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Manufacturing and evaluating a machine for cutting and raking alfalfa and barley harvest into rows

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Abstract

A machine was manufactured to belt -rake the fodder harvest with a moving finger bar . The harvest collecting machine was installed with a two-wheeled sickle mower, thus the machine group becomes a four-wheeled vehicle that performs two functions at the same time (cutting and harvesting the harvest). The study aims to reduce the effort, time, and fuel consumption required to cut the fodder crop and assemble it into rows in preparation for its subsequent transportation or treatment with silage making machines or hay. A two-factor factorial experiment with a completely randomized block design was conducted to evaluate the combined instrument. The forward speed of the compound machine has three levels: 1.19, 2.67, and 3.42 km/h, and the type of crop has two levels: barley and alfalfa. The results showed a direct relationship between the forward speed and the productivity of the machine, as it reached 0.215 ha/h with the third speed. The efficiency of harvesting and collecting the harvest reached 100% in the barley crop for all forward speeds, while the third speed failed to rake the alfalfa harvest. The cutting efficiency of the sickle mower was not affected, which was 99% when the combined machine was connected to it in cutting barley and jet crops, and the level of cutting height remained stable, as the cutting deviation reached only 1 cm, while the combine machine affected the increase in the slip rate of the combined machine.

Words key: Belt- rake , sickle mower , tedder.

I. Introduction

The two-wheel sickle mower is widely used in small farms because it reduces the effort and time of harvesting fodder, as well as being available at reasonable prices. It is preferable to use the sickle cutter for cutting crops such as barley and jet, which do not require harsh treatment when making silage, compared to thick-stemmed fodder such as corn and sunflower [1], However, using a two-wheeled sickle cutter is not without some problems. During cutting, the tractor wheels move over the harvest. In other types, the harvest is spread in two adjacent low-height rows. On the other hand, the cutting height is often unstable due to the inefficiency of the unskilled operator, who raises the scythe several times and leaves an uncut crop. After the process of cutting the fodder comes the stage of collecting the harvest for several reasons. It is easier when transporting the harvest from the field to the animals immediately after cutting, or for the purpose of paving the way for the work of baling or chopping machines, so there is a need for great effort and labor to collect the harvest. Rake is used to collect the harvest in rows after harvesting coarse fodder, or it is used to collect two or more rows in one row, or to narrow the row to facilitate the task of the baler or chopping equipment. This machine can also be used to turn the harvest, as the work of threshing requires drying the harvest to a moisture level not exceeding 16% before using the baler [2]. When coarse fodder is to be harvested for the purpose of making silage, it is preferable for the harvest to be collected in a row to reduce the loss of dry matter. There are types of harvest collectors, all of which have in common that they contain thin fingers that work to collect the harvest in one row by raking the harvest scattered on the ground. The existing types can be classified into rakes with rotary motion and rakes with linear motion perpendicular to the direction of travel of the tractor. One of the problems that

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arise when using rotary rakes are raising dust and sweeping away rocks, and this leads to poor quality of feed, especially the feed that will be used in manufacturing silage [3]. In a study by [4] a parallel bar rake was compared to a rotary rake in an alfalfa field and they found no difference in the drying rate but the rotary machine had slightly higher losses. The raking process was carried out for crops with 40% moisture on a wet basis, and the results showed that the process slightly increased the drying rate [5]. When comparing parallel bars with two belt machines, they found no difference between the three machines in terms of drying rates or losses. [6] evaluated a parallel bar hoe with a wheel rake. The parallel hoe had approximately 2 percent lower loss at all forage moisture levels. [7] found that belt combines and parallel bars had significantly less loss and did not move dirt and rocks compared to other types of rakes, and drying rates were not affected. There are deficiencies in scientific studies related to these machines. Most of the studies reviewed do not discuss the factors affecting the machine's design and performance and were limited only to evaluating its performance based on the drying rate and dry matter loss, and these two characteristics were not greatly affected among the types of shovels. In this study, we seek to manufacture and evaluate the performance of a combined machine for cutting and racking at the same time, by determining the effect of different forward speeds and two types of coarse fodder crops on productivity, field efficiency, harvest gathering efficiency, and fuel consumption without harming the cutting efficiency and quality using the sickle mower.

