2013 International Conference on Agriculture and Biotechnology
IPCBEE vol.60 (2013) © (2013) IACSIT Press, Singapore
DOI: 10.7763/IPCBEE. 2013. V60. 20

Alternative Tillage and Direct Seeding Systems on Wheat Production in Middle Anatolia

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Abstract. As a result of developing environmental awareness, and increasing the cost of fuel, farmers in Turkey has started to use alternative tillage and direct seeding systems. Because of this, showing to our farmers and adapting to our soil conditions of these techniques which are used widely in the world, is very important. The aim of this study was to compare the conventional tillage system with alternative tillage and direct seeding systems for wheat production. Wheat was sown after harvesting wheat in the dry field conditions in Middle Anatolia, during the years of 2012-2013. The effect of tillage systems on penetration resistance and surface roughness of soil and fuel consumption were examined. The mean emergence date, emerged seedlings rate and yield of wheat were also measured to assess the effect of tillage systems. According to the results, the effect of the tillage systems on the yield of wheat was found to be very significant When output-input energy ratio is considered, the highest rate (4,65) is obtained in vertical shaft rotary tiller – roller combination (AT1) but, the difference between AT1 and direct seeding (DS) applications were not found significant.

Keywords: Tillage system; Direct seeding; Wheat; Fuel consumption; Energy budget

1. Introduction

Tillage is one of the highest power-required processes of the agricultural production. Today, the high cost of energy forces farmers to find alternative economic tillage methods. No-till systems can, if not always, produce similar or higher yields compared with conventional tillage systems. As tillage operations are not required, no-till producers do not need to purchase tillage implements. This, together with the reduced labor and tractor hours, will reduce the crop production cost [1]. By maintaining the crop residue on the soil surface, no-till systems have showed considerable potential for controlling wind and water erosion, reducing soil moisture loss and increasing soil organic matter. In recent years, no-till systems were identified as a major practice to reduce greenhouse gas (carbon) emissions from agriculture.

Conservation tillage is defined to be any tillage or sowing system which leaves at least 30% of the field covered with crop residue after sowing has been completed. In such soils, erosion is reduced by at least 50% as compared to bare, fallow soils. In the last three decades, no-till sowing practices that promote soil and water conservation have slowly become an accepted alternative to conventional tillage systems. The conventional tillage needs more mechanical investment and labor when compared to conservation tillage, especially direct planting. Energy efficiency increases 25 to 100 % and consumption of energy decreases 15 to 50 % in direct planting. The direct seeding requires only 1/3 of field traffic compared to the conventional tillage [2]

Energy use and costs are decreased with conservation tillage and with this method, enough plant residues is left in soil to protect field. The main purpose of direct planting is to decrease the water and wind soil erosion and to make plant production more profitable. So, the target is protection of soil. In addition, soil moisture, energy consumption, labor and also protection of machinery will be effective.

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Emissions to the atmosphere from the conventional agriculture reduce the potential CO_2 sink effect of the soil, decreasing the organic matter content of the soil and contributing to global warming. Intensive tillage of agricultural soils has led to substantial losses of soil carbon (C), frequently over 50% in the 20-30 years of cultivation.

Aykas and Önal [3] studied the effects of different tillage methods on yield and weeding for wheat. They obtained better grain and straw yield from reduced tillage (rotary-tiller) as 3500 kg ha $^{-1}$ and 3470 kg ha $^{-1}$ as compared to the conventional and zero tillage system, respectively. They recommend that proper tillage system should be carefully selected in order to achieve a better weed control.

Barut and Akbolat [4] evaluated the conventional and conservation tillage systems. They concluded that tillage systems with crop residue improved physical properties of soil. They found the highest yield in the conventional system but the lowest time and fuel consumption were gathered 4 h ha^{-1} and 28.8 l ha^{-1} respectively on conservation tillage. According to the research findings, fuel consumptions of different tillage methods were found as 49.4 l ha^{-1} (100%), 31.21 l ha^{-1} (63.2%), 28.3 l ha^{-1} (57.3%), 25.2 l ha^{-1} (50.9%), and 13.3 l ha^{-1} (27.08%) for plough, chisel, disk harrow, ridge-tillage, and the direct seeding, respectively. The direct seeding saved 73 % of fuel energy compared with the conventional method [5].

