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Effects of Tillage Systems on Wheat Yield and Residue in Turkey

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Abstract: The general objective of this study was to evaluate the effects of tillage systems on the wheat yield and residue in the first crop wheat planting. Specifically, the objective was to determine the annual gross production of wheat yield and residue used as animal feed and alternative raw material in the industry in overall Turkey. Wheat samples from five different points of each plot were harvested by hand using a frame of 0.5×0.5 m in order to calculate the amounts of grain yields and crop residues. After harvesting, the wheat yield and the amounts of stubble, chaff and straw were measured. The ANOVA test results indicated that while, the differences in the stubble amount among the treatments (tillage applications) were statistically not significant, the differences in the other parameters among the treatments were statistically significant at p = 0.01 level. The highest wheat yield (4943 kg ha^{-1}), residue (2966 kg ha^{-1}) and chaff (2704 kg ha^{-1}) were obtained in the CP/CD treatment. When the estimated and measured values were statistically compared, the total residue had significant relationship at 0.05 level at only CP/CD treatment, but at 0.01 level at the all other treatments. The straw had significant relationship at 0.05 level at DP_2/DD treatment, but at 0.01 level at the all other treatments. Using the data of the State Statistics Institute (DIE) in 2007, 8 million tons chaff and 8 million tons straw were estimated out of approximately 18 million tons total residue in overall Turkey.

Key words: Tillage, planting, wheat, residue, straw, livestock

INTRODUCTION

Crop and livestock production are important activities in farming systems in Turkey. Feed resources for livestock are natural herbage and crop residues. The natural grasslands constitute the main feed resources for ruminants in many countries. However, since the land area under grazing has remained constant and ruminant population increased over the years, the pressure on the need for livestock increased relatively (Qureshi, 1986). Therefore, fluctuating feed resources continues to hinder animal production. This means that alternative feed resources unsuitable for human consumption, but valuable for animal feeding must be given more attention (Reddy *et al.*, 2003). Agriculture and forest lands in Turkey are formed by 34.9% forests, 27.9% agricultural lands, 24.1% pasture and grasslands, 7% fallow lands and the remaining 6.1% fruit and vegetable lands. The wheat production is made in the vast amount (80.8%) of agricultural lands. The portion of wheat production in the total crop production is 57.7% (DIE, 2007). In Turkey, where wheat is grown in large areas in addition to the yield, the use of wheat residue for animal feed resources, alternative energy sources, or raw material in industry will contribute to the national economy.

Crop residue can refer to plant biomass remaining both above and below the ground following the harvest. Most commonly, it refers only to plant biomass above the ground left in the field after the harvest. For grain, this includes the stem, leaves and chaff (Patterson *et al.*, 1995). Crop residues (straw and chaff) from annual cereal and crops are a source of forage for livestock. After the crop is harvested, the residue can either be grazed in the field or it can be packaged and transported to another location for feeding. Winter small grains, especially wheat and barley are primarily grown for their grain; however, harvesting the straw as a secondary product can provide additional income. Crop residue is a valuable biomass as maintenance feed for ruminants because it is made up of three components, lignin, cellulose and hemi-cellulose (Gebrehiwot and Mohammed, 1989). Cellulose and hemicellulose contain large amounts of energy that can be converted into biofuels but are tightly bound by lignin, which is highly inert. Understanding, the effects of crop

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residues on soil properties and crop yields may be of greater importance in the future because of interest in using crop residues for production of paper products and ethanol. In addition, the crop residues are conventionally used for fodder (Power *et al*., 1998). Removing crop residue is neither a new nor an innovative idea. It is a traditional application in developing countries where, the resource poor farmers remove residue for fodder and other alternatives uses including the construction brick making and industrial raw material (Lal, 2004). Utilizing livestock to consume excessive residue is an efficient way to manage crop residue just following the harvest. Knowing the amount of residue initially available and how much residue should remain to provide adequate protection of the soil allow the producer to determine how much residue is available to be consumed by livestock. The sustainable amount of crop residue in an area depends on the crop residue left behind the combine, the percentage of residue allowed to be removed from the land surface and the accessibility of the site for collection. The available amount of crop residue appropriate to be removed depends on the weather, crop rotation, soil fertility, the slope of the land, the wind and rainfall patterns and tillage practices (Shahbazi and Li, 2005).

