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MODIFICATION OF THE HEADER OF A JAPANESE COMBINE TO SUIT FLAX CROP PULLING

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ABSTRACT

The aim of the present investigation is to modify the header of a Japanese combine (ISEKI HL.3200) to suit pulling of flax crop and test, evaluate its performance under different operating conditions. The modified combine was evaluated and tested at El-Gemmiza Agricultural Research Station, El-Gharbia Governorate under four forward speeds of 1.6, 2.4, 3.0, 3.5 km/h, three belt speeds of 1.5, 2.0, and 2.5 m/s and three pulling device inclination angle of 15°, 30°, 45° with horizontal. Combine productivity, stalks losses, stalks damage and energy requirements had been determined. The results showed that, it is possible to use the Japanese combine with some modifications on the header to be used for pulling of flax crop. Optimum values for the operation conditions were obtained at operating forward speed of 2.4 km/h and pulling belt speed 2.0 m/s (kinematics' parameter of 3.0) and pulling header inclination angle 45° deg. Where as given the best results of pulling efficiency (9[illegible].58%), stalk damage (2.81%) actual field capacity 0.63 fed/h and capsule losses percentage 1.15%. Harvesting costs of the developed combine were compared with the manual pulling. It was found that harvesting costs were reduced using the developed combine by about 40.4% comparing with the manual harvesting costs.

INTRODUCTION

Flax plant (Linum Usitatissimum L) is considered one of the most important economical crops due to, it is a source of heavy (idle) oil and special fibers used in different scopes of industry. So, the cultivated area in Egypt reach up to 70000 feddan yearly. Harvesting operation for flax crop constitutes one of the most tedious, drudgeries and labor consuming operation. Until now flax is harvested manually by hand pulling in Egypt. The flax harvesting machine are not suitable to be used on small holdings in addition to their high initial price. The main disadvantages of the traditional flax hand pulling method are the high labor cost and the difficulty of getting the harvest in during the relatively short optimum period 4-7 days for any given crop. Using a small combines to pull (uproot) flax crop may overcome this problem with introducing a multipurpose combine to satisfy the principal of machinery intensification.

Pulling up or uprooting, as a harvest technique, is used to extract the whole plant with its roots from soil in (once over) operation. It constitutes one of the most tedious, and labor consuming operation in production sequence.

Abd El-Maksoud (1975) stated that, a very limited number of large mechanical flax combines are used in the public sector farms, but these are expensive equipment, and it needs high technical operation and maintenance.

Broddiford *et al.* (1975) developed a four-row puller header for harvesting soybean supported on a conventional combine grain platform. Pulling reduced the average gathering loss, average shatter loss, average stalk and lodged loss to be 54%, 62%, 21% respectively, of that with conventional grain platform with a flouting cutter bar.

Kanafojski and Karwowski (1976) stated that flax harvesting by mowing increased the percentage of fiber losses (18 percent). In order to avoid such losses, flax is harvested by pulling stalks out of the soil together with the roots. Singh (1981), mentioned that the power requirement increased linearly with an increase in the forward speed of the harvester machine. Ibrahim (1983) studied the physical and mechanical properties affecting the pulling process for flax. The pulling force required to uproot flax plant ranged from 8 to 34 N. The coefficient of friction ranged from 0.25 to 0.47. Hunt (1983) stated that the forward speed is probably the most important factor in optimizing the performance of machine harvester. Several investigations have determined that total losses increase rapidly as forward speed increases. Summner et al., (1984) examined effect of pulling angle on the required force to pull cotton stalks. It was found that there was no significant difference in the pull force when plants were pulled at zero and 45 degree from vertical. Abo El-Eas et al., (1985) designed a mounted cotton stalk pulling machine, using two inversely rotating drums as a pulling mechanism. To increase the coefficient of friction between the drums and the stalks, the drums were covered with a flat belt material. Klenin et al., (1985) and Rodejief et al., (1986) reported that belt and roller type pullers are used to harvest flax. Jacobs and Harrell (1986) reported that the fixed costs may vary from 60- 80% of the total machinery cost. Operating costs are these costs with develop as a result of using the machine. Abd El-Wahab (1987), designed a lentil walker puller, to uproot lentil plants. He compared harvesting costs for his developed machine with the traditional manual pulling method. It was found that harvesting costs were reduced using his developed puller, by about 27.62% of manual harvesting costs. Hamad et al., (1991) mentioned that pulling efficiency increase with a decreasing rate as the speed ratio increases. Flax capsule losses percentage decreases with a decreasing rate as the speed ratio increases from 1.0 to 3.0, then it tends to increase with the further increase in speed ratio. They added that pulling efficiency reaches its maximum value of 92% at a speed ratio equal to 4.07.

