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DEVELOPED UNIT FOR PICKING RICE STRAW FROM THE FIELD

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ABSTRACT

Within the framework of national strategy for management of agricultural wastes in the governorates of Egypt, trend prevails currently for dealing with these wastes to benefit from them. However, rice straw residues represent high quantities from these wastes. So, for the aims of this research has been carried out of two objectives. The first objective was to develop a machine which pick-up rice straw directly from the soil surface after harvesting, where mechanical design for this unit was already conducted and the efficiency of picking wastes increased than the traditional systems by a large percentage. Then, the second objective was to clean up the fields immediately after crop harvesting to increases the needed time to the next crops. The evaluation of the developed pick-up unit is carried out in 2011-2012 seasons in Agric. Eng. Dept., Mansoura Univ. to investigate the effect of some engineering parameters by analyzing the relative relationships between the various parameters such as the effect of forward speed, tilt angles and straw holders clearance on pick-up efficiency, losses, flow rate and productivity. The results indicated that the maximum value of straw pick-up efficiency was 98.60 % obtained at 0.784 km.h^{-1} of forward speed, tilt angle of 0.785 rad and straw holders clearance of 20 mm. At these operating parameters the minimum losses was obtained, the developed unit flow rate and productivity were 0.938 and 0.924 Mg.h^{-1} respectively.

INTRODUCTION

Rice straw is a major field based residue that is produced in large amounts in Egypt. In fact the total annual quantity about 3.1 million Mg (**Ministry of Agriculture and Land Reclamation, 2012**). **Nader and Ropinson (2010)** explained that the key of the marketing rice straw are identification profitable uses for it, cutting, and backing the straw in a manner that makes it most valuable to the client. Some growers have worked with end users to determine what type of processing makes the straw most valuable. They reported that some of the

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uses for rice straw; dairy feed, beef feed, erosion control, livestock bedding, building construction and mushroom production. Egyptian government is spare a good effort to transform rice straw from problems creating residue to a suitable pre-product "straw bales". **California Rice Commission (2009)** estimated that 3 to 5 % of the rice acreage has straw baled for use later for various purposes. Different balers are used in order to facilitate rice straw handling, to encourage rice straw useful use and to avoid the environment pollution due to burning of rice straw. **Nader and Ropinson (2010)** cleared that producers use a variety of methods for rice straw management as; straw walker harvester, rotary-style harvester with straw choppers, field chopping, cutter baler and swathing. **Kanafojski and Karwowski (1976)** stated that the working elements of pick-up are revolving elastic or rigid fingers arranged in several rows and the pickup mechanisms illustrate four different types: 1- The pickup with curved, radially positioned and elastic fingers. 2- Eccentric-controlled pickup types. 3- Pickups with cam-operated finger controls. 4- Band-conveyor pickups. **Sokhansanj and Turhollow (2002)** explain that the opportunities to reduce the collection cost when using the existing equipment comes from two sources: (1) eliminating some of the field operations and (2) improving field performance of the existing equipment. Any success in option (1) would result in direct cost reductions. For example, integrating cutting and raking into a single operation without sacrificing speed reduces the cost by 1.60 $\$.Mg^{-1}$ eliminating baling and instead using field chopped biomass may result in substantial cost reductions depending upon transportation distance. Reductions in costs by improving machine performance are also possible. **Abd El Mottaleb (1996)** designed combination equipment for removing, collecting, crushing, and baling field crop residues. The designed machine required less time, labour and cost and caused no soil compaction. **Kamei and Yamana (1998)** studied the effects of straw pickup operating speed on power requirement under a chain conveyor and a roller type. They showed that roller type offered higher packing density than the chain conveyor, but required more power, and the bale dry matter density per unit power was lower. **Morad et al. (2002)** found that the economic forward speed was 3 $km.h^{-1}$ corresponding to feed rates on 3.0, 2.4 and

5.7 $Mg.h^{-1}$ for rice straw, wheat straw and alfalfa respectively. **Ismail et al. (2009)** indicated that the highest value of straw pick-up efficiency was 98.21%, obtained at zero cm of straw holders height and the straw feed rate was adjusted at 2 $kg.min^{-1}$. While, the lowest value of the straw pick-up efficiency of 95.77% recorded at 102 rpm of the combined unit rotation speed at the straw feed rate was adjusted at 4 $kg.min^{-1}$. **Ismail et al. (2007)** indicated that the type of pick-up reel that used on a mower-conditioner and also used on other machines, for example, forage harvesters and combines illustrate three different types of mechanisms used in pick-up reels. There are reel teeth parallel with eccentric spider control, cam control and planetary gear control.

