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Manufacturing of a Lateral Conveyor Head Suitable for Mowing Seed-Producing Alfalfa

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ABSTRACT

Replacing the header of the reaper-binder with an alternative head suitable for mowing the dry clover crop (specifically alfalfa bred to retain seeds) aims to enhance operational efficiency by reducing mowing losses, labor costs, and saving time. The study examined several variables including reaper forward speeds, lateral velocities of the transport catenary, moisture contents in seed bolls, and plant stems. It then evaluated their impact on seed loss, machine capacity, field efficiency, specific energy, and operational costs. The research documented that the most favorable results were attained at a forward speed of 2.52 km/h, a lateral transport velocity of 0.8 m/s, and a seed boll moisture content of 18%. At these parameters, seed loss amounted to 1.94%, while achieving a field efficiency of 90.17% and a field capacity of 1.32 fed/h. The specific energy required was 9.95 kW.h/fed, and the operational cost totaled 800 EGP/fed, demonstrating a decrease of 21.5% compared to the traditional method.

Keywords: vertical conveyor reaper, transport catenary, lateral speed, clover seed losses

INTRODUCTION

Egyptian clover is the primary fodder crop for farmers to feed their livestock. The cultivated area is estimated at 1,4 million feddans annually. Recently, Egyptian clover seeds have been utilized in many pharmaceutical industries. The demand for it has increased and its price has risen. So, farmers prefer it over the early cultivation of maize. The Egyptian clover harvesting has two stages: mowing and then threshing. The mowing process was used a reciprocating mower attached to the right side of the tractor, and it requires a group of workers of no less than six workers for every 100 linear meters of the area to create a lateral shift for each tractor mowed. It is an expensive method, and the loss of seed bolls is high. Shreen *et al.* (2014); Patel and Varshney (2014) assessed the harvesting process of wheat crops using a self-propelled vertical conveyor reaper and investigated the losses caused by the cutter bar. Metwalli *et al.* (1981) and Abdrabo (2015) reported that employing a self-propelled mower for harvesting wheat and rice resulted in approximately 62% savings for wheat crops and about 63% savings for rice crops compared to the cost of manual mowing processes. The highest total grain loss 2.6% occurred at 5.1 km/h of forward speed, 16.3% of grain moisture content, and 5 cm of cutting height. Conversely, the lowest field capacity was 0.61 fed/h, observed at a forward speed of 2.1 km/h, a cutting height of 5 cm, and a grain moisture content of 23.5%. The lowest energy consumption, recorded at 5.0 kW.h/fed, occurred at a forward speed of 5.1 km/h, a cutting height of 15 cm, and a grain moisture content of 16.3%. Additionally, the highest operating cost of 30.49 EGP/fed was documented at a forward speed of 2.1 km/h, a grain moisture content of 23.5%, and a cutting height of 5 cm. Potkonjak *et al.* (2009) documented that increasing the mower speed to 8.82 km/h was associated with a notable rise in losses. Specifically, the total mowing losses of the green mass constituted 1.27% of the yield, despite achieving a peak field capacity of 1.06 ha/h). Manjeet *et al.* (2017) emphasized crop harvesting as a crucial agricultural operation requiring considerable labor. They highlighted the challenges related to the availability and cost of laborers during the harvesting season, identifying it as a vital problem. The shortage of labor during this critical period, coupled with unpredictable weather conditions, was noted as a factor causing substantial losses to farmers. Gajakos *et al.* (2013) undertook feasibility testing of a self-propelled vertical conveyor reaper designed for harvesting. The reported effective field capacity and field efficiency were 0.255 ha/h and 88.59%, respectively. The fuel consumption was 0.728 and 2.84 l/h, leading to harvesting losses in mechanical of 5.68% and manual harvesting 4.73%. In an evaluation study, Mehetre *et al.* (2014) examined a self-propelled riding-type vertical conveyor reaper. The results showed an average effective field capacity of 0.17 ha/h, achieved at an average forward speed of 1.7 km/h with a 60% efficiency rate. The vertical conveyor reaper proved suitable for harvesting crops at a height between 55 and 60 cm. The calculated cost was Rs.115.27 per hour. On a different note, Chavan *et al.* (2015) introduced a manually operated reaper designed as a highly labor-saving piece of equipment, requiring only 20 man-hours per hectare. The field efficiency surpassed 66%, and the harvesting cost was 1250.4 Rs/ha, presenting a considerable reduction compared to 2000 Rs /ha associated with the traditional method. According to Hadidi *et al.* (1984) and Khater *et al.* (2023) signed that the proportion of grain losses in wheat and rice increased with higher forward speeds of the machine. However, elevating the cutter bar speed correlated with a reduction in the percentage of grain losses. Additionally, an increase in forward speed was associated with a rise in the number of uncut stalks. El-Sharabasy (2006) engineered and produced a self-propelled machine specifically tailored for cutting diverse grain crops to optimize efficiency and lessen losses. The study showcased that the peak field capacity 0.452 fed/h and the most economical operating cost 37.50 EGP/fed were achieved under low kinematic parameters (1.8, 1.45) and a diminished grain moisture content of 21.45%, 19.11%. El-Sharabasy (1997) and Badr (2005) studied the comparison between different harvesters (power reaper, self-

