STUDY OF SOME ENGINEERING FACTORS AFFECTING THE FLAX DESEEDING METHODS

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ABSTRACT

Flax deseeding is considered one of the most important operations among the crop processing sequence. Deseeding is still done using manual method especially at the small holdings, through two stages: hacking or capsules stripping followed by capsules threshing, which is time consuming, costly, and accompanied by high losses of seeds and straw (fiber).

Since flax is grown in Egypt for both seeds and fibers, the main goal of farmers is to obtain the seeds with minimum losses and maintain the heighest fiber quality. The present work was devoted to study the engineering factors affecting deseeding process to obtain the data needed to design and develop the proper deseeding mechanisms either for stationary or combine harvesters. Three commonly system used for flax deseeding were: flax deseeding machine then cleaning using traditional winnowing machine (M1), flax deseeding and winnowing with one machine (M2) and, traditional method using tractor then cleaning with traditional winnowing machine (M3). Results indicated that, The capacity of M1, M2 and M3 were 0.5, 1.5, and 0.2 Mg/h, respectively. The minimum seed loss was 2 % for the M2, while the corresponding value for M1 was 5 %. The maximum seed loss was 30 % using M3 system.

The cleaning efficiency obtained for M1 and M2 were 92% and 96% respecitvely. The cleaning efficiency for M3 system was 87 %. Moreover, it decreased the fiber yield by 25%.

The operating cost was found to be120, 100 and 320 LE/feddan for M1, M2 and M3 system respectively.

INTRODUCTION

In Egypt, flax is being grown for both fibers and seeds. Flax area is approximately 22000 feddans (9240 ha) produce about 78.14 Mg fibers (Agricultural economics 2003). To maintain maximum fiber length and quality, flax is pulled from the ground at harvest, rather than cut, while flax capsules should be stripped carefully. Flax pulling and capsule separation are still done manually in the majority of Egyptian small holdings. Most of flax fibers are exported to other countries and some of these fibers are used in national textile industry. Fiber yields in Western Europe have recently been in the range of 1500-2000 kg/ha, while yields in Russia and Eastern Europe have usually been less than half of those amounts (Anthony 2002), This may have been due to the use of oil varieties as well as poor crop technology or management.

Klenin *et al.* (1985), showed some different types of combines that used to strip capsules from flax stalk and indicated that stalk damage percentage depends mainly on the space between the gripper and point at which the teeth enter the stalks layer as well as combing device speed.

Bainer *et al.* (1982), indicated that flax capsules can be threshed through a small mechanism consists of one rubber covered roll and one steel roll. The upper roll is spring-loaded and driven about 10 percent faster than the lower roll to give a rubbing action in addition to the squeezing effect. Adjustable stops on the spring-loaded roll are set to provide a minimum clearance sufficient for the passage of seeds without damage.

Erugin (1987), designed a thresher prototype to be used in the experimental plots. It consists of two drums . Small stocks fed by hand are pressed between the two drums, which crush the majority of seed capsules. Seeds separated and cleaned in several stages. The results showed that the total seed loss was less than 3%.

Helmy (1988) and Abdel-Mageed (1989), found that the threshing effectiveness is related to; the cylinder speed, the cylinder concave clearance, feed rate of crops, the number of rows of concave teeth used with a spike tooth cylinder, grain and straw moisture content and type of crop.

Ibrahim and Abdel-Mageed (1989), evaluated three different machines (thresher ML2.8PA, Flax thresher LKB-4A, and Yanmar TC 2400E rice harvester) in flax threshing. They found that using the Yanmar harvester at 400 rpm threshing drum speed gave a stripping efficiency about 100 %, threshing efficiency of 92.2 %, while stalks losses reached to 3.3 %.

Huynh *et al.* (1982), stated that the seed separation from the stalks and passage of seed through the concave grate is a function of some variables such as crop feed rate, threshing speed, concave length, and cylinder diameter and concave clearance. These variables also related to the threshing losses and seed separation efficiency.

Gummert (1990), found that the feed rate affects power requirement significantly. The function of the investigated range is a proximately linear and if feed rate is doubled, power requirements is 2.5 times higher.