The main objectives of the present study as following:

- Modify and test a Japanese combine to suit flax pulling by developing a combine header.
- Study the effect of some processing parameters such as, forward speeds (1.6, 2.4, 3.0, 3.5 km/h), belt speed of (1.5, 2.0, 2.5 m/s) and inclination angle (15, 30, 45 deg.).
- Comparing and evaluating the developed combine performance with the traditional method (manual pulling) with respect to, pulling efficiency and operating costs.

MATERIALS AND METHODS

To fulfill the objectives of this study, a Japanese combine has been modified and tested. The technical specifications and operating parameters of the developed combine is shown in Table (1) and Fig. (1).

Table(1):Technical specifications and operating parameters of the developed combine

Item	Specification	
Model	ISEKI	
Type	H L. 3200	
Made	Japan	
Engine power hp (kW)	32 (23.78)	
Reaping width mm	1375	
Reaping unit shift adjustment	hydraulic system	
Dimensions (mm)	**When working**	**When traveling**
Overall length	3900	4100
Overall width	2620	1700
Overall height	1890	1890
Mass (kg)	1900	

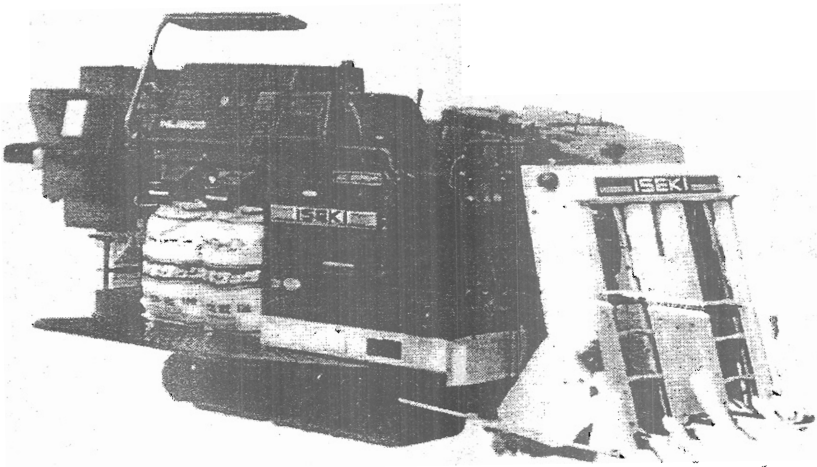


Fig. (1) The construction and the main components of the original combine.

The original combine was designed for rice harvesting. Such investigations showed that this combine is not qualified to deal with flax crop due to the difference between the original head combine and the properties of flax plants.

To cover all problems facing the combine performance the original head was modified. The modifications on the header were as following:- Design and constructed the pulling device with suitable dimensions and rotating speed on engineering basics to pull out flax plants from the soil. The pulling device consists of two endless belts running over the driving pulleys, the driven pulley and the rollers which keep the two belts passed together.

Description of the flax stalks motion through pulling header:

The motion of flax stalks is started from the crop entrance to gathering device until ejected from the combine. The dividers (A) feed the flax plants to the rollers (B) which grip them at the point of contact of the two belts. The plants are held over the zone where the belts are in close content as shown in Fig. (2). Stalks gripped by the belt through the pulling zone (C) and due to the combination of belt motion and the forward travel of the combine they jerked upwards. The plucked plants are still gripped after leaving the pulling zone and conveyed to the left of the combine travel direction.

Flax harvest experiment was conducted at a constant moisture content of 41.35% stalk- 30.2% capsules and soil moisture content of 18.72% (wet basis).

The used flax crop was of variety (Sakha 1). The physical characteristics were estimated for plants. As shown in the following Table:

Table (2): The measured physical properties for flax crop (Sakha 1):-

Physical characteristics	Average value
Plant height (cm)	101.5
Technical length of stalks (cm)	82.45
Stem diameter (mm)	1.75
Number of capsules per plant	10.05
Capsules diameter (mm)	6.5
Seed yield kg/fed	600
Straw yield (Mg/fed)	3.5
Root length (cm)	8.0
Root diameter (mm)	2-6

* The physical properties of the experimental field were measured and summarized in table (3).

Table (3) : The physical properties of the experimental soil.

