Field evaluation of tillage practices in rainfed wheat planting

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Abstract: This study is aimed to evaluate the effect of multiple tillage practices on the wheat yield in rainfed fields. The experiment was conducted in three field preparation and planting treatments including conventional tillage (moldboard plow, disc harrow, and centrifugal seed spreader) indicated as T1, chisel plow, disc harrow, and planting with deep drill as T2, and conservation tillage (plowing with heavy disc on last year's crop residues, and planting with deep drill) as T3.The performance characteristics as well as agronomic and crop yield parameters were measured and analyzed for two consecutive years. The design of experiments was carried out base on Randomized Complete Blocks Design with four replications. The analysis of results showed that the conservation tillage had desirable effects on soil moisture content, field capacity, energy consumption, seed distribution uniformity, number of grains per spike, number of spikes per unit area, grain yield and production cost when compared to the other treatments. As a comparable result, the minimum field efficiency and the minimum field capacity belonged to T1 as 0.57 and 0.39 ha/h, respectively. While the maximum values were recorded for T3 treatment as 0.72 and 0.58 ha/h, respectively. The fuel consumption for T3 was measured 23.3 L/ha as the lowest fuel consumption due to reduce of tillage and planting practices. Furthermore, T2 operation condition consumed diesel fuel at an average range of 39.2 L/ha. Besides, the maximum fuel consumption (46.7 L/ha) was in T1 treatment owing to use the moldboard plow.

Keywords: implement efficiency, conservation tillage, rainfed wheat, fuel consumption.

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1 Introduction

Wheat (*Triticumaestivum* L.) is known as an essential staple and strategic crop in most of developing countries like Iran, in where annually plants a total area of 6.9 million hectares. While rainfed farms are included near to 48% of wheat farms, only produce 25% of total yield (Kiani and Houshyar, 2012; Kiani and Houshyar, 2013). In other words, the rainfed farms have lower yield efficiency compared to irrigated farms.

Tillage operations provide sufficient soil moisture and prepare appropriate environment for seed germination and longer root development by suppressing weeds and controlling soil erosion (Ehsanullah*et al.*, 2013; YounesiAlamouti and Navabzadeh, 2007).Seedbed preparation is an important operation to achieve uniform crop emergence, plant growth and high yield under different soil and climatic conditions for any crop in drylands (Bayhanet al., 2005; AlamoutiY. and Navabzadeh, 2009).Conventional tillage disturbs soil structure and affects on temperature, mechanical properties, continuity of macropores and available water capacity of the soil as well as growth and distribution of roots (Verhulstet al., 2011).Nonetheless, development of agricultural research has revealed that tillage operations are not necessary practices to produce crops. Seedbed preparation practices are trending to a single operation (no-tillage), owing to lower soil disturbance during planting practices (Choudhary and Baker, 1993).No-tillage provides an opportunity to revive the traditional agriculture with a new concept of conservation

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agriculture (Ehsanullahet al., 2013).Indeed, conservation tillage systems are conducted to manage crop residues on the soil surface with the minimum tillage (Unger and McCalla, 1980).No-tillage or minimum tillage as well as organic and chemical fertilizers improve soil quality and organic particles in soil (Yaduvanshi and Sharma, 2008; Boloor et al., 2013).No-tillage system has some advantages when compared to the conventional tillage, for instance, reduction of machinery passes over the field, fuel consumption, field time during tillage and soil loss due to better aggregate stability, as well as the protective effect of crop residues left over the soil. Furthermore, no-tillage systems enhance soil physical properties e.g. available water, and number of biopores that may facilitate root growth (Mart ńezet al., 2008).Entirely, it could be enounce that the aims of these systems by plant residue management are control of water and wind erosion, reduction of consumed energy, and conservation of soil and water (Unger and McCalla, 1980, Wang et al., 2012).Despite these known advantages of conservation agriculture system implementing, it may display detrimental effects in future, such as increase bulk density, decrease soil temperature and oxygen diffusion rate and increase compaction of upper soil as compared to conventional tillage (Mart ńezet al., 2008).Nevertheless, deep tillage system reduces the soil compaction and improves rooting depth due to deep plowing (Qamaret al., 2012).The yield produced from no-till condition is same or even more than yield of conventional tillage farm (McMaster et al., 2002).Soil compaction, anoxic condition and immobilization of nitrogen are probably agents that have influence on no-till wheat yield (Alvarez and Steinbach, 2009).

