

## RESEARCH PAPER

# Straw Throwing Method and Tractors Forward Speed Impacts on the Straw Picking Up and Chopping Machine's Performance

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### ABSTRACT

Wheat straw is a valuable by-product of grain harvesting in Kurdistan region basically for livestock feeding. It is thrown behind the harvester on the ground in different forms like heaps, windrows or spread in the field. Straw collecting in the field needs a lot of labor; it is also a costly and time-consuming operation. Recently, there has been a new operation in the field of straw chopping machines which picks up the straw from the ground, cuts and blows it to a trolley and all of this in one operation. This study was conducted to find the effect of some operational factors on the machines performance. The results show that collecting the straw as windrows in the field by the straw chopping machine gives better performance than the heaps. A tractor with 72 HP is sufficient for operating the straw picking-up and chopping machine with a trolley behind. Five different forward speeds (S1=3.12, S2=4.22, S3=5.21, S4=6.31 and S5=7.51) km/h were examined for straw picking-up and chopping as windrows to find their effects on the performance of the machine, it was found that with S3 or S4, the machine shows the best performance in terms of fuel and time consumption, throughput capacity, straw recovery, throughput efficiency and acceptable slippage percentage.

KEY WORDS: straw chopping machine, straw heaps, wheat straw, windrow.

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### 1. INTRODUCTION

Wheat straws are an agricultural by-products consisting of the dry stalks after the grain and chaff have been removed. The grain ratio to the straw is about 1:1.5 to 1:2.0 Chandrasekaran *et al.* (2010). Straws have a number of different uses such as a fodder for livestock and bedding or for the paper industries and as biomass fuels (Vink, 2015).

In the Kurdistan region of Iraq, the main use of straws is as a livestock fodder which are produced as there are about 0.75 million hectares of

cultivated area annually with cereal crops consisting mainly of wheat and barley, and its yield is around 1 million tons (Ministry of planning, 2017). This results in nearly about 1.5 million tons of straw. Straws are always thrown behind the combine harvester in three forms: (1) directly on the ground as windrows, (2) thrown as heaps on the ground by a gathering mechanism equipped onto the harvester and it is pre-adjustable to a desired weight - which is the most common method used by farmers in the Kurdistan region of Iraq, and (3) cutting and spreading the straws in the field in one operation by the harvester for conservative agriculture Suradi *et al.* (2020). Loose straws are low in bulk density, irregular in size and shape, difficult to handle manually and difficult to transport and store. The straw in its original form is labor-intensive and costly as it should be transformed to a regular and dense form to facilitate its transportation and storage Gummert *et al.* (2020).

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Whenever combined harvesters are being used for crop harvesting, the straw which is left behind has a disposal problem. This is for the fact that it should either be collected manually, which is a laborious and a time-consuming job, or balers could be used to make bundles later to be copped to smaller particles according to the purpose of use. Recently, farmers have adopted an in-field straw picking-up and chopping machine which in one operation collects, cuts into the desired forms, and blows the straw through a tunneled pipe to a closed trolley trailing behind it. The straw chopping machine is power operated, gets its drive from tractor's PTO shaft and a small multi-purpose tractor of 75HP is sufficient to run a straw combine harvesting machine, this type of machines in addition to the three tasks (picking up, chopping, and blowing) it also cuts the remained stables in the field Mahmood *et al.* (2016).

Straw picking-up and chopping machine's performance is affected by many factors including straw moisture content during the time of collecting, straw density on the field and the forward working speed of the mechanical units Ankit *et al.* (2018). The field capacity and fuel consumption of any farm machines is considered as an important economic indicator for a successful work performance Gursoy *et al.* (2015). The forward speed of the in-field straw picking-up and chopping machine has a significant effect on the field capacity, field efficiency and fuel consumption. In other words, by increasing the forward speed, the field capacity and field efficiency decrease. On the other hand, the stability of the machine on the ground will be affected by the extra forward speed causing high rate of slippage percentage which leads to power and time losses Mahmood *et al.* (2016). Fuel consumption in most farm machines depends on the forward speed. Sometimes the various manufacturing designs of the same functioning machines affect the fuel consumption Kumar *et al.* (2017). The method of picking up straws affects the quality and quantity of the work done Afify *et al.* (2002).

