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Evaluation of wheat stubble management practices in terms of the fuel consumption and field capacity

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Abstract

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Five wheat stubble management practices i.e. chopping the stubble by the chopper mounted on combine during harvest and transmitting the straw to trailer (SCDF), chopping the stubble by the chopper mounted on combine during harvest and spreading the straw to field surface (SCDS), chopping the stubble on field surface after harvest by chopper mounted on combine and transmitting the straw to trailer (SCAF), leaving the stubble on field surface (SLS) and removing the stubble left on field surface by baling (SSB) and the cutting height of combine header (10 and 20 cm) were evaluated in terms of fuel consumption and field capacity. The result of the studies showed that the cutting height of header was increased from 10 to 20 cm, the field capacity increased from 1.195 to 1.365 ha/h and the fuel consumption decreased from 54.472 to 38.859 l/ha. While the highest field capacity was determined in SLS (1.846 ha/h), SCAF and SSB treatments had the lowest field capacity (0.954 and 0.891 ha/h, respectively). Chopping the stubble by chopper mounted on combine and transmitting straw to trailer during harvest increased the fuel consumption of combine by 3.6 times.

Keywords: combine harvester; straw chopper; cutting height; field performance

Crop residues, especially those of wheat, lentil, and barley are an important alternative feed which should be utilized as much as possible, particularly in a year when feed supplies are limited, in Turkey as well as in developing countries. Also, they could often become an important raw material for biofuels, construction, paper and wood-based panels industries (Devendra 2007; Rao, Birthal 2008; Erenstein 2010, 2011). However, harvesting crop and removing residue from the field can become very expensive and laborious. Another alternative for residue management is to leave residue on the soil surface.

Successful residue management system begins at crop harvest. A sustainable and profitable cropping system needs an integrated approach to straw management. Off-field utilization of wheat straw has initiated improvements in straw handling. One of the options for effective management of crop residues is to use specially designed pick-up type field balers to remove residual straw from fields. Another option is to chop straw for livestock feed by chopper devices and transmit the straw to trailer. In recent, the chopper mounted on combine has been increasingly used to make straw during harvest because wheat straw is an important feed

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source in animal feeding in Turkey. However, combine performance is reduced when wheat straw is chopped and transmitted to trailer. Chen et al. (2005) conducted a telephone survey to investigate crop residue burning situations on farms in Manitoba, Canada and determined that one of the most important causes of crop residue burning was the intention to reduce the cost of residue baling and transportation. They stated that further investigation is needed on the effectiveness and utilization of residue choppers and chaff spreaders.

The fuel consumption and field capacity of agricultural machinery have been considered as the important indicators of performance (Smith 1993). Proper implement selection and improving operating conditions can decrease fuel consumption and increase field capacity during residue management. The most practical way to manage crop residue is with the combine. Fuel consumption could be minimized by supplying less straw into the combine harvester. There are several methods to reduce the mass of straw supplied into the combine harvester. When the stubble height is increased from 10 cm to 40 cm, the fuel consumption of combine harvester decreases 1.5 times (Špokas, Steponavičius 2009). Also, Anderson (2009) reported that an increase in comb height of 20 cm resulted in a decreased fuel consumption of 2.1 l/ha for a crop height of 10 cm. However, setting the cutting header high at harvest time can lead to major stubble handling issues at cropping time next year. Therefore, cutting the stubble to the correct height is very important in order to minimize the problems with trash flow at sowing and the harvesting costs. Ismail et al. (2009) stated that the harvesting costs made up 35% of the total machinery costs and the robust methods should be developed to choose the optimal harvesting equipment.

More profitable harvesting and residue management systems are needed to make sustainable farming systems more economically viable. This can be accomplished by increasing field capacity and reducing fuel consumption. The objective of this study was to evaluate the effect of wheat stubble management practices and the cutting height of the combine header on fuel consumption and field capacity.

MATERIAL AND METHODS

The study was conducted at the wheat production field of the GAP International Agricultural Research and Training Center in Diyarbakir, Turkey in June 2011. Firat-93, a winter wheat cultivar widely used in the region, was used in the study. Some properties of wheat such as plant height, ear length, biological yield, grain yield and moisture content taken in experimental area before harvesting are presented in Table 1.