Gol and Nanda (1991), indicated that the efficiency of the mechanical pod-stripping element is mainly affected by operating speed of operation and condition of crop. The percentage of shelled pods increased by increasing of cylinder peripheral speed from 473 to 675 m/min.

Ajayi (1991), indicated that the material capacity of a thresher influenced by the speed of the threshing beater drum, the feed rate and the moisture content of the material. At lower speed of 300 to 500 rpm of the beater drum, the material at 13.31% moisture gave slight decrement in capacity as the speed increased to 550 rpm beyond that speed, an increase in thresher capacity was observed.

Kromer *et al.* (1995), gave an account of flax research and development work in Bonn, Germany on the production of high quality fibers for industry plus simultaneous utilization of seeds. Details are given of the design and basis specifications of tractor mounted flax puller with an encapsulation unit to separate the seed capsules from the straw. This flax puller has working width of 1.4m, an operating speed up to 3.5 km/h, and is suitable for harvesting small plots or larger fields.

Khatab (1998), developed a simple flax thresher using a feeding system. The main parts of the feeding system are chain gear and feeding chain. The ratio of feeding system speed to the speed of the drum is 5:32 to

give the stems enough time for beating. Putting the stalk on the feed tray by worker while anther was passing only the head parts of the stalk to the threshing chamber. The chain is adjusted to about 20-40 mm gap or clearance between the chain and guide rail. The head parts of stalks are fixed with feed chains, so that, the relative speed to the threshing drum is almost constant. For that reason the threshing operation is stable and grain damage or losses are low.

The purpose of this research were as follows: -
1. Measure the physical and mechanical properties of flax crops.
2. Study the engineering factors affecting the flax deseeding.
3. Compare between flax deseeding methods used in Egyptian fields.

MATERIALS AND METHODS

The present study was carried out at Agricultural Research Center, Giza, and Smanoud, El-Garbia Governorate, during growing seasons of 2001-2002, and 2003, flax variety was Sakha1. Three systems of flax desseding were studied and compared:
1. Flax deseeding machine then cleaning using traditional winnowing machine(M1),
2. Flax deseeding and winnowing with the same machine (M2) ,and
3. Traditional system using tractor then cleaning using traditional winnowing machine (M3).

Materials:
The material and equipments used in this research may be indicated as follows: -

Flax deseeding machine and cleaning using traditional winnowing machine(M1):
Deseeding machine as shown in Fig. (1), consists of two main units, capsules stripping unit and capsules threshing unit. Capsules stripping unit consists of stripping comb (fork) with 23 iron fingers mounted on crank shaft and rotates at speed about 1.5 m/s peripheral speed. Capsules threshing unit consists of three iron drums with rough surface to increase friction coefficient between flax capsules and surface of drum. Threshing operation is accomplished by rubbing action. The threshing drums rotate at speed peripheral of 1.7, 0.89 and 0.29 m/s for the three drum respectively. All threshed grain,chaff and broken pieces are drooped to ground surface under the machine and cleaning operation is accomplished by traditional winnowing machine. Flax deseeding machine is pulled by less than 40 hp tractor and powered by P.T.O drive using a flat belt.

Flax deseeding and winnowing machine (M2):
The functional components are illustrated in the schematic showen in Fig. (2). It consists of three main units, capsules stripping unit, capsules threshing unit and seeds cleaning and separating unit. Capsules stripping unit

consists of 30 iron fingers mounted on 3 forks which fixed peripherally between two desks rotate on rolling bearing. The desk has a diameter of 88 cm and rotates at 100 rpm with peripheral speed of 4.6 m/s. Stripping mechanism depends upon pulling force of iron fingers which comb the stalk twoards the capsules while the other side twoards the roots are holded between two surface of a rough flat belt and rubber tire surface. Capsules threshing unit ,the threshing mechanism consists of rasp-bar cylinder (drum) and concave. The rasp-bar cylinder consists of 15 steel bars that are mounted on several star shaped hubs to the cylinder frame. The hubs are mounted on a shaft that is supported by bearing and driven by v- belts. The concave is made of parallel bars that are held together by parallel curved bars. The threshing cylinder diameter is 32 cm and rotates 560 rpm with 9.38 m/s. Cleaning and separating unit consists of groups of sieves and paddle type fan.