The aim of the research to improve the efficiency of pick-up unit.

MATERIALS AND METHODS

The developed pick-up unit:

As shown in Figs. 1 and 2 the developed pick-up unit consists of the following components:-

1- Header system: It consisted of:

- **a-Front pick-up shaft:** It picks the straw with single pick-up tines.
- **b- Straw pickup chains:** it is the Japanese combine system.
- **c- Straw holders:** it hold the straw and controls its density.

2-Elevator: it has a straw elevator chains is a part of claw chains.

3- Header lifting system: it lifted by hydraulic cylinder connect with the hose of the lifting device.

4- Chassis: it made from iron beams with U section.

5- Cover sheets: steel sheet with 1 mm thickness.

Pick-up unit transmission system

The developed pick-up unit was side mounted on the 47.8 kW (65 hp) Nasr tractor and is supplied with power by tractor PTO. Fig. (1) shows the photograph of pick-up field residues unit. The main dimensions of the developed unit are as shown in Fig. (2) were have total length of 3840 mm, total width of 2250 mm and total height of 1540 mm. Throughout the developed pick-up unit do the following operations: -

1-The first:- Picking-up the residues of rice straw directly from the soil surface after harvesting.

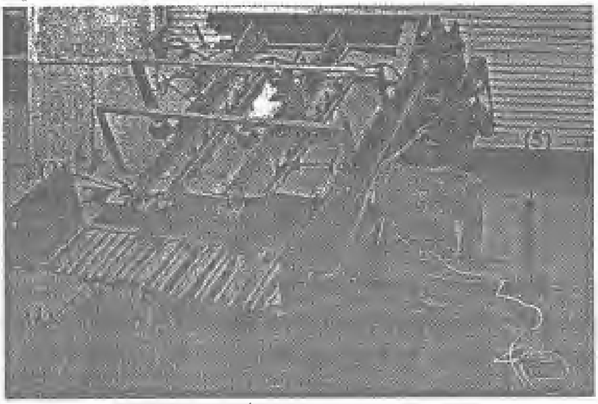

Fig. 1: The front view for the developed pick-up unit.
1- Front pick-up shaft 2- Pickup chains 3- Straw holders 4- Elevator 5- Header lifting

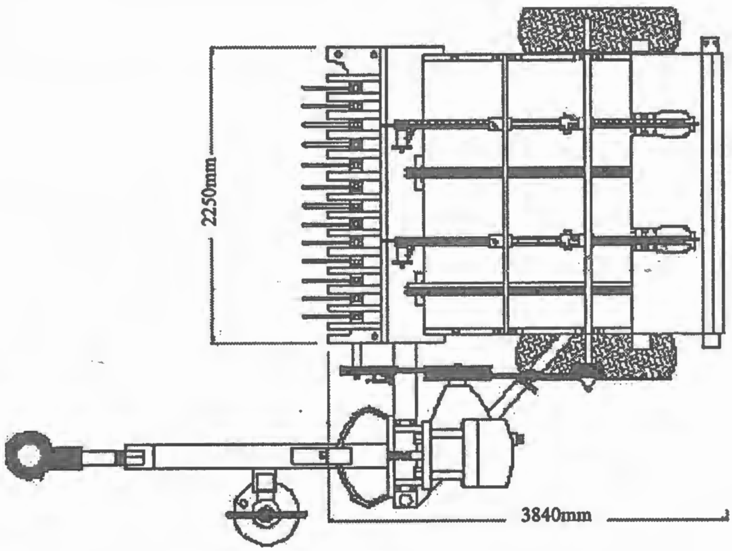

Fig. 2: The developed pick-up unit.