Wheat straw is the most plentiful source of agricultural residues. Wheat straw contains approximately 32.6% cellulose, 20.5% hemicellulose and 16.9% lignin (Shahbazi and Li, 2005). However, when it is used alone, it has a very low feeding value with poor metabolizable energy, negligible available protein and seriously deficient in mineral and vitamins. On the other hand, crop residues vary greatly in chemical composition and digestibility depending on varietal differences and agronomic practices. Their feeding values and intake can also be greatly improved through treatments and supplementation with protein and energy-rich feeds (Gebrehiwot and Mohammed, 1989). When straw is left in the field or returning of crop residue to the soil, straw maintains or builds soil organic matter, increases microbial activity and water infiltration and storage, provides and recycles plant nutrients, reduces soil erosion from water and wind (Patterson *et al*., 1995; Power *et al*., 1998). The amount of residue required to minimize soil erosion varies with the type of residue present, type of soil, the slope of the land and the presence of barriers (terraces, windbreaks, etc.). Consequently, soils are subject to severe soil degradation caused by water and wind erosions, nutrient depletion, decline in soil structure, disruption in elemental cycling, reduction in activity and species diversity of soil macro and micro-fauna and flora and drastic reduction in soil organic carbon pool (Lal, 2004). However, an excess of straw can cause or contribute to a number of problems in subsequent crops. These include increased disease, fertilizer management problems due to the nutrient immobilization, delayed or uneven germination and reduced herbicide effectiveness. It can also plug tillage and seeding equipment (Patterson *et al*., 1995).

Tillage system can affect crop yield because of their effects on water conservation and soil chemical and physical properties. Conventional tillage is a full tillage program combining primary and secondary tillage operations performed in preparing a seebed for a given crop and area. Conservation tillage is a tillage and planting system that maintains at least 30% of crop residue on the field after planting. Soil erosion is reduced by at least 50% in conservation tillage system compared to bare soils (Raoufat and Matbooei, 2007; Fallahi and Raoufat, 2008). Conservation tillage systems not only reduce soil erosion and improve the soil conditions for crop growth, but also conserve energy and decrease the labor cost of farming.

Crop residue left on the soil surface especially is effective in reducing evaporation rate of water (Cassel and Wagger, 1996), provides plants with nutrients, improves organic matter level of the soil, increases soil water content by decreasing evaporation and increasing infiltration rate and enhances crop growth (Chastin *et al*., 1995; Fallahi and Raoufat, 2008). Soil erosion is a leading cause of soil degradation due to the loss of organic matter (Govaerts *et al*., 2009). Several studies have been conducted on either the crop yield or residue (Patterson *et al*., 1995; Gebrehiwot and Mohammed, 1989; Donaldson *et al*., 2001; Reddy *et al*., 2003; Lal, 2004). However, none of these studies considered the effect of tillage systems on both crop yield and residue. Even though many studies in the research are available about the effect of tillage systems on wheat yield, the studies about the tillage systems effects on both the wheat yield and residue production, as far as the knowledge are absent or very limited.

Therefore, the general objective of this study was to evaluate the effects of tillage systems on the wheat yield and residue production. The specific objective was to determine the wheat yield and residue (straw) in terms of quantity and location and evaluate the amount of straw as livestock feed. The experimental data of stubble and straw were statistically compared with the estimated values obtained by using the wheat yield and collection factor (the ratio of crop residue to grain). Besides, the sustainable amount of residue/straw in each region in Turkey was estimated based on the wheat yield by using the Turkish Statistical Institute (DIE, 2007) data.

MATERIALS AND METHODS

The experiment was conducted in Kahramanmaras Province in the Eastern Mediterranean region of Turkey with an altitude of 640 m in 2007-2008. The soil was composed of 30% sand, 24% silt and 56% clay and classified as clay soil. The mean organic matter contents were 2.40 and 1.95% at the soil depths of 0-10 and 10-20 cm, respectively. The mean annual precipitation of Kahramanmaras Province is about 710 mm and 48.6% of it occurs in winter season. The mean annual temperature is around 29°C.

