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Comparison of deferent tillage, control traffic systems in Khuzestan province potato farmers

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ABSTRACT

Tillage is one of the key operations in crop production, although it may be sometimes omitted due to recent developments in technology. Minimum and no-tillage systems of soil cultivation have higher output and lower operational costs than the conventional system irrespective of the depth of plowing. Faster shallow plowing reduces the cost compared to standard technique. At the area of 200 ha with a 102 kW tractor the cost of the shallow plow was approximately 8% lower than that of the standard plow. Significant cost savings are possible, if minimum cultivation is performed. The cost of minimum tillage decreases by 30% compared to conventional systems. No-tillage further reduces the cost and increases the output. As the herbicide is often applied to control the weeds in no-tillage system, the cost of direct drill with pre-cultivation spray is similar to that of minimum tillage. The difference in costs at 350 ha is only 3% in favor of minimum tillage

Key words: Tillage, tractor, cost, minimum tillage, potato.

Introduction

Tillage is generally regarded as the most fundamental operation in global agriculture and has a great influence on the performance of the crop production system. The aim of the tillage is to create the optimum environment from seed germination to root growth and to enable mechanization as well as soil and water management. The set of implements chosen for tillage depends on local customs, soil and crop types and the cultivation system used. Plowing has been a traditional method of primary soil cultivation during the past centuries all over the world. The moldboard Plow has one of the most complex shapes of tillage implements and has been developing for centuries. Its main advantage over other tillage tools is soil cultivation including soil inverting in order to bury weeds. Plowing is very effective in controlling weeds, especially perennial weed species. Since the middle of last century various forms of shallow tillage have emerged in order to reduce energy consumption and to increase work rates. Mainly economic and environmental factors are the reasons why minimum tillage is popular in agriculture. Minimum tillage practices do not include the use of moldboard Plows and allow farmers to minimize costs and increase output. The combination of tines or discs and various kinds of harrows are the major types of implements used for secondary or minimum tillage. As the soil is not inverted, more organic matter is accumulating in the top soil layer, which needs more attention in terms of weed, pest and disease control [4].

Tillage is one of the key operations in crop production, although it may be sometimes omitted due to recent developments in technology. It is used to nurture crops by mechanical, soil stirring actions. Tillage provides a suitable seedbed to grow crops, from seed germination to root growth, for fertilizer and pesticide incorporation, and weed and moisture control. Soil cultivation requires approximately half of the total energy and labor expended on farms, so it is important to adopt suitable tillage practices, monitor its costs and follow up new trends [6].

Agriculture in the beginning of civilization enabled people to turn from hunting to farming, to domesticate plants and animals and to settle in one spot. Settled agriculture originated in the fertile plains along rivers and led to development of ancient civilizations. To make the land cultivation work easier, a large variety of tools for breaking and stirring the soil was designed. The first wooden Plow was developed and for the next 26 centuries remained practically unchanged. In the 18th century steel was used in place of wood; wheel Plows at that time had a cast-iron share and a rounded iron moldboard. The introduction of the steam engine meant a rapid expansion in the use of Plows. In the

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1900's the tractor era as a source of power started slowly and enhanced crop yields and work rates.

In the last century researchers focused on further increasing moldboard Plow performance in terms of understanding the forces acting on the Plow body, efficiency of tractor power and optimization of Plow components and work speed. No-tillage and conservation cropping systems, which have evolved rapidly since the early 1960's, became a competition for the traditional Plow system. A new approach to tillage was demanded to decrease the risk of erosion and soil degradation. These negative effects caused by intensive tillage and heavy machinery set in motion a trend of soil structure decline and loses of soil nutrition and organic matter. In dry areas extensive tillage resulted in degraded soil from wind and water erosion.

