Study of fuel consumption in three tillage methods

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Abstract

Akbarnia A., Farhani F., 2014. **Study of fuel consumption in three tillage methods**. Res. Agr. Eng., *60*: 142–147.

Fuel consumption per hectare of tilled land for the conventional or maximum tillage, reduced tillage using a multi-task machine, and no-tillage using a direct drill planter has been studied and compared. Time taken and number of tractor trips needed for performing tillage operations were used for comparison. Yield of crop per hectare was also used for the study. Duncan's multiple range test was used to compare and analyse the data. Results of fuel consumption were 59.33, 29.67 and 14.33 l/ha for the max. tillage, reduced tillage, and no-tillage cases, respectively. The corresponding yield of crop for these methods were 8.07, 7.90, and 6.33 t/ha, respectively. Therefore, the reduced and no-tillage methods provide enough energy saving per ton of yield to justify their use as good replacements for the max. tillage method in Iran. Also, considering land conditions in Iran, use of direct drill planters is recommended for dry cultivated or traditionally irrigated farms, and multi-task machinery for all types of irrigation systems and land conditions.

Keywords: maximum tillage; reduced tillage; no-tillage; multi multi-task machinery; direct drill planter

Agriculture, which is the most important sector in the production of food in Iran, is also a big consumer of energy in this country (Farahmandpour et al. 2009). Factors such as time lost for replacement of implements and tools used in conventional (maximal) tillage operations, wear out of tractors, high fuel consumption due to the increased number of tractor trips, and high capital investment needed for purchase of various implements result in higher production costs in the traditional agriculture practice in Iran. In addition, movement of tractors and implements on the soil results in soil compactness, which forms hard pan that prevents the penetration of water and free movement of plant roots deep inside the soil.

Mechanization of agricultural operations and use of modern machinery such as multi-task machines and direct drill planters can reduce energy consumption per ton of yield of crop, and results in lower cost of production. Moreover, application of modern tillage methods decreases soil agitation, helps in conservation of soil humus, and prevents soil erosion (Hargrave et al. 1982).

Bonari et al. (1995) studied the effect of using multi-task machines, as reduced tillage method, on the yield of crop or soil physical properties. They also focused on the reduction of energy consumption by studying the energy consumption in various tillage methods under different conditions. They reported that reduced tillage resulted in 55% less fuel consumption than the max. tillage, without a significant difference in the yield of crop. Similarly, Craciun et al. (2004) reported that in comparison with the technology with two passes on land, the fuel consumption is reduced by up to 60%.

Kosutic et al. (2005) studied the energy consumption in different tillage systems and the corresponding yield of crop in Slovenia. Tillage systems and implements used were: conventional tillage (CT) using plow and disc-harrow and combined implement; conservation tillage (RT) using the drill plow and multi-tiller; and no-tillage system (NT).

Fig. 1. Multi-task tillage machine developed by the authors

Energy requirements of the different tillage systems and their effects on the yield of crop were compared. Results indicated that the CT system was the greatest consumer of energy with 1.8 GJ/ha. The RT system with chisel plow and multi-tiller consumed 1.1 GJ/ha, or 37.5% less than the CT system, while the NT system required 0.27 GJ/ha, which is about 85.1% less energy than the CT system.

Tabatabaeefar et al. (2008) compared five tillage treatment systems for wheat production. The tillage treatments were: moldboard plow + roller + drill (T1); chisel + roller + drill (T2); cyclotiller + roller + drill (T3); sweep + roller + drill (T4); and no-till (T5). Their results showed that the energy consumption in tillage using T1 (max. tillage) and T5 (no-tillage) systems was 32.5% and 19% of the total consumed energy, respectively.

Asadi et al. (1995) studied the effects of different tillage methods on production of wheat in irrigated fields. Their experiments, which lasted for four years, aimed at finding a suitable (optimized) tillage system. Their results indicated that plow using a locally made blade, having the least capacity, needed the max. fuel. Equal fuel consumption was reported for plowing operation using moldboard and drill plows operating at equal depths. However, the drill plow had 44% more capacity than the moldboard plow. In comparison, the rotary disk tillage machine had half the capacity, but 63% more fuel consumption. They recommend the reduced tillage method (drill tillage at the depth of 15 cm) as a replacement for conventional tillage method.

Asghari et al. (2002) used a combined subsoiler and moldboard plow, and concluded that the combined machine increased soil rupture and needed less energy in comparison with the use of subsoiler and moldboard plow, separately.

Khosrawani et al. (2003) studied the effects of superficial and conventional tillage methods on the yield of wheat from irrigated fields. Comparison of the two tillage methods for the same planted seeds showed that superficial method resulted in 92% yield of crop. However, fuel consumption and operation time was higher in the conventional tillage method, and tools showed excessive erosion, all of which resulted in increased cost of production.