Traditional method using tractor and cleaning using traditional winnowing machine(M3):

The deseeding operation used to be performed on the leveled ground (El Gorn). Sheets are stretched out to perform the deseeding operation on it by stocking the plants in the form of circular windrow , then the tractor pass around over the periphery of the stock. During the tractor passing a worker turn over the plants up and down, then separating and cleaning are manually done by the winnowing machine. The workers collect the flax stalks in bundles to be ready for rotting process.

Evaluating performance of flax threshing systems: -

The performance of flax threshing systems is evaluated using the following measurements:-

1. System capacity
2. Stripping efficiency.
3. Threshing efficiency.
4. Seed losses.
5. Broken stalk (damage of fibers).
6. Cost estimation.

Measurements and measuring Instruments:

* Physical and mechanical properties of flax plant.

After harvesting operation, 100 plants were taken randomly to measure the following physical and mechanical characteristics of flax plant Sakha 1 variety (Table 1), which is the most common variety in the Egyptian fields which has high yield and quailty of the straw and recommended by El-Farouk *et al.* 2003. Agricultral Research Center (ARC)- Ministry of agricultural.

* Detachment force of flax capsule, flax stalk and seed shearing force and fiber tensile force were measured by using Detachment force gauge, Brand name Shimpo, with range of 0-500 N.
* Static crushing force of flax capsule was measured also by using force gauge.
* Static broken force of flax stalk was measured to estimate the maximum stalk broken force during threshing operation for the 3 sytems.
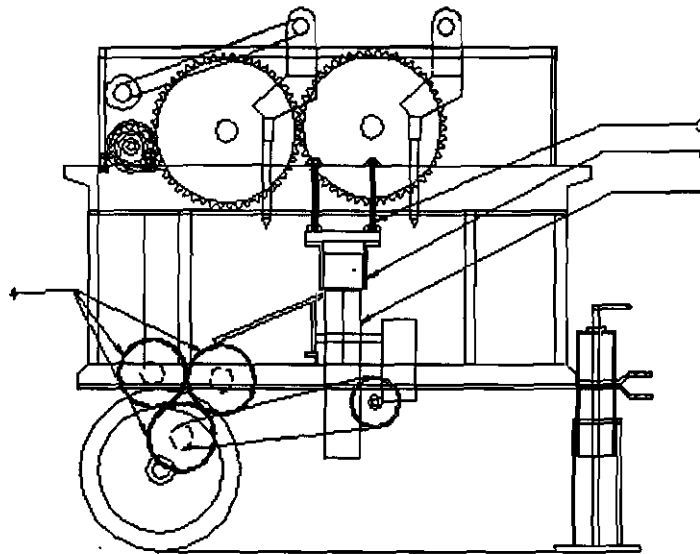
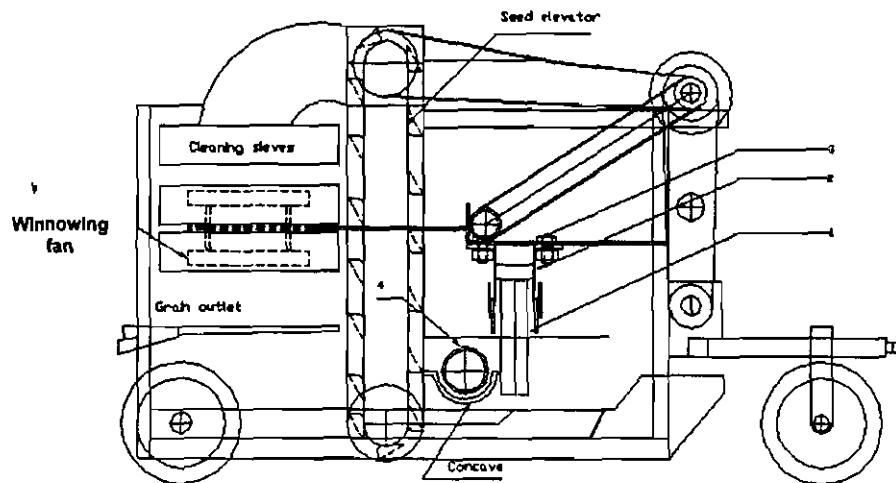Fig. (1): Schematic diagram of the flax deseeding machine