2-The second:- Elevate the straw residues to backing it.

Rice straw properties:

The rice straw properties after harvesting were measured. The rice straw moisture content is about 25±3% and the average length is about 550 mm. The developed pick-up unit was tested in farm Ag. Eng. Dept. Mansoura Univ. in 2011-2012 seasons to evaluate pick-up unit efficiency. For optimization of the affecting the performance of investigated unit, experiments were conducted with four levels of forward speed of 0.784, 1.079, 1.252 and 1.555 km.h^{-1} with three levels of pick-up unit tilt angle of 0.611, 0.698 and 0.785 rad and three levels of straw holders clearances of 10, 20 and 40 mm. The tests were replicated three times for each treatment. The data were statistically analyzed to determine the effect of the above variables on straw pick-up efficiency, straw pick-up losses, picked straw flow rate and pick-up unit productivity.

To evaluate the developed pick-up unit the following equations used (**El-Sayed, 2009**)

1- Pick-up efficiency (E, %) was calculated as follows:

$$E = \frac{Pm}{Rm + Pm} \times 100$$

Where: Pm: straw picked mass, g Rm: rest straw mass, g;

2- Pick-up losses (L, %) was calculated as follows:

$$L = \frac{Sm - Pm}{Sm} \times 100$$

Where: Sm: mass of straw residues, g

3- Picked straw flow rate (FL, Mg.h^{-1}) was calculated as follows:

$$FL = \frac{Pm}{Et} \quad , \quad Mg.h^{-1}$$

where: Et: straw elevating period, min

4- Pick-up unit productivity (P, Mg.h^{-1}) was calculated as follows:

$$p = \frac{Pm}{Pt} \quad , \quad Mg.h^{-1}$$

Where: Pt : productivity time, h.

RUSULTS AND DISCUSSION

Factors Affecting the Straw Pickup Efficiency

Generally, increasing the developed unit forward speeds decreases the straw pickup efficiency at each of different pick-up tilt angles and straw holders clearance that can be explained with using low forward speed for the developed unit requires proper adjustment for the pick-up tilt angles and the straw holders clearance, which these factors requires to be adjusted at low positions to raise the pickup efficiency and vise versa. For example the best combination set for the previous adjustable factors was recorded at the lowest value of the developed unit forward speed of 0.784 $km.h^{-1}$ with 0.785 rad pick-up tilt angle and 10 mm straw holders clearance. The peak values of straw pickup efficiency were obtained at those positions of these adjustable factors as shown in Fig. (3). Moreover, the highest value of straw pickup efficiency was 98.35 % as shown in Fig. (3-A) was obtained at 0.784 $km.h^{-1}$ of forward speed and the pick-up tilt angle was adjusted at 0.785 rad, while the lowest value of the straw pickup efficiency were 90.50 % which recorded at 1.555 $km.h^{-1}$ of forward speed when the pick-up tilt angle was adjusted at 0.611. On the other hand, the highest value of straw pickup efficiency were 97.94% as shown in Fig. (3-B) was obtained at 0.784 $km.h^{-1}$ of forward speed and straw holders clearance was adjusted at 40 mm, while the lowest values of the straw pickup efficiency were 91.05% which recorded at 1.555 $km.h^{-1}$ of forward speed when the straw holders clearance was adjusted at 10 mm. These results may be due to at the lowest forward speed the machine has a greatly chance to pick the large amount of rice straw from the soil surface then the high both of tilt angle and the holders clearance help to hurried raise the straw picked.

