		30.2	138.250	120.890	134.940	137.070
	1:1.5	21.6	178.470	157.090	171.030	173.490
		24.5	177.060	154.070	170.720	172.480
		27.4	174.350	152.480	167.060	169.170
		30.2	162.420	145.950	160.200	162.450

CONCLUSION

The main results in the present study can be summarized in the following points:

1- Using the developed Fiat combine harvester decreased the total losses by 1.8-4% in comparison to the un-developed combine.
2- The total grain damage (visible and invisible) was decreased by 15-30% due to using the developed combine harvester.
3- The performance efficiency of the developed combine was improved to 95.76% in comparison with 95.14% for un-developed combine.
4- The developed combine recorded the highest values of field capacity and efficiency (3.03 fed/h and 67.4%) in comparison to the un-developed combine (2.88 fed/h and 63.3%).
5- The minimum value of criterion cost (120.89 L.E / fed) was recorded with the developed combine harvester at drum speed of 30.2 m/s, reel index 1:1.3 and grain moisture content of 20.2%.
6- It could be concluded that the best combination of 30.2 m/s drum speed, 1:1.3 reel index and 20.2% grain moisture content with the developed Fiat combine achieved the best harvesting performances and highest yield.

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تطوير وحدة نقل وتوزيع الحبوب لتنك الحبوب فى آلة الحصاد الجامعة (FIAT)

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أوضحت تقارير المشغلين ومهندسى الصيانة لآلة الحصاد الجامعة فيات (Fiat) ذو عرض التشغيل ٤,٢م والمستخدمة فى حصاد العديد من محاصيل الحبوب المختلفة مثل القمح والأرز والشعير. وجود تآكل سريع للتروس المخروطية التى تنقل الحركة من ساقية رفع الحبوب إلى بريمة تفريغ وتوزيع الحبوب داخل الخزان ومن ثم حدوث توقف لهذه البريمة وبالتالى حدوث أعطال أخرى كثيرة. وبدراسة هذه المشكلة تبين ان بريمة تفريغ وتوزيع الحبوب مثبتة عند مستوى منتصف ارتفاع الخزان تقريبا مما يقلل من سعة الخزان الفعلية وبالتالى تكدس الحبوب عند مخرج بريمة التفريغ قبل امتلاء الخزان وبالتالى زيادة الحمل الواقع عليها وما يترتب على ذلك من تآكل سريع لتروس نقل الحركة إلى البريمة واستهلاك التروس و البريمة، هذا فضلا عن حدوث طحن وكسر لحبوب القمح مما يقلل من جودة الحبوب الناتجة وسرعة تلفها. بالإضافة إلى زيادة الوقت المفقود فى تغيير تروس نقل الحركة و إصلاح الأعطال المترتبة على ذلك وأيضا الوقت المفقود فى تفريغ الخزان لزيادة عدد مرات تفريغ خزان الحبوب لوحدة المساحة وبالتالى انخفاض السعة والكفاءة الحقلية للألة هذا فضلا عن زيادة تكاليف التشغيل الناتجة عن الاحلال المستمر لتروس نقل الحركة وتكاليف الإصلاح والصيانة.

لذا كان الهدف الرئيسى من هذه الدراسة هو تطوير وحدة نقل وتوزيع الحبوب لتنك الحبوب بآلة الحصاد الجامعة " فيات Fait" وذلك بتعديل وضع بريمة توزيع وتفريغ الحبوب داخل الخزان من مستواها عند منتصف الخزان إلى قمة الخزان فى مستوى أسفل غطاء الخزان مباشرة وذلك بزيادة طول ساقية الحبوب ٦٠ سم ، أيضا تطوير نظام نقل الحركة بين ساقية رفع الحبوب وبريمة التفريغ والتوزيع باستخدام عجلتين مسننتين وجنزير بدلا من التروس المخروطية. وقد اظهرات النتائج مايلى:

- ادى تطوير وحدة نقل وتوزيع الحبوب بالة الحصاد الجامعة إلى انخفاض قيم الفواقد الكلية للجبوب بنسب تراوحت من ١,٨ إلى ٤ % وكانت أقل قيم للفواقد الكلية للألة بعد التطوير بالمقارنة بها قبل التطوير وذلك عند جميع المتغيرات الأخرى تحت الدراسة. كما انخفضت قيم التلف الكلية(الظاهرى وغير الظاهرى) بحوالى ١٥-٣٠% باستخدام الألة المطورة. وقد تحسنت كفاءة الاداء للألة بعد التطوير حيث قد سجلت الالة بعد التطوير اعلى قيم لكفاءة الأداء (٩٥,٧٦%) مقارنة بـ (٩٥,١٤%) للالة قبل التطوير.
- ازدادت كل من السعة الحقلية الفعلية والكفاءة الحقلية إلى ٣,٠٣ فدان/ساعة و ٦٧,٤% على الترتيب مقارنة بـ ٢,٨٨ فدان/ساعة و ٦٣,٩ % على الترتيب قبل التطوير ويرجع ذلك إلى خفض الوقت المفقود فى الإصلاح والصيانة وتفريغ الخزان. كا انخفضت قيم التكلفة الفعلية (Criterion cost) إلى ١٢٠,٩جنيه/فدان للألة المطورة مقارنة بـ ١٨٣,٠٣ جنيه/فدان للألة قبل التطوير .
- هذا ويوصى باستخدام آلة الحصاد (Fiat) بعد التطوير وباستخدام سرعة درفيل ٣٠,٢ م/ث ونسبة سرعة ١ : ١,٣ ويتم الحصاد عند ٢٠,٢% محتوى رطوبى للحبوب حيث أعطت هذه التوليفة من المعاملات أفضل أداء لعملية الحصاد بالألة المطورة وأعلى إنتاجية.