Laverda SPA combine (2004 Model 2150 LXE, 248 type; Laverda Spa, Breganze, Italy) was used during the study. The width of the combine cutting header, the radius of threshing-separation rotor, the length of all the concaves, general area of all the concaves, the wrapping angle of the concaves, the separation surface of straw-walker, the capacity of the grain tank and the engine power were 4.80 m, 0.60 m, 1.60 m, 2.25 m^2, 120°, 9.06 m^2, 8.60 l, 203 kW/2,000 rpm, respectively. The engine of combine was operated in the second gear setting and 2,200 rpm.

The chopper and blower fan (both manufactured by Uludag Combine Ltd., Diyarbakir, Turkey) were mounted on combine to chop the stubble and transmit the straw to the trailer. This system was also used to spread the straw to field surface. The chopper mounted on combine had two-rotor and equipped with 176 fixed-blade rotating knives with 88 adjustable intermeshing counter knives (Fig. 1).

The baler (Elibollar Agricultural Machinery Ltd., Afyonkarahisar, Turkey) was used to remove the loose stubble behind combine after harvest. It was operated by a Steyr 768 tractor (Steyr Traktoren, Valentin, Austria) of 64 hp at the third gear setting, engine tour of 2,200 rpm and tail shaft tour of 540 rpm.

The experiment had a split plot design with three replications, in which two cutting heights of the combine header (10 ± 3 and 20 ± 3 cm) were main plots and five stubble management methods (chop-

Table 1. Some properties of Firat-93 wheat variety in experimental area before harvest

Plant height (cm)	Ear length (cm)	Biological yield (kg/ha)	Grain yield (kg/ha)	Grain moisture content (% d.b.)
92 ± 5	15 ± 3	7,900 ± 400	3,500 ± 300	13 ± 0.5

d.b. – dry basis

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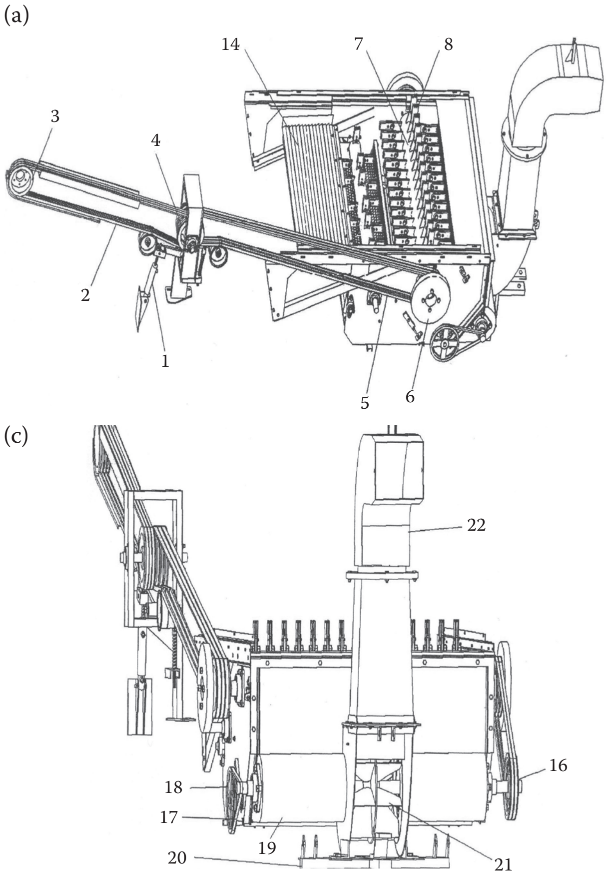
(a) (c)



(b)

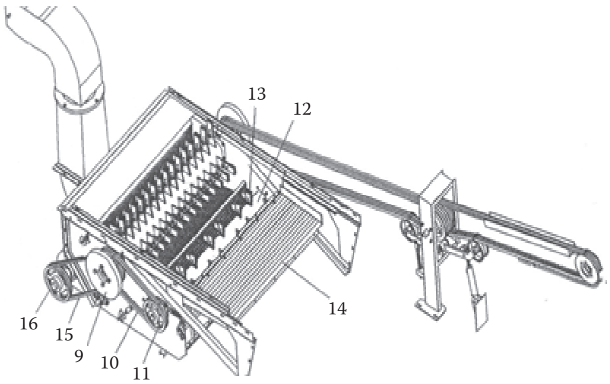


Fig. 1. Sketch of chopper mounted on combine (a) left and top view (b) right and top view (c) rear view

