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ENGINEERING STUDIES ON THE FACTORS AFFECTING THE PERFORMANCE OF SHELLING AND GRADING CORN MACHINE

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ABSTRACT

The performance of an Italian made combined machine was tested and evaluated for shelling and grading two different Egyptian corn crop varieties. Whereas, the optimum design, and operating parameters were determined in order to increase the mechanical shelling and grading efficiency and machine productivity. The crop was feed at a constant rate of 25 kg and at the grains recommended moisture content range of 12-14% (d.b).

The shelling unit of the machine was deduced at four different drum speed levels (from 370 up to 820 rpm, those corresponding drum linear speeds from 4.84, up to 10.74 m/s). Also, shelling unit was tested under three concave clearance levels (32, 42 and 52mm). While, the grading unit deduced at different cylindrical screen speed levels (from 55, up to 95 rpm corresponding to linear cylinder speeds from 1.38, up to 2.39 m/s). The grading unit was also tested versus different cylindrical screen inclination angle up to 9 degrees.

The tested machine performances were evaluated in terms of the grading and cleaning efficiency. In addition, costs per unit weight of production and energy unit requirements were estimated and compared with the traditional shelling and grading methods of corn crop.

The obtained results revealed the following important points:-

The optimum parameter levels for the mechanical shelling

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operation were drum speed of 670 rpm (8.77 m/s) and concave clearance of 42 mm. These parameters levels were recommended to match the performance of the grading unit.

The promising parameters levels for operating the grading both tested crop varieties were 80rpm (2.00 m/s) for cylindrical screen speed and 3 degrees for inclination angle.

As operating at the optimum parameter levels the highest values of grading efficiency (83.68 and 82.84 %), grading cleanliness (77.78 and 77.18 %), and machine capacity (0.51 and 0.47 ton/h) were achieved. for both tested corn varieties, SC10 and TC310 respectively. Also, the lowest values of specific energy consumption (25.94 and 29.29 kW.h/Mg) and cost unit (76.12 and 78.28 LE/ton) for both tested corn varieties, SC10 and TC310, respectively.

Keywords: Engineering factors, cylindrical screen speed, inclination angle, cleaning efficiency, separation efficiency, shelling and grading corn machine

INTRODUCTION

Corn is considered as one of the most important cereal crops in Egypt. It is used in human feeding, industrial aspects for producing corn oil, starch and dry food for animal. The cultivated area ranges from 1.8 to 1.9 million feddans yearly with total grain productivity of 3.7 million ton (Ministry of Agriculture 2008). Shelling, cleaning and grading of corn grain are considered as the most important operations affecting the quality of grains after harvesting. It is known that the manual method of shelling and grading corn is very tedious, time and labor consuming and thus too expensive. Vice versa, the mechanical methods require less time and labour so the operating cost may be reduced. Hence, such care had to be taken to optimize the performance of a shelling, and grading combined machine in order to obtain grains with high quality features and more homogeneous.

The kernels damage in maize shelling by rasp-bar cylinder is affected by grain moisture content, cylinder speed, and concave clearance stated by Fouad *et al.*(1981).

The slop of the sieve is a main factor affecting separation efficiency. That efficiency is increased significantly by increasing the sieve slope up to 25 degrees in both vertical and lateral motion. While, in frontal motion it tends to increase with increasing sieve slope at small stroke lengths and decreased at high stroke length. The separating efficiency was increased in the compound motion as the sieve slope is increased in the range of from zero to 20 degrees but at higher slope the separating efficiency was decreased stated by Ismail (1981).

The effects of some factors on the productivity of a locally manufactured rasp-bar corn sheller were studied by Mettwalli *et al.* (1995). They concluded that the unshelled grain losses was 2.81%, the visible grain damage was 5.71% the invisible damage was 7.19% and the cost per unit weight of production was about 7.5 L.E/Mg. Furthermore, the previous criteria were at optimum condition included cylinder speed of 10.26 m/s, moisture content of 20% (W.B) and clearance ratio ranged from 1.8 to 2.1.

The effect of mechanical properties on grading efficiency and found that the separating efficiency increased by increasing the time of separation from 3 to 12 min, cylinder speed from 375 to 750 osci/min for vibratory machine and from 50 to 250 rev/min for rotary machine, and inclination of sieves up to 9 degree stated by Amin (2003)

The performance of a developed Bakistan corn sheller machine was evaluated by El-shal (2007). It was found that the optimum drum speed and concave clearance for shelling both Yellow and White corn varieties were 6.29 m/s (500 rpm), and 40 mm respectively.

