Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)
2008, 4 (2), 171 - 178

Energy Consumed for Barley Production in the Reclaimed Lands of Egypt

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Abstract: A field experiment was conducted through season (2006/2007) to study the effect of tillage and irrigation practices on energy consumed; some soil properties and barley yield. The required energy and operational cost for different field operations were also investigated. Mechanization of field operations led to improve the soil properties and barley yield. Soil bulk density was reduced under chiseling twice and leveling as compared with no-tillage treatment. The highest yield was obtained under chiseling twice and leveling using 100% F.C regime. The total required energy for seedbed preparation, planting and mechanical harvesting operations varied between 509.61 and 1213.09 MJ/ha.
Keywords: Tillage techniques, Energy consumed, Irrigation regime and Bulk density.

Mısır'da Islah Edilmiş Alanlarda Arpa Üretiminde Enerji Tüketimi

Özet: Çalışma 2006-2007 üretim sezonunda arpa veriminde ve değişik toprak koşullarında; toprak işleme ve sulama uygulamalarının enerji tüketimine etkilerinin ortaya konulması amacıyla yapılmıştır. Çalışmada farklı arazi uygulamalarında gerekli enerji ve işletme giderleri incelenmiştir. Arpa üretiminde kullanılan mekanizasyon düzeyinin toprak özelliklerinin ve arpa veriminin iyileştirilmesine katkısının olduğu belirlenmiştir. Toprak yoğunluğunun işlenmeyen alanla kıyaslandığında azaldığı görülmüştür. En yüksek verim ikinci işleme ve seviye de % 100 F.C. kullanımında elde edilmiştir. Toplam enerji tüketimi; tohum yatağı hazılanması, ekim ve mekanik hasat operasyon çeşitleri için 509.61 ve 1213.09 MJ/ha arasında hesaplanmıştır.
Keywords: İşleme teknikleri, Enerji tüketimi, Sulama rejimi ve hacimsel genişlik.

INTRODUCTION

In arid and semiarid environments the ability of soil to store water plays an important role in the success of crops. Tillage is the most effective way to modify the soil physical and water characteristics. In general, moisture content was reported to be greater under no-tillage than in tilled soils (Azooz et al., 1996; McGarry et al., 2000) due to the larger number of macro pores. Disruption of macro pore continuity by tillage is reported to reduce water retention (Godwin, 1990; Logsdon et al., 1990). However, in other studies, moisture content was found to be higher under no-tillage than inversion tillage (Ferreras et al., 2000). Reasons for this may be increased bulk density found in no-tillage soils and increased porosity produced by tillage (Hubbard et al., 1994; Pelegrin and Moreno, 1994). These soil properties are normally altered by tillage, but the magnitude of change can vary according to the irrigation techniques. Greater bulk density in no-tillage or direct drill than in conventional tillage was observed for sandy loam to clay loam soils cropped to barley for 7 years in Scotland (Pidgeon and Soane, 1977). (Malhi and Nyborg, 1990) reported that no-tillage with crop residue retained resulted in similar or better yield of barley as compared to conventional tillage in Alberta if the environmental conditions were adequate. Regarding irrigation (Abd El-Maksoud et al. 1994) found that the total energy consumed in irrigating barley using sprinkler irrigation system was 5223.1 MJ/ha which produced yield of 3.78 ton/ha. The work of (Allen et al. 1980) pointed out that limited tillage (conservation tillage) and sub-soiling increased irrigation water intake by 10% and grain yield by 8% as compared with clean tillage (Traditional tillage) and chiseling, also time and fuel energy requirements for limited tillage were only about half those for clean tillage. Energy consumed with different operations for main Egyptian crops was determined (El Shazly 1989) he found that fertilization recorded the highest values of energy consumed ranging from 43.3 to 70.93% of the total energy, while harvesting consumed the lowest values ranging from 1.3 to 5.67. The objective of this work was to investigate the effect of different tillage and irrigation regimes and its conservation under semiarid Mediterranean conditions. In addition a part of the work will deal with energy consumption and its cost under the management and irrigation regimes.

MATERIALS AND METHODS

A. Soil characteristics:

Soil of the experimental site was preliminarily investigated to determine some physical and chemical properties. Soil samples were taken from a profile 60 cm deep to represent successive layers. The physical and chemical soil properties are shown in table 1.

B. The soil bulk density was measured through the first, middle and end of season irrigation cycle. The soil bulk density was measured at each treatment plot on 100 and 75 % of the field capacity at the upper soil layer (0-30 cm). At the same time, distribution of the moisture content in soil profile was determined.