The slippage percentage is one of the indicators of the performance of the tractor and the straw picking-up and chopping machines; limitation or reducing the slippage percentage leads to a good, economic and effortless work (Al-Auobi and Taha,

2009). The tractor driver's skills can decrease the slippage ratio according to the type of the agricultural operation Thakur *et al.* (2018). From an economic perspective, the cost of fuel represents at least 16% and it could reach a 45% of the hourly costs of an agricultural tractor, and this represents the largest share of the total cost of an hour of machine work Farias *et al.* (2017).

The objective of this study was to obtain the best combination of working parameters in the field for best performance of the straw picking up and chopping machine, because it is recently introduced to the region and no scientific studies have been done on it yet.

## 2. MATERIALS AND METHODS

The experiment was carried out after the wheat harvesting process in 10/6/2019 in a private field in Kharabadraw village, located 18 km northwest from Erbil city center in the Kurdistan Region of Iraq, the field was planted with wheat (*Triticum spp.*). The field was a normal leveled land with some natural girders. Crop harvested (10) cm above the ground by a combined harvester when the grain moisture content reached around 16%, the moisture content was determined according to the ASABE standard S358.2, (2008).

Two areas in the same field had been selected for the experiment; the first area was 0.4 hectare for throwing the straw behind the combine harvester in heaps forms on the ground (STH), the second area was 2 hectare for throwing the straw as windrows (STW), to study their effects on the performance of the straw picking up and chopping machine drawn by the tractor. The travelling distance of the tractor with the straw chopping machine and the trolley were limited by 200 m line long by placing guide poles in the beginning and the end of the distance as indicators.

Two experiments were conducted. First one was for comparing between picking up and chopping straws as heaps and picking up and chopping as windrows by a straw picking up and chopping machine with closed trolley trailing behind the chopping machine and both are drawn by a tractor with a forward speed limited by 3 km/h according to the straw density situation on the ground Mahmood *et al.*, (2016). Second experiment

was applied for comparing different forward speeds ( $S_1=3$ ,  $S_2=4$ ,  $S_3=5$ ,  $S_4=6$  and  $S_5=7$ ) measured in km/h for selecting the ideal forward speed for wheat straw picking up and chopping as windrows. All the experiments were conducted using a straw picking up and chopping machine type (Özen iş) Turkish made. The technical specifications of the chopping machine were (pickup reel width 175cm, cutting unit is rotary drum with blade system, 48HP need for operating, field capacity 1.9 ton/h and 540 rpm need from the P.T.O). The straw picking up and chopping machine and the trolley are drawn by a universal tractor (New Holland TD75D, 2004, Turkish made, pneumatic, 4 wheel drive, 4 cylinder, 72HP at 2500 rpm and P.T.O single speed of 540 rpm at 1800 engine rpm) figure (1).



**Figure 1.** Tractor, straw picking up and chopping machine, and trolley.

The mechanical units moved 10 m before reaching the guide poles toward the experimental lines to take its stability and desired speed for each treatment. The time spend for cutting the distance was recorded by a digital stopwatch in the starting pole and at the end of the line without any loads and later with loads to calculate the slippage percentage of the mechanical units. The chopped straws in the trolley for each line were collected and weighed and converted to tons in hectare area base.

The performance of the straw picking up and chopping machine was evaluated according to the following indicators:

- 1) Mechanical units stopping numbers measured by normal counting.
- 2) Straw recovery percentage calculating equation driven from the equation formed by Ankit *et al.* (2018) as follows:

$$SR = \frac{SPU}{SOG}$$

Where: **SR** = straw recovery (%), **SPU** = straw picked up (g/m) and **SOG** = straw on the ground (g/m). For the heaps form the straw recovery were determined by weighing 4 heaps from 4 straw lines as heaps and the average weight was calculated, as for determining the windrow straw form recovery, the straw weight of 4 times of 5m long in 4 straw line as windrows was taken and their average weight has been calculated. The chopped straw in the trolley for each line collected and weighed and converted to tons in one-hectare area base (the area containing loose straw were excluded in this operation).