II. Materials and working methods

1 - Equipment: The combined machine consists of a sickle mower and a harvesting machine with a finger-holding tape

1-1 Sickle cutter: A sickle cutter was used that was powered by a self-propelled two-wheeled tractor (13 HP diesel engine, 3000 RPM). The width of the sickle was 1.5 m, with 31 reciprocating moving blades above the fixed blades. It was made in Italy, Girllo Model: 82HB2 2011 (Figure 1). It takes the rotary motion from the PTO and turns it into a reciprocating arm that moves the blade bar from the middle. Some parts of the guillotine have been modified to facilitate connecting the collecting machine to the guillotine (Figure 2).

Figure 2 rake machine & sickle mower

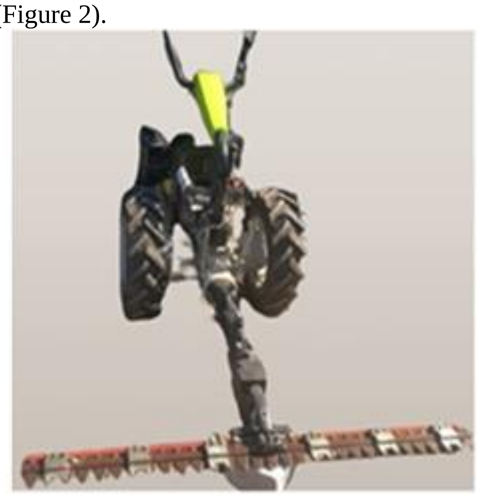

Figure 1 sickle mower

2-1: Belt –rake machine was manufactured in the workshop of the Agricultural Machinery and Machinery Department. It consists of the parts shown in Figure (3A-B) and Table 1. It takes its movement and power from the ground wheels of the machine NO:1 (the diameter of the wheel is 40 cm and the width is 12 cm) and through the transmission group via the wheel shaft NO:6, the speed increases by 1: 2.5 times, then through the transmission of the movement using the chain and gears NO:2 and NO: 7 The speed increases by a ratio of 1:2, so the ratio of the change

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in speed from the ground wheels of the Al-Hasid collector to the belt driving pulley becomes 1:4.5.