Fig.(2): Schematic diagram of the flax deseeding and winnowing machine

1- Feeding wheel   2- Flax Holding belt
3- Tension belt   4- Flax threshing drums

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Table 1. Some physical properties of flax plant Sakha 1 variety

Physical characteristics	Value
Total plant height, cm	91.1
Length of flowering zone, cm	13
Stalk diameter, cm	0.4
Number of capsules/plant.	11
Number of seed/capsule.	10
Seed / straw ratio of the yield.	1:8
Grain moisture content, %	14
Stalks moisture content, %	17

System capacity: Time of deseeding (threshing) and cleaning (winnowing) process were measured by stopwatch to determine the capacity of the three systems. Three feeding rates were used during the tests for both machines under study.

Unstripped capsules (UnC): -

Unstripped capsules, it is the losses due to remaing capsules on the stalks after passing the combing forks or tractor. The percentage of unstripped capsules were calcultaed using the following formula: -

$$Un\ C = Wuc/wt \times 100$$

Where   Wuc = weight of unstripped capsules

     wt = total weight of capsules on the stalk

Stripping efficiency (StE):

Stripping efficiency was calculated according to the following formula:

$$St\ E = (Wsc/wt)*100$$

     Where: Wsc = weight of stripped capsules.

Seed losses

It is the seed losses due unstripped and unthreshing capsules, and seed losses due to threshing and winnowing operation.

The percentage of seed losses were calculated using the following equation:

$$SL= (Sew/Tw)*100$$

Where:

     SL= seed losses%

     Sew = seed weight, gm,

     Tw = Total weight of sample, gm.

Broken stalk: -

100 plant were taken reandomly after deseeding operation from each of the three systems under study. The number of broken parts were determined in each stalk, and the average of broken parts was calculated.

Stalk loss (StL):

Stalk loss is not only the spilled parts of the stalks but also include the stalk broken parts. This is because the broken parts don't produce fibers of good quality. Stalk loss was calculated according to the following equation:

$$St\ L = (Wsps /Wst)*100$$

Where:

     Wsps = Weight of spilled parts of stalks during deseeding.

     Wst = Total weight of stalks rather than capsules.

Unthreshed flax capsules (UnFC): -

The percentage of unthreshed flax capsules was calculated according to the following formula: -

$$UnFC = (Wus/Wts) \times 100$$

where   Wus = weight of unthreashed capsules

Wts = weight of total capsules

Threshing efficiency(ζ): -

Threshing efficiency was calculated according to the following formula: -

ζ = 100- unthreshed capsules.

RESEULTS AND DESCUSION

1.Physical and mechanical properties of flax plant.

The physical and mechanical properties of the tested flax variety have been evaluated. The obtained results could be used in designing and fabricating flax combine harvesters. The average values of physical characteristics of flax plant Sakha 1 were shown previously in table1.

Capsules detachment force:

Results indicated that the minimum and maximum capsule detachment force were 5.1 N and 14.1 N respectivily. The average value of capsule detachment force was 9.6 N.

Shearing force of flax stalk:

The statistical analysis showed that the stalk shearing force depends mainly on the stalk diameter. The relationship between shearing force and stalk diameter at 14 % moisture content is plotted in Fig.(3) .It can be seen that the shearing force increased as the stalk diameter increased with a high correlation coeffecient of R^2 = 0.93. Comparing the results of shearing force along the plant height, it was found that the shearing force at the bottom was the highest followed by the middle and top of plant.This may be due to the diameter at the bottom was the highest followed by the middle and top of plant, which mean more cells in the botton than the top of plant. The relationship between shearing force (F_s) and stalk diameter (S_d) could be described by the following relationship:

$$F_s = 54.051 \, S_d + 36.612 \quad R^2 = 0.93$$
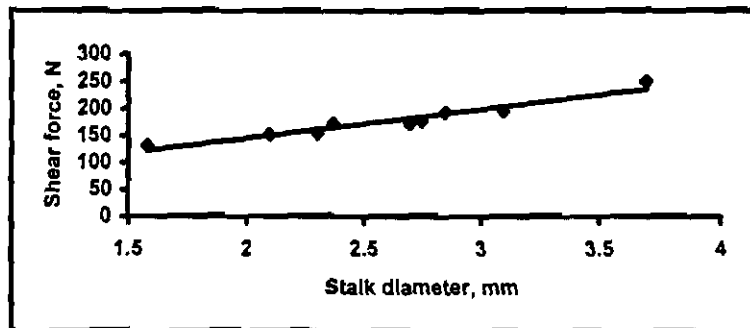