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propelled mower, rear-mounted mower, and small combine harvester) in wheat and rice fields; it was observed that the smallest grain loss 1.66% occurred with the small combine harvester. They evaluate their performance across various parameters, including grain losses, fuel consumption, energy requirements, harvesting time, and cost. Fouda *et al*. (2019) indicated that the highest efficiency of cutting height was 90.2% for operating the developed reciprocating mower of 2.9 m/s for cutting knife speed with a forward speed of 0.89 m/s.

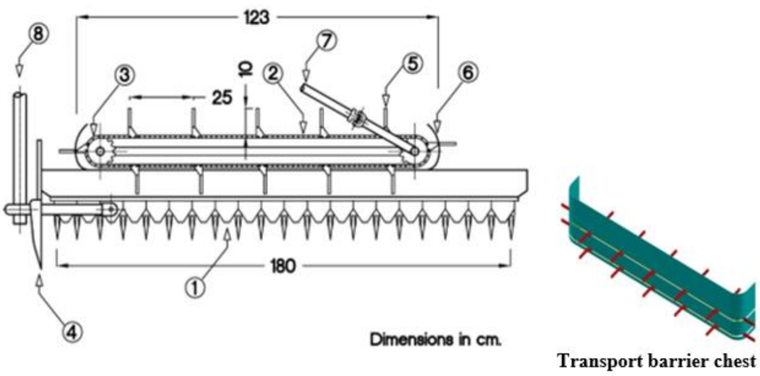
In light of the aforementioned considerations, it was essential to adapt the self-propelled reaper-binder to efficiently harvest the Egyptian dry clover crop, specifically alfalfa bred for seed, with heightened operational efficiency. This is done by replacing the header of the reaper-binder with an alternative head equipped with a transport chest to suit the intertwined alfalfa crop and replacing the cutting knife with a knife with a larger operating width to increase the field capacity of the modified machine. Also, maximizing the benefit of the machine by adding an operating season increases the machine's productivity and the economic return from its operation, as the alfalfa harvest season comes at least a month after the wheat harvest.

MATERIALS AND METHODS

Field trials were performed at Tag Elez Agricultural Research Station, Dakahlia Governorate, Egypt, during the 2022/2023 agricultural season of bools clover crop (alfalfa bred to take seeds) and with about areas of two feddans. A modification was made to the header part with the self-propelled wheat reaper-binder in the technical workshop in the city of Sinbillawin, Dakahlia Governorate, to suit mowing the dry clover crop for seed production. The variables of this study were; four different forward speeds 2.52, 2.88, 3.38 and 3.96 km/h, three values of seed bolls moisture contents 13, 16 and 18%, while the moisture content of the bolls stems at the base of the plants was 12, 14, and 15% respectively, at the same moisture contents as the bolls and three lateral transport velocities 0.8, 1.0 and 1.2 m/s. And in the all treatments the cutting knives speed were operated at 2.11 m/s. Impact of the above-mentioned factors on the seed losses %, field efficiency %, field capacity fed/h, energy consumption, kW.h/fed, and operating cost, EGP/fed were taken into consideration.