Quantity of the recent researches in field of conservation agriculture is an enormous confirmation for acceptability of conservation tillage around the world.Wang et al. (2012) were found that soil physical properties, such as bulk density, and water storage during the summer unplanted and winter, as well as water conservation and soil protection in spring were improved for the conservation tillage as compared to the traditional tillage. Moreover, it has reported that the reduced tillage produced yield around 9–37% higher than and no-till yield were very close to those of conventional method (Wang *et al.*, 2012). Afzaliniaet al. (2006) in a comparison study evaluated performance of conversional grain drills in Iran including Hassia, Nordstone, Hamadan Machine Barzegar, and Keshtgostar in irrigated condition. The obtained results showed a significant difference between the grain drills for uniformity of the seed planting depth and draft requirement. The Machine Barzegar grain drill had the best planting depth uniformity (81.9%) and the highest draft requirement (7665 N), as well as the highest overall performance index (0.91). Bayhanet al. (2005) carried out a study, from 2001 to 2003, to investigate the effects of three tillage systems (chisel plowing, chisel plowing and disc harrowing, and chisel plowing and combine harrowing) on planting performance, aggregate properties, and crop yield of a loam soil with a rotation system (sunflower-barley-Hungarian vetch and triticale).The results showed that the percentage of gaps was reduced, and the percentage of double seedlings was increased by secondary tillage operations. Canakciet al. (2005), examined the energy use patterns and energy input–output analysis of some field crops and vegetables widely grown in the Antalya region.The value of the operational inputs was found to be 3735.4 MJ/hafor wheat crop.

The aim of this study is investigation of different tillage and planting systems on rainfed wheat yield in farmers' lands in order to achieve a knowledge that reveal the importance of the conservation agriculture.

2 Materials and Methods

This study was carried out to evaluate performance characteristics of rainfed wheat production in the north region of Ilam province is located in Iran (Eyvan-e-Gharb; coordinates: 33° 29′ 24″N, 46° 10′ 12″ E) during two consecutive years. The region has a Mediterranean climate and also, the fieldshavea loam soili.e 38% sand, 44% silt, and 18% clay.

The experiments were performed in three field preparing and planting treatments including; conventional tillage (moldboard plow, disc, and centrifugal seed spreader) denoted as T_1, Chisel plowing, disc, and planting with deep drills as T_2, and T_3 represents conservation tillage (plowing with heavy disc on last year's crop residues, and planting with deep drill).Cross-Sabalan as a common domestic wheat variety was planted at rate of 160 kg/ha in the all treatments. As advised by the Water and Soil Department of Ilam Agricultural and Natural Resources Research Center, the fertilizers (N_2:130; P_2O_5:90 kg/ha) were applied using a centrifugal spreader. 2,4-D (1.5 L/ha) and Topik (1 L/ha) herbicides were applied to eradicate broadleaf and narrow-leaf weeds, beside, 1 L /ha Pheniteriteyon pesticide. The design of experiments was conducted according to the Randomized Complete Blocks design with four replications. The technical performance parameters including soil moisture content, field efficiency, field capacity, fuel consumption, energy input-output values, plant density per unit area, seed distribution uniformity, emergence percentage, number of grains per spike, number of spikes per unit area, crop yield, and 1000-grain weight, were scrutinized. The following procedures were followed to measure and calculate the parameters. Finally, the data were statistically analyzed, and Duncan's new multi-range test was used for mean comparison purposes using PASW statistics 18 (SPSS Inc., Chicago, IL).In order to report the results, due to the large number of the data obtained, the data related to two years were averaged. Economic analysis carried out to compare the tillage practices on wheat productions cost.

2.1 Soil moisture content

Soil moisture was regularly determined for two consecutive years from the beginning of tillage practices (December 5,2012 and 2013) to the end of harvest (June 20, 2013 and 2014) at 15-day intervals. Due to evaluate the effect of conservation tillage on top-soil moisture content, samples were taken from 0-10 cm depth in four replications. To do so, ten samples were taken from different parts of the field on every sampling day. According to the standard method, the samples were dried using an oven at 105℃ for 24h.The wet basis moisture content was finally determined by the difference of wet and dry weights per wet weight of soil samples (Baveret al., 1972; Afzalniaet al., 2011).

2.2 Implements Field capacity and efficiency

To measure the field efficiency, a test field in a specified area (20×50 m^2) was selected for each treatment. The planting operations were performed using the particular seeders in three replications. During planting practices, the effective operating times as well as non-effective times (i.e. the tractor turning and the seed-hopper refilling times) were measured. Consequently, the field efficiency of the treatments was determined using Equation 1 (ASABE, 2006).

$$e = (T_e / T_t) \times 100 \quad (1)$$

where, e is field efficiency (%), T_e and T_t are effective operating time and total time spent (min), respectively.

Moreover, the forward speed and the effective width of implements were recorded to determine the field capacity using Equation 2 (ASABE, 2006).

$$C_e = W \cdot S \cdot e / 1000 \quad (2)$$

where, C_e represents effective field capacity (ha h^{-1}), W is the implement effective width (m) and S is the forward speed of the machine (km h^{-1}).

2.3 Energy consumption

In order to measure fuel consumption, the full-tank method in three replications was used. In this approach, the fuel tank of the engine was completely filled before starting the field tests. After each practices, the fuel tank was refilled using a 1 L graduated cylinder. The amount of fuel that need to fill the tank is the fuel consumed during the practice (Canakci *et al.*, 2005). Energy equivalent of inputs and outputs during wheat production processes are listed in Table 4. The energy ratio or energy use efficiency, energy productivity and the specific energy were calculated as follows (Demircan *et al.*, 2006; Sartori *et al.*, 2005; Ghorbani *et al.*, 2011):

Energy Use Efficiency= E_o / E_i(3)

Energy Productivity= Y_w/ E_i (4)

Specific Energy= E_i/ Y_w(5)

Net Energy= E_o - E_i (6)

Where, E_i and E_o are energy input and energy output(MJ/ha), respectively, and Y_w is wheat yield output(kg/ha).