Fig. (3): The relationship between shearing force and flax stalk diameter

Tensile force of fibers:

Fiber tensile force was measured for the most common variety Sakha 1. The obtained results indicated that the fiber tensile force ranged from 3.6 to 0.5 N with average value of 2.05 N.

Capsules crushing force:

The relationship between capsule diameter and its crushing force is shown in Fig. (4). Results indicated that larger capsule diameter required higher crushing force. The data indicated that the capsule crushing force and capsule detachment force are increased by increasing capsule diameter. This may be due to the walls inside the larger capsules diameter and between the seeds are stronger that smaller one. The capsuale crushing force ranged from 19.75 to 35.5 N.
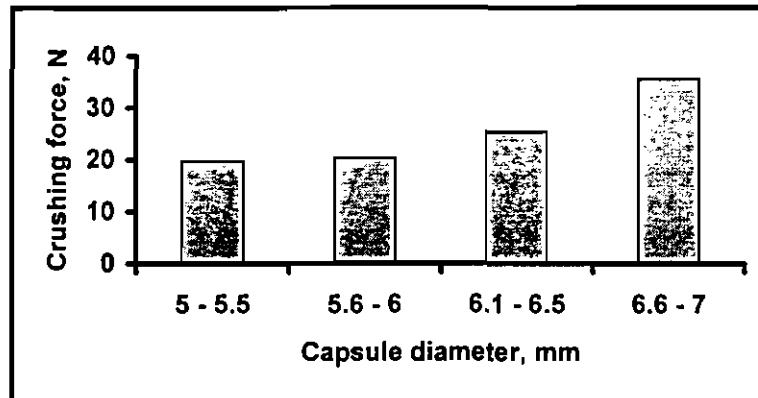

Fig. (4): The relationship between capsule diameter and crushing force

Shearing force of flax seeds:

Laboratory tests showed that the seed shearing force ranged from 9.2 to 15. 1 N at an average value of 12N .

2- Performance evaluation of flax deseeding systems:

In the flax deseeding machine and flax deseeding and winnowing machin, the stripping operation is accomplished by combing action. For deseeding flax, materials within the stripping chamber may be subjected to stripping fingers one or more times until flax seeds are separated from the stalks. The stripping performance was affected by feed rate and the speed of fingers (comb).

Machines deseeding capacity:

The obtained data showed that the flax deseeding machine then cleaning using winnowing machine (M1) and flax deseeding and winnowing machine (M2) capacities were 0.5 and 1.5 Mg/h respectively. It was also observed that the higher capacity of flax deseeding and winnowing machine (M2) attributed to the three separating forks (stripping mechanism) compare with one for the flax deseeding machine.

On the other hand prepareing flax crop for deseeding operation required one hour per feddan for M3, the tractor spent 2 hours for threshing capsules. Separating the seed from stalks needs also 4 hours, and the time consumed for cleanning was 6 hours. The total time consumed was 13 hours per feddan.

Effect of feeding rate on capsules losses:

The effect of increasing feed rate on capsule losses is shown in Fig. (5) Results indicated that increasing feed rate lead to increase capsules losses. Comparing the results of capsule losses at different levels of feeding rates, it is clear that the M1 system gave higher losses than the M2 system at the same value of feeding rate. The maximum value of capsule losses was (27.6 kg/Mg) for M1. On the other hand there is no capsules losses using traditional system (M3), as it was found that all the capsules were separated from the stalks and crushed (threshing) due to the high number of passes that the wheels of the tractor make in this system.
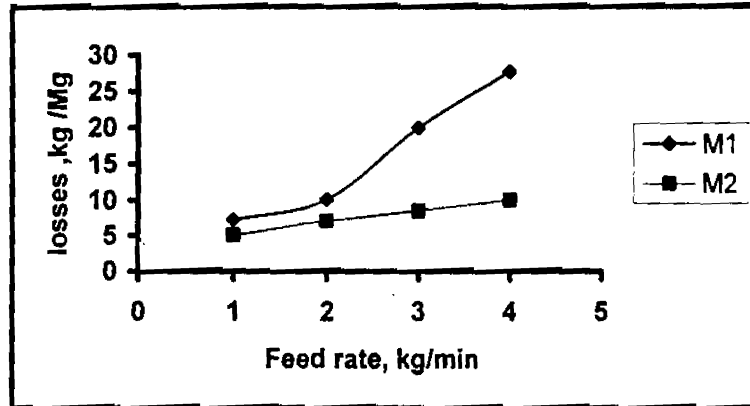