One main method of barley mechanical planting was carried out namely by drilling. The mechanical harvesting was done by a combine machine

The experimental work included the following tillage treatments:

Treatment (A): No- tillage

Treatment (B): Chiseling once, and leveling

Treatment (C): Chiseling twice, and leveling

Treatment (D): Chiseling once, harrowing once, and leveling

Treatment (E): Harrowing once, and leveling

This investigation was conducted at El Salheaa (Ismailia Governorate). *Giza 126* barley variety was used as an indicator plant, at a rate of planting of 60 kg/ha. Sowing was carried out on the 10th, of December through the season, 2006/2007, and fertigation, herbigation and irrigation were applied using center pivot sprinkler system.

C. Equipments used in field operation:

1-A tractor: having the following specification: MTZ90 4 cylinders U.S.S.R. Engine: Diesel, 4strokes, 90 hp (66.24 kW), mass 3460kg.

2-Chisel plow: locally manufactured, 9blades, arranged in three rows 2-3-2 mounted on the tractor, plowing the soil at 17-cm. depth.

3-Landleveller: Locally manufactured mounted, working width 200cm, pulled by tractor.

4-Seed drill: model TYE, mounted, number of rows 10, row spacing 20cm. between rows.

5-Disk harrow: model ALLIS-CHALMERS 2300,with 36 discs arranged in four gangs ,two front and two rear gangs ,pulled by tractor with 10cm depth ,width of cut 300cm,diameter of disks 40cm.

6-Combine Yanmar: model CA 385 EG, with 5 rows and reaping width of 145cm, the grain handing type was bagging and power used was 27.9 kW.

D. Measurements and Calculations:

1. Power requirements

Power consumption and operation time per unit area hectare for different field operations were estimated through measuring the fuel and time consumed for each field operation over adequate duration applying the following formula :(Elmo, 1981):

$$P(kW) = H \,.\, Wf \,.\, \eta \qquad (1)$$

Where:

P: Fuel equivalent power, (kW),

Wf: Fuel consumption rate, kg/h,

H: Gross heating of fuel which represent the mechanical value of the fuel = 45000 kJ/kg.

η: Thermal brake efficiency equal to ≈25%, which represents the brake horse power divided by power value of fuel.

2. Energy requirements:

Machine energy

Machine energy represent manufacture, transport and repair of machine used, it was calculated according to the following formula: (Pimental et al., 1977 and Lower et al., 1977):

Table 1. Some physical and chemical properties of soil profile representing the experimental site.

Soil Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Texture class.	Organic Matter (%)	Bulk Density gm/cm^3
0 – 30	7.44	29.07	63.49	Sandy Loam	0.47	1.59

$$Em\ (MJ/ha) = \frac{Cm}{F.C}(Wt/TDL + Wm/MDL) \quad (2)$$

Where:
Em: Energy required for machinery, (MJ/ha)
Cm: Energy input coefficient used to represent the embodied energy in a piece to equipment or tractor = 101 (MJ/kg).
F.C.: Operational field capacity, (ha/h)
Wt: Mass of tractor, (kg)
Wm: Mass of machine, (kg)
TDL: Tractor design life, (h)
MDL: Machine design life, (h)

3. Irrigation energy

Irrigation energy included input in operation for irrigation system used; it was calculated according to the following formula: (Keller, 1965).

$$Ei\,(MJ/ha) = \frac{C.DN.TDH}{E} \quad (3)$$

Where:
Ei: Irrigation energy, (MJ/ha)
C: Conversion factor=0.97
DN: Net amount of irrigation water, (m$^{3)}$
TDH: Total dynamic head, (m)
E: Irrigation efficiency, %

4. Energy ratio

The energy ratio expresses the efficiency of consumed energy for barley production (Tony, 1975) and can be calculated as follows:

$$Energy.ratio = \frac{Total\ yield(kg/ha) \times Digestable\ Energy\ for\ barley(MJ/kg)}{Total\ Energy(MJ/ha)} \quad (4)$$

5. Estimating the total costs of all operations:

Wages of equipments:

The cost of mechanized processes was determined according to the following wages in Egyptian pound (L.E.):

Tractor MTZ 90hp + chisel plow: 46.20 L.E/h
Tractor MTZ 90hp + disc harrow: 44 L.E/h
Tractor MTZ 90hp + land-leveler: 44 L.E. /h
Tractor MTZ 90hp + seed drill: 52.38 L.E. /ha
Combine Yanmar: 524 L.E./ha
Chemical fertilizers (N, P, K): 1395 l.E./ha
Herbicides: 238 L.E./ha

6. Water Use Efficiency (WUE):

Water use efficiency (kg/m^3) was calculated as follows:

$$WUE(kg/m^3) = \frac{Barley\ yield\ (kg/ha)}{Volume\ of\ applied\ water(m^3/ha)} \quad (5)$$

7. Yield measurements:

The design of the experimental area was split-plot, with four replications for each investigated treatment. Each experimental plot was 11m width and 14m length of a total area 154 m^2. A wooden frame 1x1 m was used to determine yield of barley: grain and straw, at harvesting time. For each investigated treatment three samples were taken randomly from each plot.