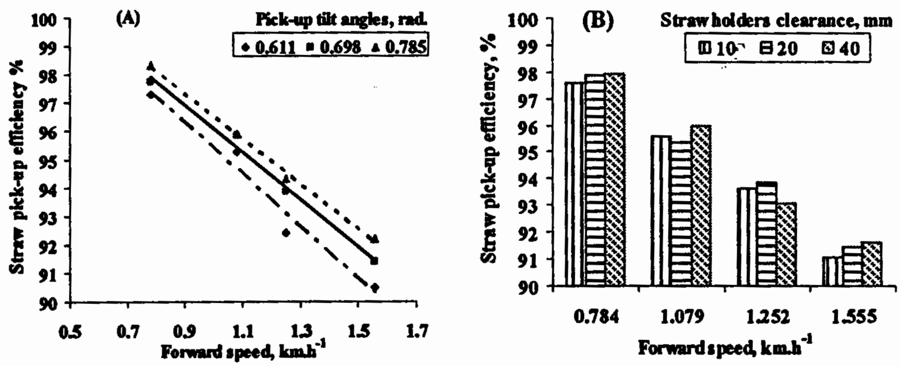

Fig. 3: Effect of the forward speed on the straw pick-up efficiency at the different pick-up tilt angles and straw holders clearance.

The statistically analysis of SAS shows that there is high significance differences between the treatments of forward speed, pickup tilt angles and straw holders clearance with the straw pickup efficiency. Also the total interaction between different treatments show high significant effect with (P = 0.0001) and (C.V = 0.5818). The multiple regression analysis applied to relate the change in straw pickup efficiency with the change in the forward speed, tilt angles and straw holders clearance for all treatments. The obtained regression equation was in the form of:

$$\mathbf{Eff = 71.495\, f + 6.543\, fa + 0.045\, fc}$$

Where: Eff: pick-up efficiency, % f : forward speed, $km.h^{-1}$
a : pick-up unit tilt angle, rad c : straw holders clearance, cm

The analysis of variance for the data of straw pickup efficiency at different of the developed unit forward speeds, tilt angles and straw holders clearance indicated a highly significant differences between the treatments with (R^2 = 0.9557).

Factors Affecting the Straw Pickup Losses

The relationships between the developed unit forward speed and the straw pick-up losses at the different pick-up tilt angles and straw holders clearance are illustrated in Fig. (4). Hence, from the figure it can clear that the increasing of forward speeds increases the straw pickup losses at each of different pick-up tilt angles and straw holders clearance. On the other side, the maximum and minimum values of the straw pickup losses were 9.50 and 1.65% respectively as shown in Fig. (4-A) for 1.555 $km.h^{-1}$ of forward speed, 0.611 rad of pick-up tilt angle and straw holders clearance of 10 mm, whereas the maximum and minimum values of the straw pickup losses were 8.95 and 2.06% respectively as shown in Fig. (4-B) for 0.784 $km.h^{-1}$ of the prototype forward speed at 0.785 rad of the pick-up tilt angle and straw holders clearance of 40 mm. Consequently,

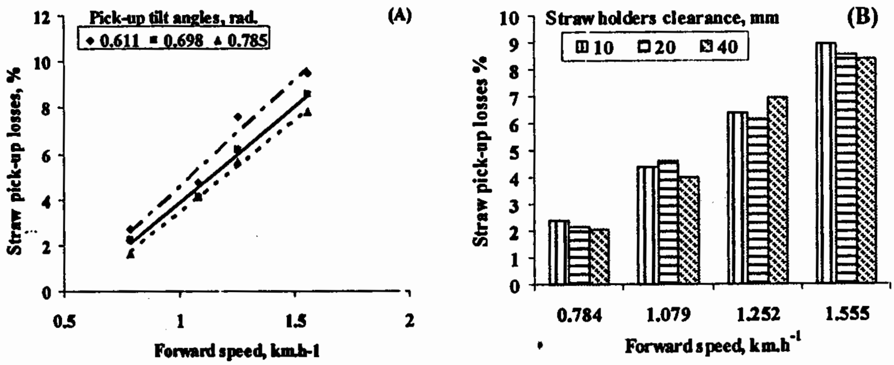

Fig. 4: Effect of the forward speed on the straw pick-up losses at the different pick-up tilt angles and straw holders clearance.

the lowest losses or the best combination set for the units adjustments were achieved at 0.784 $km.h^{-1}$ of the forward speed and 40 mm of straw holders clearance respectively. The pick-up losses results may be due to the fact of the high forward speed the low pick-up straw, by the same way the lowest the holders clearance the straw accumulate then the losses increase.