The second crop maize was grown in the entire experimental field prior to the wheat. The treatments used in the experiment were three different tillage systems with six replicates for the second crop maize production and two different tillage systems with three replicates for the first crop wheat on the subplots of maize. Therefore, the effects of six tillage methods on the wheat yield, stubble and straw were investigated with three replicates.

Completely randomized block design with three replicates was used for 6 applications and the data was analyzed using Analysis of Variance (ANOVA) with the SPSS software package. The experimental area and the size of the experimental plots were 55.4×158 m (8.7 day) and 8.4×50 m, respectively, as shown in Fig. 1. The plots were 1 m apart along the long-side and 4 m apart along the short-side to prevent the interactions among them (Fig. 1). The tillage equipment used in each tillage method was as follows.

Conventional Planting (maize) (CP): Chisel + disc harrow + fertilizer spreader + disc harrow + float + planter (Sönmezler).

Direct Planting 1 (maize) (DP_1): Direct planter (JD 1700).

Direct Planting 2 (maize) (DP_2): Modified direct planter (Sönmezler).

Conventional Drilling (wheat) (CD): Chisel + disc harrow + broadcasting seed + fertilizer spreader + disc harrow + float.

Direct Drilling (wheat) (DD): Rototiller + direct driller (Özdöken).

Broadcasting seeding method was used for wheat (27.5 kg ha^{-1}) in CD application. Seeded preparation in CD application before seeding consisted of chiseling to an approximate depth of 17 cm, disk harrowing (twice) and leveling. A direct driller was used for direct drilling method (DD) of wheat (Ceyhan 99) (20 kg ha^{-1}).

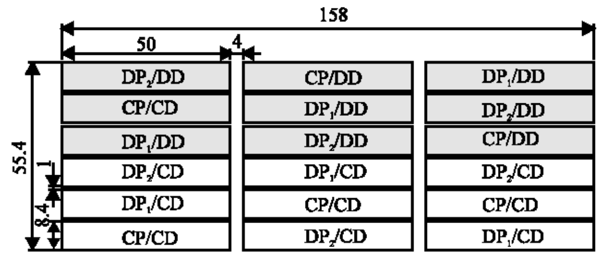

Fig. 1: Experimental design

Measured wheat yield and residue: Wheat samples from 5 different points of each plot and 5 cm above the soil surface was harvested by hand using a frame of 0.5×0.5 m in order to calculate the amounts of grain yield, stubble and straw. The heads of samples were cut and then grains were separated from heads by rubbing to determine the wheat yield. The grain was weighed by a precision balance and the yield was found as g/0.25 m^2. Then the yield was calculated as kg ha^{-1} by using conversion coefficients. Finally, the mean yield for a plot was obtained by averaging the yields of the five replicates.

In the harvesting made by combine, crops are mowed approximately 15-20 cm above the soil surface by considering the field conditions. It is known that the residue remained on the soil surface protects soil from water and wind erosion. The heads and the part of residue remained on the soil surface are not considered while calculating the amount of residue used for animal feeding, alternative energy and raw materials. Therefore, the stubble was determined by cutting the hand-harvested wheat samples 0-15 cm above the soil surface. The amount of straw was determined from the part between the stubble and the head. Therefore, the amounts per area of stubbles and straw/raw material were determined and then these values were converted to kg/ha by using the conversion coefficients.

Estimation of wheat residue: The estimated amount of total crop residue (plant material above the ground surface)/ha is based on the crop grown, variety, fertility, growing conditions, soil type, weather and some other factors (Korucu and Mengeloglu, 2007). These conditions affect the yield and also the ratio of crop residue to grain (Table 1). Typical residues to grain ratios are shown in Table 1.