Fig. (5): Effect of feed rate on the capsule losses

Total seed losses for different three systems:

The total seed losses for three systems Fig. (6) were calculated. The data indicated that the minimum seed loss was 2 % for the M2 system. The maximum seed loss was 30 % using the M3 system. Meanwhile the corresponding value of M1 system was 5%.
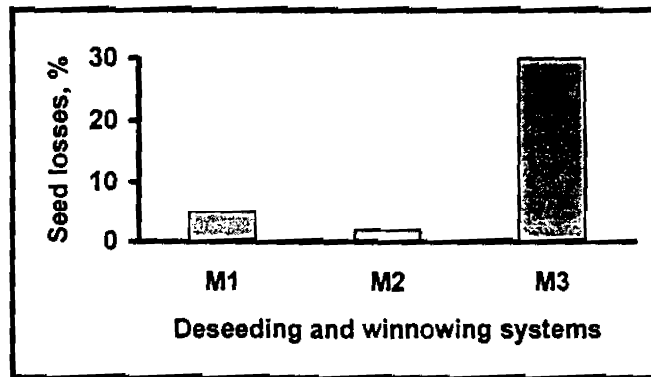

Fig. (6): Effect of different systems on seed losses

Seed separation efficiency:

The seed separation efficiency was determined for all deseeding systems under investigation. The highest efficiency 96% was obtained with M2 system. The seed separation efficiency for M1 system was 92%. Meanwhile the corresponding value was 87% for M3 system. Although the cleaning method for M1 and M3 was the same "using the same traditional winnowing machine" but the input material was different. The input material from the M3 system was collected from the ground with small partical of clay and material other than grain (MOG).

Effect of different systems on flax fiber:

Both of M1 and M2 systems gave the maximum flax fiber yield. On the other hand the M3 system decreased the fiber yield by 25%. Increseing the fibers loss associated with M3 system could be attributed to the increase of the number of broken stalks caused by tractor passing over the stalks during threshing operation, which lead to more fiber losses during the fiber prosseccing operation (rotting).

The operation cost:

The operation cost LE/fed. For the three systems Fig.(7) was calculated (**according to Awady 1987**). The maximum obtained cost was found to be 320LE/feddan for M3, While the cost for M1 was 120 LE. The minimum operation cost found to be 100 LE/fed. for M2.
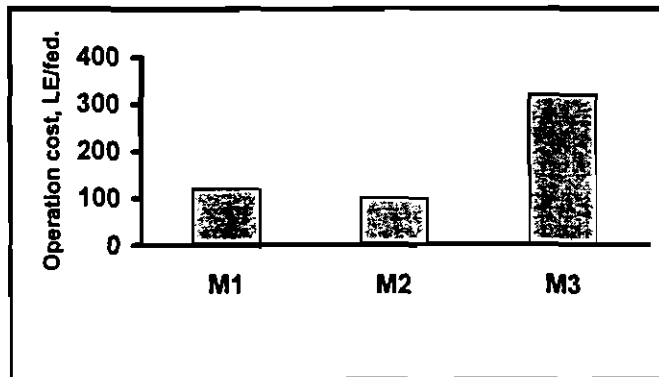

Fig. (7): Effect of different systems on operation cost

Conclusions and recommendations

The special flax deseeding and winnowing machine (M2 system) gave better performance than M2 and M3 systems, which had the minimum seed losses and minimum flax stalk damage (M3 system decreased the fiber yield by 25 %.). Also the M2 has low cost than M1 and M3.