The aim of the present study is mainly focused on increasing mechanical shelling and grading efficiency and machine productivity for two different corn varieties by reducing total grain losses and damage. To achieve that aim the following objectives were studied:-

1- Determining the main operating and design parameters affecting the performance of a combined machine during shelling and grading different varieties of corn. The investigated parameters included (peripheral drum speed, concave clearance, speed of cylindrical screen and cylindrical screen inclination).

2- Estimating and comparing both costs per unit weight of production and energy unit (requirement) with the traditional shelling and grading methods of corn crop.

MATERIALS AND METHODS

The experiments of the present study were carried out at Gemmiza Research Station, Gharbia Governorate in season 2009-2010, whereas, the effects of main machinery parameters on the performance of the combined shelling and grading corn machine were studied

Materials

Corn Crop

Two corn varieties namely single hybrid (SC10) and triple hybrid (TC310) were taken under all tests runs.

Tractor

Naser tractor of 48 kW and P.T.O speed of (540 rpm) was used in this study as the power supply source for operating the investigated machine.

The investigated machine

The investigated machine was Italian made. It is mainly consisted of three main units for shelling, cleaning and grading operations as shown in Fig.1.

1- Shelling unit

The tested shelling unit as shown in Fig.2 is consisting of steel drum with a length of 1800 mm, and a diameter of 120 mm. The drum is supported horizontally by two bearings fixed on the frame; it consists of four parts namely: feeding screw, shelling plates, spike tooth, and crash cob unit discharges. In order to convey the shelled grain to the second screw a concave having thickness of 3 mm, hole diameter of 21mm, and horizontally screw with 48mm O.D was used.

2- Cleaning and grading units

These units include, screw which is equipped vertically to convey the grains towards the grading unit. The later consists of sieving unit of cylindrical screen as shown in Fig.3,4. The total length of cylindrical screen is 200cm and divided according to the included round holes diameter into four parts of (60, 50,50and 40 cm) excluded holes diameters of (8,9.5,11 and 12.5mm) respectively. Also four discharge spouts for grading grains were included.

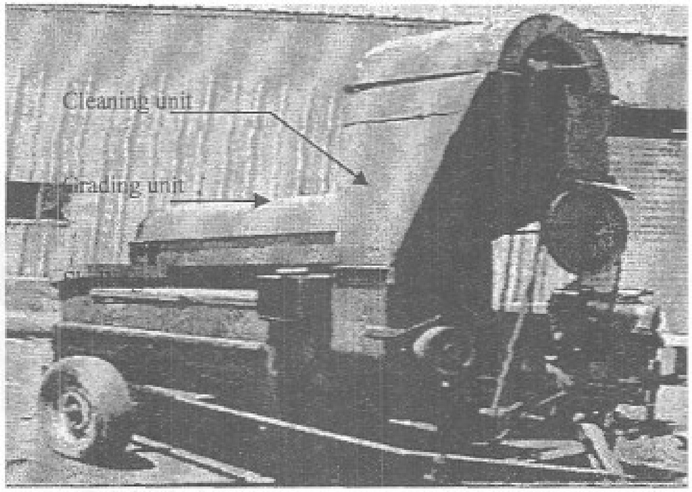


Fig. 1. View of corn combined machine.