Fine sand	Coarse sand	Silt	Clay	Clay rate	Soil texture
14.64	0.68	40.83	43.85	0.75	Clay loam

Treatments and experimental measurements:-

During the experiments, the following parameters were examined:

1- Four different combine travel speeds (1.6, 2.4, 3.0, and 3.5 km/h)
2- Three linear speeds of pulling unit (1.5, 2.0, 2.5 m/s)
3- Three pulling head inclination angles (15°, 30°, 45°)

The relation between combine forward speed (km/h) and pulling belt speed is considered (kinematics parameters, K), which were (3.38 , 2.25 , 1.8 , 1.54 , 4.5 , 3 , 2.4 , 2.06 , 5.6 , 3.75 , 3 and 2.57).

Measurements:-

During test performance of the modified combine the following items were measured:

Pulling efficiency (E_p):-

Pulling efficiency is calculated by using the following equation (Hamad *et al.* 1991) and (Abo El-Eas et. al. 1985)

$$E_p = \frac{N_1}{N_1 + N_2} \times 100$$

where:-

N_1= Number of uprooted stalks (pulled plants)

N_2= Number of missed stalks (unpulled plants)

Stalk damage percentage (S_d):-

$$S_d = \frac{D_s}{T_s} \times 100$$

where:-

D_s= The mass of damaged stalks, (kg).

T_s= The total mass of stalks, (kg).

Capsule losses (C_L):-

$$C_L = \frac{C_m}{C_T} \times 100$$

where:-

C_m= The mass of capsule loss, g.

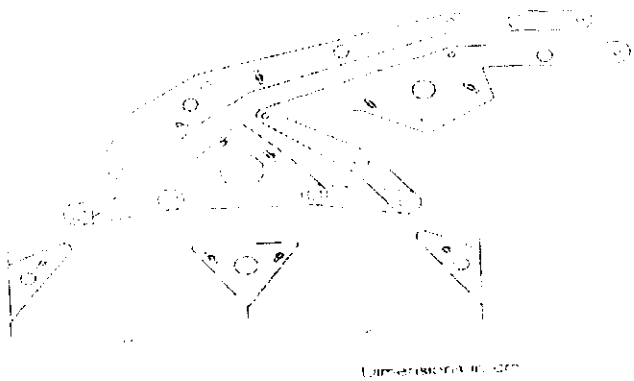
C_T= The mass of capsule, g.

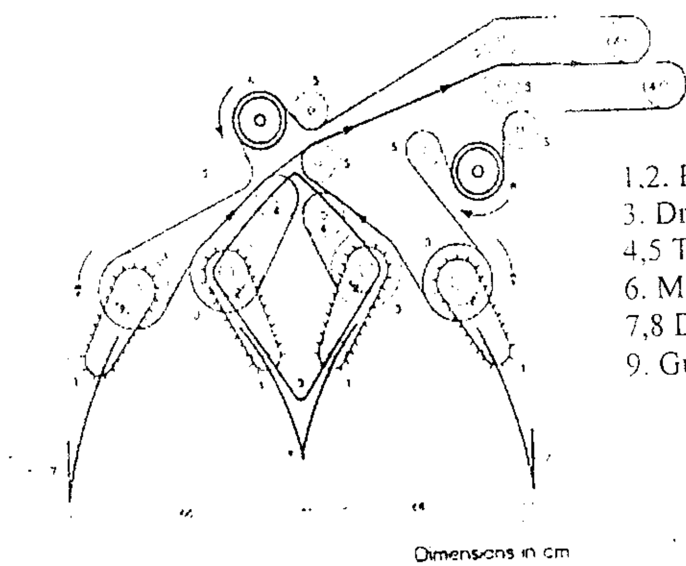
- Actual field capacity, field efficiency, and pulling cost were determined according to Kepner *et al.* (1982).
- The required mechanical energy (EM) was calculated by using the following equation (Taieb 1990).

$$EM = \frac{36.10 \times Fc}{F_{ce}} .... Mj/fed$$

Where:-

F_c = Fuel consumption, L/h. F_{ce}= Effective field capacity, fed/h.





1,2. Feeding pulley.
3. Driving pulley.
4,5 Tension pulley.
6. Main driving pulley.
7,8 Dividers.
9. Guiding cover.

Fig. (2) Schematic diagram of the modified header.

RESULTS AND DISCUSSION

In order to evaluate the combine performance during pulling flax crop using modified head, the different criteria of pulling operation, such as quality properties of yield, stalk damage percentage, and other factors related to pulling efficiency, capsule losses percentage, machine productivity and energy requirements during pulling operation were taken into consideration.