- 3) Effective throughput capacity, the concepts of theoretical and effective capacity are also applicable to throughput capacity. Throughput is based on time, but because the throughput usually refers to the flow of material through a machine, the units may be different from those used for capacity. For example, the performance of a baler could be evaluated using units of bales per hour or tons per hour, the principles of field working of straw chopping machine is the same as for the balers in the picking up mechanism and the feeding inside the machine; hence, the same equation formed by (Field and John, 2007) is applied as follow:

$$ETC = \frac{WSR}{T}$$

Where: **ETC**= Effective throughput capacity (ton/h), **WSR**= weight of straw picked up (ton) and **T**= time (h).

- 4) Slippage percentage calculated according to the equation formed by (Albanna, 1990) as follow:

$$S.P = \frac{Vt - Vp}{Vt} \times 100$$

Where S.P= slippage percentage (%).  
**Vt** = Theoretical speed (without load), km/h.  
**Vp** = Practical speed (with load), km/h.

- 5) Fuel consumption was determined using the volumetric method by refilling the fuel tank with a graduated cylinder (Hunt, 2001), fuel consumption calculated according to the

equation suggested by (Jasim and Jebur, 2015) as follow:

$$F.C. = \frac{q.d \times 10000}{B.p \times s \times 1000}$$

Where  $F.C.$  = fuel consumption (L/ha),  $q.d$  = fuel consumed in one round (ml).  $B.p$  = actual working width (m) and  $S$  = distance of one round (m).

6) Throughput efficiency is used instead of field efficiency to describe machines that handle or process a product, such as grain augers, balers, forage harvesters, and combines. The throughput efficiency was determined according to the equation formed by (Field and John, 2007) as follows:

$$TE = \frac{ETC}{TTC} \times 100$$

Where:  $TE$  = throughput efficiency (%),  $ETC$  = effective throughput capacity (ton/h),  $TTC$  = theoretical throughput capacity (ton/h).

Theoretical throughput capacity was given in the technical specification brochure of the straw picking up and chopping machine.

Statistically the experiments were carried out by applying the randomized complete block design (RCBD) with four replicates for each treatment. 24 lines were specified, each line considered as a block and replicate, 4 lines for heap form and 20 lines for windrow form. The data was analyzed using SAS program according to the

applied design, and the least significant differences test (LSD test) and T. test applied to compare between the means at ( $p \leq 0.01$ ) and ( $p \leq 0.05$ ).

### 3. RESULTS AND DISCUSSION

#### 3.1. Experiment 1

Table (1) shows the effect of the wheat straw throwing method on some performance parameters of the straw picking up and chopping machine. Significant differences ( $P < 0.01$ ) were found in the stopping number of the mechanical units between (STH) and (STW), the means were (112, 5) stop/ha respectively, reducing the number of stopping during working leads to extending of machines and mechanical parts lifespan as well as a reduction in the total working time as it is shown also in the table which the average time taken for straw picking up and chopping machine was (01:38, 01:19) h/ha for (STH) and (STW) respectively.

The straw chopping machine throughput capacity was also significantly lower when using (STH) method compared to the (STW) method and the averages were (1.565, 1.685) ton/h respectively, this increase is due to continually picking up straw from the ground when it is thrown as windrows. For the same reason, there were significant differences in the mean of throughput efficiency of straw picking up and chopping machine, the values were (82%, 88.5%) for (STH) and (STW) respectively. The table shows that there were non-significant differences in straw recovery percentages between both methods.