These parameters as well as direct and indirect, and renewable and non-renewable energy values were calculated and compared for different treatments. During this study, indirect energy is including the energy embodied in seeds, chemical fertilizers (NPK), herbicides, pesticide, and machinery, while direct energy is human labor and diesel used in the wheat production. Non-renewable energy includes diesel, chemical pesticides, chemical fertilizers and machinery, and subsequently, renewable energy consists of human labor and seeds.

2.4 Plant density per unit area

Before the tillering stage, the plants emerged in 10 points of each plot, were counted using a 1×1 m^2 wooden frame.

2.5 Seed distribution (vertical and horizontal) uniformity

The 1×1 m^2 wooden frame was used to evaluate the horizontal distribution of seeds. The frame was randomly laid down in three points of each plot, and each plant's distance from its neighboring plants was also measured. The mean values were determined and using Equation 7, the horizontal uniformity of seed distribution (spacing) was calculated (Senapati *et al.*, 1992, Afzalnia et al., 2006; Afzalnia et al., 2012).

$$S_e = 100(1 - Y/D)\,(7)$$

Where, S_e is coefficient of seed distribution uniformity (%), Y is the average numerical deviation of number of plants per meter length of row from average number of plants per meter run, and D is average number of plants per meter length of row.

After planting and seed emergence, the depth of planting was also determined by selecting 20 points in each plot. Plants in these points were then removed from soil, and the distance between seed placement and the point on the stem which was not turned green due to lack of light was measured as the depth of plating. This length was considered as a criterion to compare the seeding depth of the drills. The coefficient of vertical distribution uniformity was calculated using Equation 8 (Senapati et al., 1992).

$$S_d = 100(1 - Y_d / D_d)\,(8)$$

Where, S_d is coefficient of vertical distribution uniformity (%), Y_d is average numerical deviation of depth of seeds planted from pre-set planting depth, and D_d is average depth of seeds planted.

2.6 Emergence percent

The 1000-seed planted weight was used to determine the number of planted seeds per unit area. The 1×1 m^2 wooden frame was laid again on ten random locations, to count the emerged plants. The mean values were determined, and emergence percentage was calculated by Eq. 9(Smith and Millet, 1964):

$$E = (P/S) \times 100\,(9)$$

Where, E is emergence percentage (%), P is number of emerged plants, and S is number of planted seeds.

2.7 Mean spike per unit area and grains per spike

At the time of harvest, the 1×1 m^2 wooden frame was used once more to count the spikes in 10 random locations. The average was calculated as the mean number of spikes per unit area. Then, 30 spikes were randomly selected from each plot in order to count grains per each spike, separately.

2.8 Thousand-grain weight

From crops harvested from each plot, 10 samples were taken using a grain counter and weighed using a precise balance to determine the thousand-grain weight.The thousand-grain weight was reported based on the moisture at the time of harvest (about 10%-15%).

2.9 Crop yield (grain and grain + straw) and harvest index

Using the 1×1 m^2 wooden frame at three points in each plot, the crop was harvested. Then, grains and straws were separated and weighed to determine the grain and the grain + straw yield per hectare. Furthermore, the harvest index, *i.e.* the ratio of grain yield to crop yield was calculated.

2.10 Economic analysis of wheat production

The wheat production from the different treatments were analyzed, economically. Total cost of production was calculated, and gross return was computed by subtracting the total return of production from the grain and straw production per hectare.Net return was calculated by subtracting the total cost of production from the gross value of production per hectare. Benefit to cost ratio was computed by dividing the gross value of production by the total cost of production per hectare (Ghorbani et al., 2011; Mohammadi et al., 2008; Demircan et al., 2006)

3 Results and Discussion

3.1 Soil moisture content

Mean soil moisture values at 0-10 cm depth are presented in Figure 1.In the studied region, the low precipitation during February to April causes a sharp decrease in the surface soil moisture during two consecutive years. This, in turn, gives rise to negative impacts on crop yield at the time of harvest. On May 5th, soil moisture content increased and the surface soil became saturated, due to a rainfall on the last days. These scatter rainfalls continued till mid-May. Data proved the positive effect of conservation tillage on maintaining soil moisture content during both rainfalls and lack of precipitation conditions.