Pulling efficiency

Pulling efficiency is considered one of the most important functions for pulling. The observations reported in Fig. (3) show the effect of combine travel speed, linear speed of pulling unit and pulling head inclination angle on pulling efficiency.

The data revealed that at any head inclination angle, the pulling efficiency decreased as the combine forward speed increased, the results indicated that increasing forward speed from 1.6 to 3.5 km/h cause a corresponding decrease in the pulling efficiency from 93.17 to 86.44, 95.71 to 89.23, and 97.35 to 91.17% at three different belt speed of 1.5, 2.0, 2.5 m/s at 45° pulling head inclination angle. The decrement in pulling efficiency while increasing forward speed is due to the excessive load on feeding roller, so that some of stalks tends to go down to soil surface before catching by pulling belts causing more header losses and low header efficiency.

Meanwhile, the data indicated that pulling efficiency tends to increase as the belt speed increased from 1.5 to 2.5 m/s. This increase in pulling efficiency with the increasing in the belt speeds may be attributed to the increase in pulled stalks number in time unit, which leads to maximum pulling efficiency. Also, it can be seen that pulling efficiency increased with increasing the pulling inclination angle from 15° to 45°, this trend was due to the decrease of pulling resistance. This leads to maximum pulling efficiency.

Stalk damage percentage (Sd) :-

The obtained results (Fig. 4) indicated that stalk damage increased as travel speed increased from 1.6 to 3.5 km/h. Meanwhile, the data indicated that stalk damage tends to decrease as the pulling inclination angle increased from 15 to 45 deg.. This decrease in stalk damage with the increase in the inclination angle with horizontal may be attributed to the incensement of contact area between flax stalks and pulling belt which in turn led to reducing the pressure on a unit length of stalks. The minimum value of stalk damage of 2.6% was obtained at forward speed of 1.6 km/h, belt speed of 1.5 m/s and pulling inclination angle of 45°. Whereas the maximum value of stalk damage reached 6.15% at forward speed of 3.5 km/h, belt speed of 2.5 m/s and 15 deg. pulling inclination angle.

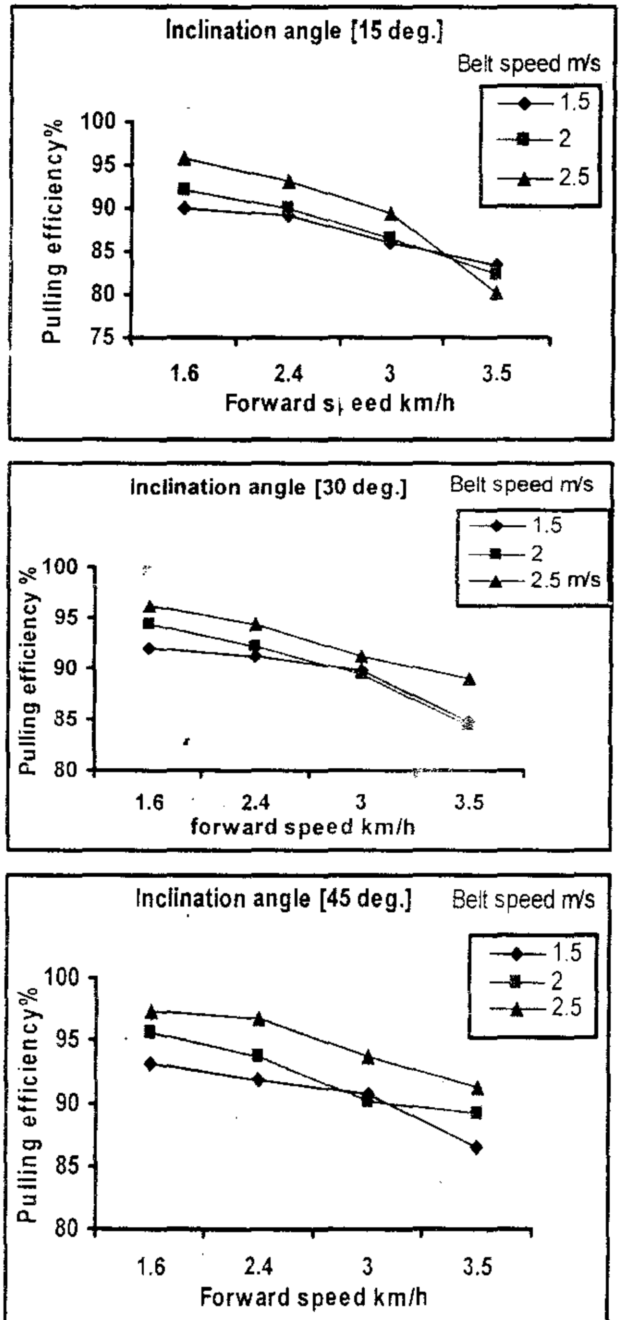


Fig. (3): The effect of forward speed and belt speed on pulling efficiency at the different inclination angles.