The present study aims at the evaluation of performance of the max. tillage, the reduced tillage using a multi-task machinery with rotary tiller, developed by the authors (Fig. 1), and planting using a direct drill planter (considered as the no-tillage case), on basis of fuel consumption and yield of crop per hectare of tilled land. For this purpose, fuel consumption and corresponding yield of crop per hectare of tilled land for the three tillage methods have been studied and compared. Based on land conditions and irrigation methods, recommendations have been given for the use of suitable tillage methods in the agricultural sector in Iran.

MATERIAL AND METHODS

All tillage operations were carried out on a wheat farm in Shahryar, an agricultural hub in the neighborhood of the Iran's Capital, Tehran. The farm area was 9 ha, and rain water was used for irrigation of this land (Fig. 2). Implements used in each tillage method are as follows:

(1) *Multi-task machine* (Model 150, IROST, Tehran, Iran): effective width of work: 1.5 m, weight:

Fig. 2. Selected farm for performing tillage operations

Fig. 3. Maximum (conventional) tillage operations

Fig. 4. Reduced tillage operations using the multi-task machine (Akbarnia et al. 2013)

about 1,200 kg, nominal power requirement: 68 HP. The machine has (i) a tiller unit, consisting of chisel plow, rotary tiller, roller, and (ii) a seed planter unit, consisting of mechanical seed planter and roller. Speed of multi-task machine: 3.6 km/h.

(2) *Direct drill planter* (Model 2007, Ozdoken Agricultural Machinery and Equipment Co., Konya, Turkey): effective width of work: 2 m, weight: about 1,800 kg, nominal power requirement: 85 HP. The planter consists of mechanical seed planter, seed furrower, and roller. Speed of direct drill planter: 3 km/h.

(3) *Maximum tillage implements*: (i) moldboard plowing (speed approximately 4.7 km/h), (ii) tandem disk harrow (operation performed in three stages, max. speed: 7.3 km/h, min. speed: 5.2 km/h), (iii) leveler (speed: 10 km/h), (iv) seed planter (speed: 5.7 km/h).

In all the cases, a tractor (John Deere-3140; John Deere, Moline, USA), having an engine power of 100 HP was used as the power source.

The moisture content of soil was 13%. Working depth for the max. tillage was 30 cm, and that for the reduced and no-tillage systems was 20 cm. The irrigation system was rain water.

Determination of fuel consumption for the three tillage methods was planned as a completely randomized block design with three replications and three cases (maximum, reduced, and no-tillage systems) analysed. Therefore, the farm was divided into 9 plots, each having an area of 1 ha, and fuel consumption, for each tillage method carried out on these plots of land, was recorded. Experimental data were analysed using the analysis of variance (ANOVA). Duncan's Multiple range test (DMRT) was used to compare and analyse the data. Figs 3 to 5 show tillage operations associated with the three tillage methods.

Fig. 5. No-till system using the direct drill planter (a), the intertwined trash in the drill planter (b) (Akbarnia et al. 2013)

Fig. 6. A quadrat, a meter square of wood, is being thrown randomly to take samples of the yield of crop for each tillage method

The harvesting operations were performed uniformly, which was important for an unbiased study of performance of the tillage methods based on their corresponding yield of crop. Fuel consumption per hectare of tilled land were then determined for each tillage method.

To evaluate the yield of crop of tilled land for the three tillage methods, samples were taken randomly. A quadrat, a meter square of wood shown in Fig. 6, was used for this purpose. The quadrat was thrown randomly and the production falling within the quadrat was harvested and weighed, and the results were used for the estimation of the yield of crop in tons per hectare for the tillage methods.

RESULTS AND DISCUSSION

Fuel consumption and yield of crop for the three tillage systems were determined. For each tillage method, three replications were taken. The experimental data are shown in Figs 7 and 8.

Experimental data were analysed using the analysis of variance (ANOVA). The results showed a significant difference among the fuel consumption values for the three tillage methods at 1% probability level. But there was no significant difference among replications of each tillage method (Table 1). The means of fuel consumption and yield of crop for the three tillage methods, applying Duncan's multiple range test at 5% probability level, are presented in Table 2.

As shown in Table 2, the tillage systems were grouped into three statistical classes. The fuel consumptions for the reduced and no-tillage methods were approximately 1/2 and 1/4 of that for the max. tillage method, respectively. This big difference in fuel consumption is due to the larger number of tractor trips and tilling operations associated with the max. tillage method.

Although the difference between fuel consumption of the maximum and other tillage systems is noticeable, the decision to use a particular tillage method will depend on other factors, too. For example, when operating in frail soils, difference between fuel consumption of multi-task machine and direct drill planter is negligible. However, in heavy soil, the performance of direct drill planter on lands with furrowers will be associated with higher fuel consumption and longer operation times, while the multi-task machine operates in frail soil, produced by its tillage equipment, which results in comparatively less fuel consumption.