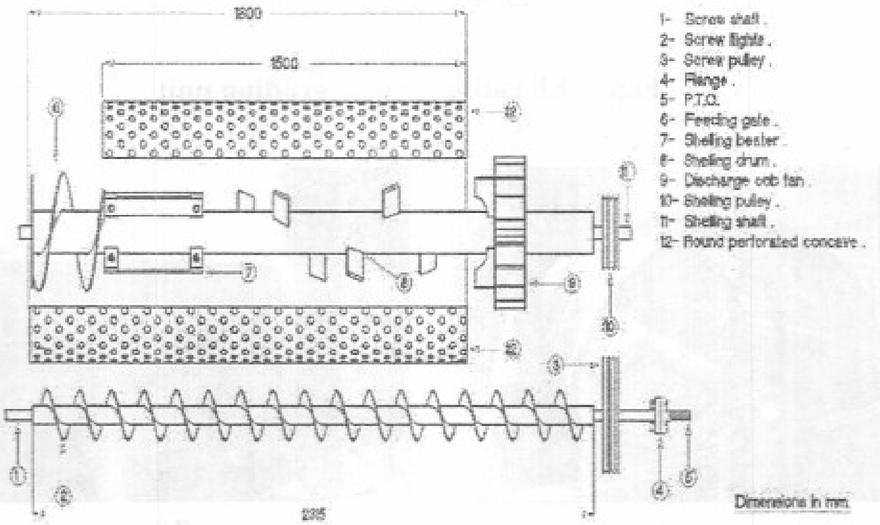


Fig. 2. Elevation view of shelling unit

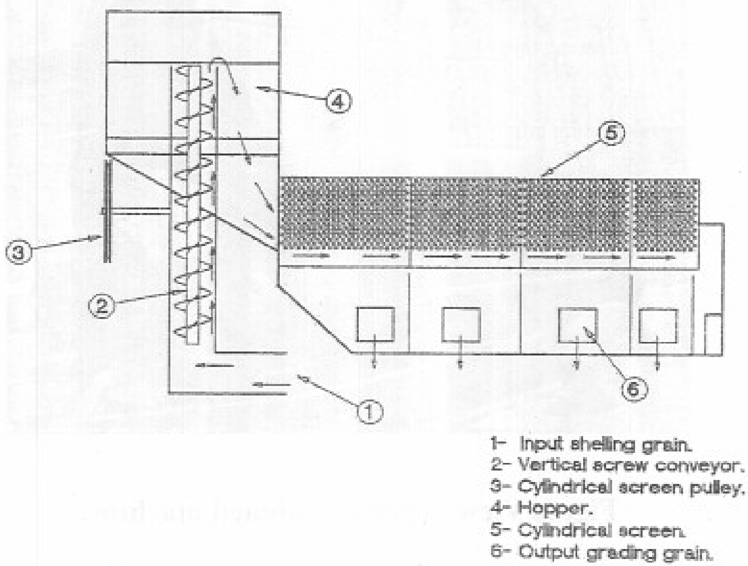
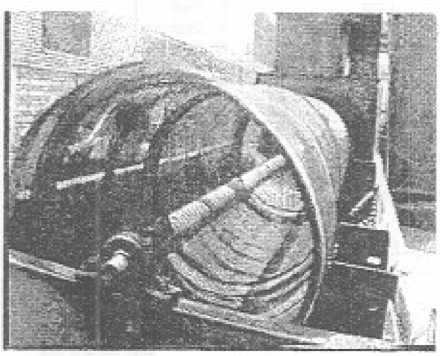
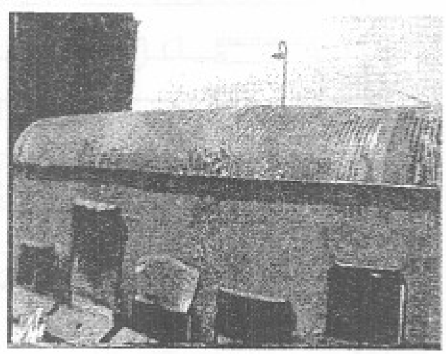


Fig. 3. Elevation view of grading unit



(a)

Grading unit



(b)

Discharge spouts

Fig. 4. Views of grading unit and the discharge spouts

The power was transmitted from tractor P.T.O. to operate all machine units at different operational speed by means of pulley and belts.

Methods

The crop was feed at constant feeding rate of 25 kg, and the crop was at recommended moisture content range of 12-14% (d.b). While, the deduced operating and design parameters affecting the performance of tested machine during shelling and grading two different varieties of corn were as follows:

1- For deducing the shelling unit four different drum speed levels were tested namely: - 370,520,670 and 820 rpm, which corresponding to linear speeds of 4.84, 6.81, 8.77 and 10.74 m/s respectively. Also three concave clearance levels of (32, 42 and 52mm) were evaluated in the shelling unit.

2- For deducing the grading unit, four different cylindrical screen speed levels were evaluated namely: - 55,65,80 and 95 rpm, which corresponding to linear speeds of 1.38.1.63 ,2.00 and 2.39 m/s respectively. In addition, three different inclination angle for cylindrical screen namely: - zero, 3.6 and 9 degrees.

Measurements

Determination of grain damage

1- Visible grain damage

The damaged grains were separated by hand and weighted, and then visible grain damage (%) was estimated as a percentage of total grain weight as follows:

$$S_d = \frac{W_d}{W_s} \times 100$$

Where

S_d: Grain damage, (%)

W_d: Weight of damage grains, (g)

Ws: Total grain weight (100 g)

2-Invisible grain damage

The germination test was used to estimate, the percentage of the invisible grain damage as follows:

Invisible grain damage (%) = a/b X 100

Where:

a: Number of ungerminated grains from the samples taken after machine shelling operations.

b: Total number of grains in the sample.