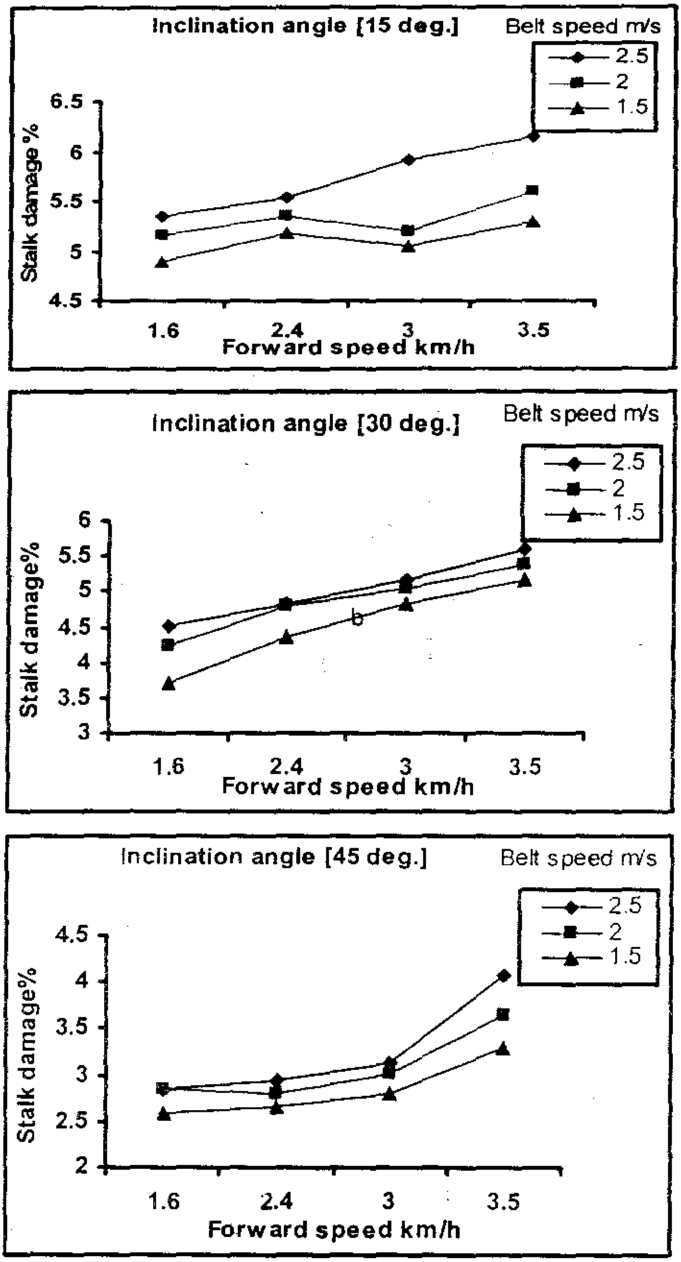


Fig. (4): The effect of forward speed and belt speed on stalk damage at different inclination angles under study.

Capsule losses:-

The observations reported in (Fig.5) show the relation between combine forward speed and capsule losses at three various levels of belt speed and 45° pulling inclination angle. The increase of combine forward speed from 1.6 to 3.5 km/h increases capsule losses from 0.6 to 2.25, from 0.8 to 2.35 and form 1.28 to 3.35% at belt speed of about 1.5, 2.0, and 2.5 m/s, respectively.

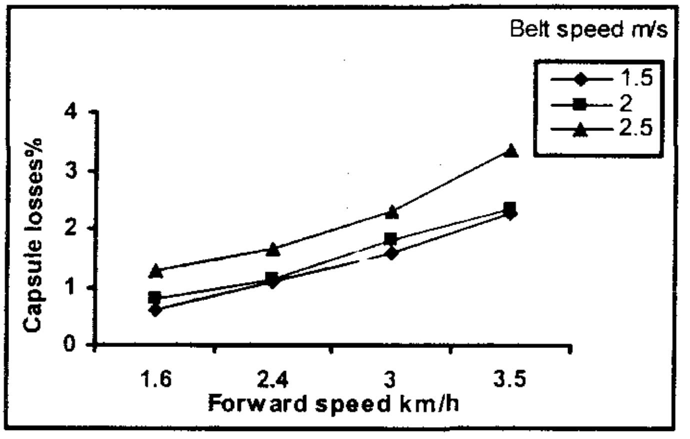


Fig. (5): The effect of forward speed and belt speed on capsule losses at 45 deg. inclination angle.