1 – hydraulic piston; 2 – V1 belt; 3 – the pulley powered by motor of combine; 4 – pulley for moving transmission mechanism; 5 – V2 belt; 6 – left blade pulley of big rotor; 7 – blade shaft of big rotor; 8 – blade of big rotor; 9 – right blade pulley of big rotor; 10 – V3 belt; 11 – blade pulley of small rotor; 12 – blade shaft of small rotor; 13 – blade of small rotor; 14 – blunt sieve of small rotor; 15 – V4 belt; 16 – fan pulley; 17 – V5 belt; 18 – straw mixing pulley; 19 – straw suction chamber; 20 – linkage mechanism to trailer; 21 – fan; 22 – tube to transfer the straw to trailer

ping the stubble by chopper mounted on combine during harvest and transmitting the straw to trailer (SCDF), chopping the stubble by chopper mounted on combine during harvest and spreading the straw to field surface (SCDS), chopping the stubble on field surface after harvest by chopper mounted on combine and transmitting the straw to trailer (SCAF), leaving the stubble on field surface (SLS) and removing the stubble left on field surface by baling (SSB)) were sub-plots. Plot size was 675 m^2 (150 × 4.5 m).

In order to determine the theoretical field capacity of treatments, the combine and baler used in residue management practices were run a fixed distance of 150 m in the field and the time required to cover this distance was noted. The theoretical field capacity was calculated for each equipment by using Eq.(1). The theoretical field capacity for each plot was determined by summing the theoretical field capacity of equipments used in treatments (Celik 2006; Sağlam et al. 2010).

$$TFC = \frac{3.6 \times B \times L}{10 \times t} \quad (1)$$

where:

TFC – theoretical field capacity (ha/h)

B – working width of combine or baler (m)

L – plot length (m)

t – time (s)

The fuel consumption of the combine and tractor used to operate the baler was determined by refilling the fuel tank. In this method, before harvesting or baling, the fuel tank of the combine and tractor was filled completely and after harvesting or baling a plot, the fuel tank was refilled. The fuel consumption was calculated by using Eq. (2). The fuel consumption for each plot was determined by summing the fuel consumption of equipments used in treatments (Celik 2006; Sağlam et al. 2010).

$$FC = \frac{AFC \times 10}{A} \quad (2)$$

where:

FC – fuel consumption (l/ha)

AFC – amount of the fuel consumed (ml)

A – area of the plot (m^2)

The data for all variables were subjected to the analysis of variance (ANOVA) using SAS 2002 (SAS Institute Inc., Cary, USA) and mean compari-

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Table 2. Significance of analysis of variance (ANOVA) for theoretical field capacity and fuel consumption as affected by residue management practices and the cutting height of header

Source of variation	DF	Mean squares	
		field capacity (ha/h)	fuel consumption (l/ha)
Residue management practices (RM)	4	0.8964[a]	3073.74[a]
The cutting height of header (CH)	1	0.2146[a]	828.17[b]
CH × RM	4	0.04574[a]	227.69[a]
Error	16	0.00375	7.63
CV		4.45	5.92

DF – degree of freedom; [a]significant at 0.01 probability; [b]significant at 0.05 probability; CV – coefficient of variation

son was made using the Fisher's unprotected LSD at $P \leq 0.05$ (SAS 2002).

RESULTS AND DISCUSSION

The ANOVA showed that the residue management practices and the cutting height of header significantly influenced the field capacity (Table 2). The field capacity was the highest in SLS and the lowest in SSB among residue management practices. The difference between SCAF and SSB residue management treatments was not significant. Chopping the stubble by chopper mounted on combine and transmitting the straw to trailer during harvest and chopping the stubble by chopper mounted on combine and spreading the straw to field surface decreased the field capacity of combine by 29.90 and 23.29%, respectively (Table 3).

The results of study showed that when the cutting height of combine header was increased from 10 to 20 cm, the field capacity increased by 14.22 % (Table 3). This resulted from lesser straw flow supplied into combine. When the stubble height was increased to 20 cm, less straw was supplied into combine. Thus, combine could move quicker and could harvest a larger wheat area. The obtained results support the view of Douglas et al. (1989), Listner and Axmann (1993), Kehayov et al. (2004), and Špokas and Steponavičius (2009, 2010), who reported that when the cutting height of combine header was increased, the combine capacity increased and the fuel consumption decreased.

There was a significant residue management practices and the cutting height of header interaction for the field capacity (Table 2). This indicates that the effect of residue management practices on field capacity changed according to the cutting height of cutter. Although the field capacity was lower in the SCDF than in SCDS at 10 cm cutting height of header, there was no significant difference between SCDF and SCDS treatments at 20 cm cutting height of header (Table 4).