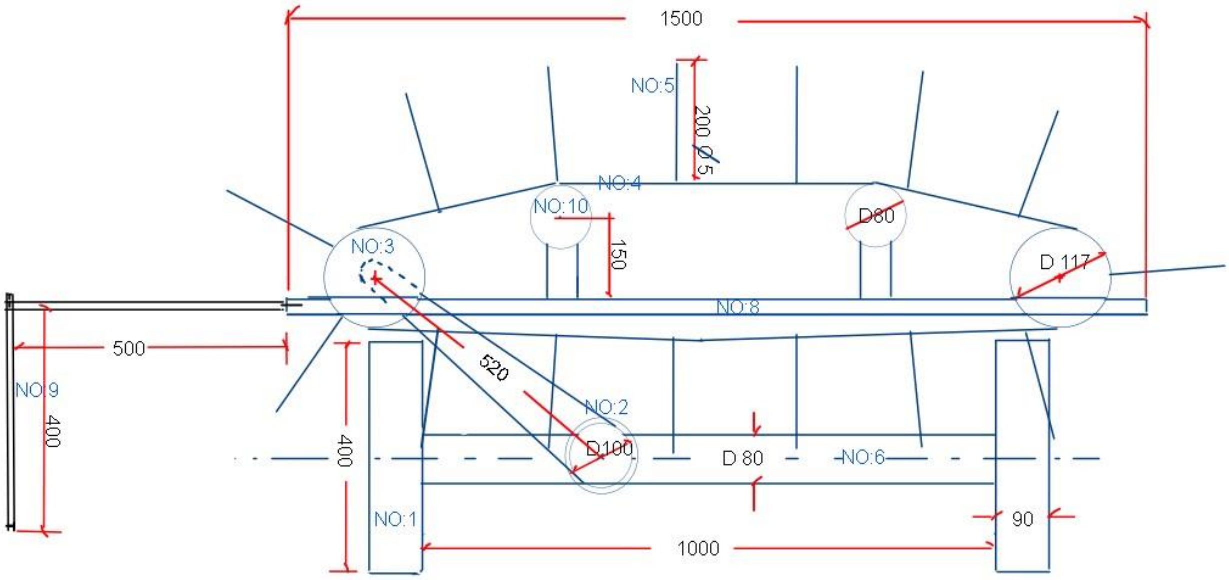

Figure 2-A front face of rake

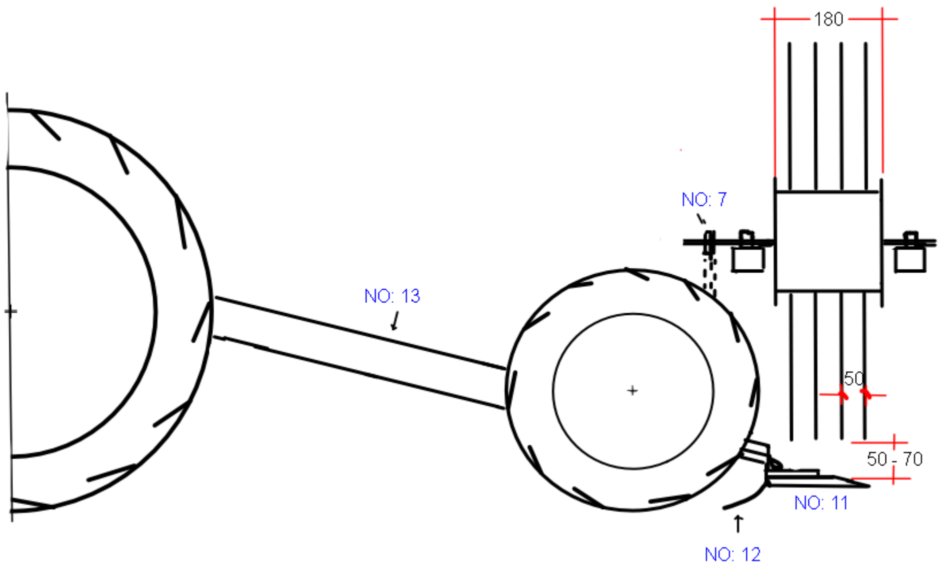

Figure 2-B Side face of rake

Table 1 Details of the machine installed for cutting and racking harvest

Rake			Sickle mower	
Details (Figure 3)	NO:		13 HP 3000 rpm	Engine capacity Engine speed

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Floor wheels of combining machine The wheel diameter is 400 mm and the width is 110 mm	1		Diesel	Fuel
A gear that transmits movement from the wheel hub gear to the drive tape reel rotating gear. Diameter 100 mm, number of teeth: 31 teeth	2		1.5 m	Sickle length (working width)
The guide pulley of the tape holds the fingers .The pulley diameter is 170mm and the length is 180mm	3		31 blades	Number of moving blades:
The belt holding the shovel toes. Width 170 mm	4		13 cm	Cutting bar width
Collecting fingers, 15 sets - each set includes 4 fingers, finger length 200 mm, diameter 5 mm.	5		has 2 sliders NO: 12	The scythe height control mechanism
The distance between the fingers in the group is 5 mm, the distance between the groups is 200 mm.	6		6.5/80-12	Wheel size
Gear transmission by a double chain of gear 2 and rotating the drive pulley No. 3 (the diameter of the gear is 60 mm and the number of teeth is 19 teeth	7		1028 rpm	The maximum speed of the drive shaft (pto)
Iron frame to hold pulleys and finger tape, 1.5 meters long, section dimensions 2.5 inches x 1 inch	8			
Harvest reservation board and row width determination, 400mm wide and 400 mm high, with a telescopic arm to control the distance between the board and the machine.	9			
Roller number 2 to tighten the loose side of the belt.	10			

The forward speeds of the combined machine were obtained from 1.19 km/h to 2.67 km/h by adjusting the fuel lever to half for the first and second cylinders, respectively. The speed was obtained at 3.42 km/h when the fuel lever was set to full position. The machine was moved and the time required to cover a distance of 50 m was measured.