The statistically analysis of SAS showed that, there is high significance differences between the treatments of forward speed, pickup tilt angles and straw holders clearance with the straw pickup losses. Also the total interaction between different treatments show high significant effect with (P = 0.0001) and (C.V = 10.1649). The multiple regression analysis applied to relate the change in straw pickup losses with the change in the forward speed, pickup tilt angles and straw holders clearance for all treatments. The obtained regression equation was in the form of:

$$L = 9.519\ f - 6.543\ fa - 0.045\ fc$$

Where: L : pick-up losses, %

The analysis of variance for the data of straw pickup losses at different of the developed unit forward speed, pickup tilt angles and straw holders clearance indicated a highly significant differences between the treatments with ($R^2 = 0.972$).

Factors Affecting the Picking Straw Flow Rate

The benefits of evaluating the picking straw flow rate are arranges as the following, first recognize about the maximum ability of the pick-up unit capacity, second determine the best combination limits for the pick-up unit factors which dealing with the different densities of straw residues for the various rice species. The relationships between the forward speed and the picking straw flow rate at the different pick-up tilt angles and straw holders clearance can be shown in Fig. (5).

Direct relationships are presented in Fig. (5-A) between the forward speed and the picking straw flow rate at the different pick-up tilt angles. The results indicated that the highest value of picking straw flow rate was 2.01 $Mg.h^{-1}$ obtained at 1.555 $km.h^{-1}$ of forward speed and pick-up tilt angle was adjusted at 0.785 rad, while the lowest values of straw feed rate was 0.969 $Mg.h^{-1}$ obtained when the forward speed was 0.784 $km.h^{-1}$ and at pick-up tilt angle of 0.611 rad. Meanwhile, Fig. (5-B) shows that the direct relationships between the forward speed and the picking straw flow rate at the different straw holders clearance. The results indicated that the highest value of picking straw flow rate was 2.021 $Mg.h^{-1}$ obtained at 1.555 $km.h^{-1}$ of forward speed and the straw holders clearance was adjusted at 10 mm. While the lowest values of straw flow rate was 0.951 $Mg.h^{-1}$ obtained when the forward speed was 0.784 $km.h^{-1}$ and the straw holders clearance was adjusted at 10 mm. The results may be due to the lowest forward speed and high the holders clearance make together to opportunity the straw flow smoothly with the little amount of straw picked per unit area.

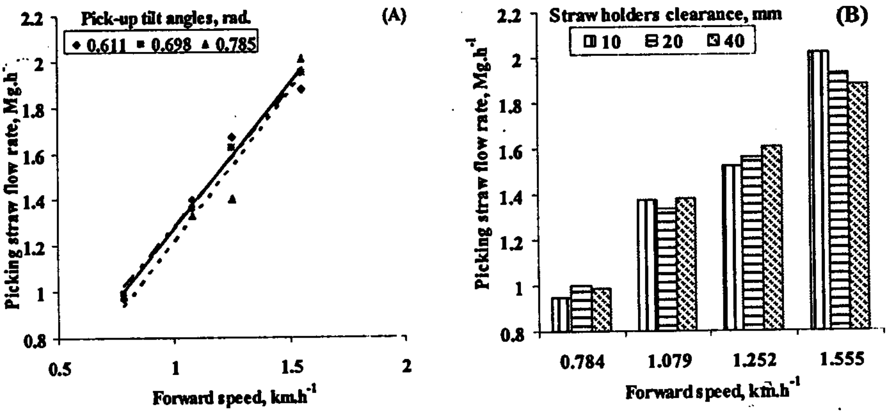

Fig. 5: Effect of the forward speed on the picking straw flow rate at the different pick-up tilt angles and straw holders clearance.

The statistically analysis of SAS shows that there is high significance differences between the treatments of the forward speed, tilt angles and straw holders clearance with the picking straw flow rate. Also the total interaction between different treatments show high significant effect with (P = 0.0001) and (C.V = 5.4480).