Description of the reaper:

On the base of a reaper-binder is a unique harvesting machine that reaps the crop as well as binds it simultaneously with a twine. The following modification wear, replacing the header of the reaper-binder with an alternative head equipped with a cutting knife with a working width of 180 cm and a barrier chest equipped with a transport catenary for transporting the stuffed plants to the left side of the machine, to utilize for mowing the dry clover crop (Figs 1 and 2). The investigated prototype contains the following components; the frame spans a length of 155 cm, a width of 125 cm, and stands at a height of 160 cm. The design incorporates essential components such as a hitch unit for the hitching system, a gearbox, parts of the power units, a harvesting unit, and four ground wheels, each with 75 cm and 45 cm diameters. The machine is equipped with a single-cylinder, engine of 10.5 kW. The transmission system components, including: disc clutch, gearbox, steering wheel, and ground wheels. The cutting part is a reciprocating knife with 48 blades, the total length of the cutting knife equal 180 cm. The horizontal conveying is measuring 123 cm in length and 75 cm in height. The barrier chest is directly installed above and behind the cutting knife. The crop stems are cut and transported to the left side of the machine in the form of a strip.



1- cutter bar, 2- lateral transport catenary, 3- conveyor chain, 4- guide of cutting knife, 5- lateral conveyor fingers, 6- barrier chest, 7- catenary drive shaft, 8- cutting knife drive shaft

Fig. 1. The diagrams of the proposed header with a barrier chest equipped with a transport catenary

Fig 2. The modified prototype

Measurements

Field tests were carried out to study the effect of different operating parameters on the performance of modified a self-propelled vertical conveyor reaper.

Determination of stem and bolls moisture content

The moisture contents were measured for stems and seed bolls on mowing time using a portable moisture meter for cereal straw, bran, forage grass equipped with a humidity sensor. Model, ZOEYEC TK100H 0-80%.

Operating seed losses

These were calculated by collecting clover bolls within a square meter frame after cutting the crop by the modified header, manually extracting the seeds and then weighed them. The operating loss percentage was computed utilizing the equation provided by Hassan *et al.* (1994):

$$\textbf{Operating seed losses}(\%) = \frac{\textbf{Operating losses/fed}}{\textbf{Total yield/fed}} \times \mathbf{100}$$

The theoretical field capacity

It was calculated by the next equation of Kepner *et al.* (1982):

$$\mathbf{F.C_{th}} = \frac{\mathbf{W \times V}}{\mathbf{4.2}} \times \mathbf{100}$$

Where:

F. C $_{th}$: Theoretical field capacity (fed/h.).
W : Theoretic width (m.).
V : machine speed (km/h).

The actual field capacity

Represents the actual time spent during the cutting operation, which includes both lost and productive time. The calculation for actual field capacity was derived from the next formula:

$$\mathbf{F.C_{act}} = \frac{\mathbf{60}}{\mathbf{Tu + Ti}}$$

Where:

F.C$_{act}$ is the actual field capacity of the cutting machine.
Tu is the utilization time/feddan.
Ti is the total lost time/feddan.

Field efficiency

It was determined by employing the following equation:

$$\mathbf{F.C} = \frac{\mathbf{F.C_{ACT}}}{\mathbf{F.C_{th}}} \times \mathbf{100}$$

Where:

F. E is the machine field efficiency (%).
F.C$_{act}$ is the actual field capacity of the cutting machine (fed/h).
F.C$_{th}$ is the Theoretic field capacity of the cutting machine (fed/h).