Shelling losses:

1- after shelling operations, the unshelled grains were shelled manually from the ears and weighted then unshelled grain percentages were calculated as follows:

$$L_k = \frac{W_2}{W_1 + W_2 + W_3} \times 100$$

Where:

L_k= Unshelled grain percentage.

W_1:= Weight of shelled grains, kg.

W_2:= Weight of unshelled grains, kg

W_3= Weight of shelled and received at the outlet of cobs, kg.

2-The free grains which found with the cobs were weighted and then its percentage calculated as follows

$$L_c = \frac{W_3}{W_1 + W_2 + W_3} \times 100$$

Total losses = $(L_k + L_c)$ %

Shelling efficiency ,%

Shelling efficiency of corn sheller (E) was estimated as follows

$$E = [100 - L_k]$$

Grading efficiency, %

A randomized sample of 500 grains were taken from each spout for measuring seed width and compare with the hole diameter at the existing cylindrical screen, then the efficiency calculated as follows

$$\text{Grading efficiency \%} = \frac{\text{mass of sample} - \text{mass of (the under and overseeds)}}{\text{mass of sample}}$$

Cleaning efficiency, %

A randomized sample of 1 kg grains were taken from each spout to calculate seed cleanliness as follows

$$\text{Cleaning efficiency \%} = \frac{\text{mass of sample} - \text{mass of impurities}}{\text{mass of sample}}$$

Machine productivity

can be determined according to (Amin, 1994) as follows

$$W = m_i \times \frac{60}{t}$$

Where

W: Machine capacity, Mg/h,

m_i: Mass of classified crops from the unit ,Mg,

t : Operation time, min.

Fuel consumption, (L/h)

Determined as follows

$$Fc = \frac{V_f}{T} \times 3.6$$

Where

F_c: Rate of fuel consumption, L/h,

V_f: Volume of fuel consumed, cm^3,

T: Time of operation, s.

Power requirements, (kW)

Estimated by using the following formula according to (Barger *et al.*, 1963).

$$Pc = F_c \times \frac{1}{3600} \times \rho_f \times Lcv \times 427 \times \eta_m \times \frac{1}{75} \times \eta_{th} \times \frac{1}{1.36}$$

Where

F_c : The fuel consumption, L/h.

ρ_f : Density of fuel, (for solar fuel = 0.81 kg/l)

Lcv: Lower calorific value of fuel, kcal/kg, (average l.c.v. of diesel fuel is 11000 kcal/kg)

427: Thermo-mechanical equivalent, kg.m/kcal.

η_{th}: Thermal efficiency of the engine, (considered to be (30%-35%)for diesel engine.

η_m : The mechanical efficiency of the engine, (considered to be 80% for diesel engine).

Energy requirements

It was estimated by using the following equation:

$$Es = \frac{power\ required\ (kW)}{machine\ productivity (Mg/h)}$$

Cost Estimation

It was determined considering the conventional method of estimating both fixed and variable costs (kepner, 1982 and Hunt, 1983) according to price level of 2009 – 2010.

1- Total costs (TC)

The total costs, L.E/h are the summation of fixed costs, (L.E/h) and variable costs, (L.E/h) as follow

Operating costs (L.E/h) = Fixed cost (L.E/h) + Variable cost (L.E/h)

Operating costs (L.E/Mg) =Total cost (L.E/h) / machine capacity (Mg/h)

A- Fixed costs (Fc)

Include depreciation, interest, insurance, taxes and housing.

Deprecation and interest costs have been calculated by using the straight line method as follows:

Deprecation = P-S/N

Where

P : Purchase price, L.E .

S :Salvage price ,L.E.

N : Total life in years (h).

$$\text{Interest} = \frac{(p+s)}{2} X \frac{r}{100} \quad L.E$$

where

(p+s)/2 : average investment.

r : interest rate % .

Taxes, insurance and housing (T.I.H) these costs were considered to be 4% of purchase price (Hunt, 1983).

B- Variable costs (vc)

Include repair and maintenance cost, fuel cost and labor cost.

Repair and maintenance per hour as percent of the purchase price where considered to be0.032% (Kepner *et al.*, 1982)

Fuel costs (L.E/h) = fuel consumption (L/h) × fuel price (L.E/L).