8. Net income:

The net income of crop production was calculated according to the following equation (El-Said et al., 1988):

$$\textbf{NI (L.E.)= GC1 + SC2 – CF} \quad (6)$$

Where:
G and S are crop yields ton/ha, of grain and straw respectively, C1 and C2 are prices of grain and straw respectively L.E / ton, and CF is the cost of field operations L.E / ha.

RESULTS AND DISCUSSION

A-Soil Properties:

A.1: The effect of different treatments on soil bulk density:

The averages for the bulk density under the investigated tillage practices with in the growing barley season are given in table (2). The presented data indicate that under each treatment this parameter did not show and significant variation in its value due to the changes in irrigation regime. This was also the keys for the three investigated season time, where measurements took place. This is clearly demonstrated by taking the average value of the bulk density for each individual tillage treatment being of the same value under the 100% and 75% F.C irrigation regimes. However this was not the case by changing the tillage treatment. The data show that for the treatment (A) where no-tillage was practiced the bulk density showed to be with the highest values. Contrary was the case for treatment (C) being with the lowest value and this could be attributed to the effect of chiseling as it was two times practiced in comparison with treatment (B). Such data coordinated with ones of (Pelegrin and Moreno, 1994), because the shape and volume of soil tend to be changed due to replacement of water instead of air. Regarding the (D) and (E) treatments both were of the same bulk densities, but, with values slightly lower than (A) treatment and relatively exceeding the ones corresponding to both (B) and (C) tillage treatment. This leads us to the conclusion, with the progress with the growing season reaching its maximum value at end of the season. The data also indicate that there is a tendency to a gradual increase in this parameter.

A.2: Soil moisture pattern as affected by different tillage treatments:

Soil moisture content during the cropping season under the investigated tillage treatment for 100% and 75% F.C irrigation regime are given in table (2). The presented data show that the moisture content under both irrigation regimes varied according to the variation in the tillage treatment. Generally the ability of soil water retention through the season revealed that under the low irrigation regime the 75% F.C on all treatments averaged to be lower value than that under the 100% F.C irrigation regime. Taking the tillage treatment into consideration, it can be observed that similar to the bulk density, the treatment (A) where no-tillage was practiced was the one among the other treatments having the highest moisture content values under both investigated irrigation regime. This can be explained on the ground that where tillage is not practiced we avoid any changes in the soil structure, the pore size distribution and the micro to macro pores proportions, those governing the available capillary water in the soil profile. Of interest to mention here that where tillage was practiced the changes in the tillage operation did not result to any significant differences in the moisture content among the tillage treatments being more or less with the same average value nearly 13% and 11% lower than that for (A) treatment for the 100% and 75% F.C irrigation regime respectively. Following the moisture status during the cropping season under both irrigation regimes, from table (2) it can be observed that it followed a trend opposite to the one characterizing the bulk density (Logsdon and Kaspar, 1995).

B- Energy requirements and costs:

B-1- Required energy:

Tillage treatments can be evaluated taking into consideration its impact on the physical properties of the soil particularly those related to aeration and water retention in soils those fundamentally affected by changes subjected in the soil structure due to mechanical tillage operations. However, beside such technical impacts, the economic aspects expressed by the required energy and its estimated cost are essential parameters to be carefully considered in deciding on the tillage operations to be practiced. Regarding required machine energy Fig. (1), it can be seen that it varies greatly with the variation in the mechanical operation practice within each individual tillage treatment. Taking treatment (A) as a reference where no-tillage was practiced and comparing the energy required for the investigated tillage treatments, it is observed clearly that the energy required are shown to be the maximum for both (B) and (C) tillage treatments whereas the lowest values were found to be under both (D) and (E) tillage treatments. Such variation in energy required among the tillage treatments could be mainly attributed to the type and the number of operations characterizing each individual tillage treatment. Generally the greater is the number of operations the higher will be the energy required. Concerning irrigation energy, both irrigation regimes at 100% and 75% were consumed 37721 and 28290 (MJ/ha) respectively under all tillage treatments. The data in table (3), declare that this parameter was not subjected to any changes in its value due to the variation in the tillage treatments being more or less with similar value for both tillage and no-tillage treatments. This also holds true under the two investigated irrigation regimes, but, where irrigation was practiced at 100% F.C, irrigation energy showed values amounting to nearly 25% more than that under the 75% F.C, irrigation regime which more or less corresponds to the differences in the irrigation time between the two investigated irrigation regimes. These results were in harmony with (Abd El-Maksoud et al.1994).