The engineering factors that studied in this work which gave the best performance "The drum of rasp bar, rotate at speed of 9.38 m/s. No. of combing fork are 3, rotate at 4.6 m/s, at feeding rate ranged between 15-20 kg/min".

The measured physical properties of flax crop could be used to determine dimensions of the capsule separation chamber. Also the measured mechanical properties could be used to determine the designed dimensions of the threshing and separating unit, calculate the force required to overcome the stripping and threshing resistances for both the stationary and combine harvesters.

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دراسة العوامل الهندسية المؤثرة على نظم دراس محصول الكتان

صفوت الخواجة و يوسف شاروبيم
قســم التصميــم - معهد بحــوث الهنــدسة الزراعيـــة - مركــز البحـــوث الزراعيـــة-
جمهورية مصر العربية

يعد محصول الكتان أحد المحاصيل الاستراتيجية لانتاج الزيوت والالياف فــي مصــر والعالم. حيث بلغت المساحة المنزرعة منة حوالي ٢٢ ألف فدان, تنتج ما يقدر بحوالــي ٧٨,٤١٠ ميجا جرام ألياف، يتم استخدامها محليا ويصدر جزء كبير منها إلى الخارج. وتقدر إنتاجية البــذور من نفس المساحة بحوالي ١٥,١٢٧ ميجا جرام (نشرة الإحصـــاءات الزراعيـة-وزارة الزراعـة ٢٠٠٣).

لذا يهدف هذا البحث إلى دراسة العوامل الهندسية المؤثرة على دراس وتذرية (هدير) محصول الكتان للوصول إلى انسب هذه العوامل الهندسية تأثيرا على كفاءة عملية الــهدير مــع المحافظة على سيقان النبات من أي ضرر لتعظيم إنتاجية الألياف مــن هـذا المحصــول الــهام، بالإضافة إلى توظيف هذه العوامل الهندسية في تصميم وتطويـــر آلــة حصــاد ودراس جامعــة (الكومباين) لمحصول الكتان. ولقد تم دراسة العوامل الهندسيـة المؤثـرة علـى دراس وتذريـة محصول الكتان من خلال ثلاث طرق للدراس والتذرية اشتملت على : دراس بالــة متخصصــة والتذرية بالة التذرية البلدية – دراس وتذرية بآلة متخصصه – دراس بواسطة الجرار،وآلة التذرية البلدية (الطريقة التقليدية). وقد تم تقييم هذه النظم على أساس سعة النظام، كفــاءة عمليــة فصــل الكبسول،كفاءة عملية الدراس، نسبة الفاقد في البنور والسيقان، و تكاليف التشغيل. وتشــير أهــم النتائج المتحصل عليها إلى أن أعلى إنتاجية كانت ١,٥ ميجاجرام/ساعة باســتخدام آلــة الــدراس والتذرية المتخصصة مع اقل نسبة فاقد كلية للبنور بلغت ٢%.، في حين وصلت نسبة الفقــد فــي البنور والالياف إلى ٣٠، ٢٥% على التوالى باستخدام الطريقة التقليدية. كانت اقل تكلفة اقتصاديــة للتشغيل ١٠٠ جنية/للفدان وذلك باستخدام آلة الدراس والتذرية المتخصصة، في حين كــانت ١٢٠، ٣٢٠ جنية /للفدان بآلة الدراس المتخصصة والتذرية بالة التذرية البلديـــة و باســتخدام الطريقــة التقليدية على التوالى.

هذا وتوصى الدراسة باستخدام النتائج المتحصل عليها من خلال دراســـة الخصــائص الطبيعية في تحديد الابعاد التصميمية لغرفة فصل الكبسول، بالاضافه الى اســتخدام الخصــائص الميكانيكية في تحديد الابعاد التصميمية لغرفة الدراس وكذلك القدرة اللازمــة لوحدتــى الــدراس والتذرية وحسابات قدرة المحرك الكلية المطلوبة مع استخدام افضل النظم المختبرة فـــى عمليــة فصل ودراس الكبسول، واختيار السرعة المثلى الموصى بها من خـــلال اختبــار الآلات تحــت الدراسة فى تطوير الة دراس وتذرية ثابتة اومتحركة (كومباين) لمحصول الكتان.