Lubrication costs =15% of fuel costs (Hunt, 1983)

The cost of labour varies with geographic location for hired operators the prevailing wage rate for local labour was found to be 3.57 L.E/h, it needs two labours and one driver for the tractor.

RESULTS AND DISCUSSION

The obtained results from shelling and grading (SC10 and TC310) corn by the combined machine are summarized under the following heads.

Effect of Relative Peripheral Drum Speed and Concave Clearance on

Total grain losses, (%)

Fig.5 showed that the total grain losses increases from 3.55 to 6.86% and from 4.16 to 7.00% as drum speed increase from 4.84 to 10.74 m/s (370 to 820 rpm) for two varieties of corn (SC10 and TC310) respectively at concave clearance of 32mm. and the total grain losses increased from 3.55 to 6.83% and from 4.16 to 7.28% as concave clearance increase from 32 to 52mm at 4.84m/s (370 rpm) drum speed for two varieties under study, this is due to the decrease of unshelled grain and increase of the free grain losses.

Total grain damage, (%)

Fig.6 showed that the total grain damage increases from 5.1 to 6.63% and from 5.64 to 7.43% as drum speed increase from 4.84 to 10.74 m/s (370 to 820 rpm) for two varieties of corn under study (SC10 and TC310) respectively at concave clearance of 32mm, this is due to great bulk material at high drum speed which cause high friction and pressure on the grain which in turn will cause more damage. And the total grain damage decreased from 5.1 to 2.35% and from 5.64 to 2.82 % as concave clearance increase from 32 to 52mm at 4.84m/s (370 rpm) drum speed for two varieties under study, this decrease is due to the decrease of friction between kernels at the higher concave clearance.

Shelling efficiency, (%)

From Fig.7 the shelling efficiency increased by increasing drum speed and decreasing concave clearance, so using a combined corn machine increased shelling efficiency to (100 and 99.57%) for shelling two varieties of corn SC10 and TC310 respectively at drum speed of 8.77m/s (670 rpm) and 42mm concave clearance ,due to the unshelled grain losses decreased .

Effect of Cylindrical Screen Speed and its Inclination Angle on

Grading efficiency,(%)

Fig.8 indicated that the grading efficiency increased from 82.26 to 92.64 % and from 81.43 to 91.71 % as cylindrical screen speed decrease from 2.39 to 1.38 m/s (95 to 55 rpm) for corn varieties SC10 and TC 310 respectively at zero inclination degree, this may be due to the grain remain on the screen as long as possible to give every rain an opportunity to pass through an opening.

And the grading efficiency decreasing from 92.64 to 85.68 and from 91.71 to 84.82 % as cylindrical screen inclination increase from zero to 9 degrees at 1.38 m/s (55 rpm) cylindrical speed. At the optimum value of drum speed 8.77 m/s (670 rpm) and concave clearance 42mm for shelling operation, this may be due to the grain fall down quickly before the grading operation completed.

Cleaning efficiency,(%)

Fig.9 indicated that the cleaning efficiency increased from 77.02 to 80.24 % and from 76.45 to 79.08 % as cylindrical screen speed increase from 1.38 to 2.39 m/s (55 to 95 rpm) for corn varieties SC10 and TC 310 respectively at zero inclination degree, and also the cleaning efficiency decreased from 80.24 to 77.3 and from 79.56 to 76.58 % as cylindrical screen inclination increase from zero to 9 degrees at 2.39 m/s cylindrical speed, at the optimum drum speed of 8.77 m/s

(670 rpm) and concave clearance of 42mm for shelling operation.

Machine productivity, (Mg/h)

From Fig.10 the machine productivity increased by increasing the cylindrical screen speed and inclination angle, so the increasing of cylindrical screen speed from 1.38 to 2.39m/s (55 to 95 rpm) tends to increase the machine productivity from 0.32 to 0.47 Ton/h and from 0.30 to 0.43 Ton/h for corn varieties SC10 and TC310 respectively at zero inclination degree, also the increasing of inclination degrees from zero to 9 degree tends to increase machine productivity from 0.47 to 0.58 Ton/h and from 0.43 to 0.56 Ton/h at 2.39 m/s (95 rpm) cylindrical speed and the optimum drum speed of 8.77 m/s (670 rpm) and concave clearance of 42mm for shelling operation.