The kinematic velocity ratio of the rake (λ_b) was calculated from relationship 1 at the three forward speeds as shown in Table 2

$$\lambda_b = V_b/V_f \quad \text{………(1)}$$

Where

Vb = belt rake speed m/s

Vf = forward speed of combined machine m/s

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The kinematic speed of the cutting sickle ($ʎ_m$) is from relationship 2 at the three forward speeds, as shown in Table 1.

$$V_m / V_{f\ m} = ʎ_m \text{.........(2)}$$

Where

V_m = linear speed of blades' mower

Table 2: Forward speeds and kinematics of the harvesting machine with belt and sickle cutter

Forward speed (Vf)	Third speed3.42 Km\h	Second speed2.67 Km\h	First speed1.19 Km\h
kinematic velocity of rake (ʎb)	2	2	1.92
kinematic velocity of sickle (ʎm)	3.6	3.25	4

The machine was installed with the mower (directly above and along the sickle), as shown in Figures 2 and 3, so that it became a four-wheeled machine with the possibility of separating it from the mower and using it independently. The scythe takes its movement from the PTO, while the machine takes its movement from its ground wheels. The distance between the tips of the fingers and the blades of the cutting sickle is 3-6 cm from the middle to the ends. This phenomenon usually occurs with strip racking machines [8]. There are two pulleys designed to tighten the belt from the slack upper end. The height of the cutting sickle can be controlled using two side sliders, Figure 3 NO: 12.

2– Evaluation of the companied machine:

2-1 Planning and conducting the experiment: It was planned to conduct a factorial experiment with two factors, with three levels for the first factor and two levels for the second factor (3 forward speeds x 2 crop type x 3 replicates = 18 treatments). Forward speed represents the first factor with three levels: 1.19 km/h, 2.67 km/h and 3.60 km/h. The second factor is the type of coarse fodder crop at two levels: barley and alfalfa. The experiment was designed with a completely randomized block design with three replications for the purpose of distributing the treatments to the 18 experimental units. A field planted with alfalfa and barley was divided into 18 panels with dimensions of 25 m and a width of 2 m per panel. 9 panels for alfalfa crop and 9 others for barley crop. . The average crop density was 550 plants/m2 and 950 plants/m2. The average relative humidity when the test was conducted was 70.7% and 60.6% on a wet basis, and the average plant height was 44.4 cm and 78.6 cm for alfalfa and barley, respectively.

2-2 Measurements and making calculations

The effect of forward speed, crop type and interference on the following characteristics was evaluated:

Actual field capacity (PCA) was calculated from Equation 1 [9]

$$PC_A = \frac{Vf \times w \times 3600}{10000} \text{ ....(1)}$$

Where

FC_A = Actual field capacity (ha\h)

V_f = forward field speed of the machine (m/s)

W = Actual working width (m)

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Field efficiency from Equation 2 [10]

$$\eta = \frac{PCA}{PC} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where

η_M = field efficiency of the companied machine (%)

P_C = theoretical field capacity of the installed machine (ha/h)

Racking efficiency: calculated from Equation 3

$$\eta r = \frac{WHF}{WHB} \times 100 \quad \ldots\ldots\ldots\ldots\ldots(3)$$

where

ηr Racking efficiency (%)

WHB, WHF, weight of harvest before racking, weight of harvest actually transported after racking in kg, respectively.

Slip ratio from Equation 4 [11]

$$S = \frac{Vfth - Vfa}{Vfth} \times 100 \quad \ldots\ldots\ldots\ldots\ldots(4)$$

Where

S = percentage of slippage of the machine wheels (%)

V_{fth} = theoretical forward speed (km/h)

V_{fa} = actual forward speed (km/h)

Fuel consumption from Equation 5 [12]

$$Fc = \frac{V}{T} \div PCA \quad \ldots\ldots.(5)$$

where

Fc = Diesel fuel consumption (L/ha)

T = time (h)

V = volume of fuel consumed (L)

Cutting efficiency: A tape tool was used to measure the height of the plant before cutting and its height after cutting at points distributed at intervals of 15 cm at a distance of 1.5 meters, which represents the working width of the cutting sickle. Then the percentage of cutting efficiency was calculated from Equation 6 as follows: [13].

$$Ec = \frac{Ha - Hb}{Hb} \times 100 \ldots\ldots\ldots..(6)$$

Where

Ec = cutting efficiency (%)

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Ha = plant height before cutting (cm), Hb plant height after cutting (cm).