Table 2. The effect of tillage treatment on soil bulk density and moisture content.

Treatment	Season investigations	Bulk density gm/cm^3)		Moisture content (%) by weight	
		100% F.C	**75% F.C**	**100% F.C**	**75% F.C**
No- tillage	Beginning of season	1.59	1.60	16.42	11.82
	Middle of Season	1.60	1.60	16.93	12.19
	End of Season	1.64	1.64	12.70	9.14
Average values		**1.61**	**1.61**	**15.35**	**11.05**
Chiseling once, and leveling	Beginning of season	1.45	1.45	14.34	10.32
	Middle f Season	1.56	1.60	15.28	11.16
	End of Season	1.66	1.66	11.09	8.48
Average values		**1.55**	**1.57**	**13.57**	**9.98**
Chiseling twice, and leveling	Beginning of season	1.51	1.51	14.00	10.08
	Middle f Season	1.54	1.55	14.22	10.32
	End of Season	1.55	1.55	11.04	8.88
Average values		1.53	1.53	13.08	9.76
Chiseling once, harrowing once, and leveling	Beginning of season	1.58	1.59	14.02	10.14
	Middle f Season	1.59	1.59	14.26	10.67
	End of Season	1.60	1.60	11.10	8.02
Average values		**1.59**	**1.59**	**13.12**	**9.61**
Harrowing once, and leveling	Beginning of season	1.54	1.54	14.41	10.37
	Middle f Season	1.56	1.59	15.33	11.03
	End of Season	1.66	1.66	11.21	8.07
Average values		**1.58**	**1.59**	**13.65**	**9.82**

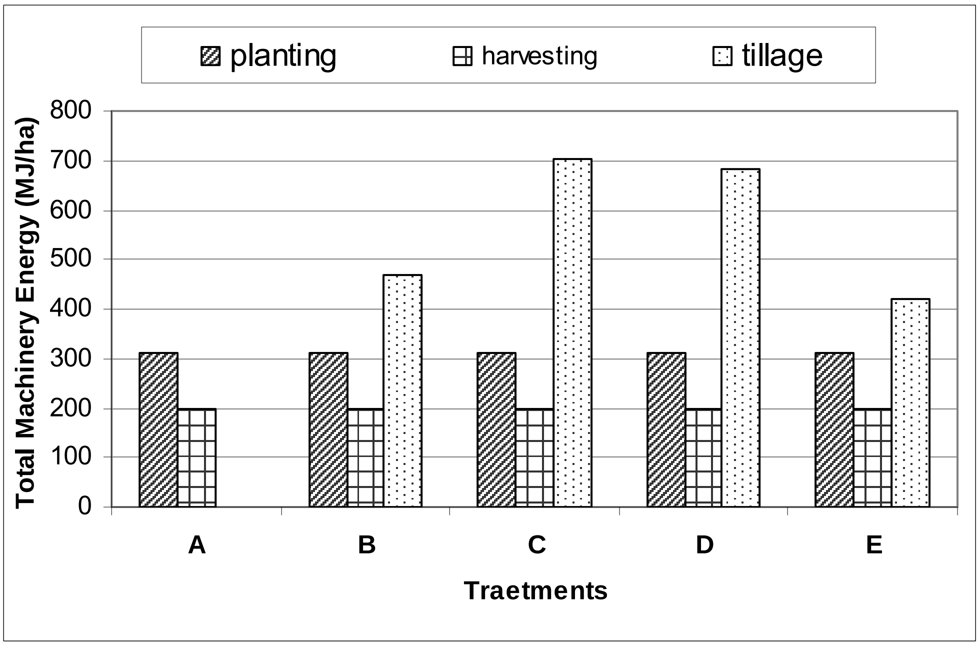

Figure 1. The effect of different treatment on machine energy required.

Table 3. Effect of mechanical treatments on energy requirements.