Actual performance rate and field efficiency

The field capacity affected mainly by the forward speed as shown in (Fig. 6). The results revealed that, the actual field capacity increased and field efficiency decreased with increasing the forward speed. this may be due to the increasing rate of the actual field capacity was smaller than the increasing rate of the theoretical field capacity.

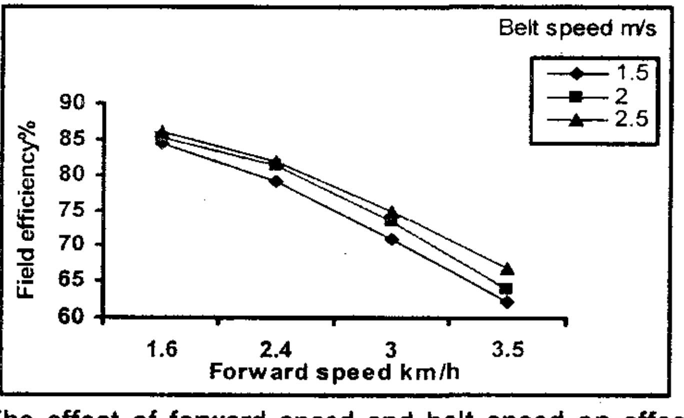


Fig. (6): The effect of forward speed and belt speed on effective field capacity at 45 deg. inclination angle.

The field capacity was increased from 0.44 to 0.71 fed/h as the combine forward speed increased from 1.6 km/h to 3.5 km/h. Where the kinematics' parameter decreased from 3.38 to 1.54, at the same belt speed 1.5 m/s. The maximum actual field capacity of (0.76 fed/h) under belt speed of 2.5 m/s and forward speed of 3.5 km/h (kinematics' parameter of 2.57). While the minimum actual field capacity of (0.44 fed/h) was recorded under belt speed 1.5 m/s and combine forward speed of 1.6 km/h (kinematics parameters of 3.38). Compared with manual pulling (one worker) which recorded field capacity of 0.03 fed/h.The data indicated that field efficiency tends to decrease as the forward speed increased, (Fig. 7). The highest value of field efficiency (86.12%) was occurred at forward speed of 1.6 km/h. Meanwhile, the lowest value was 62.15% at 3.5 km/h.

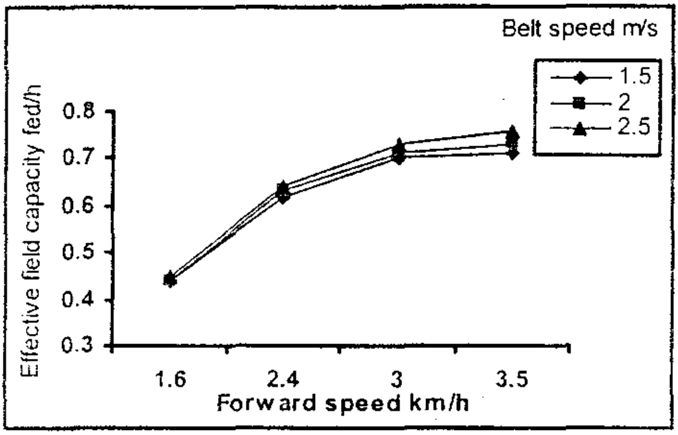


Fig. (7): The effect of forward speed and belt speed on field efficiency at 45 degree inclination angle.

Fuel consumption and energy required for pulling process:-

Figure (8 and 9) show the fuel consumption and energy requirements as affected by different combine forward speed and belt speed.

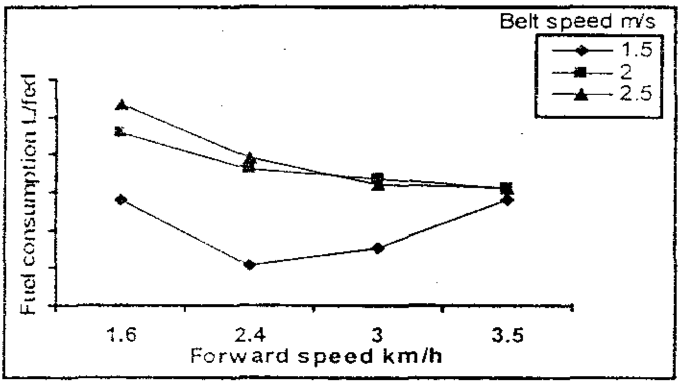


Fig. (8): The effect of forward speed and belt speed on fuel consumption at 45 degree inclination angle.