The fallowing equations illustrate the process of determining the amount of straw for livestock:

$$A = k \times V \quad (1)$$

$$S_1 = A \times 0.2 \text{ (assume 20\% chaff)} \quad (2)$$

Table 1: The ratio of crop residue to grain (Korucu and Mengeloglu, 2007)

Crops	Residue/yield (k) Min.-Max.	Mean
Wheat	1.0-3.1	2.05
Barley	0.8-1.3	1.05
Oats	0.9-1.7	1.30

$$S_2 = A \times 0.2 \text{ (assume 20\% stubble)} \quad (3)$$

$$M = A - S_1 - S_2 - C \quad (4)$$

Where:

- A = The total residue (kg ha^{-1})
- V = The crop yield (kg ha^{-1})
- k = The ratio of crop residue to grain (2 for wheat)
- S_1 = The chaff (kg ha^{-1})
- S_2 = The stubble (kg ha^{-1})
- M = The straw (kg ha^{-1})
- C = The residue for conservation (includes the chaff 1500 kg ha^{-1})

It is considered that the amount of crop residue is two times the mean wheat yield while determining the crop residue by using the estimation method. It is assumed that the 20 and 20% of the residues are the chaff and stubble, respectively. The amounts of chaff and stubble are subtracted from the total crop residue while estimating the straw (Eq. 1-4). The straw production (M) was calculated using the residue/yield coefficients shown in Table 1.

RESULTS AND DISCUSSION

Measured wheat yield and residue: The yield, stubble, straw and chaff values (kg ha^{-1}) of the first crop wheat production were statistically evaluated based on the completely randomized block design and the mean values and ANOVA test results are shown in Table 2-5, respectively.

The ANOVA test results indicated that the differences in the yield among the treatments (tillage applications) were statistically significant at p = 0.01 level (Table 2). The highest mean wheat yield (4943 kg ha^{-1}) was obtained in the treatment of the CP/CD. The yields of conventional wheat planting were higher than that of the direct wheat planting. Even though the yields are variable due to the regional and climatic conditions, the mean yield in Turkey was 2320 kg ha^{-1} in 2007. The wheat yields obtained from either the conventional or direct planting were over the mean yield of Turkey (Table 2).

The ANOVA test results showed that the differences in the stubble among the treatments (tillage applications) were statistically not significant at p = 0.05 level (Table 3). The amount of stubble remained on the field surface after both the conventional and direct wheat planting was higher than that of the mean value of Turkey. However, it can be said that the stubble amount remained on the surface after the applications is low when that at least 30% or approximately 1100 kg ha^{-1} of the stubble of the first crop should be left on the soil surface is considered in order to protect agricultural soils against water and wind erosions.

The ANOVA test results revealed that the differences in the wheat straw among the treatments were statistically significant at p = 0.01 level (Table 4). The highest mean straw (2966 kg ha^{-1}) was obtained in the treatment of the CP/CD. This was followed by the treatment, which was statistically within the same group as the DP_1/CD application.

While, the straw of approximately 2500 kg ha^{-1} is produced as animal feed or industrial usage from conventional wheat production, approximately 1850 kg ha^{-1} of the straw is produced in the direct planting. According to statistics of 2007 in Turkey, when wheat production of 8.480.729 ha year^{-1} is considered, approximately 21.201.823 and 15.689.349 ton year^{-1} of the straw is produced in conventional and direct plantings, respectively.

Table 2: Wheat yield (kg ha^{-1})

Applications	N	Mean±SD	F-value	Sig.
CP/DD	15	3210.1±0891.20c	6.12	0.00**
DP_1/DD	15	3217.9±1106.07c	-	-
DP_2/DD	15	3235.8±1114.91c	-	-
CP/CD	15	4943.7±1587.35a	-	-
DP_1/CD	15	4628.3±1423.00ab	-	-
DP_2/CD	15	4002.2±1021.37bc	-	-

*p<0.05; **p<0.01, Values with different letters are not significantly different

Table 3: Total wheat stubble production (kg ha^{-1})

Applications	N	Mean±SD	F-value	Sig.
CP/DD	15	993.33±292.73	0.344	0.88
DP_1/DD	15	913.33±329.81	-	-
DP_2/DD	15	961.86±347.35	-	-
CP/CD	15	1004.80±212.23	-	-
DP_1/CD	15	936.00±221.44	-	-
DP_2/CD	15	900.00±252.75	-	-