**Table 1:** Effect of straw throwing method on the performance of the straw picking up and chopping machine

Parameters	Straw throwing form as	
	Heaps (STH)	Windrows (STW)
Number of mechanical working units stop per hectare	112±3.2	5**±0.51
Time required for straw picking up and chopping, (h/ha)	01:38±0:06	01:19*±0.05
Throughput capacity, (ton/h)	1.565±19	1.685*±23.9
Throughput efficiency, (%)	82±1.8	88.5*±1.96
Straw recovery, (%)	83±1.6	86±2.1

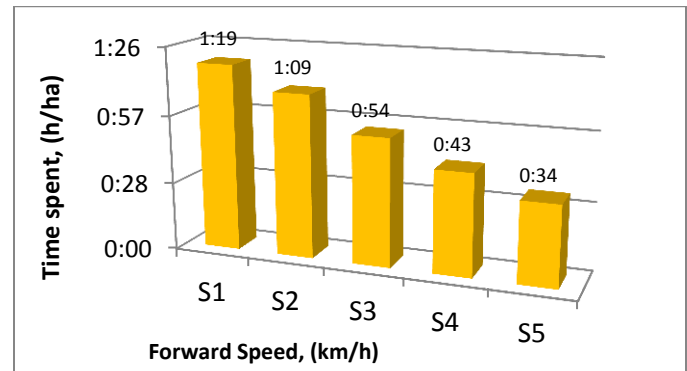
<b>Fuel consumption, (L/ha)</b>	5.9±0.12	4.6*±0.1
<b>Slippage percentage, (%)</b>	N	1.9 ±0.09

(\*), (\*\*) within the rows indicates to significant differences between means under probability level of ( $P \leq 0.05$ ), ( $P \leq 0.01$ )

Fuel consumption was significantly higher for (STH) compared with (STW) as it shown in the table, the averages were (5.9, 4.6) L/ha respectively, the reason of increasing in the fuel consumption is having an increase in the number of stops when using (STH) method which requires more working time to complete the specified area. Generally, the fuel consumption was within the acceptable ranges which were determined by Grisso *et al.* (2010) for the hay pickup and chopping machines.

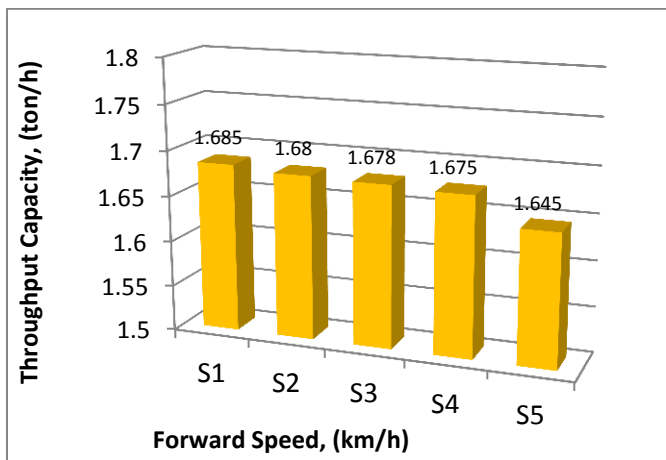
### 3.2. Experiment 2

The actual forward speeds in the field without any breakage and clogging were ( $S_1=3.12$ ,  $S_2=4.22$ ,  $S_3=5.21$ ,  $S_4=6.31$  and  $S_5=7.51$ ) km/h; working speeds were not exactly like as proposed in the methods of the experiment. Effects of forward speeds on the time spent by the straw picking-up and chopping machine as windrows in the field are shown in the figure (2). In general, the time spent for straw picking up and chopping machine decreased as the forward speed increased and the averages were (1:19, 1:09, 0:54, 0:43, and 0:34) h/ha for all forward speeds respectively. The shortest time recorded with  $S_5$  and the longest time spend was with  $S_1$ ; the reason of reduction was that there were not any stops during the work process, so it's common sense to say that the faster speed will complete its task sooner. There were non-significant differences between  $S_4$  and  $S_5$ .