It is remarkable that the fuel consumption and energy required were decreased from 6.98 to 5.85 L/fed and 251.9 to 211.38 MJ/fed as combine forward speed was increased from 1.6 to 3.5 km/h, where the kinematics' parameter decreased from 5.6 to 2.57, at the same belt speed 2.5 m/s. The minimum fuel consumption and energy required of 5.70 L/fed and 205.92 MJ/fed under belt speed of 1.5 m/s and combine forward speed of 3.5 km/h (kinematics parameter of 1.54). On the other side, the maximum fuel consumption and energy required of 6.98 L/fed and 251.9 MJ/fed were recorded under belt speed of 2.5 m/s and combine forward speed of 1.6 km/h (kinematics' parameter of 5.6)

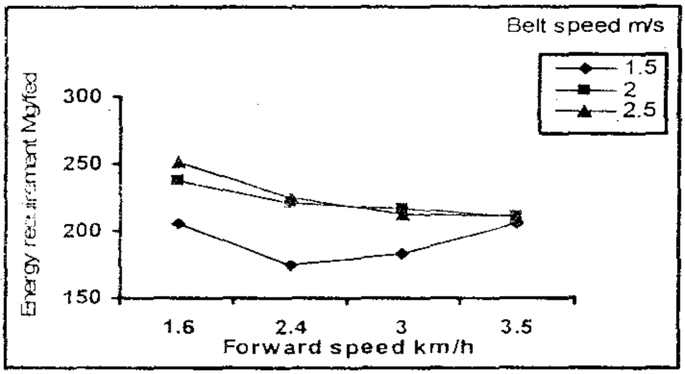


Fig. (9): **The effect of forward speed and belt speed on energy requirements at 45 deg. inclination angle.**

Cost Estimate:-

The cost analysis has been conducted to find out the profitability gained from using developed flax pulling combine. Results showed that the operating cost of developed combine 149 LE/fed consumed 1.59 h / fed was occurred at the optimum forward speed, linear speed of pulling unit, and head inclination angle of 2.4 km/h, 2.0 m/s, and 45 degree. respectively. The traditional pulling method (manual) had the highest total cost of 250 LE/fed needs about 10 man/day within 5 hours to harvest one fedan. The developed combine saving about 101 LE / fed (40.4 %) compared with manual pulling method of flax plants. An economical analysis has been conducted to find out the profitability gained from using the Japanese combine for additional working hours with flax crop. By assuming 300 hours per annuals, if the combine acts as rice harvester only, the total cost would be 180 LE/fed. The effect of additional use of combine for flax pulling in 200 hours intervals, the total cost decreases considerably as the hours of increase until it reaches 149 LE/fed at its maximum use for rice and flax crop.

Conclusions

- The results showed that possibility to use the Japanese combine after making some modification on its harvesting header in pulling of flax crop.
- The optimum operating conditions of pulling combine were found to be as follows: forward speed 2.4 km/h, belt speed 2.0 m/s and pulling inclination angle 45° were gave the best result of productivity rate, energy consumption and pulling efficiency.

- Using the developed combine for pulling flax crop beside harvesting rice crop reduced its operating costs, and increase combine working hours per year.

REFERENCES

Abd El-Maksoud, S.E. (1975): Development of small flax threshing machine. Annuals of agriculture Sciences, Moshtoher Vol. 3 Pp: 31- 38.

Abd El-Wahab, M.K. (1987): Prototype of lentil walker puller harvester. Misr Journal of Agricultural Engineering. Vol. 4 No.(4). Pp. 351- 364.

Abo El-Eas, N.A.; El-Ashi, M.E. and Kasim, M.A.(1985): Studied on the possibility of using a specially made cotton stalk pulling machine. Misr Journal of Agricultural Engineering. Vol. 2 No.(3). Pp. 61- 67.

Broddiford, J.K.; J.R.; Richey, C.B. and (1975): Development of a puller-header for combining soybeans. Transaction of A.S.A.E. Vol. 18 (6): 1003- 1005, 1010.