Energy requirement, (kW.h/Mg)

Fig.11 indicated that increasing of cylindrical screen speed and decreasing inclination angle tends to increase the energy requirement at the different operational conditions, so the energy required at the optimum recommended point (drum speed of 8.77m/s (670 rpm) , concave clearance of 42mm for shelling operation) and(cylindrical screen speed of 2.00m/s (80 rpm) and inclination angle of 3 degree for grading operation for corn varieties (SC10 and TC310) is 25.94 and 29.29 kW.h/Mg respectively.

Cost Estimation, (LE/Mg)

Resulted showed that the hand shelling and grading operations required 630 L.E/ton, while the cost of mechanical operation required (76.12 and 78.28 L.E/Mg) for corn SC10 and TC310 respectively at the optimum recommended point (drum speed of 8.77 m/s (670 rpm), concave clearance of 42 mm , cylindrical screen speed of 2.00 m/s (80 rpm) and inclination angle of 3 degree).

CONCLUSIONS

The results concluded that the optimum operating parameters can be used are drum speed of 8.77m/s (670rpm), concave clearance of 42mm for shelling operation and cylindrical screen speed of 2.00 m/s(80r.p.m) and inclination angle 3 degree for grading operation at SC10 and TC310 this parameters achieved the highest value of grading efficiency of (83.68 and 82.84 %), cleaning efficiency of (77.78 and 77.18 %), machine

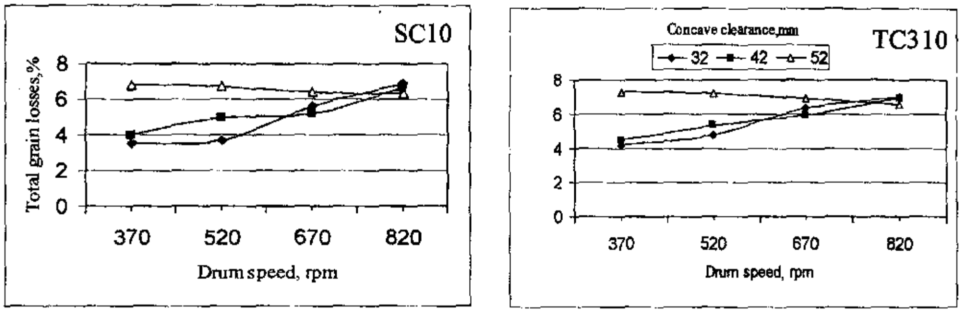


Fig. 5. Effect of relative peripheral drum speed and concave clearance on total grain losses for the corn varieties (SC10 and TC310)

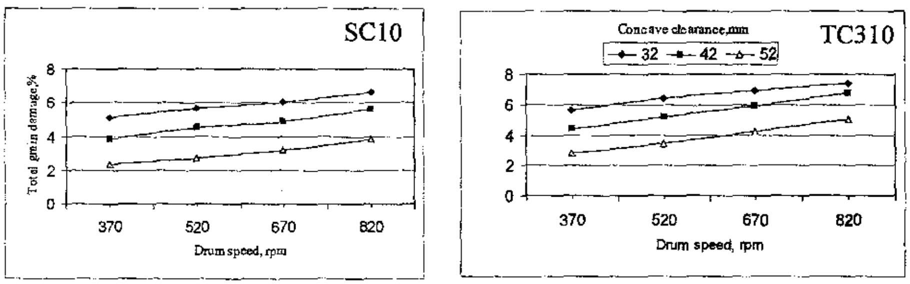


Fig. 6. Effect of relative peripheral drum speed and drum -concave clearance on total grain damage for the corn varieties (SC10 and TC310)

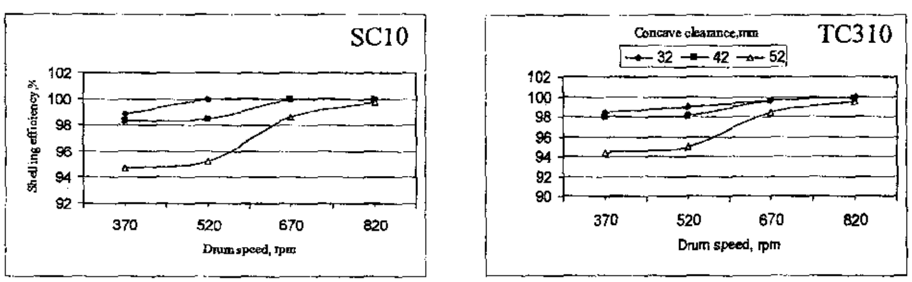


Fig. 7. Effect of relative peripheral drum speed and drum -concave clearance on shelling efficiency for the corn varieties (SC10 and TC310)