Tillage operations:

All tillage practices are carried out to increase yield and improve soil conditions; any activity beyond that cannot be justified on the basis of tradition or habit. Each tillage operation is aimed to reach one of the following goals [2]:

- Management of crop residue
- provide optimum soil aeration
- Incorporation of fertilizers
- promote optimum moisture level
- Insect control
- Temperature control
- provide good seed-soil contact
- Improvement of soil tilt
- Erosion control

The various operations of soil cultivation can be classified as follows:

- *Primary cultivation* works the undisturbed soil to loosen it down to around 25 cm depth, buries trash and weeds by inversion, mixes it into the tilled layer or leaves it on the surface.
- *Secondary cultivation* prepares the relatively rough surface after primary cultivation for planting. It works the soil shallower to the required clod size and distribution and firms the soil to give good contact with the seed or plant and conserves moisture.
- *Seeding* is placing the seed or seedling at the correct depth and spacing in the soil. Some tillage practices combine shallow soil cultivation and crop establishment in one pass over field. There are many tillage practices and a number of different titles. Three specific tillage Systems can be determined by soil type and crop to be grown:

1) **Traditional tillage** refers to a sequence of operations performed to prepare a seedbed for a given crop. It is called traditional, because it has been evolving for centuries as a basic soil cultivation. This system involves usually stubble cleaning down to 8 cm depth, primary cultivation down to 25 cm depth (Figure1) and secondary cultivation down to 10 cm depth [8]. Major types of implements used are tines or discs stubble cultivators, moldboard, disc or chisel Plows and tined seedbed cultivators or various kinds of harrows. Traditional tillage is suitable for organic farms, when weed control is one of the main problems, and also for poorly structured soils or soils prone to water logging.

2) **Minimum tillage** describes crop establishment systems that embrace fewer passes and minimal soil disturbance in comparison to traditional tillage. Crop residues well chopped by a combine harvester are usually incorporated without soil inversion into the top 10 cm of soil leaving a proportion on the surface (Figure 2). This type of cultivation also controls weed and pests such as slugs, together with a reduction of energy inputs and labor requirements. Disc or tine stubble cultivators and power tillers are an example of implements for minimum tillage. Conservation or ecological tillage follows the trend of soil care systems for sustainable agriculture. These techniques are similar to minimum tillage, but their main aims are not only economical factors, but primarily improving soil structure and conditions.

3) Where a **no-tillage** system is used, no soil cultivation is done from harvest until sowing and no soil is moved into the seeding area. A narrow slot is created by discs, coulters or chisels for obtaining the desired seed placement. Direct drills usually have trash wheels to clear through the row area of the previous crop and extra weight for soil openers for adequate penetration. This system is useful where land is too steep for conventional tillage and where there is a short turnaround between crops. Residues left on the surface may help prevent crusting and erosion. Weeds represent the biggest problem of no-tillage systems, which often require a heavy use of herbicides or mechanical cultivation.

Tillage economics:

Machinery costs are one of the key components distinguishing tillage systems. Those techniques which are less energy and time demanding can be advantageous to the farmers. More advanced, more efficient and thereby more expensive machines are being developed, but the yield targets also continue to increase. This and other factors in today's agriculture, as higher prices for parts and energy together with decreasing product prices put more pressure on machine management to adopt smart policy of owning and using farm machinery. It is, therefore, important to fully exploit expensive high-output machinery as well as to monitor their costs to improve their performance. Machinery and equipment represent a substantial input in crop production and can make up 40% of the cost of the production of winter wheat [7]. There is also a large

amount of capital invested in machinery. The main factors affecting machinery costs are:
- Annual cropped area
- Local soil conditions (heavy or light) and local climate (number of days available between harvest and drilling)
- Tractor availability (average size and age of the tractors, contractor use)
- Labor availability


Fig. 1: Two operations in traditional tillage system: stubble cultivation and plowing.

To assure high efficiency, the full potential of each machine needs to be exploited. On smaller farms, which are usually over-mechanized, because the utilization of the machines is low, the use of a contractor is a cost-effective option. A contracting service can reduce the number of operations and machines. Medium-sized farms can use contractors for a particular operation. In peak periods, short-term hire may also be attractive. On large farms mechanization strategy needs to be carefully selected to allow optimizing of costs and minimizing labor and machine requirements [3].

There are several options when a tractor or tillage implement is needed:
- purchase a new machine
- purchase a second-hand machine
- use a contractor
- short term hire
- joint purchase
- machinery ring [9]

Material and Methods

The experiment was conducted at Shoushtar region (49º 14′ E and 23º 2′ N), 90 Km north of Khuzestan, at an average altitude of 670 m. The field experiment was conducted on the demonstration field of Islamic Azad University at Shoushtar. The experiment field (pervious planting) in a 2 year alternative rotation was wheat, and wheat in order be in 2009-2010 was under wheat planting as well. The soil was Cotton ham series, sandy loam type [5] with physical properties similar to the parameters of the soil used for the laboratory experiment. The measured soil moisture content was 13.62% and the mean cone penetration resistance (30º cone with 12 mm base diameter) was 0.85 MPa. The field site had been tilled and then set-aside.