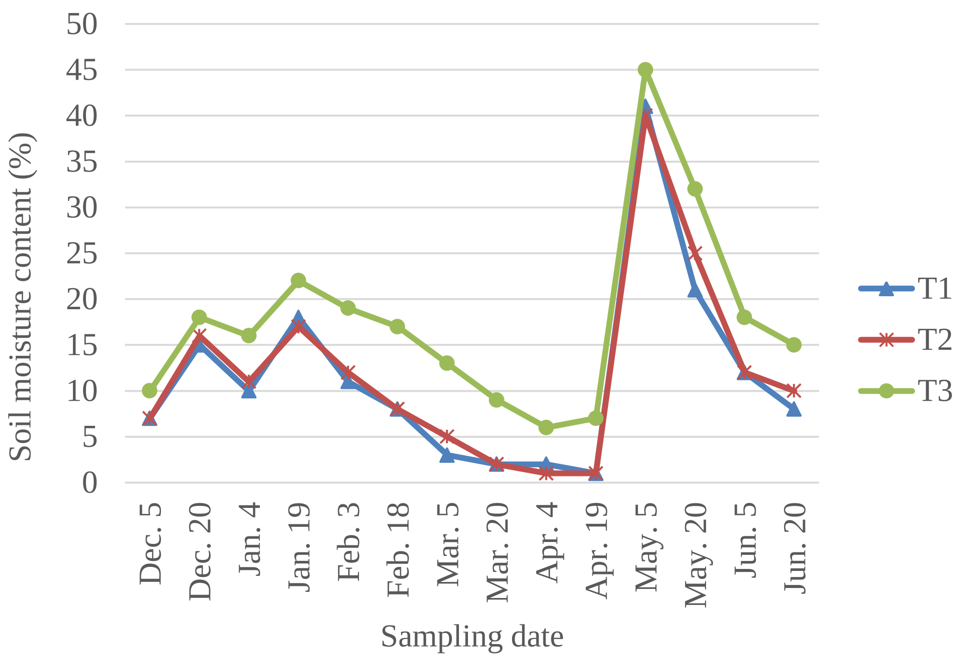

Figure 1 Mean soil moisture content of different treatments

3.2 Field Efficiency

ANOVA results showed that the different treatments had significant differences at the 5% level in term of the field efficiency (Table 1).Although this value was different in T_2 and T_3, both treatments were placed into a same group. The conservation tillage (T_3) and the conventional tillage (T_1) had the highest (0.72) and lowest (0.57) field efficiencies, respectively (Table 2).The low field efficiency of T_1 was a result of using one-way moldboard plow and its time spent on its turns and settings.

Table 1ANOVA results of the effect of tillage practices on field efficiency, field capacity, fuel consumption, horizontal and vertical seed distribution, and emerged plant percent.

Source of variations (SV.)	Degrees of freedom (df)	Mean squares (MS.)					
		Field efficiency (%)	Field capacity (ha h^{-1})	Fuel consumption (L ha^{-1})	Horizontal seed distribution (%)	Vertical seed distribution (%)	Emergence Percentage (%)
Treatment	2	0.024*	0.103**	108.90**	45.84*	51.23**	231.17*
Block	3	0.002^{ns}	0.004^{ns}	1.66^{ns}	0.825^{ns}	1.125^{ns}	0.004^{ns}
Error	6	0.001	0.006	0.970	5.13	3.65	0.011

*P <0.05, **P <0.01 and^{ns} non-significant.

Table 2The mean comparisons of the effect of tillage practices on field efficiency, field capacity, fuel consumption, horizontal and vertical seed distribution, and emerged plant percent.

Treatment	Field efficiency (%)	Field capacity (ha h^{-1})	Fuel consumption (L ha^{-1})	Horizontal seed distribution (%)	Vertical seed distribution (%)	Emergence Percentage (%)
T_1	0.58 ^{b}	0.39 ^{c}	46.70 ^{a}	71.55 ^{a}	44.88 ^{c}	46.33 ^{c}
T_2	0.71 ^{a}	0.45 ^{b}	39.20 ^{b}	59.06 ^{b}	63.84 ^{b}	58.23 ^{b}
T_3	0.72 ^{a}	0.58 ^{a}	23.30 ^{c}	60.60 ^{b}	69.58 ^{a}	64.94 ^{a}

Means with similar letters in each column are non-significant at the 5% level (Duncan's test)

3.3 Field capacity

For this parameter, the difference between different treatments was significant at the 1% level (Table 1).T_1 treatment recorded the lowest value with 0.39 ha/h while T_3 scored the highest value with 0.58 ha/h among different planting treatments. Less passes of tractor and implement as well as shorter operation time are among the major reasons for using conservation practices.T_3 reduced tractor and implement passes on the field and, therefore, recorded the highest field capacity (Table 2).

3.4 Energy consumption

ANOVA results indicated that there is a significant difference among different treatments at the 1% level in terms of fuel consumption (Table 1).The mean fuel consumption of T_3 was 23.3 L/ hathanks to its reduced tillage operations. This was 39.2 L/hain T_2.The conventional tillage treatment (T_1) had the highest value (46.7 L/ha) in this regard, due to the application of the moldboard plow (Table 2). Safa and Tabatabaeefar (2008) measured fuel consumption based on operations for wheat production as 75, 17.5, 2.5, 2.8, 27 and 2.2 L/ha belong to tillage, planting, spraying, fertilizer distributor, harvesting and transportation, moreover, according to energy content of diesel fuel reported correspond to 3767.25, 879.02, 125.57, 140.64, 1356.21 and 110.51 MJ/ha, respectively. Their results validate the results of the currentstudy. The energy used for tillage practices of T_1, T_2 and T_3 treatments were calculated 2345.74, 1969.02 and 1170.36 MJ/ha, respectively. The lower energy that measured in our study compared to results reported by Safa and Tabatabaeefar (2008) may be related to lower tillage practices, beside, completely compatible with the fuel consumption details that reported as 27, 16, 20, 7 and 5 L/ha correspond to moldboard plow, disc, grain drill, fertilizer spreader and sprayer, respectively.