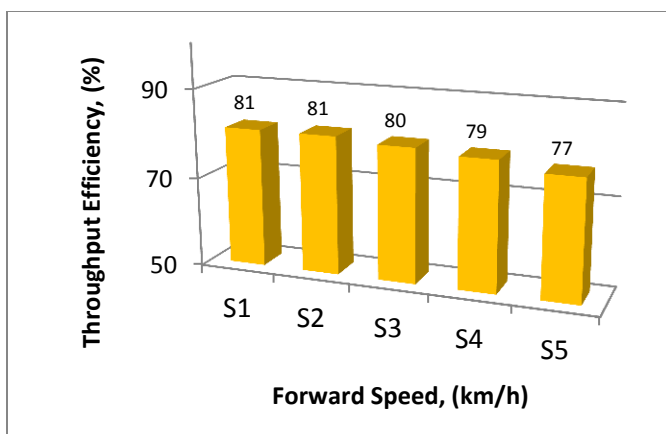
**Figure 2.** Effect of forward speed on the time spent for straw picking up and chopping machine.

Figure (3) shows the effect of the forward speed on the straw picking up and chopping machine's throughput capacity. As it can be seen that increasing the forward speed of the machine from  $S_1$  to ( $S_2$ ,  $S_3$ ,  $S_4$ , and  $S_5$ ) gradually did not cause any significant differences on the throughput capacity. The means of the throughput capacities were (1.685, 1.680, 1.678, 1.675 and 1.645) ton/h respectively, although there was a mathematical decrement with  $S_5$  when compared with other speeds: this decreasing is attributed to the instability of the mechanical units in high speeds and non-synchronization between the tractor forward speed and the picking up reel fingers of the straw picking up and chopping machine which leads to skipping of some straw stems on the ground and losses occur due to it. These results contradict the results found by Ankit *et al.* (2018).



**Figure 3.** Effect of forward speed on the throughput capacity of straw picking up and chopping machine.

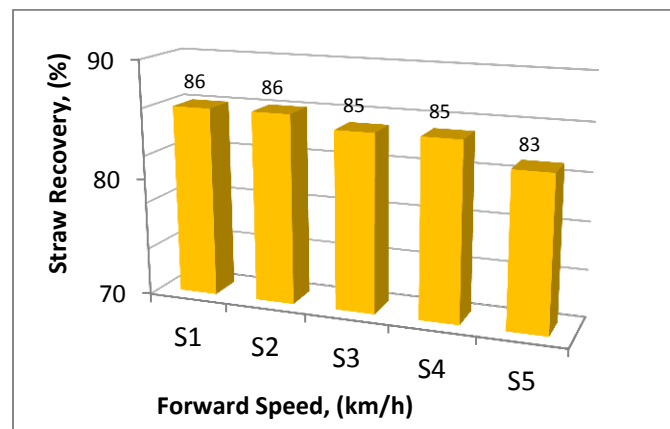
The effect of the forward speed on the throughput efficiency of the straw picking up and chopping machine is shown in figure (4). As it can be seen there is a slight mathematical gradually decreasing in the throughput efficiency of the straw picking up and chopping machine by increasing the forward speed from  $S_1$  to  $S_5$ , the averages were (81, 81, 80, 79, and 77) % respectively. The reason of having a drop in the straw chopping machine throughput efficiency is due to the reduction of throughput capacity when the forward speed increased because the throughput efficiency basically depends on the theoretical throughput capacity and effective throughput capacity as a numerator in the equation, and it is usually lower than theoretical throughput capacity Mahmood *et al.* (2016).



**Figure 4.** Effect of forward speed on the throughput efficiency of straw picking up and chopping machine

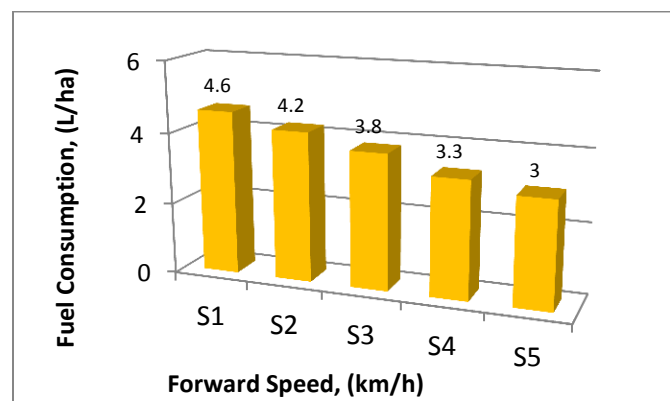
The straw recovery of the picking up and chopping machine was not statistically affected by the forward speed as it shown in figure (5). The straw recovery means for the speeds were (86, 86, 85, 85, 83,