The multiple regression analysis applied to relate the change in picking straw flow rate with the change in the prototype forward speed, tilt angles and straw holders clearance for all treatments. The obtained regression equation was in the form of:

$$\mathbf{Fr = 20.475\ f - 1.197\ fa - 0.052\ fc}$$

Where: Fr: picking straw flow rate, $Mg.h^{-1}$

The analysis of variance for the data of picking straw flow rate at different of the developed unit forward speed, pickup tilt angles and straw holders clearance indicated a highly significant differences between the treatments with ($R^2 = 0.9939$).

Factors Affecting the Pick-Up Unit Productivity

The evaluation of the pick-up unit is carried out to investigate the effect of the engineering parameters on the performance of the connected units totally together. From the economical point of view to operate the machines, the evaluation of the productivity to any new design is very important to make the comparison between the conducted pick-up and the other connected units as balers drum, to make the decision of replacing the best one. The relationships between the developed pick-up unit forward speed and the pick-up unit productivity at the different tilt angles and straw holders clearance are illustrated in Fig. (6). Generally, there are a direct relationship between the developed unit productivity and the forward speed as shown in Fig. (6). The results cleared in Fig. (6-A) indicated that the highest value of the pick-up unit productivity was 1.85 $Mg.h^{-1}$ obtained at 1.555 $km.h^{-1}$ of the forward speed and the pick-up tilt angle was adjusted at 0.785 rad. Also the results indicated that the lowest value of pick-up unit productivity was 0.94 $Mg.h^{-1}$ obtained at the forward speed of 0.784 $km.h^{-1}$ and the tilt angle of 0.611 rad.

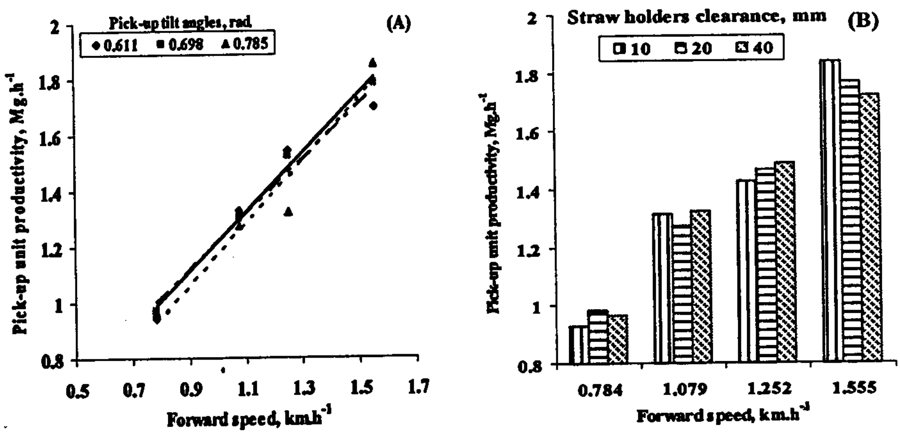

Fig. 6: Effect of the forward speed on the pick-up unit productivity at the different pick-up tilt angles and straw holders clearance.

Consequently, the results as shown in Fig. (6-B) indicated that the highest value of pick-up unit productivity was 1.84 $Mg.h^{-1}$ obtained at 1.555 $km.h^{-1}$ of the forward speed and the straw holders clearance was adjusted at 10 mm. Moreover, the results indicated that the lowest value of pick-up unit productivity was 0.93 $Mg.h^{-1}$ respectively obtained when the forward speed of 0.784 $km.h^{-1}$ and the straw holders clearance was adjusted at 10 mm. The results of pick-up unit productivity may be due to the high forward speed cause the high production although the high losses that is because the high losses don't more than 10.56 % then the obtained production at the high forward speed increased about 1.16 $Mg.h^{-1}$ from the lowest it.