Table 3 shows the calculated energy values in details for the different treatments in terms of energy equivalent reported in the literatures. As it is observable, despite of higher total energy input in T_1, the total energy output is lower than the others. Moreover, the results illustrated higher yield energy in both grain and straw for T_3 treatment. The results reported by the other researchers, for instance, Ghorbani et al. (2011), Mohammadi et al. (2008) and Tabatabaeefar et al. (2009) confirm our

Table 3Energy input–output relationship for the different treatments

Energy	Energy equivalent (MJ unit^{-1})*	Total energy equivalent (MJ)			Total energy ratio (%)		
		T_1	T_2	T_3	T_1	T_2	T_3
A. Inputs							
1. Human labor (h)	1.95	70.20	73.12	65.32	0.39	0.42	0.39
2. Machinery (h)	62.7	627	620	501.6	3.50	3.53	3.02
3. Diesel fuel (L)	50.23	2345.74	1969.02	1170.36	13.09	11.22	7.04
4. Chemical fertilizers							
(a) N_2 (kg)	75.46	9809.8	9809.8	9809.8	54.73	55.92	59.03
(b) P_2O_5 (kg)	13.07	1176.3	1176.3	1176.3	6.56	6.71	7.08
5. Chemical herbicides							
(a) TopiK (L)	271.38	271.38	271.38	271.38	1.51	1.55	1.63
(b) 2,4-D (L)	84.91	127.36	127.36	127.36	0.71	0.73	0.77
6. Chemical Pesticide							
Pheniteriteyon (L)	280.44	280.44	280.44	280.44	1.56	1.60	1.69
7. Seeds (wheat) (kg)	20.10	3216	3216	3216	17.94	18.33	19.35
Total energy input (MJ)		17924.23	17543.43	16618.57			
B. Outputs							
1. Wheat grain yield	14.48	18437.82	19550.75	19596.22	80.57	81.11	81.07
2. Wheat straw yield	2.25	4447.6	4552.06	4574.27	19.43	18.89	18.93
Total energy output (MJ)		22885.42	24102.81	24170.49			

*Energy equivalent of inputs and outputs in wheat production (Ghorbani *et al.*, 2011; Tabatabaeefar *et al.*, 2009).

Table 4Total energy input in the form of direct, indirect, renewable and non-renewable energy for the different treatments.

Type of Energy	T_1		T_2		T_3	
	(MJ ha^{-1})	%	(MJ ha^{-1})	%	(MJ ha^{-1})	%
Direct energy	2415.94	13.48	2042.14	11.64	1235.68	7.44
Indirect energy	15508.29	86.52	15501.29	88.36	15382.89	92.56
Renewable energy	3286.20	18.33	3289.12	18.75	3281.32	19.74
Non-renewable energy	14638.03	81.67	14254.31	81.25	13337.25	80.26

achievements.

As shown in Table 4, 13.48%, 11.64% and 7.44% of the total energy consumed in each treatment are related to direct energy of T_1, T_2 and T_3, respectively. Subsequently, 89.52, 88.36 and 92.56% belong to indirect energy, respectively. In other words, 3286.20, 3289.12 and 3281.32 MJ /ha renewable energy as well as 14638.03, 14254.31 and 13337.25 MJ/hanon-renewable energy were consumed during the wheat production practices, respectively.

Table 5 Energy input-output ratio in wheat production

Items	Unit	T_1	T_2	T_3
Energy input	MJ/ha	17924.23	17543.43	16618.57
Energy output	MJ/ha	22885.42	24102.81	24170.49
Energy use efficiency	-	1.28	1.37	1.45
Specific energy	MJ/kg	14.08	12.99	12.28
Energy productivity	kg/MJ	0.071	0.077	0.081
Net energy	MJ/ha	4961.20	6559.39	7551.93

According to input and output energy as well as wheat grain yield, the energy input-output ratio parameters including energy use efficiency, specific energy, energy productivity and net energy were calculated (Table 5).Higher energy use efficiency, energy productivity and net energy as well as lower specific energy were computed for T_3 compared to T_2 and T_1.Obviously, it is occurred due to lower input energy along with higher output energy and wheat grain yield in T_3 treatment.

Furthermore, Canakci *et al.* (2005) found that the highest value of the operational inputs was found to be 17,629.5 MJ/ha for tomato cultivation, followed by cotton crop at 14,348.9 MJ/ha and, finally, wheat crop at 3735.4 MJ/ha. In these operational inputs, the highest energy requirements were found for seedbed preparation and irrigation with shares of 13.7%–65.1% and 26.3%–40.4%, respectively.