Yalcın et al., [6] studied tillage parameters and economic analysis of the direct seeding, minimum and the conventional tillage in wheat. They found that wheat yields were 6800 kg ha^{-1} and 7400 kg ha^{-1} for the direct seeding and minimum tillage, fuel consumption were 8.9 l ha^{-1} and58.4 l ha^{-1} for the direct seeding and the conventional tillage, respectively.

Bayhan et al., [7] studied possibilities of direct drilling and reduced tillage in second crop silage corn. The direct seeding method gave the best result for mean of emergence dates and percentage of emerged seedling. The best result for silage yield was found in tillage combination. The lowest yield was found in the heavy-duty disc harrow tillage method. The direct seeding gives the best results for tillage efficiency parameters, such as fuel consumption, effective power requirement and field efficiency.

Yalçın and Çakır [8] studied tillage effects and energy efficiencies of subsoiling and the direct seeding in light soil on yield of second crop corn for silage in Western Turkey. They found that the fuel consumptions were 60.5 l ha^{-1} and 7.5 l ha^{-1} for the conventional system and the direct seeding, respectively. Çarman and Marakoğlu [9] compared reduced tillage and direct planting applications in chick pea production. The biggest and least fuel consumptions were obtained in the conventional method (52.02 l ha^{-1}) and the direct seeding (9.72 l ha^{-1}), respectively. The lowest output-input energy ratio was found in conservation tillage with 3.12 and the highest output-input energy ratio was found in the direct seeding + herbicide application with 4.05 [10].

Barut and Çelik [11] evaluated the direct drill and conventional tillage system in the dry farming conditions. They found wheat yield in the conventional tillage system and direct drill as 3556.7 kg ha^{-1}, 3130.0 kg ha^{-1} and 3413.3 kg ha^{-1}, 2880.0 kg ha^{-1} in the first and second years, respectively.

The objective of this study was to determine tillage effects and energy efficiencies of alternative tillage and direct seeding on yield of wheat. Direct seeding were compared with the alternative tillage system.

2. Materials and Methods

The experiments were conducted in the field of Soil, Water and Combating Desertification Research Station during the years of 2012-2013. It is 10 km away from Konya province, which is located in the Middle Anatolia region of Turkey.

The soils are classified as Typic Xerfluent in the US Soil Taxonomy. Physical and mechanical properties of the soil in the experiment field are given in Table 1. The average annual temperatures and rainfall data in October – July during the years of 2012-2013 are given in Table 2. The tillage methods are given as follows:

- CT: The conventional method: plough + Cultivator – float (2 times) + seeding.
- AT1: Vertical shaft rotary tiller – roller + seeding.
- AT2: Horizontal shaft rotary tiller (L type) – roller + seeding
- AT3: Winged chisel – roller + seeding

- DS: The direct seeding.

Table 1. Physical and mechanical properties of the soil in the experiment field

Particle size distribution	
Sand (%)	36.88
Clay (%)	42.94
Silt (%)	20.18
Bulk density (g cm^{-3}) (0-20cm)	1.32
Moisture content (%) (0-20cm)	18.2
$EC.10^{-3}$ (mmos/cm)	0.67
Organic matter (%)	0.76

Table 2. Monthly averages of air temperatures and rainfall at Konya measured in 2012 – 2013.

Months	Air temperature (℃)	Rainfall (mm)
	2012 – 2013	2012 – 2013
October	14.7	20.4
November	7.7	69.2
December	3.9	61.4
January	2	30
February	5	37.6
March	7.7	7.2
April	11.9	35.2
May	18.4	47.4
June	21.3	14.6

The conventional method, alternative tillage and the direct seeding applications were conducted in five different plots. For the conventional tillage method, the soil was first ploughed with four bottom moldboard plough. After plowing, the field was harrowed with cultivator-roller and leveled with float. In the alternative tillage method, seed bed was prepared with only one pass of soil tillage, and seeded. For the direct seeding application, seeding was made without tillage.