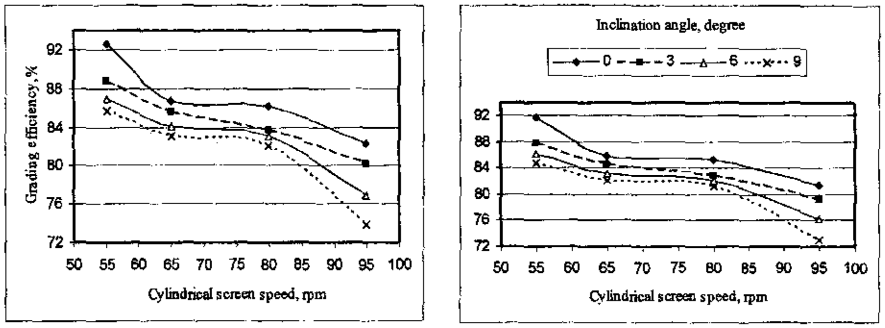


Fig. 8. Effect of peripheral cylindrical screen speed and inclination angle on grading efficiency for the corn varieties (SC10 and TC310)

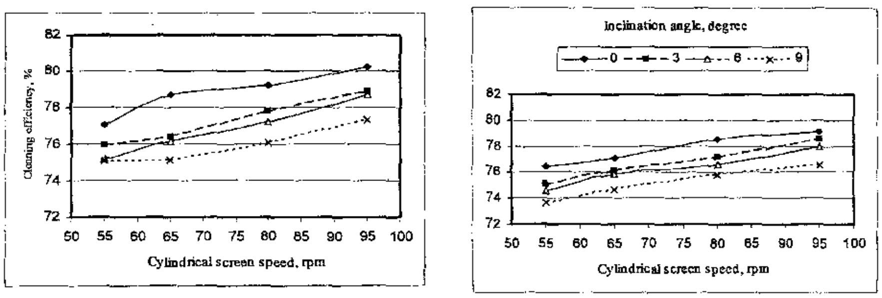


Fig. 9. Effect of peripheral cylindrical screen speed and inclination angle on cleaning efficiency for the corn varieties (SC10 and TC310)

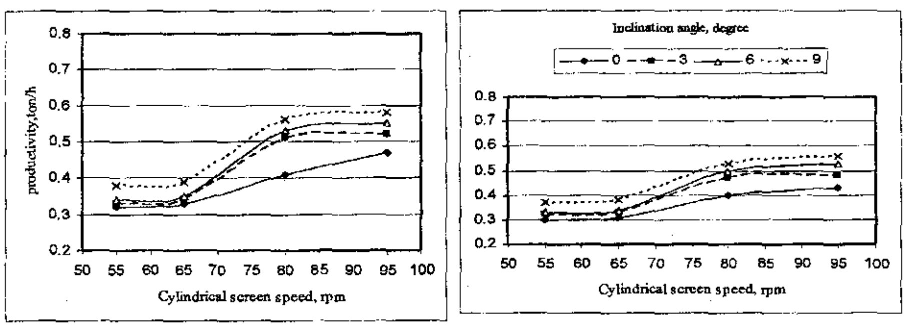


Fig. 10. Effect of peripheral cylindrical screen speed and inclination angle on productivity Mg/h for the corn varieties (SC10 and TC310)

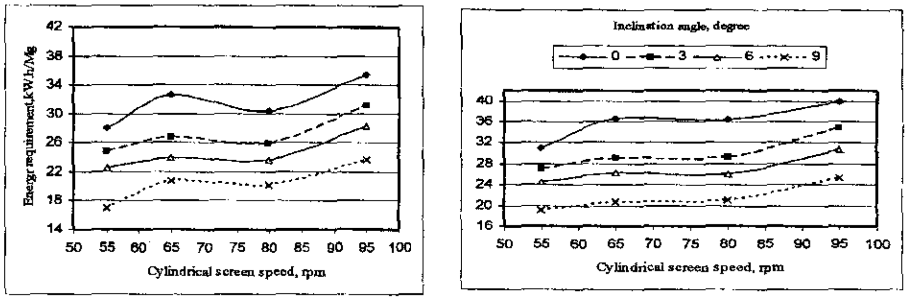


Fig. 11. Effect of peripheral cylindrical screen speed and inclination angle on energy requirements for the corn varieties (SC10 and TC310)

productivity of (0.51 and 0.47 ton/h), the lowest value of total damage is (4.88 and 5.93%), total losses of (5.22 and 5.93 %) , fuel consumption of (4.92 and 5.12 L/h), power consumption of (13.23 and 13.77kW),specific energy of (25.94 and 29.29 kW.h/Mg) and cost estimation (76.12 and 78.28 LE/ton) for corn varieties SC10 and TC310 respectively.