3.5 Horizontal seed distribution uniformity

According to Table 1, ANOVA results showed that the difference among the horizontal seed distribution is significant for different treatments ($P < 0.05$).The mean comparison of horizontal seed distribution suggested that planting with the centrifuge spreader (T_1) with an average of 71.55% was better than the other two treatments (Table 2).This was natural and expectable since the centrifuge seeder spreads seeds throughout the field. Reports of other authors also suggest that the precise seed drill has the best vertical distribution uniformity while the best distribution per unit area belongs to the spreading practice (Heege, 1993).

3.6 Vertical seed distribution uniformity (planting depth)

ANOVA results presented (Table 1) illustrate that there is a significant difference among different treatments in terms of their vertical distribution ($P < 0.01$).The improved vertical distribution uniformity in practices using drills (deep drills) was predictable. The most uniform vertical distribution belonged to T_3 with 69.58% thanks to using disc for plowing, drill for planting and not using moldboard plow. The second treatment (T_2) was ranked second with 63.84% which could be due to using chisel plow for the tillage stage (Table 2). Heege (1993) also reported that the best vertical uniformity can be achieved through seed drilling.

3.7 Emerged plant percent

Table 1 shows a significant difference ($P < 0.05$) between different planting treatments and emerged plant percent.Mean comparison results showed that the emerged plant percent is different for seeds planted using the centrifugal spreader compared to the seed drill practices (T_2 and T_3 treatments) which place seeds at a preset depth. When placed in soil, seeds failed to emerge under low precipitation conditions and became dry during rainfall periods. Despite having a similar planting method for T_2 and T_3, the conservation tillage had the highest emerged plant percent with 64.94% (Table 2).This could be due to more moisture held by the conservation tillage than other practices.

3.8 Plant density per unit area

ANOVA results showed that the difference among different treatments in terms of plant density per unit area was significant at the 5% level (Table 6).The minimum and maximum plant densities per unit area belonged to the conventional (T_1) and conservation (T_3) treatments, respectively. Although the mean plant density per unit area was higher for the conservation treatment (T_3), both T_2 and T_3 treatments were placed in one statistical group (Table 7).

Table 6ANOVA results for the effect of tillage practices on plant density, number of spikes per

Source of variations (SV.)	Degrees of freedom (df)	Mean squares (MS.)					
		Plant density	Spikes	Grains per spike	1000-grain	Grain yield	Crop yield
Treatment	2	366.44**	3576.81	2.96*	18.651^{ns}	302.78*	5433.33*
Block	3	2.86^{ns}	0.981^{ns}	0.09	0.091^{ns}	1.254^{ns}	0.158^{ns}
Error	4	4.97	0.024	1.07	0.03	28.321	23.135

*P <0.05, **P <0.01 and ^{ns} non-significant.

Table 7Mean comparison for the effect of tillage practices on plant density, number of spikes per unit area, number of grains per spike, 1000-grain weight, grain yield and total crop yield

Treatment	Plant density	Spikes	grains per spike	1000-grain weight(g)	Grain yield (kg ha^{-1})	Crop yield (kg ha^{-1})
T_1	337.30 ^{b*}	565.79 ^{c}	14.17^{b}	35.28 ^{a}	1273.33 ^{b}	3250.04 ^{b}
T_2	358.59 ^{a}	629.09 ^{b}	14.37 ^{b}	35.31 ^{a}	1350.19 ^{a}	3373.33 ^{a}
T_3	366.01 ^{a}	658.51 ^{a}	15.77 ^{a}	35.77 ^{a}	1353.33 ^{a}	3386.34 ^{a}

*Means with similar letters in each column are non-significant at the 5% level (Duncan's test)

3.9 Spikes per unit area

As shown in Table 6, there is a significant difference at the 5% level for different planting treatments in terms of average number of spikes per unit area. The maximum number of spikes of 658.51 plants per m^2 was obtained in the seedbed prepared by disc and planted by grain drill (Table 7). The higher number of spikes in T_3 than T_2 can be a result of the conservation tillage and the higher soil MC brought about by maintaining plant residues, especially during the spike emergence season.

3.10 Number of grains per spike

ANOVA results showed that there is a significant difference ($P < 0.05$) between different seedbed preparation and planting treatments in terms of the mean number of grains per spike (Table 6). Although, according to Duncan's test, the mean values of this characteristic were different between treatments, treatments were divided into two groups. The mean number of grains per spike was 14.17 and 14.37 for T_1 and T_2, respectively. The conservation tillage treatment (T_3) had the highest value with 15.77 in this regard (Table 7).

3.11 Thousand-grain weight

According to ANOVA results, there is no significant difference between different planting treatments in terms of the thousand-grain weight (Table 6).Despite higher mean values of the conservation practice, the mean comparison results also showed that there is no difference between the 1000-grain weight of all three seedbed preparation and planting practices (Table 7).