Leveling of cutting :

The levelness of the mowing or cutting using the mower expresses the stability and regularity of the height of the cut using the cutting sickle. The levelness of the cut was measured based on the amount of deviation from the average height of the cut. Three locations were taken at a distance of 20 m, which represents the length of each treatment, and the height of the remaining part of the cut plant was measured at distances of 15 meters. cm between one measurement and another along the working width of the pieces, then extract the mean and standard deviation.

III. Results and discussion

The actual field capacity of the combined machine: The results showed (Table 2 and Figure 4) that the field capacity increases with the increase in the forward speed of the combined machine , This agrees with the researcher [14] in the crops of barley and alfalfa, with a significant superiority of the third forward speed, 3.42 km/h, over the rest of the treatments, where it recorded 1.10 ha/h and 0.62 km/h when the machine was working on alfalfa and barley crops, respectively, while the first speed recorded 1.19 km/h, the lowest field capacity amounted to 0.33 ha/h.

Table 2: The effect of forward speed, crop type, and interference on the actual field capacity

forward speed / crop type	actual field capacity (F_{CA}) ha/h		Average of F_{CA} at forward speed
	Alfalfa	Barley	
First speed	0.41de	0.33e	0.37^c
Second speed	0.50c	0.44cd	0.47^b
Third speed	1.10a	0.62b	0.86^a
Average of F_{CA} at crop type	0.67^a	0.46^b	

On the other hand, the results demonstrated a significant superiority of the companied machine in field capacity while working in the alfalfa field compared to barley, as the field capacity in alfalfa recorded a value of 0.67 hectares/hour, while in barley it was 0.46 hectares/hour. The reason is due to the relative increase in the forward speed of the installed machine. While working on the alfalfa crop, compared to the relative decrease in the forward speed of the machine while working on the barley crop, which occurred as a result of the resistance of the barley (due to its density and height), which prevented the machine from moving forward compared to the alfalfa crop, which led to significant slippage in the wheels (Figure 5).

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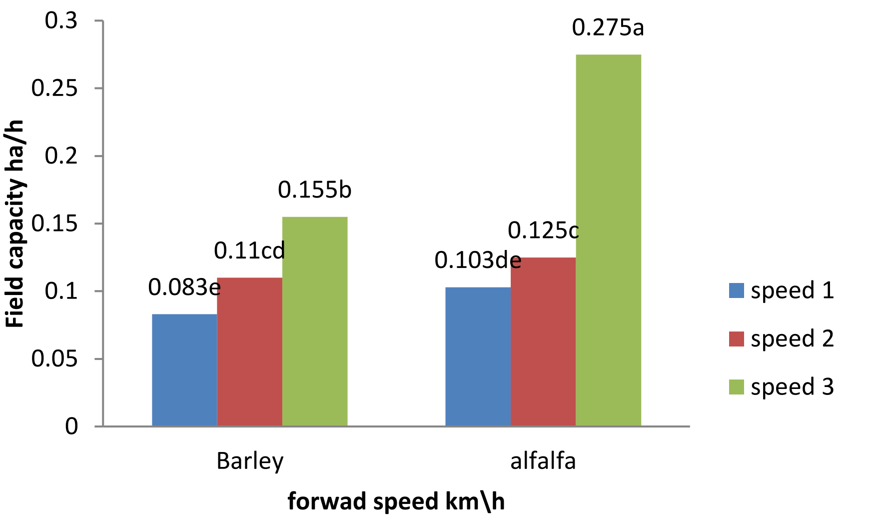

Figure 4: Effect of forward speed and crop type on field capacity

Sliding wheels of the compound machine:

