

Economic comparison of tillage and planting operations in three tillage systems

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Abstract: To study the economy of tillage operations and present suitable systems for land preparation and planting, costs of execution of three different tillage operations in irrigated wheat crop were compared for three successive years. The three systems include: conventional or maximum tillage (Max-till), reduced tillage (Red-till) using multitask machine, and using direct planting machinery to represent the no-tillage case (No-till). Costs were composed of rental cost of tractor, the used implements, multitask machine and direct planting machine. For each case, data were compared and analyzed in randomized block design. The variance of wheat yield in the three tillage systems was significant at the 1% level. Total costs per hectare were 109 and 78 and 46 Dollars for Max-till, Red-till and the No-till case, respectively. Since, the test area under cultivation was part of a 200 hectare farm, crop protection and harvesting operations were carried out alike in the whole farm. Accordingly, operations costs were estimated as 445 Dollars ha⁻¹ tare. Average yields of 7.85, 7.68, 5.2 t ha⁻¹ were obtained, respectively, for Max-till, Red-till and No-till systems. Since, the price per kg of wheat was equal to 0.36 Dollars ha⁻¹, the profits of the harvest was equal to 2,271 Dollars ha⁻¹ for the Max-till, 2,242 Dollars ha⁻¹ for Red-till and 1,384 Dollars ha⁻¹ for the No-till system. In tillage and planting operations, usage of the reduce tillage system is offered as an alternative to the conventional tillage and no-till systems. The Red-till system reduces fuel consumption, operation time, soil compaction due to decrease in the number of tractor trips, which leads to reduced production costs. In addition, less investment in purchasing implements and preparation of the soil, which breaks the soil cohesion, are achieved with the reduced tillage system.

Keywords: costs of production, field performance, Max-till, Multitask machine, no-till, red-till, soil compaction

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1 Introduction

Agriculture, considered as the most important food producing sector, is a big consumer of energy in any country. However, it also offers the potential for being an important and sustainable source of energy in very near future. Although, agriculture sector is faced with the limitations in the available production resources, it must provide the food needed by the growing population. In addition, the trend in using the available production resources should be such that it satisfies the needs of the present generation as well as guaranteeing the food

security for the future generations. This is the foundation of the sustainable agriculture. In order to increase agricultural products, in terms of increased yield per unit of the cultivated land and reduce production costs, it is necessary to use modern and mechanized agricultural methods. Tillage and plantation operations in a cultivation season include plowing, seedbed preparing, leveling, seed planting, seed covering, irrigating and fertilizing. Traditionally, for the execution of these operations, the relevant implement is attached to a tractor and the operation is carried out by multiple trips of the tractor on the field.

One of the effective solutions for reducing the tillage operations, and hence, producing costs, is using multitask machines. No tillage system, which is more suitable for dry farming or farms irrigated by rain water, is another

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method, in which a direct planting machine is used for this purpose. Industrial and developed countries are increasingly using multi task machines for reducing the number of tractor trips and minimizing tillage operations. An immediate advantage of using multitask machines is the reduction in energy consumption, planting operations, increased yield per unit of cultivated land and a reduction of soil compaction.

Chapline et al. (1988) determined the energy consumption for tillage operations in sand-loam soil. They observed that use of chisel plow, as primary tillage, results in consumption of about 60% more drawbar power than the conventional tillage. Behrouzilar (1991) also reported the same results and showed that tillage operation constitutes about 60% of the consumed energy in agricultural operations. Platonov et al. (1992) performed tests on a field with medium soil texture for comparing six tillage methods. They reported that all tillage methods, which resulted in reduced tillage operations, increased the yield, in this case, wheat. In addition, oat yield, except the No-till method, the other tillage methods resulted in increased yield. 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 the reduced tillage resulted in 55% less fuel consumption than the conventional 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%.

Bokhari et al. (1992) studied fuel consumption in different tillage methods. For example, they showed that in soil with 4.3% moisture content, consumption is more in plowing with moldboard plow compared to the energy consumption for the same tillage operation, but in a soil with 7.9% moisture content.

Sojka et al. (1997) studied the effects of shallow plowing and deep plowing on the physical properties of soil and the yield. In their research, the effects of

different methods of tillage including: primary tillage (PT), deep plowing (DP), shallow plowing (SP), reduced tillage (Red-till), plowing in the depth of 15 cm by rotary tiller and roller (RT) and No-till (No-till) on production of oat were compared. Experiments showed that in the case of plowed land plots, soil porosity, hydraulic conductivity of water and air penetration was improved. Also, by plowing, the soil condition was improved, resulting in higher oat yield.