Specific Energy consumed

To evaluate the specific energy consumed, kW.h/fed during the cutting process, the estimation was carried out using the formula provided by Hunt (1983):

$$\mathbf{E} = (\mathbf{F_c} \times \boldsymbol{\rho}_\mathbf{f} \times \mathbf{L.C.V} \times \mathbf{427} \times \boldsymbol{\mu}_\mathbf{th} \times \mathbf{1/3600} \times \mathbf{1/1.36} \times \mathbf{1/75})/\mathbf{F.C_{act}} \quad \mathbf{kW.h/fed}$$

Where:

F_c is the consumption of fuel (l/h); ρ_f is the fuel density (kg/l, for benzene = 0.72); L.C.V is the lower calorific value of fuel (11000 kcal/kg). η_{th} is the thermal efficiency of the engine (25% for Otto engine), 427 is the thermo-mechanical equivalent (kg.m/kcal), and η_m is the mechanical efficiency of the engine (85% for the Otto engine).

The operating cost (EGP/fed)

The operating cost was calculated by using the next equation. (Awady, 1978)

$$\mathbf{C} = \frac{\mathbf{P}}{\mathbf{h}}\left(\frac{\mathbf{1}}{\mathbf{a}} + \frac{\mathbf{i}}{\mathbf{2}} + \mathbf{t} + \mathbf{r}\right) + (\mathbf{1.2W.S.F}) + \frac{\mathbf{m}}{\mathbf{50}}$$

Where;

C is the hourly cost (EGP/year), P is the price of the machine (EGP), H is the yearly working hours (h), a is the life expected of the machine (year), i is the interest rate/year ratio, t is the taxes, overheads ratio, r is the repairs and maintenance ratio, S is the specific fuel consumption (kW.h), F is the fuel price (EGP), 50 is the working time per month (h), m is the salary of the operator per month (EGP/h).

The working cost per feddan can be computed utilizing the next formula:

$$\textbf{The operating cost/fed} = \frac{\textbf{Hourly cost}(\textbf{EGP/h})}{\textbf{Effective field capacity}(\textbf{fed/h})}$$

The split-split plot design was used in this study, and the data was collected and analyzed using the statistical analysis program (Excel). The linear regression analysis was done for all experimental tests of; the total stem and bolls seed losses %, field efficiency %, field capacity fed/h, energy consumption, kW.h/fed, and operating cost, EGP/fed.

RESULTS AND DISCUSSION

Seed losses arising from the losses of bolls seed

In Fig (3), the data showed the effect of the modified reaper forward speeds on the percentage of seed losses arising from the losses of seed bolls at different moisture levels at 0.8 m/s of the lateral transport velocity. It found that with an increase in operating speed, there was an increase in the percentage of boll seed loss with a decrease in moisture content. The maximum seed losses of 3.05% was at a forward speed of 3.96 km/h, and the boll seed moisture content was 13%. The minimum seed losses are 2% at a forward speed of 2.52 km/h, and the boll seed moisture content is 18%. However, the seed losses increase as forward speed increases and seed moisture content decreases; this is due to the vibration of the harvester head, the weakness of the neck of the seed bolls, the force of friction, and the collision of the seed bolls with the fingers pointing to the other side.

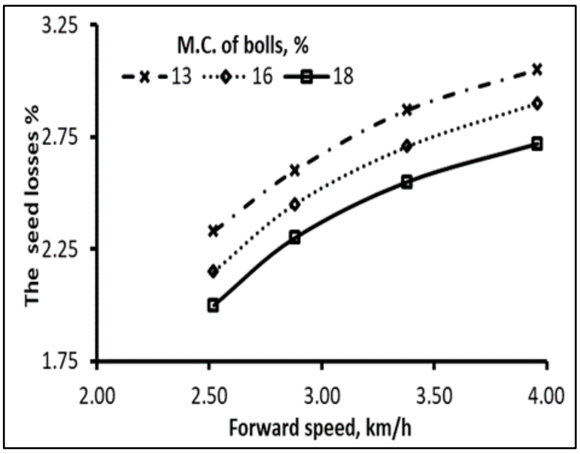


Fig. 3. Impact of forward speeds and boll moisture content on seed losses

In Fig (4), the results showed the effect of lateral transport velocity and reaper forward speed on the seed losses at 18% of seed bolls moisture content. By increasing lateral transport velocity and reaper forward speed there was an increase in the percentage of seed losses of clover. The maximum seed losses of 3.53% were recorded at lateral transport velocity and forward speed of 1.2 m/s and 3.96 km/h, respectively.