Figure 5 shows the relationship between the combined effect of forward speed and crop type and the percentage of wheel slip. Slippage occurs as a result of the resistance faced by the machine in moving forward and as a result of the loss of friction between the wheels and the soil. Since field soil moisture and soil type are similar in both barley and alfalfa fields, the increase in the slip rate of the machine wheels in the barley field can be attributed to the increased resistance to machine movement due to the higher density and height of the barley compared to the density and height of alfalfa, in other words due to the larger size and weight. What is required is to push it to the side using the racking machine. On the other hand, we notice from Figure 5 that the largest slip occurred at the second speed, 2.67 km/h, and not at the third speed, in both fodder crops. We believe that this result is due to the fact that the kinematic speed of the rake fingers was not sufficient and appropriate with the second forward speed, that is, (ʎ (3.25) is small, and the fingers were not able to displace the harvester at the appropriate speed with the forward speed of the machine. In general, from Figure 5, there is a high percentage of slipping in all treatments, ranging from 42% to 72%. These percentages are very large and affected the results shown in Figures 4 and 6. The reason may be due to increased resistance to the machine moving forward and perhaps due to the weight of the machine or the collision of the crop with the wall designated to prevent the crop from crossing behind the cutting bar to force it to move to the side.

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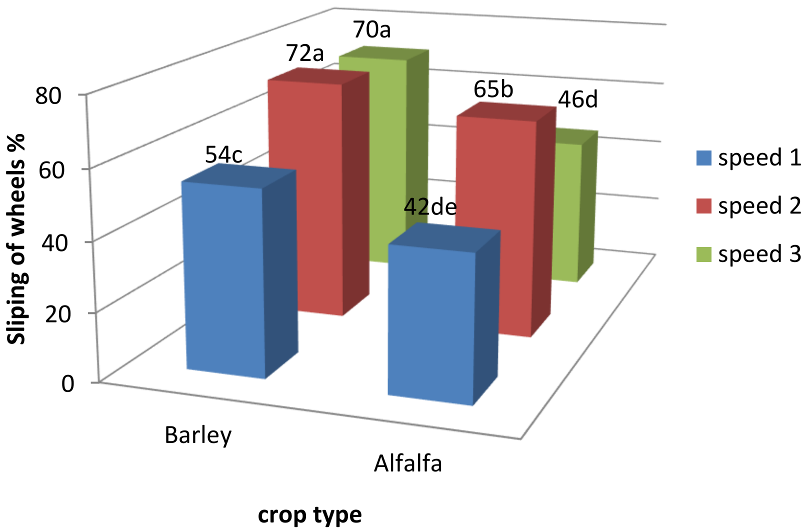

Figure 5: The effect of forward speeds and crop type on the wheel slip ratio

As a result of the superiority of the installed machine in field capacity with the alfalfa crop compared to the barley crop (Figure 4), the superiority of the machine in field efficiency occurred as it recorded 48% and 36% in alfalfa and barley, respectively. The forward speed also had a significant effect, as field efficiency increased with an increase in forward speed (Figure 5).

The results presented in Figure 6 are the results of the combined effect of forward speeds and crop type on the efficiency of the field machine based on the area completed. In the alfalfa crop, the first speed was superior in recording an efficiency of 56%, followed by the third speed with 53%, then the first speed in the barley crop field with 46%. The reason may be due to the increase in slippage at the second speed and then the third speed, which in turn was the reason for the decrease in the speed of the belt rake, which depend on the ground wheels rotating due to the force of friction with the ground, which is the source of kinetic energy for the belt rake.

Raking Efficiency:

Figure 7 shows of efficiency of the companied machine in raking and collecting the harvest . The results did not record a significant difference in the effect of the three front speeds on the raking efficiency of the harvest when the machine was operating in a barley field, as the three speeds recorded a complete efficiency of 100%. While the raking efficiency of the machine ranged when working on alfalfa crops, the results showed that the first speed was superior to the second and then third speed, as follows, respectively, 75%, 67%, and 37%. The reason may be due to many factors related to the design of the machine and others related to the properties of alfalfa under the current experiment.