Asadi et al. (1998) conducted a research on the effect of different tillage methods on an irrigated wheat farm to find a suitable tillage method. Experiments, which lasted for four years, were conducted considering factors such as machine and product performance and physical properties of soil. The experiments illustrated that yield from irrigated wheat farming would face a significant reduction if No-till method is used. As an alternative, the reduced tillage method would be a suitable substitute for conventional tillage (plowing with chisel to a depth of 15 cm).

Solhjo and Niazi (2001) performed a one year study on the effect of two working depth levels of 30-35 and 40-45 cm of subsoiler, without utilizing moldboard plow, compared to conventional method, on the yield performance and physical properties of soil. Their results showed that: (i) subsoiling at the depth of 30-35 and 40-45 cm had significant effect at 5% level on the reduction of bulk density, (ii) all tillage treatments cause increase in penetration rate of soil (in comparison with no tillage case), and (iii) the results of analysis of variance of yield related to wheat efficiency for all treatments did not show any difference among treatments.

Jory (2002) suggested that for combined tillage systems in sustainable agriculture one can use disc, cultivator and/or chisel shank as tillage tools. Khosravani and Hemmat (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 times were higher in the conventional tillage method, and tools showed excessive erosion, all of which resulted in

increased cost of production.

The purpose of this research work was to study the economy aspects of three tillage methods, namely conventional tillage, considered as maximum tillage (Max-till), tillage using a multitask machine, named as Red-till, and cultivation using a direct planting machine, termed as the No-till method. During the study, which lasted for three consecutive years, the economy and performance of wheat production was investigated for each case, by considering the wheat yield, fuel consumption for the total produce, operation time and reduction in the number of tractor trips and the use implements in the cultivated field.

2 Materials and methods

To determine the costs of field preparation and sowing operations with the aim of identifying the suitable tillage system for reducing fuel consumption, operation time, tractor trips, soil compaction, and minimizing the number of used implements, for an acceptable wheat cultivation performance, three aforementioned tillage systems were analyzed and compared in the span of three consecutive years. Different equipment and implements were used for this purpose, such as:

i) Max-till: Moldboard plowing, first and second pass disk (at least twice), leveler, fertilizer distributor, third disk (covering fertilizer with soil), planter, furrow opener (for conventional irrigation)

ii) Red-till: Multitask machine for plowing (in the depth of 20 cm), preparing the seed bed, planting, covering and stabilizing seed, and making irrigation furrows (if needed) in a single pass.

iii) No-till: A direct sowing machine (OZDOKEH, Model 2007, Turkey) was used in furrows needed for cultivating by chisel shanks in front toolbar, and seeds were covered and stabilized by roller in the back of the machine.

All tillage operations were carried out on a 9 ha agricultural field, in Shahryar, an agricultural hub in the neighborhood of capital Tehran. The type of soil was loamy with moisture content between 10%-14%. The working depth of tillage was 30 cm in Max-till and 20 cm in Red-till and No-till systems. Rotating water sprinkler

guns were used for the irrigation purpose during the operations. The amount of seeds used was 180 kg ha^{-1} . A tractor (John Deere tractor-3140) was used as the power source. The farm was divided into nine plots, each having an area of 1 ha, and fuel consumption for each tillage method carried out on these plots of land was recorded. Figures 1 and 2 show the Red-till and No-till systems, respectively.



Figure 1 The reduced tillage operation using a multi task machine



Figure 2 The sowing by a direct planter machine (No-till method)

At the start and the end of operations on each land plot, the amount of fuel consumption was measured using a graded vessel attached to the tractor fuel system. The operation time was also registered. Determination of fuel consumption in the three tillage methods was planned as a completely randomized block design with three replications and three cases (Max-till, Red-till and No-till system) analyzed.

The harvesting operations were performed uniformly, which was important for an unbiased study of performance of the three tillage methods based on their corresponding yield of crop. Random samples were taken, using a square wooden frame, as shown in Figure 3,

to evaluate the three tillage methods in terms of the yield of crop per hectare ($t\ ha^{-1}$) of the tilled plots of land. Fuel consumption per ton of yield of crop was then determined for each tillage method.



Figure 3 Random samples being taken to evaluate yield of crop per hectare

3 Results and Discussion

Experimental data were analyzed in a completely randomized block design for the three tillage systems. For each tillage method three replications were taken. Experimental data were analyzed using analysis of variance (ANOVA). The results showed significant difference among the three tillage methods at 1% probability level (see Table 1). As shown in Table 2, in the case of Max-till, fuel consumption in tillage and planting operations is approximately twice that of the Red-till and four times the corresponding fuel consumption for the No-till system. This big difference in fuel consumption is due to the larger number of tractor trips and tilling operations associated with the maximum tillage method.