The minimum seed losses of 1.94 % were recorded at lateral transport velocity and forward speed of 0.8 m/s and 2.52 km/h, respectively. At the end, the seed losses of clover increase as lateral transport velocity and forward speed increase; this is due to, the same previous causes.

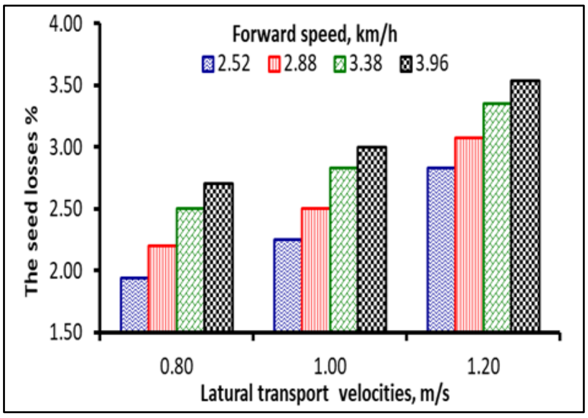


Fig. 4. Impact of lateral transport velocity and forward speed on the seed losses

Field reaper capacity and efficiency

Field capacity and efficiency stand as critical factors in assessing machine performance. The effective cutter bar width, moisture content of seed bolls, and machine forward speed, are among the diverse factors impacting the actual field capacity. Together, these elements hold considerable importance in establishing the machine's actual field capacity, underscoring the need to account for them when evaluating overall performance.

The findings (Fig 5) illustrate the impact of varying forward speeds on reaper field capacity (fed/h) at different moisture content levels in the stems with neglected the effect of the lateral transport velocity. As the forward speed increased, the field capacity also increased, particularly as the stem moisture content decreased. Conversely, a decrease in forward speed and an increase in stem moisture content led to a reduction in the field capacity of the clover crop. The peak field capacity value, reaching 2.03 fed/h, was observed at a forward speed of 3.96 km/h with a stem moisture content of 12%. Notably, the difference in field capacity between the highest and lowest percentage of stem moisture content at the same forward speed was 0.5 fed/hour.

Conversely, the lowest field capacity value of 0.85 fed/h was documented at a forward speed of 2.52 km/h with 15% stem moisture content. At the same forward speed, the difference in field capacity between the highest and lowest percentage of stem moisture content was 0.47 fed/hour. These results underscore the intricate relationship between forward speed, stem moisture content, and field capacity in the context of clover crop performance.

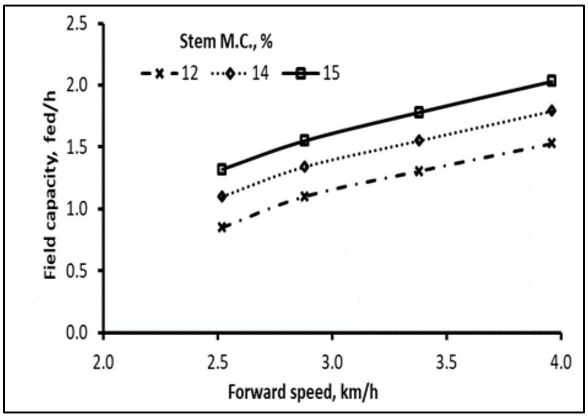


Fig. 5. Impact of forward speed on the modified reaper field capacity

The data (Fig 6) depict the impact of machine forward speed on the field efficiency of the modified reaper. As the forward speed of the modified machine increased and the stem moisture content decreased, there was a corresponding decrease in field efficiency. The highest field efficiency percentage, reaching 94.5%, was attained at a forward speed of 2.52 km/h with a stem moisture content of 12%. Conversely, the lowest field efficiency percentage, 87%, was observed at 3.96 km/h forward speed with 15% of stem moisture content.