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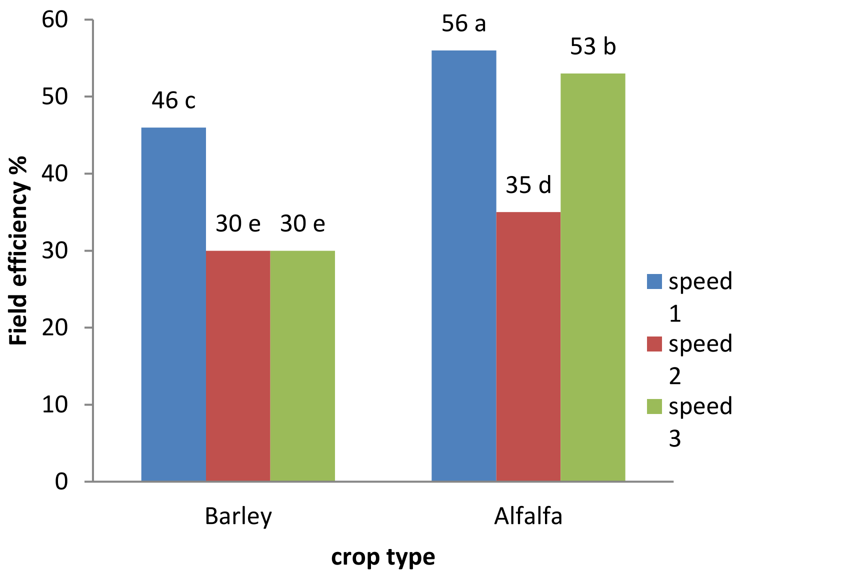

Figure 6: The effect of forward speed and crop type on the field efficiency of the combined machine

On the other hand, the distance between the fingers and the length of the fingers of the raking machine may not be suitable for working at high speeds and in plants with low density and low height, as in the field conditions of the alfalfa crop under experiment, as its density was 550 plants/m^2 and its height was 44.4 cm, as it was observed that the crop passed through Between the fingers. As for the barley crop, the density and height of the plant were appropriate for low and high speeds, and therefore the distance between the fingers and the length of the fingers were sufficient to sweep the crop without passing through it.

Diesel fuel consumption:

Fuel consumption in liters per unit area completed (Figure 8). This measurement is not directly related to the raking efficiency of the machine and collecting the harvest, but it is related to the amount of area completed (field capacity). The results showed that the amount of fuel consumed in the barley field was greater than the amount consumed in the alfalfa field due to the larger amount of area completed in the alfalfa field compared to the barley field and for the same recorded time, as it recorded 0.288 liters/ha for alfalfa and 0.358 liters/ha for barley. However, as we explained in Figure 7, the machine excelled in the barley field in the raking efficiency of the harvest at the three speeds and recorded a sweeping efficiency of 100% despite the decrease in its field capacity. Because fuel consumption is linked to field capacity and not to raking efficiency, so From Figure 8, the fuel recorded in the barley field at the third speed was 0.323 liters/ha, thus surpassing the first speed, which recorded a fuel consumption of 0.418 liters/ha, and the second speed, which recorded 0.335 liters/ha.

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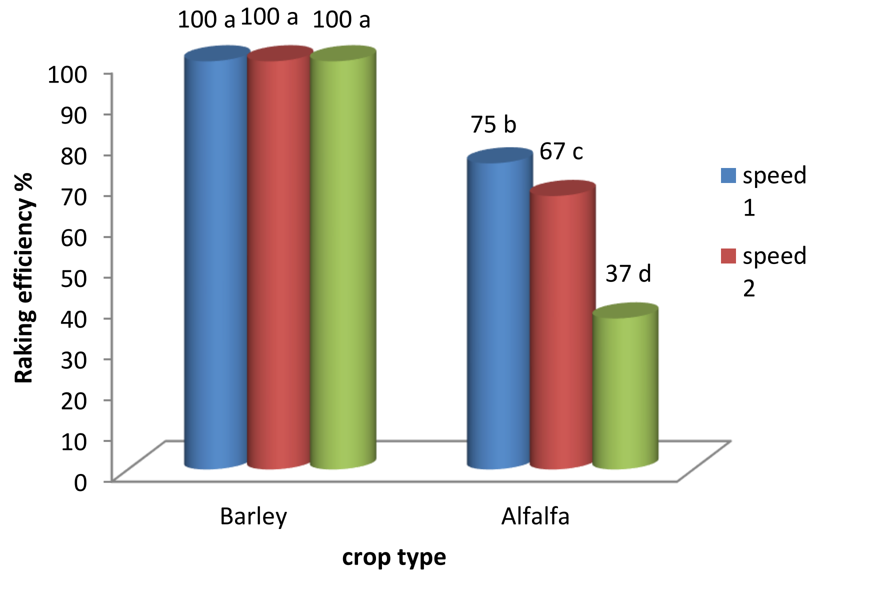

Figure 7: The effect of forward speed and crop type on the raking efficiency

On the other hand, the third speed in the alfalfa crop recorded the lowest fuel consumption, amounting to 0.228 liters/ha (Figure 8), but it was the least efficient in collecting the harvest, reaching 37% (Figure 7).