In the present study, the selected farm (Fig. 2) was previously used for planting corn, where the simultaneous passage of harvesting machinery and the crop carrier resulted in soil compaction and formation of hard pan. In the case of the no-tillage system, soil compaction affected the operation of the direct planter to some extent, which explains the reason for higher yield of crop associated with the maximum and reduced tillage methods in comparison to the no-tillage method (Fig. 8, Table 2). This observation is supported by Platonov et al. (1992), who observed that in case of oat cultiva-

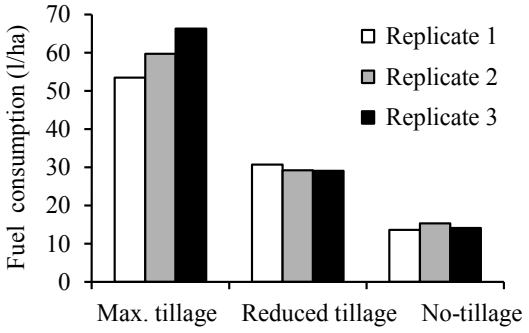

Fig. 7. Fuel consumption for the three tillage methods

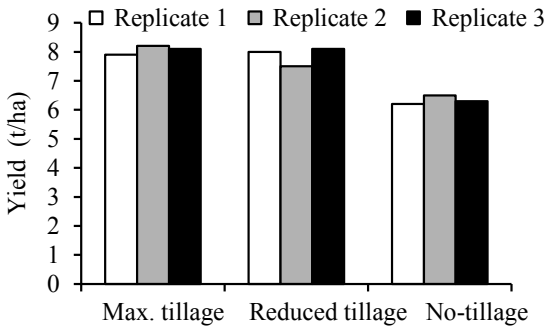

Fig. 8. Yield of crop for the three tillage methods

Table 1. Analysis of variance for fuel consumption and yield of crop for the three tillage methods

Variance	Degree of freedom	Fuel consumption		Yield of crop	
		sum of squares	*F*	sum of squares	*F*
Tillage system	2	1,570.11	107.03[a]	2.74	9.60[b]
Block	2	10.77	0.73[c]	0.01	0.035[a]
Error	4	14.67	–	0.285	–
Total	8	–	–	–	–

[a]significant at 1%; [b]significant at 5%; [c]not significant; *F* – *F*-test

Table 2. Comparison of fuel consumption, yield of crop and cost of production for the three tillage methods

Tillage system	Fuel consumption (l/ha)			Yield of crop (t/ha)		Cost of production (USD/t)
	1	2	3	1	2	
Max. tillage	59.83	–	–	8.07	–	103.22
Reduced tillage	–	29.67	–	7.90	7.90	88.73
No-tillage	–	–	14.33	–	6.33	108.53

classification based on 5% significant difference

tion, productivity is increased for all but the no till method.

Another observation was that after the multi-task machine passage the trash on soil surface was shattered and mixed with the soil (Fig. 4), while it remained intact after the passage of the direct drill planter (Fig. 5a). In the case of dry farming, or lands irrigated using classic methods, the surface trash does not pose any problems. However, if operations are carried out on lands irrigated using the gravity method, and if furrows must be made, the trash after the direct drill planter passage will pose serious problems as they obstruct the movement of water on the land surface. Therefore, it is important that the tillage operations reduce soil compaction, loosen and soften the soil to improve soil aeration for better contact between the seeds and soil and more absorption of water and nutrients by the soil, which insure improved growth of the crop and the subsequent higher yield of crop.

CONCLUSION

In addition to having higher fuel consumption, the max. tillage operations result in formation of hard pan due to an increased number of tractor trips, soil erosion due to an increase in tillage operations, and rapid dissociation of soil humus due to the increased soil agitation.

In spite of its extreme importance, fuel consumption is not the only factor for deciding the kind of tillage for any particular application, and the choice is dependent on additional factors such as land conditions and method of irrigation, which affect the yield of crop per hectare of tilled land. For example, soil compaction affects the operation of a direct planter, which explains the reason for higher yield of crop for the max. and reduced tillage methods in comparison with the no-tillage method, as reported in this study. Therefore, yield of crop per hectare of tilled land was used along with the fuel consumption for making realistic comparison of the three tillage methods.

Based on the results for both the fuel consumption and yield of crop per hectare of tilled land, the reduced and no-tillage methods are justified as good replacements for the max. tillage on agricultural lands in Iran. Also, considering the land conditions in Iran, the present work recommends the use of direct drill planter**s** for dry cultivated farms or farms irrigated using classical irrigation systems, and multi task machinery for all types of irrigation systems and land conditions.

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Received for publication September 10, 2012
Accepted after corrections October 17, 2012

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