*p<0.05; **p<0.01

Table 4: Total wheat straw (kg ha^{-1})

Applications	N	Mean±SD	F-value	Sig.
CP/DD	15	1909.33±722.76b	6.027	0.00**
DP_1/DD	15	1775.73±581.20b	-	-
DP_2/DD	15	1892.53±680.16b	-	-
CP/CD	15	2966.66±882.67a	-	-
DP_1/CD	15	2672.00±1035.28a	-	-
DP_2/CD	15	2028.00±637.88b	-	-

Table 5: Total wheat chaff (kg ha^{-1})

Applications	N	Mean±SD	F-value	Sig.
CP/DD	15	1633.92±735.25bc	6.113	0.00**
DP_1/DD	15	1455.46±520.52c	-	-
DP_2/DD	15	1550.34±510.37bc	-	-
CP/CD	15	2704.26±1013.46a	-	-
DP_1/CD	15	2089.01±691.38b	-	-
DP_2/CD	15	1805.76±772.43bc	-	-

*p<0.05; **p<0.01, Values with different letters are not significantly different

The ANOVA test results indicated that the differences in the wheat chaff among the treatments were statistically significant at p = 0.01 level (Table 5). The highest mean wheat chaff (2704 kg ha^{-1}) was obtained in the treatment of the CP/CD. This was followed by the treatment of the DP_1/CD.

Estimated wheat residues: Estimated crop residues by utilizing the actual yields of the treatments are shown in Table 6.

The ANOVA test results indicated that the differences in the total residue (A), chaff (S_1), stubble (S_2) and straw (M) among the treatments were statistically significant at p = 0.01 level (Table 6). The highest values were obtained in the CP/CD treatment and this was followed by the other conventional wheat planting methods. The lowest values were observed in the direct wheat planting methods.

According to the DIE (2007), the wheat yield of Turkey is approximately 2320 kg ha^{-1}. The straw of 2212 kg ha^{-1}, chaff of 928 kg ha^{-1} and stubble of 928 kg ha^{-1} are produced based on the mathematical relationship between the yield and the residue. When wheat is grown in overall 8.480.729 ha land in Turkey, approximately the total wheat residue of 18 million, chaff of 8 million and straw of 8 million tons are produced. The regional wheat residue production in Turkey is shown in Fig. 2.

The straw production of Turkey was estimated by using the relationship between the yield and the residue. This relationship can be expressed as a weight ratio of grain to straw, i.e. 1:2, as shown in Fig. 2. The highest straw production (approximately 3.9 million tons) was observed in the Marmara region and this was followed by the Southeast Anatolia and the Central Anatolia regions with approximately 3.4 and 2.9 million tons, respectively (Fig. 2). Patterson *et al.* (1995) reported that approximately 5.4 kg ton^{-1} N, 1.4 kg ton^{-1} P_2O_5, 9.6 kg ton^{-1} K_2O and 1.4 kg ton^{-1} S major nutrients were produced from per ton of wheat straw. In Turkey, approximately 98000 tons N, 26000 tons P_2O_5, 174000 tons K_2O and 26000 tons S are produced annually from 18 million tons wheat residue.

The total wheat residue, stubble, chaff and straw in the experimental plots were estimated by using the actual yields in the plots. The estimated results were compared with the field measurements using the Pearson's correlation test and the results are shown in Table 7.

Since, the residues were estimated from the yield values, it is shown that a high relationship (1.000) was observed between the residues and yield (Table 7). The residue had significant relationship at 0.05 level at only CP/CD treatment but at 0.01 level at the all other treatments. The available straw had significant relationship at 0.05 level at DP_2/DD treatment but at 0.01 level at the all other treatments.