The specifications of the tools used in the experiment are given Table 3. New Holland TD90 tractor was used in the experiments. The wheat variety was Sönmez 2001, which is the most commonly used wheat in the Middle Anatolia.

Table 3. The specifications of the tools used in experiment

Tool	Average speed (km h^{-1})	Working depth (cm)	Working width (cm)
Plough	5.5	22	1.20
Cultivator-roller combination	7.0	12	210
Vertical shaft rotary tiller – roller combination	3.2	18	230
Horizontal shaft rotary tiller (L type) – roller combination	2.6	13	260
Winged chisel – roller	2.9	23	230
Seeding machine	6.5	4	168
Direct seeding machine	5.5	4	168

The direct seeding was home made. Row spacing was 13 cm, seeding rate was 200 kg ha^{-1} and there were 12 seeding units. Diameter of press cylinder in direct drill is 490 mm, it has a width of 53 mm, height of 32 mm and has a pressing ability of 0.25 daN cm^{-2}. A soil penetrometer, with a cone angle of 30^o and cone diameter of 12.83mm, was used to determine of soil penetration resistance. It was pushed by hand into the soil to a depth of 30cm penetrometer resistance for each 1cm depth interval was recorded.

Surface relief was measured using surface profilemeter. This consisted of a set of vertical rods, spaced at 2.5cm intervals, sliding through an iron bar of 100cm length. The surface roughness was calculated by using the Kuipers equation [12].

The numbers of emerged seedlings were measured in rows and mean emergence dates (MED) and percentage of emerged seedlings rates (PE) were calculated using formulae (1) and (2) [13].

$$MED = \frac{N_1 D_1 + N_2 D_2 + ... + N_n D_n}{N_1 + N_2 + ... + N_n} \quad (1)$$

$$PE = \left(\frac{Total\ emerged\ seedling\ per\ meter}{Number\ of\ seeds\ planted\ per\ meter} \right) x100 \quad (2)$$

MED, PE, fuel consumptions and yield were determined to compare the methods. MED, PE, fuel consumptions, and yield were measured with three replications in plots of 100 m long and 6 m wide. Yields were measured from samples taken from an area of 3.5 m^2 at harvest time.

For energy balance in wheat production, the total energy equivalent of inputs and output was calculated. The data were analyzed using MSTAT statistical software for analysis of variance. LSD Test $P \leq 0.05$ was used to compare the means of the obtained results in this research.

3. Results and Discussion

Penetration resistance of soil depends on its physical and mechanical properties, the operating conditions and the penetrating tool geometry. The effect of tillage systems on the penetration resistance was significant (P<0.01). The penetrometer resistance of DS in which tillage was not made, was found to be close to the values, which occurred pre-tillage. Consequently, the penetrometer resistance was maximum value in DS. Minimum penetrometer resistance was measured in vertical shaft rotary tiller. Horizontal shaft rotary tiller (L type) with an working depth of 13 cm had higher penetration resistance values than other applications. Erbach et al. [14] found similar results.

Surface roughness of cultivated soil is an important characteristics in assessing tillage performance. It affects the resulting seedbed properties and can reduce the amount of irrigation water required. The effect of tillage systems on soil surface roughness was significant at the 1% level. The soil surface after application of Winged chisel had the greatest roughness (24.23 %). Çarman [15] reported that the surface roughness varied from 33.72 to55.10 % for different tillage tools.

The effects of different tillage systems on the mean emergence date, emerged seedlings rate and yield of wheat are summarized in Table 4. The mean emergence dates were varied from 29.72 to 30.04. The effects of the tillage systems on mean emergence date and the emerged seedlings rate of wheat were found to be not significant (P>0.01). The lowest PE was found in DS with 67.85% and the highest PE was found in horizontal shaft rotary tiller (L type) with 70.67%. Gemtos et al. [16] also pointed out that reduced tillage plots had higher water content and obtained higher emergence rates. PE was found to be the lowest in method of DS due to the reason of the presence of weeds. Tillage methods affected significantly the yield of wheat (P<0.01). The highest yield was obtained from vertical shaft rotary tiller application, and horizontal shaft rotary tiller method gave the the lowest yield. There were no significant difference between methods CT and DS, and between methods CT and AT2 with regard to yield.