Hamad, S.A; A.F. El-Sahrigi; M.M. Ibrahim; and A.S.Hamam (1991) Development of harvesting machine suitable for flax in Egypt. Misr Journal of Agricultural Engineering. Vol. 8 No.(2). Pp. 142- 153.

Hunt, D. (1983) Farm power and machinery management. Iowa St. U. Press. Ames, Iowa, 8 th edition.

Ibrahim, M.M. (1983). Study of the different variables found in flax harvesting device Ph.D Thesis Agric. Eng. Inst. Minsk U.S.SR.

Jacobs, C.O. and W.R Harrel (1986): Agriclture power and machinery management. Chapter 25 – Determining Machinery Cost. Pp. 425- 438.

Kanafojski, C.Z.; and Karwowski, T. (1976): Agricultural machines, theory and construction. Vol. 2 Published for the us department of Agricultural and national science foundation, Washington, D.C.

Kepner, R. A.; B. Roy Bainer and E.L. Barger (1982). Principles of farm machinery , 3rd Edition , Pub. By the AVI PUB.Com. 23-47 and 209-236.

Klenin, N.I.; I.F. Popve; and V.A. Sakun (1985). Agriculture machines. A merind Publishing Co. PVT. LTD. New York.

Rodejief, F.; B. Tokarief; and B. Besakhoriedge (1986): The agricultural mechanical reference. MIR Publishers Moscow U.S.S.R.

Singh, M.S. (1981): Design, development and testing of an animal-drawn harvester. Agricultural Mechanization In Asia, Africa and Latin America (AMA), Winter 1981, Pp. 22- 24.

Summner, H.R.; G.E. Monroe; and R.E. Hellwing (1984). Design elements of cotton plant puller. Trans. ASAE 27(2): 366- 369.

Taieb, A. Z. (1990). The demands and constraints of energy utilization in sugar beet crop production. Cairo Univ. Ph. D. Thesis, Ag. Eng.

تعديل صدر كومباين ياباني ليلائم تقليع محصول الكتان

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يعتبر محصول الكتان من المحاصيل الاقتصادية الهامة في مصر ويزرع في مصر بغرض الحصول على الألياف والزيت. وتعتبر عملية الحصاد لمحصول الكتان من أكثر العمليات الزراعية صعوبة ومشقة وتكلفة لحاجته لأعداد كبيرة من العمالة المدربة لإتمام عملية التقليع في وقت محدد. ويهدف هذا البحث لتطوير وتعديل صدر الحصاد لكومباين ياباني مخصص لحصاد الأرز والإستفادة منه في تقليع نباتات الكتان ليصبح آلة متعددة الأغراض يمكن تكثيف استخدامها ولا يقتصر على حصاد الأرز فقط وإنما يمكن بالإضافة إلى ذلك من أن يقوم بحصاد الكتان. ودراسة بعض العوامل المؤثرة في أداء الكومباين للوصول إلى أنسب وأعلى إنتاجية بأقل تكلفة ممكنة. وقد تم تحديد الخصائص الطبيعية والميكانيكية لنباتات محصول الكتان والتي استخدمت لتصميم جهاز التقليع كما تم دراسة تأثير بعض العوامل التشغيلية على أداء الكومباين المعدل خلال موسم 2006 بمحطة البحوث الزراعية بالجميزة محافظة الغربية. واشتملت الدراسة على أربعة مستويات للسرعة الأمامية (1.6, 2.4, 3.0, 3.5 كم/ساعة)، وثلاث مستويات للسرعة الخطية لسير التقليع (1.5, 2.0, 2.5 م/ث) وثلاث مستويات لزاوية الميل على الأفقي لجهاز التقليع (15°, 30°, 45°). وأظهرت النتائج المتحصل عليها إمكانية استخدام كومباين حصاد الأرز الياباني بعد عمل بعض التعديلات على صدر الحصاد في تقليع محصول الكتان.

كما أظهرت النتائج المتحصل عليها أن العوامل المثلى لتشغيل الكومباين كانت باستخدام سرعة أمامية 2.4 كم/ساعة وسرعة خطية لسير التقليع 2.5 م/ث (معامل كينماتيكي 3.75) وذلك عند زاوية ميل الجهاز على الأفقي 45° حيث أعطى الكومباين عند تشغيلة تحت هذه الظروف أفضل النتائج من حيث أعلى كفاءة تقليع (93.68%) وإنتاجية (0.63 فدان/ساعة) و نسبة مئوية للفقد في الكبسول(1.15%) وأقل نسبة مئوية لتلف السيقان (2.81%).