The tractors used in the execution of the experiment were an MF 399 (110 HP) and an MF 285 (75 HP) 4WD. The tillage implements involved were:
- A 4-furrow reversible Dowd swell DP 10 moldboard Plow with a furrow width of 381 mm operating at depths of 200 mm (*moldboard Plow deep*) and 150 mm (*moldboard Plow shallow*).
- A 3-furrow Par miter DPM Series disc Plow (*disc Plow*) with a furrow width of 305 mm, disc diameter 660 mm, disc angle 49º and tilt angle 22º.
- 7 Cousins winged tines, CM series, and cultivator consisting of 235 mm wide full sweep bottoms, a rake angle of 25º, two tine spacing's of 224 mm (*close tines*) and 336 mm (*wide tines*).
- Tandem abreast MF 280 disc harrow (*disc harrow*) comprised of a four gangs assembly. The front gangs are made up of 12 scalloped discs each of 508 mm diameter with a disc spacing of 235 mm and a gang angle 23º. The rear gangs consisted of 14 plain discs (of the same diameter as the front discs) with a disc spacing of 187 mm and a gang angle of 18º.

The total width, working depth and speed of the implements are summarized in Table 1.

Both moldboard and disc Plows were working at a depth of 200 mm, as it was considered as a standard Plowing depth used in agriculture. To determine, how depth affects draught force, shallow Plowing was included in the experiment. A depth of 150 mm was chosen representing the minimum depth, at which a standard moldboard body could work, as found in previous studies. Winged tines and a disc harrow were considered as the implements for secondary or shallow primary cultivation; hence the depth of 100 mm was chosen. The measured depth of the disc harrow varied about a value of 60 mm, and extra weight ballast would be needed for additional penetration. It is necessary to note that the actual depth of all implements differed from the desired value due to the uneven surface of the field. The speed of work was maintained at 5 km/h for all implements.

Table 1: Width, working depth and speed of the implements in the field experiment.

Tractor type	Implement type	Width of the implement (mm)	Working depth (mm)	Speed of work (km/h)
MF 399	Moldboard plow deep	1524	200	5
MF 399	Moldboard plow shallow	1524	150	5
MF 285	Disc plow	914	200	5
MF 285	Disc harrow	2700	60	5
MF 285	Wide tines	2251	100	5
MF 285	Close tines	1579	100	5

To achieve a reasonable quality of work the setting and adjustment of all implements was done on adjacent plot. The preliminary measurements were carried out to investigate the rolling resistance of the two tractors. The rolling resistance is defined as the pull required moving a wheel across a horizontal surface. The rolling resistance of a wheel with a pneumatic tyre consists of two main components. The internal component is caused by loss of energy, which results from the continuous flexing of the tyre carcass as the wheel rotates in contact with the ground. The external component is equal to the energy which the wheel is expending in order to deform the soil surface [1].

The calculations of the costs of alternative tillage systems are beneficial for the farmer, because they show the cheapest system for an individual operation. Selection of the implements and tractors is dependent on the cultivated area and time availability. The area, which needs to be worked, is usually constant, but the number of days available for tillage operations varies upon the weather conditions and soil type. Number of workdays in Scotland in months, when autumn tillage is performed is given in Table 12. The number of workdays presented in the table when cultivation is possible has a probability level of 75%. For the costing examples a 35 day limit was chosen for a single operation or tillage system. This takes into account that August is not always available due to late harvesting and in November it is not a common practice to do primary cultivation, because crop hold be establish earlier for smooth dormancy. A 10 hour working day was considered for all calculations. All compared implements and tractors are new.