3.12 Crop yield (grain and grain + straw) and harvest index

ANOVA results indicated that the difference between different planting treatments was significant ($P<0.05$) in terms of the grain yield and crop yield (grain and straw) (Table 6). Although the conventional tillage treatment (T_1) had the lowest yield with 1273 kg/ha, both T_2 (with 1350 kg/ha) and T_3 (with 1353 kg/ha) placed in one statistical group. The ANOVA and mean comparison results of total crop yield were similar to those of the grain yield. The crop yield values of T_2 and T_3 were also in one statistical group (Tables 6 and 7).These results are similar to literature findings in this regard, as found by Murillo et al.(1998), that conservation tillage improves crop yield in a drought condition. Furthermore, the harvest index, *i.e.* the ratio of grain yield to crop yield, was 39.17, 40.03 and 39.96 percent for T_1, T_2 and T_3, respectively.

3.13 Economic analysis of production

The economic analysis data was reported in Table 8. Obviously, total cost of production for T_3 is lower than the others, owing to lower farming practices. The returns based on land area (ha) were 599.44, 627.60 and 629.63 \$[2]/ha (gross) and 384.04, 417.40 and 439.33 \$/ha (net) correspond to T_1, T_2 and T_3, respectively. Moreover, the benefit cost ratio was 3.31 for T_3 compared to 2.78 and 2.99 belong to T_1 and T_2, respectively. Accordingly, the results demonstrated that conservation tillage owing to lower practices, fuel consumption and input energy as well as higher product yield, is economic system for wheat production. The slight differences that observed between these results and the results reported in literatures (Gorbani et al., 2011; Mohammadi et al. 2008; Tabatabaeefar et al., 2009) are related to different operations, conditions and equipment during planting period.

2 USD

Table 8Economic analysis of wheat production for the different production treatments.

Cost and return components	T_1	T_2	T_3
Grain yield (kg/ha)	1273.33	1350.19	1353.33
Sale price (\$/kg)	0.3	0.3	0.3
Straw yield (kg/ha)	1976.71	2023.14	2033.01
Sale price (\$/kg)	0.11	0.11	0.11
Total cost of production (\$/ha)	215.4	210.2	190.3
Gross return (\$/ha)	599.44	627.60	629.63
Net return (\$/ha)	384.04	417.40	439.33
Benefit to cost ratio	2.78	2.99	3.31

4 Conclusion

This study is conducted to evaluate the effect of multiple tillage practices on the wheat yield in rainfed fields. The experiment was carried out in three field preparation and planting treatments. The data trend proves the positive effect of the conservation tillage on maintaining the soil moisture content during precipitation and no-precipitation periods. According to ANOVA results, moisture content, field capacity, energy consumption, seed distribution uniformity, number of grains per spike, spikes per unit area, grain yield and production cost, improved for conservation tillage when compared to other studied treatments.

References

Afzalinia, S., M. Shaker and E. Zare,2006.Performance evaluation of common grain drills in Iran. *Canadian Biosystems Engineering*48:239-243.

Afzalinia, S., Karami A., M.H. Talati and S.M. Alavimanesh,2011.Effect of tillage on the soil properties and corn yield. CSAEManitoba, Canada, 10-13 July.

American Society of Agricultural & Biological Engineers [ASABE].2006.ASABE Standards EP. 496.3:*Agricultural Machinery Management*.St. Joseph, MI, USA.

Alvarez, R. and H.S.Steinbach,2009.A review of the effects of tillage systems on some soil physical properties, water content, nitrate availability and crops yield in the Argentine, Pampas. *Soiland tillage research* 104: 1-15.

Baver, L.D., W.H. Gardner and W.R. Gardner,1972.*Soil Physics*.Fourth edition.John Wiley & Sons, Inc., New York. pp. 284-286.

Bayhan, A.K., A.A. Isildar and M. Akgul,2005.Tillage impacts on aggregate stability and crop productivity in a loam soil of a dryland in Turkey. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science.*55:214-220.

Boloor, E., H.R. Asgari and F. Kiani,2013.Assessment of the Influences of Different Soil Tillage Systems on Some Soil's Chemical Properties in a Rain-fed Agricultural System, Northern Iran (Case study: Kalale district, Golestan province).*International Journal of Agriculture and Crop Sciences*6 (4):191-196.

Canakci, M., M. Topakci, I. Akinci and A. Ozmerzi, 2005. Energy use pattern of some field crops and vegetable production: Case study for Antalya Region, Turkey. *Energy conversionand management* 46:655–666.

Choudhary, M.A. and C.J. Baker, 1993. Conservation tillage and seeding systems in the South Pacific. *Soil and tillage research*27:283-302.

Demircan, V., K. Ekinci, H.M. Keener, D. Akbolat and C. Ekinci, 2006. Energy and economic analysis of sweet cherry production in Turkey: a case study from Isparta province. *Energy conversion and management*47:1761–9.

Ehsanullah, A.R., S. Khan, R. Qamar, A. Ghaffar and G. Mustafa, 2013.Impact of tillage and mulch on water conservation in wheat (triticum aestivum l.) Under rice-wheat cropping system. *Journal of Agricultural Research*51(3): 255-265.

Ghorbani, R., F. Mondani, S. Amirmoradi, H. Feizi, S. Khorramdel, M. Teimouri, S. Sanjani, S. Anvarkhah and H. Aghel,2011.A case study of energy use and economical analysis of irrigated and dryland wheat production systems.A*pplied energy*88:283–288.