The effect of residue management practices and cutting height of header on the fuel consumption

Table 3. Effect of residue management practices and the cutting height of header on theoretical field capacity

Residue management practices	Field capacity (ha/h)
SCDF	1.294[c]
SCDS	1.416[b]
SCAF	0.954[d]
SLS	1.846[a]
SSB	0.891[d]
Cutting height of header	
10 cm	1.195[b]
20 cm	1.365[a]

SCDF – chopping stubble by chopper mounted on combine during harvest and transmitting straw to trailer; SCDS – chopping stubble by chopper mounted on combine during harvest and spreading straw to field surface; SCAF – chopping stubble on field surface after harvest by chopper mounted on combine and transmitting straw to trailer; SLS – leaving stubble on field surface; SSB – removing stubble left on field surface by baling; values within a column for the five residue management treatments and values in the row for the two cutting height of header followed by the same or no letter(s) are not significantly different at the 5% level of the LSD test

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Table 4. Effect of residue management practices and the cutting height of header interaction on field capacity (ha/h)

Residue management practices	Cutting height of header	
	10 cm	20 cm
SCDF	1.088^{c}	1.499^{b}
SCDS	1.269^{b}	1.564^{b}
SCAF	0.932^{d}	0.975^{c}
SLS	1.805^{a}	1.887^{a}
SSB	0.883^{d}	0.898^{c}

for abbreviations see Table 3

Table 6. Effect of residue management practices and the cutting height of header interaction on fuel consumption (l/ha)

Residue management practices	Cutting height of header	
	10 cm	20 cm
SCDF	92.346^{a}	55.408^{b}
SCDS	50.483^{c}	36.938^{c}
SCAF	71.168^{b}	59.102^{a}
SLS	23.148^{e}	17.854^{e}
SSB	35.215^{d}	24.995^{d}

for abbreviations see Table 3

is seen in Table 2. Statistical analysis showed that the residue management practices and cutting height of header had a significant effect on the fuel consumption. The SCDF, SCDS, SCAF, SSB residue management practices had higher fuel consumption by 53.38, 23.21, 44.63, 9.6 l/ha than the SLS residue management practice, respectively (Table 5). The chopping stubble by chopper mounted on combine and transmitting straw to trailer during harvest increased the fuel consumption of combine by 3.6 times. Fuel consumption is a very important parameter because it is directly related with the economics of agricultural machineries. Therefore, a profitable cropping system needs minimizing the fuel consumption of equipments in agricultural production.

Comparasions between two cutting heights of header indicated that when the cutting height of header was increased from 10 to 20 cm, the fuel consumption decreased by 29% (Table 5). The fact that less straw was supplied into combine at 20 cm than 10 cm cutting height of header resulted in reduced fuel consumption of combine as well as the field capacity. Likewise, Listner and Axmann (1993) reported that when the wheat crop was cut below ears, the straw mass supplied into combine was approximately 50% less, thus combine capacity increased by 20% and fuel consumption decreased by 30%.

Table 5. Effect of residue management practices and the cutting height of header on fuel consumption

Residue management practices	Fuel consumption (l/ha)
SCDF	73.88^{a}
SCDS	43.71^{c}
SCAF	65.13^{b}
SLS	20.50^{e}
SSB	30.10^{d}
Cutting height of header	
10 cm	54.472^{a}
20 cm	38.859^{b}

for abbreviations see Table 3

There was a significant residue management practices and the cutting height of header interaction impact for the fuel consumption (Table 2). It indicates that the effect of residue management practices on the fuel consumption changed according to the cutting height of cutter. Among residue management practices, the fuel consumption was the highest in the SCDF at 10 cm cutting height of header; at 20 cm cutting height of header, it was the highest in the SCAF (Table 6).

CONCLUSION

Results of the study showed that the field capacity was the lowest in removing the stubble left on field surface by baling among residue management practices. Chopping stubble by chopper mounted on combine and transmitting straw to trailer during harvest and chopping stubble by chopper mounted on combine and spreading straw to field surface decreased the field capacity of combine by 29.90 and 23.29% and increased the fuel consumption by 3.60 and 2.13 times, respectively. When te cutting height of combine header was increased from 10 to 20 cm, the field capacity increased by 14.22% and the fuel consumption decreased by 29%.

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