Wheel slip:

Wheel slip may be seen as an indicator of the efficiency of conversion of potential forward movement of the tractor into actual forward movement. Slip is defined as the lost travel distance in relation to the theoretical travel distance [1]. Generally a driven wheel must always experience some wheel slip, which enables to propel itself forward. Excessive wheel slippage is a major problem, especially when Plowing with one wheel in the furrow. The furrow wheel usually gets enough traction, as a result of tractor tilt during Plowing, which exerts more weight on it. The land wheel may spin on trash, green plants or loose soil. Wheel slip of more than 15% should be reduced, because it causes unnecessary tyre wear and waste of time and fuel. The most common method of improving traction is to add weight (ballast) to the tractor front and to the drive wheels [2]. The tyre pressure is often reduced for field work in order to put a greater area of the tyre casing in contact with the soil surface. A greater area and number of the tyre tread bars helps to improve traction, but very low pressure can lead to damage of the tyre. The tyre pressures maintained during the field experiment are given in Table 2.

Table 2: Tyre pressures maintained during the field experiment.

Tractor Type	Front wheel size	Rear wheel size	Wheel pressure front (kN/m2)	Wheel pressure rear (kN/m2)
MF 285	12.4/11-24 (cross ply)	18.4/11-30 (cross ply)	96.526	113.421
MF 399	380/70 R28	480/70 R38	110.316	124.104

The procedure below was followed in order to determine the wheel slip of the tractor under load with alternative tillage implements:
- The 4WD was disengaged to enable the front and rear wheels to rotate independently.
- The sidewall of the tyre was marked.
- The ranging pole was erected on the spot where the mark on the tyre met the ground.
- The tractor was driven under load with the implement in a straight line.
- 10 complete rotations of the tyre were counted and another ranging pole was erected on the spot, where the mark on the tyre met the ground.
- The distance between the ranging poles was measured by measuring wheel.

To investigate the theoretical distance, both tractors were driven without an implement.

The procedure was repeated at least three times with all the implements used in the field experiment.

Work rate:

Work rate is used to assess an agricultural machine or implement. It determines the upper limit of the implement performance and is usually expressed as a rate over available time in a season or year. Witney, 1988 describes the overall rate of work as a performance of a machine over the complete operational cycle (productive work time plus routine interruptions for turning and product handling). The seasonal rate of work then includes major breakdowns, mealtimes, travelling from field to field and any other delays, which prevent the implement from working, while weather and soil conditions would be suitable. Work rate, which was measured during the field experiment, accounted for the performance of the implement in productive work and turning. The following times were measured for conventional and reversible Plows:

- Time, when the implement was working the soil over a distance of approximately 70 meters.
- Turning time, when the implement was raised from the soil until the moment when it was ready for next pass.

Work rate was calculated for different widths of Plows over the range of areas.
Working, turning time and time allowing to process a headland, an area providing room for turns, were included in the calculations.

Draught force:

To determine the energy requirements, the gross draught force of each implement was measured. The distance of each test was approximately 70 meters. The field experiment was completely randomized with two replications. To ensure proper working conditions for moldboard and disc plows, an open furrow was created, into which the soil slice was turned. This requirement influenced the layout of the experiment (Figure 3).

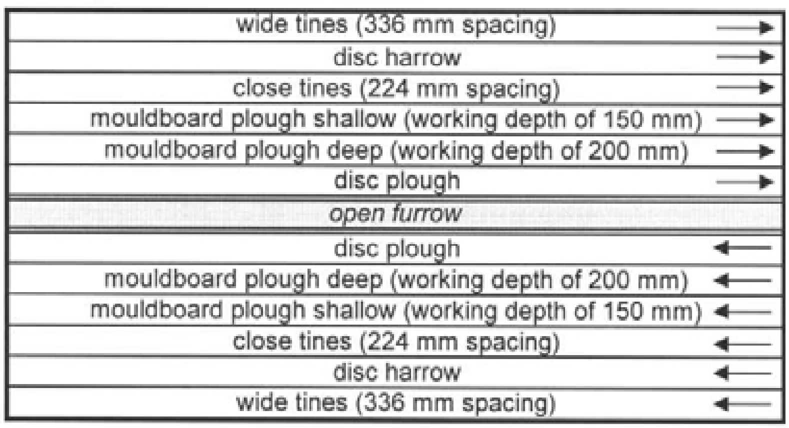

Fig. 3: Layout of the field experiment.