Table 6: Estimated crop residues

Applications	Grain production (kg ha^{-1})	A (kg ha^{-1})	S_1 (kg ha^{-1})	S_2 (kg ha^{-1})	M (kg ha^{-1})
CP/DD	3210.1c	6420.2c	1284.0c	1284.0c	3636.1c
DP_1/DD	3217.9c	6435.7c	1287.1c	1287.1c	3648.6c
DP_2/DD	3235.8c	6471.6c	1294.3c	1294.3c	3677.3c
CP/CD	4943.7a	9887.5a	1977.5a	1977.5a	6410.0a
DP_1/CD	4628.3ab	9256.6ab	1851.3ab	1851.3ab	5905.3ab
DP_2/CD	4002.2bc	8004.5bc	1600.9bc	1600.9bc	4903.6bc
Sigificant	0.00**	0.00**	0.00**	0.00**	0.00**

*p<0.05; **p<0.01

Table 7: Pearson correlation coefficients (R)

		Measured			
Application	Estimated	Total residue	Chaff	Stubble	Straw
CP/DD	Total residue	0.784**	-	-	-
	Chaff	-	0.692**	-	-
	Stubble	-	-	0.830**	-
	Straw	-	-	-	0.798**
DP_1/DD	Total residue	0.713**	-	-	-
	Chaff	-	0.505	-	-
	Stubble	-	-	0.457	-
	Straw	-	-	-	0.782**
DP_2/DD	Total residue	0.731**	-	-	-
	Chaff	-	0.812**	-	-
	Stubble	-	-	0.719**	-
	Straw	-	-	-	0.584*
CP/CD	Total residue	0.624*	-	-	-
	Chaff	-	0.235	-	-
	Stubble	-	-	0.601*	-
	Straw	-	-	-	0.805**
DP_1/CD	Total residue	0.943**	-	-	-
	Chaff	-	0.851**	-	-
	Stubble	-	-	0.859**	-
	Straw	-	-	-	0.937**
DP_2/CD	Total residue	0.824**	-	-	-
	Chaff	-	0.682**	-	-
	Stubble	-	-	0.855**	-
	Straw	-	-	-	0.842**

*Correlation is significant at 0.05 level (<0.05); **Correlation is significant at 0.01 level (<0.01)

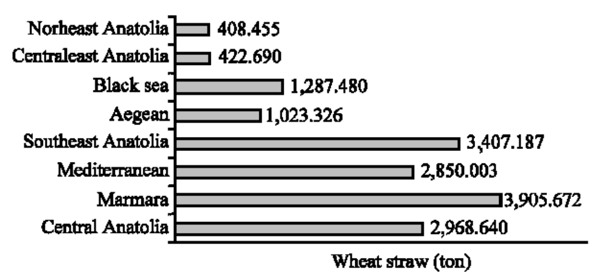

Fig. 2: The regional mean wheat residues in Turkey

CONCLUSION

The evaluation of tillage systems and the benefits of wheat residues are concluded as follows:

- In Turkey, where wheat residue potential is very high, the use of straw as animal food and raw material in the industry will be an income for farmers as well as a contribution to the national economy

- The removal of residue from fields will reduce power requirements of machines during the tillage operations, as a result, fuel consumptions
- Since the residue is not burned, some problems such as the degradation of soil biology, the decrease in soil organic matter content, adverse effects on microbiologic activities will disappear. Besides, the stubble remained on the soil surface will protect soil against water and wind erosions
- The ANOVA test results indicated that the differences in the yield among the treatments were statistically significant at p = 0.01 level. The highest yield was obtained in the treatments of the conventional first and second crop production (CP/CD). The yield of direct wheat planting was lower than that of the conventional planting
- The best application (treatment) in both the stubble and straw was also found as CP/CD
- The differences between the estimated and measured values among the treatments were statistically significant at p = 0.01 level. A high degree of relationship between the estimated and measured values was observed
- As animal food or industrial usage approximately 2500 and 1850 kg ha^{-1} straw were produced in the conventional and direct wheat planting, respectively According to statistics of 2007 in Turkey, when wheat production was made in an area of 8,480.729 ha, approximately 2,201.823 and 15,689.349 ton year^{-1} wheat residue could be produced in the conventional and direct plantings, respectively
- Approximately a total of 18 million wheat residue was produced in overall 8.480.729 ha wheat land in Turkey and approximately 8 million ton of this residue was available straw

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