85, 85 and 83) % respectively. Increasing the forward speed to  $S_5$  caused a slight mathematical decreasing in straw recovery of the machine. These results contradict the results obtained by Ankit *et al.* (2018) because the range of the forward speed they used for straw combining harvester was (1.5 to 2.5) km/h, this range was smaller than the least speed in this study.



**Figure 5.** Effect of forward speed on the straw recovery of straw picking up and chopping machine

Figure (6) illustrates the effect of forward speed on the fuel consumption of the straw picking up and chopping machine. Increasing the forward speed significantly affected on the fuel consumption of straw picking up and chopping process. Fuel consumption averages for the forward speeds were (4.6, 4.2, 3.8, 3.3 and 3) L/ha respectively. The main reason of this reduction in fuel consumption was the constant speed of the tractor engine rpm for all operations for all treatments which was limited by 1800 rpm to keep the PTO shaft running at 540 rpm. These results agree with Anjum *et al.* (2015). The least amount of fuel consumption was with the  $S_4$  and  $S_5$ .

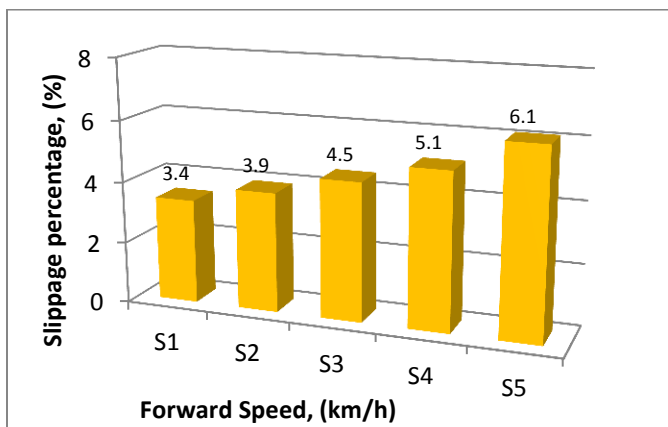


**Figure 6.** Effect of forward speed on the fuel consumption of straw chopping machine.

Figure (7) shows the forward speed effects on the straw picking up and chopping machine drawn by the tractor on the slippage percentage. The slippage percentage increased with increasing the forward speed. The averages were (3.4, 3.9, 4.5, 5.1, and 6.1) % for all speeds respectively. The highest slippage percentage recorded was with S<sub>5</sub> while the lowest slippage percentage recorded was with S<sub>1</sub>. The reason of slippage percentage occurrence is the instability of the mechanical units of the wheels on the ground with high speed operations which reduces the chances of tires cohesion with the ground. These results are in line with the results obtained by Al-Ayoubi and Taha, (2009).

#### 4. CONCLUSIONS

Since the straw picking up and chopping machine is a newly adapted in the region, it needs to be studied for economical usage. According to the results obtained from this study, throwing the straw



**Figure 7.** Effect of forward speed on the slippage percentage of straw chopping machine.

as heaps (which is the most common method used by farmers in Kurdistan region) and picking them up by the machine is not practical at all because of its negative effects. Straw picking up and chopping as windrows by the straw chopping machine give positive results for most studied parameters. The forward speed of the machine has many effects on the performance of the straw picking up and chopping machine. Operating the mechanical units with forward speed of (5.21 or 6.31) km/h gives the best results in terms of fuel and time consumption, throughput capacity and efficiency, and straw recovery. For these reasons, our recommendation to

the farmers is to get away from throwing the straw behind the harvester as heaps on the ground; instead, they are recommended to throw the straw as windrows with the mentioned forward speed for obtaining best results when it is collected by a straw picking up and chopping machine.

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