The tractor with the selected implement was drawn in two runs to determine the Implement's gross draught force in both descending and ascending field applications. A 5 ton digital tension meter was located between the towing cables connecting the two tractors to display the actual draught force (Figure 10). This solution of using two tractors was chosen, because the tension meter could not be directly attached between a tractor and the implements. The net draught forces of the implements were calculated by subtracting the rolling resistance from the measured values of the draught force. The disturbed soil of the cross-sectional area of a single pass of the implement was excavated and a profile meter was used to measure the area of disturbance remaining. To indicate overall tillage efficiency, specific resistance was calculated. A statistical analysis was carried out on the force measurements including an analysis of variance and the least significant difference test at a 5% probability level.

Results:

The mean wheel slips of the tractors driven with all tested implements are presented in *Table 3*. The only excessive slippage was experienced during the preliminary measurements, when the implements were being set and adjusted with the tractors. A wheel slip of 35% measured for the tractor engaged with disc harrow was caused by negative weight transfer. Due to unsuitable engagement of the implement and the three-point linkage, the rear wheels of the tractor had not enough traction.

Adv. Environ. Biol., 6(1): 487-493, 2012

Table 3: Wheel slip of the tractors during the field experiment.

Tractor type	Implement type	Wheel slip
MF 399	Moldboard plow deep	8%
MF 399	Moldboard plow shallow	5%
MF 285	Disc plow	12%
MF 285	Disc harrow	7%
MF 285	Wide tines	6%
MF 285	Close tines	7%

The draught forces of each implement measured in the field experiment are plotted in Figure 4. The draught force of the moldboard Plow is significantly higher than the draught force of the disc Plow working at same depth. A reduced draught force of close tines can be seen in comparison to that of wide tines. The draught force per unit implement was calculated by dividing the draught force by the number of discs, tines or Plow bodies. This enables to determine the draught force for different number of implement bodies, but it is not valid for comparison between different implements. Figure 4 (down) shows the values obtained for the draught force per unit implement device.

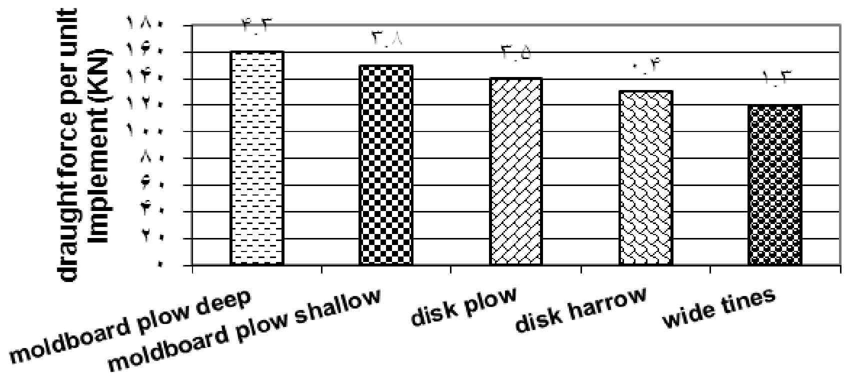

Fig. 4: Draught force of the implement and draught force per unit implement of the field experiment (error bars indicate a confidence interval at 95% probability level).

The cost comparison can be made for a single implement and tractor combination or for a complete tillage system as was described earlier. The calculated costs of different implements and alternative tillage systems are described in this section. As it was calculated earlier, the 86 kW tractor used in the field experiment is capable to operate the 5 furrow plow, although the 4 furrow plow was used in the experiment. Costs of these two plows with the same tractor and working speed. The cost of the 5 furrow plow is lower from the area of Khuzestan 58 approximately 18 ha compare to that of the 4 furrow plow. The 5 furrow plow has higher work rate at the same speed as the 4 furrow plow, therefore this combination covers the given area in shorter time, which reduces the cost of operation of the tractor as it is calculated as cost per hour. The 4 furrow plow covers 269 ha in 35 working days, where the cost of £ 47.85/ha is 18% higher than the cost of 5 furrow plow. The 5 furrow plow has the cost of £ 39.36/ha at its maximum output. This example shows that the cost of plowing can be reduced by utilizing the maximum available power of the tractor. The advantage of covering larger area must be also noted. The higher work Rate of the 5 furrow plow to 4 furrows enabled to cover greater area per day In 35 working days the difference between two plows is 67 ha in favor of 5 furrow plow.

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