Table 4. The effects on mean emergence date (MED), emerged seedlings rates (PE) and yield of wheat of different tillage methods

Methods	MED (day)	PE (%)	Yield (kg/ha)
CT	29.75	69.55	3200 ac
AT1	29.72	67.92	3810 b
AT2	29.85	70.67	3090 c
AT3	29.92	68.60	3600 b
DS	30.04	67.85	3490 ab
LSD (P < 0.05)	-	-	363,62

The total calculated fuel consumptions is shown in Fig. 1. The fuel consumption of applications were varied from 3.54 to 0.535 L/da. The lowest fuel consumption was found in DS with 5.35 l/ha. The conventional method required 5.6 times more fuel compared to the direct seeding. The findings are also in agreement with the research results of Köller (2003). The effect of tillage systems on fuel consumption was significant at the 1% level. There was no significant difference between methods AT2 and AT3 with regard to the fuel consumption.

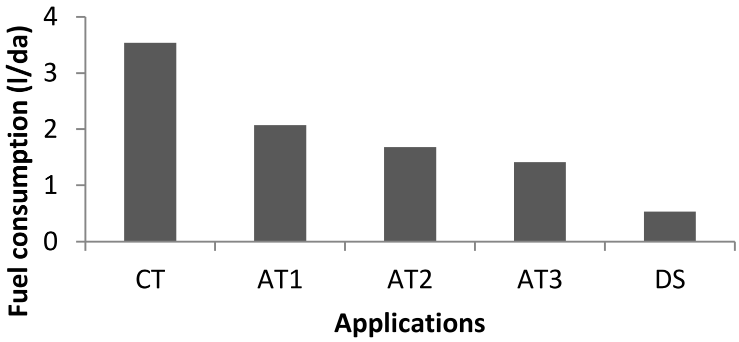

Fig. 1: Average of total fuel consumption for different tillage methods.

The total energy equivalent of inputs and outputs in wheat production and output-input energy ratio are summarized in Table 5. The highest total energy equivalent of inputs was calculated as 12.283,24Mj ha^{-1} in conventional tillage. In this method, seed had the highest share of 39.69%, followed by fertilizer (38.68%), diesel-oil (15.79%) and chemicals (2.48%) respectively. The lowest total energy equivalent of inputs was found for DS with 10.963,24 Mj ha^{-1}. The highest total energy equivalent of outputs was found in AT1 with 54.140,10 Mj ha^{-1}. The effect of tillage systems on output-input energy ratio was significant at the 1% level. The lowest output-input energy ratio was found in CT with 3.70 and the highest output-input energy ratio was found in AT1 with 4.65. Considering this rate, it can be seen that direct seeding is much more profitable production method when compared to conventional tillage applications. There was no significant difference between methods AT1, AT3 and DS with regard to output-input energy ratio.

Table 5. General energy budget in wheat production.

Methods	Total energy input (EI)	Total energy output (EO)	EO/EI
CT	12.283,24	45.472,64	$3{,}70_a$
AT1	11.636,77	54.140,10	$4{,}65_b$
AT2	11.478,92	43.908,90	$3{,}83_a$
AT3	11.699,64	51.156,00	$4{,}37_b$
DS	10.963,24	49.592,24	$4{,}52_b$
LSD ($P < 0.05$)	-	-	*0.364*

These findings indicate that wheat can be grown successfully under conservation tillage systems with yields equal to those of conventional tillage and lower labor and fuel inputs. In addition, it can be concluded that the direct seeding can be easily applied in wheat production in the Middle Anatolia region.

4. Acknowledgements

This project was supported by The Scientific and Technological Research Council of Turkey (TÜBİTAK, project code: 111 O 182).

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