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

Awad, M. A.*; O. A. Fouda; Fatma. A. Abdelgawad and W. M. Elbalkemy

Agric. Eng. Res. Inst. Dokki, Giza 12611, Egypt

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 caterany, 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 caterany, 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 Abdalabo (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. Manjjet 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-
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 bolls clover crop (alfalfa bred to take seeds) with heightened operational efficiency. 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.
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):

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

The theoretical field capacity
It was calculated by the next equation of Kepner et al. (1982):

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

Where:
F.C_{th} : Theoretical field capacity (fed/h).
W : Theoretical 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:

F.C_{act} = \frac{60}{T_u + T_l}

Where:
F.C_{act} is the actual field capacity of the cutting machine.
T_u is the utilization time/feddan.
T_l is the total lost time/feddan.

Field efficiency
It was determined by employing the following equation:

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

Where:
F. C 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):

E = (F_x \times \rho_f \times L.C.V \times 427 \times \mu_p \times \frac{1}{\mu_s} \times \frac{1}{1.36} \times \frac{1}{1.75})/F.C_{act} \times \text{kW.h/fed}

Where:
F is the consumption of fuel (l/h), \rho_f is the fuel density (kg/L for benzene = 0.72l), L.C.V is the lower calorific value of fuel (11000 kcal/kg), \mu_p is the thermal efficiency of the engine (25% for Otto engine), 427 is the thermomechanical equivalent (kgm/kcal), and \mu_s 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)

\[
C = \frac{P}{H} \left( \frac{1}{a} + \frac{i}{2} + t + r \right) + (1.2 \times W.S.F) + \frac{m}{50}
\]

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 (kWh/l), F is the fuel price (EGP/l), 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:

\[
\text{The operating cost/fed} = \frac{\text{Hourly cost (EGP/h)}}{\text{Effective field capacity (fed/h)}}
\]

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 %, seed efficiency %, field capacity fed/h, energy consumption, kwh/fed/h, 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](image-url)
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.

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.
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/ha, 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/ha, 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.

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 moved. 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

<table>
<thead>
<tr>
<th>Field measurements</th>
<th>Manufactured header</th>
<th>Traditional method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed losses, %</td>
<td>1.94</td>
<td>3.5</td>
</tr>
<tr>
<td>Effective field capacity, fed/h</td>
<td>1.32</td>
<td>0.8</td>
</tr>
<tr>
<td>Operating costs, EGP/ha</td>
<td>800</td>
<td>1020</td>
</tr>
</tbody>
</table>

The statistical analysis

The linear regression analysis was done for all-experimental tests of:
- Seed losses "SL1" at neglected the effect of the transport velocity and seed losses "SL2", 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 "SL1, SL2 and FC" only. The regression coefficient shows the highest at FC followed by OC, EC, CEff, SL1 and SL2 respectively.

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

<table>
<thead>
<tr>
<th>Evaluations parameters</th>
<th>BMC</th>
<th>SMC</th>
<th>FS</th>
<th>LTS</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>SL1</td>
<td>1.7455</td>
<td>-0.0631</td>
<td>0.4978</td>
<td>-</td>
<td>0.9644</td>
</tr>
<tr>
<td>SL2</td>
<td>-0.9949</td>
<td>-</td>
<td>0.5114</td>
<td>2.8525</td>
<td>0.9840</td>
</tr>
<tr>
<td>FC</td>
<td>-0.9310</td>
<td>0.0791</td>
<td>0.4704</td>
<td>-</td>
<td>0.9915</td>
</tr>
<tr>
<td>CEff</td>
<td>87.277</td>
<td>0.1698</td>
<td>-2.0904</td>
<td>10.7539</td>
<td>0.9850</td>
</tr>
<tr>
<td>EC</td>
<td>14.8018</td>
<td>0.3333</td>
<td>-2.699</td>
<td>-</td>
<td>0.9888</td>
</tr>
<tr>
<td>OC</td>
<td>1068.93</td>
<td>41.4113</td>
<td>-245.816</td>
<td>-</td>
<td>0.9908</td>
</tr>
</tbody>
</table>

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.hr/1000 fed. Additionally, the operating cost amounts to 800 EGP/fed, reflecting a decrease of 21.5% compared to the traditional method.

REFERENCES
ASAE, (2005). American National Standards Institute, S358.2
FEB 03.

تصنيع رأس ذو ناقل جانبي لضم محصول البرسيم الرياحي

محمود علي عوض ، أ.م.أ.أحمد فودة، فاطمة الزهراء على عبد الجواد و وائل محمد البلكيمى

معهد بحث الهندسة الزراعية - مركز البذور الزراعية

الملخص
في الألواح الأخيرة نقل الروتين المحاكي للبرسيم الرياحي لألف المتراقصات العامل الزراعي في تقليل عمليات البذول والمعدات الزراعية في تقليل عمليات البذول والمعدات الزراعية في تقليل عمليات البذول والمعدات الزراعية في تقليل عمليات البذول والمعدات الزراعية في تقليل عمليات البذول والمعدات الزراعية

436
جنيها للفداء بانخفاض مقارنة 21.5% عن الطريقة التقليدية. يوصى بتشغيل الألة المعدلة عند سرعة تقدم 2.52 كم/ساعة وسرعة 0.8 م/ث للكتاتيب القبل الجابي ومحتوى رطوبة للوزات البذور 18%.