These findings suggest that the variation in field efficiency could be attributed to the challenges associated with operating the machine in moist plants, which may consume more time. The inverse relationship between forward speed, stem moisture content, and field efficiency underscores the importance of considering these factors for optimal performance in clover crop harvesting.

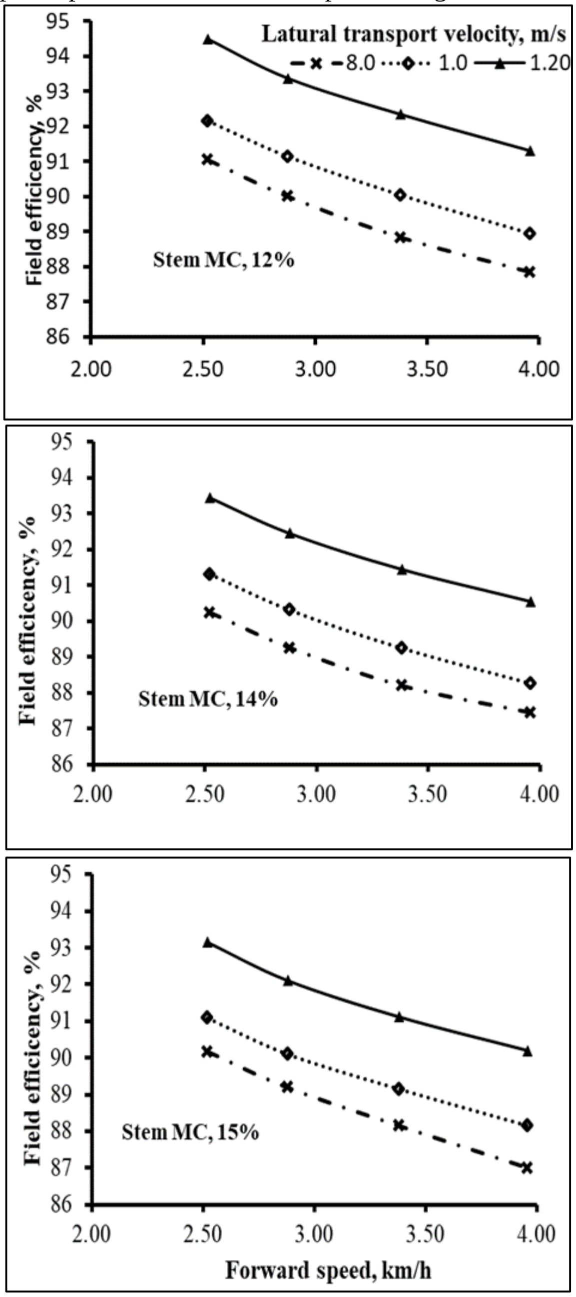


Fig. 6. Impact of reaper forward speed on the field efficiency

Forward speed impact on the specific energy

The data (Fig 7) elucidate the influence of forward speed on the specific energy of mowing clover crops using the modified reaper. With the increment of the forward speed of the machine and the stem moisture content decreasing, there was a concurrent decrease in energy consumption. The maximum energy consumption value, reaching 9.95 kW.h/fed, was recorded at a forward speed of 2.52 km/h with a stem moisture content of 15%. In contrast, the minimum energy consumption, 4.07 kW.h/fed, was attained at a forward speed of 3.96 km/h with a stem moisture content of 12%. These results indicate increasing forward speeds and lesser stem moisture contents contribute to more efficient energy utilization during the mowing of clover crops. The observed decrease in energy consumption aligns with the notion that drier crops and higher machine speeds often result in improved energy efficiency.