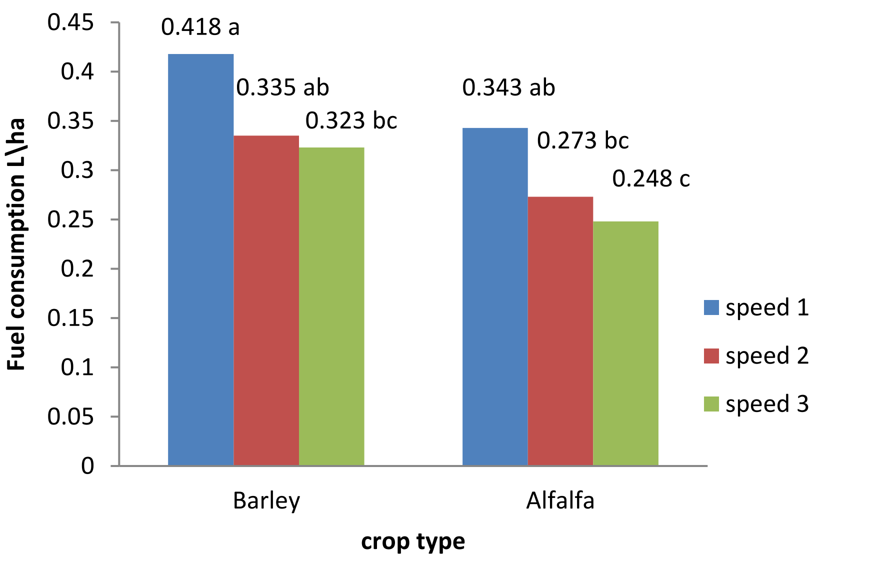

Figure 8: Effect of forward speed and crop type on fuel consumption

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Cutting efficiency and cutting leveling:

The results did not show significant differences in the cutting efficiency of barley and alfalfa crops, both at the three front speeds. The cutting efficiency reached 99.2% and 99.1%, respectively. There were no significant differences in the deviation of the cutting level for both crops.

Figure 5: A photograph of the machine in an barley field

Figure 4: A photograph of the machine in an alfalfa field

IV. Conclusions and recommendations:

- There is a direct relationship between the forward speed and the actual field capacity of the companied machine by keeping the ratio of the speed of the raking's fingers to the forward speed of the machine constant.

-The machine's performance of the raking function was very suitable for barley crops at a density of 950 plants/m^2 and a height of 78.6 cm, as the raking efficiency reached 100% for the three front speeds, while it was not suitable for alfalfa (with a density of 550 plants/m^2 and a height of 44.4 cm) at the second and third speeds.

-It is preferable to use the third speed, 3.42 km/h, to work in barley fields because it gave the best harvest efficiency of 100%, and the highest actual field capacity of 0.115 ha/h. While it is preferable to use the machine at the first speed of 1.19 km/h in the alfalfa field with its specifications under the current experiment.

- Fuel consumption at the best field capacity of the combined machine ranged from 0.323 liters/ha at third speed with the barley crop to 0.335 liters/ha at first speed with the alfalfa crop.

- The use of the raking machine did not negatively affect the quality of cutting the barley and alfalfa crops using the sickle mower. The cuts were clean and level when they were connected together and working as one mechanical unit. However, the combining machine added weight to the mechanical group, which led to a negative impact on the actual field capacity and field efficiency due to the decrease in The actual forward speed of the set. We therefore recommend using a lightweight drivetrain (between the floor wheels and the raking's belt).

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- It is preferable to conduct other experiments to study the effect of different kinematic speeds (raking's belt speed: forward speed) higher than those used in this research. And a study of different distances between the raking's fingers with fodder crops of different densities and lengths.

- Evaluating the companied machine for turning and tedding crops and collecting more than one row, and determining the effect of this on the machine's efficiency, dry matter loss, and drying rate.

V. Acknowledgments

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