The statistically analysis of SAS shows that, there is high significance differences between the treatments of forward speed, pickup and straw holders clearance with the pick-up unit productivity. Also the total interaction between different treatments show high significant effect with (P = 0.0001) and (C.V = 5.4453). The multiple regression analysis applied to relate the change in the pick-up unit productivity with the change in the forward speed, pickup tilt angles and straw holders clearance for all treatments. The obtained regression equation was in the form of:

$$P = 1.228\ f - 0.072\ fa - 0.003\ fc$$

Where: P: the pick-up unit productivity, $Mg.h^{-1}$

The analysis of variance for the data of the pick-up unit productivity at different of forward speed, pickup tilt angles and straw holders clearance indicated a highly significant differences between the treatments with (R^2 = 0.956).

CONCLUSION

The conclusions of this paper are summarized as follow:

1- The results indicated that the maximum value of straw pickup efficiency was 98.60 % and the lowest value of the straw pickup losses was 1.40% obtained at 0.784 $km.h^{-1}$ of forward speed, tilt angle of 0.785 rad and straw holders clearance of 20 mm.

2- The results indicated that the highest values of picking straw flow rate and pick-up unit productivity were 2.20 and 2.03 $Mg.h^{-1}$ respectively at 1.555 $km.h^{-1}$ of the forward speed, tilt angle of 0.785 rad and straw holders clearance of 20 mm.

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الملخص العربى

تطوير وحدة للقط قش الأرز حقليا

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** ناهد خيري اسماعيل   *أحمد شوقي السيد السيد

يهدف البحث إلى رفع كفاءة وحدة لقط قش الأرز وذلك عن طريق تطوير آلة بسيطة محلية الصنع تناسب الحيازات الصغيرة لصغار المزارعين حيث تقوم هذه الآلة بالتقاط ورفع مخلفات قش الأرز آليا من علي سطح الأرض كبديل للتصميم الحالي لدرفيل الإلتقاط الخاص بآلات التبييل الحقلية, ولتحقيق الهدف من هذا البحث تم تنفيذ مراحل الدراسة على النحو التالي:

١ - تصنيع وحدة جديدة ذات سعة اعلي من التصميم الحالي لدرفيل الالتقاط حيث تعتمد فكرة التصميم الجديد علي استخدام درفيل أمامي ذو شوك لاقطة مفردة بالإضافة إلي الجنازير اللاقطة وكذلك الجنازير الناقلة بواسطة الأصابع ذات السرعة العالية حيث تم الاستعانة ببعض الأجزاء الموجودة في كومباين الأرز الياباني لتنفيذ التصميم الجديد، كذلك تم تزويده بإسطوانة هيدروليكية للتحكم في ارتفاع صدر الالتقاط عن مستوي سطح الأرض كبديل للنظم الميكانيكية الحالية مما أدي لزيادة كفاءة الالتقاط بشكل ملحوظ.

٢- تقييم الأداء للوحدة المطورة والتى صُمّمت لكي تعمل جانبيا علي يمين الجرار .

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متغيّرات الدراسة: تم إختبار وتقييم أداء الوحدة المطورة تحت متغيرات دراسية بمستويات مختلفة وكانت عوامل الدراسة كالأتي:-

١- أربعة سرعات أمامية للوحدة المطورة وهي (٠,٧٨٤, ١,٠٧٩, ١,٢٥٢, ١,٥٥٥ كم.ساعة-١).

٢- ثلاثة زوايا ميل لصدر الالتقاط وهي (٠,٦١, ٠,٧٠, ٠,٧٦ زاوية نصف قطرية).

٣- ثلاثة خلوصات لماسك القش وهي (١٠, ٢٠, ٤٠ مم) .

وقد أظهرت النتائج أن أعلي كفاءة إلتقاط ٩٨,٦٠% وذلك عند إستخدام سرعة أمامية للآلة الجديدة ٠,٧٨٤ كم.ساعة-١ وكانت زاوية ميل إطار وحدة الالتقاط ٠,٧٨٥ بالتقدير دائري بينما تم استخدام ٢٠ مم خلوص ماسك القش لجهاز الالتقاط. ووجد أنه عند نفس مستويات عوامل الدراسة كانت أقل نسبة لفقد القش، كما كان معدل السريان وإنتاجية الآلة ٠,٩٣٨ ، ٠,٩٢٤ ميجاجرام.ساعة-١ على التوالى.