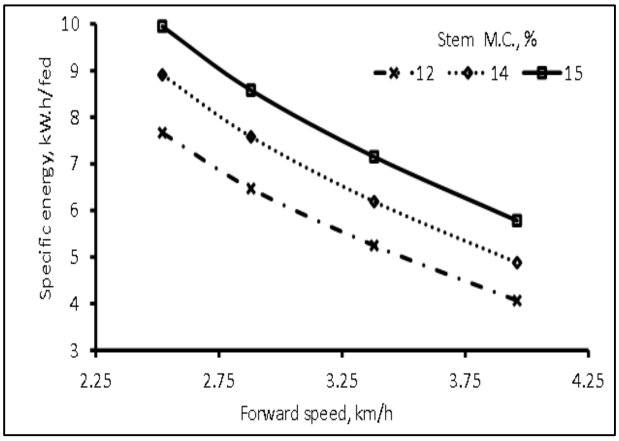


Fig. 7. Impact of reaper forward speed on energy consumption

The operating costs

The data in Fig (8) depicts the impact of the forward speed of the modified reaper on the operating cost of mowing clover crops. With the rise in the machine's forward speed and the decrease in stem moisture content, there was a corresponding decrease in energy consumption. The highest operating cost, reaching 800.82 EGP/fed, was observed at 2.52 km/h forward speed with a stem moisture content of 15%. Conversely, the minimum operating cost, amounting to 240 EGP/fed, was achieved at a forward speed of 3.96 km/h with 12% stem moisture content.

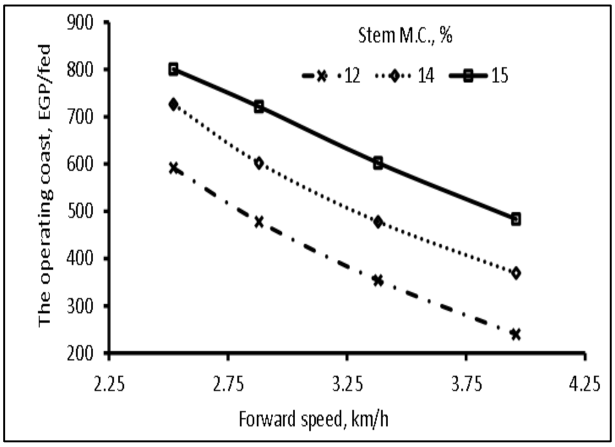


Fig. 8. Impact of forward speed and stem moisture content on operating cost

Finally, the manufactured lateral conveyor head was adjusted to the optimum operating parameters, including a forward speed of 2.52 km/h, a lateral transport velocity of 0.8 m/s, and a moisture content of the seed bolls about of 18%. Subsequently, a comparison was conducted with the traditional method, which involves using a reciprocating mower attached to the right side of the tractor. This conventional approach requires a team of no fewer than six workers for every 100 linear meters of the area to create a lateral shift for each tractor mowed. The differences in field performance between the two methods are presented in Table 1."

Table 1. A field performance comparison between the manufactured header and the traditional method

Field measurements	Manufactured header	Traditional method
Seed losses, %	1.94	3.5
Effective field capacity, fed/h	1.32	0.8
Operating costs, EGP/fed	800	1020

The statistical analysis

The linear regression analysis was done for the all-experimental tests of;

- Seed losses "SL_1" at neglected the effect of the transport velocity and seed losses"SL_2", at neglected the effect of the moisture content at the relations of bolls moisture contents "BMC", and stem moisture contents "SMC", lateral transport velocity "LTS" and forward speeds "FS";
- Field reaper capacity "FC" at neglected the effect of the transport velocity and efficiency "CEff", at stem moisture content "SMC", lateral transport "LTS" and forward speeds "FS";
- Energy consumption "EC" and operating cost "OC", at stem moisture content "SMC", and forward speed "FS" by neglected the effect of the transport velocity.

The constants values of coefficient of studied variables and regression coefficients tabulated in table (2). From the table can cleared that all studied variables had a directly proportional to the evaluation parameters, except the bolls and stem moisture content affects the losses in relations with the reaper forward speeds, and the reaper forward speeds affects the "CEff, EC and OC at the relation with the stem moisture content and "LTS" by "CEff" had an inversely proportions. However, the constants of slope of the curve cleared the inversely proportion by "SL_1, SL_2 and FC" only. The regression coefficient shows the highest at FC followed by OC, EC, CEff, SL_1 and SL_2 respectively.