Heege, H.J.1993.Seeding methods performance for cereals, rape and beans.*Transactions of the ASAE. American Society of Agricultural* 36(3): 653-661.

Kepner, R.A., R. Bainer and E.L. Barger, 1978.*Principles of Farm Machinery*.Third ed. Westport, CT: AVI Publishing Company Inc.

Kiani, S. and E. Houshyar, 2012.Energy Consumption of Rainfed Wheat Production in Conventional and Conservation Tillage Systems. *International Journal of Agriculture and Crop Sciences*4(5): 213-219.

Kiani, S. and E. Houshyar, 2013. Sustainability of Rainfed Wheat Production: A Case Study in Southwest Iran Using Fuzzy Modeling. *International Journal of Farming and Allied Sciences* 2(21): 944-948.

Mart ńez, E., J.P. Fuentes, P. Silva, S. Valle and E. Acevedo, 2008.Soil physical properties and wheat root growth as affected by no-tillage and conventional tillage systems in a Mediterranean environment of Chile, *Soil and tillage research*99:232–244.

McMaster, G.S., D.B. Palic and G.H. Dunn.2002.Soil management alters seedling emergence and subsequent autumn growth and yield in dryland winter wheat-fallow systems in the central Great Plains on a clay loam soil.*Soil and tillage research*65, 193-206.

Mohammadi, A., A. Tabatabaeefar, S. Shahin, S. Rafiee and A. Keyhani,2008.Energy use and economical analysis of potato production in Iran a case study: Ardabil province.*Energy conversion and management* 49: 3566–3570.

Murillo, J.M., F. Moreno, F. Pelegrin and J.E. Fernandez,1998.Responses of sunflower to traditional and conservation tillage under rainfed conditions in southern Spain.*Soil and tillage research*49(3): 233-241.

Qamar, R., A.R. Ehsanullah and M. Iqbal.2012.Response of wheat to tillage and nitrogen fertilization in rice-wheat system. *Pakistan Journal of Biological Sciences*49(3), 243-254.

Safa, M. and A. Tabatabaeifar, 2008.Fuel consumption in wheat production in irrigated and dry land farming.*World Journal of Agricultural Sciences*1: 86-90.

Sartori, L., B. Basso, M. Bertocco and G. Oliviero, 2005. Energy use and economic evaluation of a three year crop rotation for conservation and organic farming in NE Italy. *Biosystems Engineering*91:245–56.

Senapati, P.C., P.K. Mohapatra and U.N. Dikshit, 1992.Field evaluation of seeding devices for finger-millet.*Agricultural Mechanization in Asia, Africa, and Latin America*23(3): 21-24.

Smith, P.G. and A.H. Millet,1964.Germinating and sprouting responses of tomato at low temperature. *Journal of the American Society for Horticultural Science*84: 480-484.

Tabatabaeefar, A., H. Emamzadeh, M. Ghasemi, R. Rahimizadeh and M. Karimi, 2009. Comparison of energy of tillage systems in wheat production.*Energy* 34: 41–45.

Unger, P.W. and T.M. McCalla, 1980.Conservation Tillage Systems.*Advances in Agronomy*33:1-58.

Verhulst N., F. Kienle, K.D. Sayre, J. Deckers, D. Raes, A. Limon-Ortega, L. Tijerina-Chavez and B. Govaerts,2011.Soil quality as affected by tillage-residue management in a wheat-maize irrigated bed planting system. *Plantand soil* 340:453–466.

Wang, X.B., D.X. Cai, U.D. Perdok, W.B. Hoogmoed and O. Oenema, 2007.Development in conservation tillage in rainfed regions of North China. *Soil and tillage research*93, 239–250.

Wang, X.B., K. Dai, D.C. Zhang, X.M. Zhang, Y. Wang, Q.S. Zhao, D.X. Cai, W.B. Hoogmoed and O. Oenema.2011.Dryland maize yields and water use efficiency in response to tillage/crop stubble and nutrient management practices in China, *field crops research* 120, 47–57.

Wang, X., H. Wu, K. Dai, D. Zhang, Z. Feng, Q. Zhao, X. Wu, K. Jin, D. Cai, O. Oenema and W.B. Hoogmoed, 2012. Tillage and crop residue effects on rainfed wheat and maize production in northern China, *field crops research* 132:106–116.

Yaduvanshi, N.P.S. and D.R. Sharma,2008.Tillage and residual organic manures/chemical amendment effects on soil organic matter and yield of wheat under sodic water irrigation.*Soil and tillage research* 98:11–16.

YounesiAlamouti, M. and M. Navabzadeh, 2007.Investigation of plowing depth effect on some soil physical properties.*Pakistan Journal of Biological Sciences*10 (24): 4510-4514.

Younesi Alamouti, M. and M. Navabzadeh, 2009. Traffic effects of two common tractors on some soil physical properties and crop yields in *Iran. Journal of Agriculture, Biotechnology and Ecology*2(2): 102-110.