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دراسات هندسيه عن العوامل المؤثرة على آداء آلة تفريط و تدريج الذرة

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تم إجراء التجربة في محطة البحوث الزراعية بالجميزة بمحافظة الغربية خلال الموسم الزراعي ٢٠٠٩–٢٠١٠ لدراسة العوامل الهندسية المؤثرة علي آله مجمعه لتفريط وتدريج الذرة ايطاليه الصنع .تتكون الآله من ثلاث وحدات رئيسيه ،وحده التفريط ، وحده التنظيف ، وحده التدريج .استخدم صنفين من الذرة هما (هجين فردي ١٠ ، وهجين ثلاثي ٣١٠).تمت الدراسة تحت عوامل تشغيل مختلفة تشمل أربع سرعات مختلفة لدرفيل التفريط (٣٧٠ ، ٥٢٠ ، ٦٧٠ ، ٨٢٠ لفه/دقيقه) (٤,٨٤، ٦,٨١، ٨,٧٧، ١٠,٧٤ م/ث) وثلاث قيم للخلوص بين الدرفيل والصدر (٣٢، ٤٢ ، ٥٢ مم) كذلك أربع سرعات لغربال الفصل الاسطواني (٥٥ ، ٦٥ ، ٨٠ و ٩٥ لفه/دقيقه) واربع زوايا ميل مختلفه لاسطوانة الفصل (صفر ، ٣ ، ٦ ، ٩ درجه) وذلك عند معدل تغذيه ثابت ٢٥ كجم والرطوبة المثلي لحبوب كل صنف من الأصناف تحت الدراسة (١٢ – ١٤ %) .

وأوضحت النتائج المتحصل عليها أن كفاءة التفريط تزداد بزيادة سرعة درفيل التفريط من (٣٧٠ الي ٨٢٠ لفه/دقيقه) (٤,٨٤ الي ١٠,٧٤ م/ث) وخفض قيمه الخلوص لصدر الدرفيل من (٥٢ الي ٣٢ مم) وذلك لانخفاض نسبه الذرة الغير مفرطة وان القيم

المثلي لتشغيل وحده التفريط كانت عند سرعه درفيل التفريط ٦٧٠ لفـــه / دقيقـــه (٨,٧٧ م/ث) وخلوص بين الدرفيل والصدر ٤٢ مم حيث حققت أفضل نتائج لكل من الفواقد الكلية للحبوب (٥,٢٢ ، ٥,٩٣ %)، الكسر الكلي للحبوب (٤,٨٨ ، ٥,٩٢ %)، وكفاءة التفريط (١٠٠ ، ٩٩,٥٧ %) وذلك لصنفي الذرة المستخدم هجين فردي ١٠ وهجين ثلاثـــي ٣١٠ علي الترتيب .

والقيم المثلي لتشغيل وحده التدريج كانت عند ســـرعه٢,٠٠ م/ث (٨٠ لفـــه/دقيقـــه) وزاوية ميل(٣ درجه علي الأفقي) لاسطوانة الفصل لصنفي الذرة المستخدم حيـــث حققـــت أفضل نتائج لكل من كفاءة التـــدريج (٨٣,٦٨، ٨٢,٨٤ %)،كفـــاءة النظافـــة(٧٧,٧٨ ، ٧٧,١٨ %) واعلي سعه للماكينة (٠,٥١، ٠,٤٧طن/ساعة) وحققت اقل قيمه لكـــل مـــن الوقود المستهلك(٤,٩٢، ٥,١٢ لتر/ساعة) ، القدرة المستهلكة (١٣,٢٣ ، ١٣,٧٧ كيلـــو وات) ،ومتطلبات الطاقة (٢٥,٩٤، ٢٩,٢٩ كيلو وات.ســـاعة/ميجـــا جـــرام) والتكـــاليف (٧٦,١٢ و ٧٨,٢٨جنيه/ميجا جرام) وذلك لصنفي الذرة المستخدمين هجـــين فـــردي ١٠ وهجين ثلاثي ٣١٠ علي الترتيب.