Table 2. The values of constants coefficient of studied variables and regression coefficients

Evaluations parameters	BMC	SMC	FS	LTS	R^2
SL_1	1.7455	- 0.0631	0.4978	-	0.9644
SL_2	-0.9949	-	0.5114	2.8525	0.9840
FC	-0.9310	0.0791	0.4704	-	0.9915
CEff	87.277	0.1698	- 2.0904	10.7539	0.9850
EC	14.8018	0.333	- 2.699	-	0.9888
OC	1068.93	41.4113	- 245.816	-	0.9908

CONCLUSION

The utilization of the manufactured lateral conveyor head for mowing the dry clover crop (alfalfa bred to produce seeds) is recommended. The optimal combination of operating parameters includes a forward speed of 2.52 km/h, a lateral transport velocity of 0.8 m/s, and a moisture content of the seed bolls set at 18%. This combination yields the best results, achieving a seed loss of 1.94%, a field efficiency of 90.17%, a field capacity of 1.32 fed/h, and a specific energy consumption of 9.95 kW.h/fed. Additionally, the operating cost amounts to 800 EGP/fed, reflecting a decrease of 21.5% compared to the traditional method.

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تصنيع رأس ذو ناقل جانبي لضم محصول البرسيم الربابة

محمود على عوض ، أسامة أحمد فودة ، فاطمة الزهراء على عبد الجواد و وائل محمد البلكيمي

معهد بحوث الهندسة الزراعية ـــ مركز البحوث الزراعية

الملخص

في الآونة الأخيرة دخلت بذور البرسيم المصري في العديد من الصناعات الدوائية وزاد الطلب عليه وارتفع سعره مما دفع المزارعين إلى تفضيله عن الزراعة المبكرة لمحصول الذرة الشامية. ويتم حصاده على مرحلتين الضم (الحش) ثم الدراس. عملية الحش تتم بواسطة المحشة الترددية والمعلقة على الجانب الأيمن للجرار وتحتاج لمجموعة من العمال لا تقل عن ٦ عمال لكل ١٠٠ متر طولي من المساحة المراد حشها لعمل ترحيل جانبي لكل جرة يتم حشها. وهي طريقة مكلفة وفواقد لوزات البذور بها عالية. لأجل ذلك تمثل الهدف من هذه الدراسة بتصنيع رأس جديد لماكينة ضم وتربيط القمح ذاتية الحركة واستبداله بالرأس القديم ليناسب ضم محصول البرسيم الربابة بكفاءة تشغيلية عالية وزيادة العائد الاقتصادي للآلة حيث يأتي موسم حصاد البرسيم الربابة بعد حصاد القمح بشهر. تم دراسة تأثير عوامل التشغيل على الآلة المعدلة والمتمثلة في السرعة الأمامية للآلة وسرعة كاتينة النقل الجانبي والمحتوي الرطوبي لسيقان المحصول وللوزات البذور و تأثير هذه العوامل علي فواقد المحصول والسعة والكفاءة الحقلية للآلة واستهلاك الطاقة وتكاليف التشغيل لحش المحصول. وتحققت أفضل النتائج عند سرعة تقدم للآلة ٢,٥٢ كم/ساعة وسرعة ٠,٨ م/ث لكاتينة النقل الجانبي ومحتوي رطوبي للوزات البذور ١٨% حيث كان فاقد البذور ١,٩٤% والسعة الحقلية للآلة ١,٣٢ فدان/ساعة وكفاءة حقلية نسبتها ٩٠,١٧ % وطاقة نوعية مستهلكة قدارها ٩,٩٥ كيلووات.ساعة/فدان وتكلفة مقارها

٨٠٠ جنيها للفدان بانخفاض مقاره ٢١,٥% عن الطريقة التقليدية. يوصى بتشغيل الالة المعدلة عند سرعة تقدم ٢,٥٢ كم/ساعة وسرعة ٠,٨ م/ث لكاتنية النقل الجانبي ومحتوى رطوبي للوزات البذور ١٨%.