Table 1 Analysis of variance (ANOVA) for fuel consumption and yield of crop in the three tillage systems

| Resource | Freedom degree | Root mean square | | | | | |
|-------------------|----------------|------------------|--------------------|----------------|--------------------|----------------|--------------------|
| | | Crop yield | F | Operation time | F | Consuming fuel | F |
| Tillage operation | 2 | 6.55 | 385.3** | 29436.1 | 1059.5** | 1525.5 | 116.4** |
| Replication | 2 | 0.11 | 6.47 ^{ns} | 3.44 | 0.12 ^{ns} | 12.1 | 0.92 ^{ns} |
| Error | 4 | 0.02 | --- | 27.78 | --- | 13.01 | --- |

Table 2 Comparison of fuel consumption ($L\ ha^{-1}$) and yield of crop ($t\ ha^{-1}$) in the three tillage systems

| | Cropyield/ $t\ ha^{-1}$ | Operation time/ $min\ ha^{-1}$ | Consuming fuel/ $L\ ha^{-1}$ |
|----------------------|-------------------------|--------------------------------|------------------------------|
| Conventional tillage | 7.85 ^a | 281.33 ^a | 58.33 ^a |
| Reduced tillage | 7.68 ^{ab} | 115.87 ^b | 29 ^b |
| No tillage | 5.21 ^c | 97.33 ^c | 14 ^c |

The Red-till shows the same yield compared to Max-till. However, Red-till consumes about 30 L less fuel than the Max-till. Similarly, although the No-till method consumes 44 L less than the Max-till, it yields 40% less crop compared to Max-till system. The time taken for tillage and planting operations in Max-till system is 2.5 times that of Red-till and three times the consumed time in No-till system. Similar results were reported by other researchers (Behrouzilar, 1991; Khosravani and Hemmat, 2003; Patterson et al., 1980; Platonov et al., 1992; Sojka et al., 1997). For example, Platonov et al. (1992) performed their research work on a medium soil texture for comparing six tillage systems and observed that all the methods, which resulted in reduced tillage operations, increased the wheat yield, and the

worst performance was reported when no tillage was performed on the soil. Sojka et al. (1997) studied the costs of tillage and planting operations by estimating the hiring costs of tractor, implements, planters, multitask machine and direct planting machine in three methods of Max-till, Red-till and No-till. With Determining the costs associated with the three systems, the costs of each system were calculated based on the duration of each operation (registered time).

The results of this study (see Figure 4) show that the total costs were 109 Dollars ha^{-1} for the Max-till, 77.6 Dollars ha^{-1} for the Red-till and 45.9 Dollars ha^{-1} for the No-till system. Since, the cultivated test area was part of a farm of 200 hectares, crop protection and harvesting operations were carried out alike in the whole farm.

Accordingly, the cost of these operations was estimated to be 4.45 Dollars ha^{-1} . Average yield of 7.85, 7.68, 5.21 t ha^{-1} were reported respectively for the Max-till, Red-till and No-till systems. Since the price of each kg of wheat was equal to 0.36 Dollars ha^{-1} , the profit was equal to 2,271 Dollars ha^{-1} for the Max-till, 2,242 Dollars ha^{-1} for Red-till and 1,384 Dollars ha^{-1} for the No-till system.

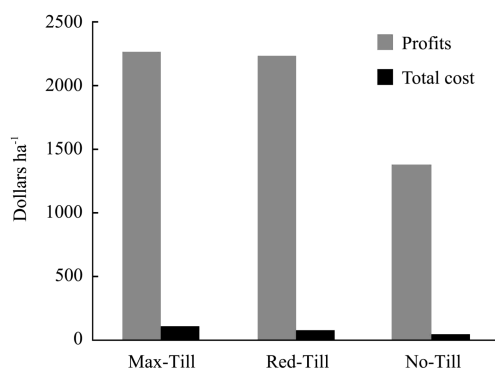


Figure 4 Costs and profits of the three studied tillage systems

4 Conclusions

Conclusions from this study can be summarized as follows:

1) Conventional tillage and cultivation (Max-till) resulted in increased costs of production and consume more time and energy, and result in higher soil compaction.

2) Average yields of 7.85, 7.68, 5.21 t ha^{-1} were obtained, respectively, for the Max-till, Red-till and No-till systems. Therefore, the yield performances of the Max-till and Red-till systems are not significantly different.

Considering the operation costs, the total costs per hectare were the highest for the Max-till, and the minimum for the No-till system.

3) Finally Red-till system is suggested as a suitable substitute for conventional farming (Max-till system).

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