Treatment	Total machine energy (MJ/ha)	Irrigation Energy (MJ/ha)	
		100% F.C	75% F.C
No- Tillage + Mechanical Planting + Mechanical Harvesting (A)	509.61	37721.4	28290.5
Chiseling Once + Leveling + Mechanical Planting + Mechanical Harvesting (B)	979.49	37721.4	28290.5
Chiseling Twice + Leveling + Mechanical Planting + Mechanical Harvesting (C)	1213.09	37721.4	28290.5
Chiseling Once + Harrowing Once + Leveling + Mechanical Planting + Mechanical Harvesting (D)	1191.31	37721.4	28290.5
Harrowing Once + Leveling + Mechanical Planting + Mechanical Harvesting (E)	929.08	37721.4	28290.5

B-2-Costs:

To decide on the tillage management to be practiced, we have to consider not only the technical aspect, but, equally the economical ones (Table 4). The economical evaluation was carried out considering the fuel consumption (L/ha) and its actual cost in Egyptian pounds under each individual investigated tillage treatment. Taking the (A) treatment as reference where no-tillage was practiced, it can be observed that treatment (C) is the one with the highest fuel consumption with values nearly 13 times greater than the ones for the (A) treatment. Following the same trend the presented data indicate that both (B) and (D) treatments are of intermediate fuel consumption with an average value 50 L\ha corresponding to nearly 67% of that for the (C) treatment. In such two treatments (B) and (D) the fuel consumption showed to be relatively high with an average value nearly 10 times greater than the one of treatment (A) where no-tillage was practiced. The data also show that treatment (E) is the one among the tillage treatments with the lowest fuel consumption corresponding to nearly one third and one fourth of the ones referring to treatments (D) and (C) respectively. The presence of the highest fuel consumption in treatment (C) with an intermediate values in both (B) and (D) treatments with the lowest consumption in the (E) treatment could be attributed not only to the number of the tillage operations but also to its type. Indeed, the tillage treatments (B), (C) and (D) those where fuel consumption was remarkable, in all, chiseling was a dominant practice, where as in the treatment (E), there was a notable reduction in the fuel consumption. Regarding the other two parameters, power (kW) and cost (L.E\h), table (3), both followed a trend similar to the one previously discussed concerning the fuel consumption under the investigated tillage treatments. Generally keeping the soils without any tillage, both studied parameters were of minimum values as compared to the ones where tillage management was practiced. Regarding the tillage treatments similar to the fuel consumption both parameters varied from one treatment to the other due to the variation in the operation numbers and its type

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Table 4. The effect of tillage treatment on fuel consumption, power and costs.

Treatment	Fuel Consumption (L/ha)	Tillage Cost (LE/ha)	Planting Cost (LE/ha)	Fertilizers Cost (LE/ha)	Herbicides Cost (LE/ha)	Harvesting Cost (LE/ha)	Total Cost (LE/ha)
A	23.6	0	37.4	1395	238	524	2194.4
B	65.15	160.02	37.4	1395	238	524	2354.42
C	92.94	238.56	37.4	1395	238	524	2432.96
D	71.34	218.82	37.4	1395	238	524	2413.22
E	35.25	121.8	37.4	1395	238	524	2316.2

C- Effect of tillage treatments on yield, water use efficiency (WUE) and energy ratio:

C-1-Yield:

Regarding yield production under the investigated tillage treatments, Fig (2), it can be seen that through soil tillage that there is a better improvement in the barley yield with respect to that recorded on the same soil where no-tillage management was practiced. Comparing the barley yield under the investigated treatments it can be observed that treatment (C) where chiseling was practiced twice followed by leveling is the one where barely production was the highest being with an average value nearly 50% exceeding that for the (A) treatment where tillage was absent. These data fully support those obtained by (Blevins et al., 1984). The presented data also indicate that the yield production is highly affected by the type of the tillage under practice. This is clearly demonstrated by considering the variations in the yield between (B) and (C) tillage treatments. In treatment (C) where chiseling was two times practiced resulted in a yield nearly 30% greater than that of treatment (B) where chiseling was only one practiced. This is again confirmed by considering the barley yield in treatment (E) being the lowest hence chiseling was not included in the tillage management. Such observations hold true for both the two investigated irrigation regimes the 100% and the 75% F.C, but, under the latter the yield was subjected to nearly 22% reduction with respect to that where irrigation was practiced at 100% F.C.

C-2-Water use efficiency (WUE) and energy ratio:

In general results in table (4) showed that the (WUE) under 75% F.C. was higher than calculated under 100% F.C., the treatment (A) represented the lowest value of (WUE), in both 100% F.C. and 75% F.C., due to soil compaction and less above ground biomass under no-tillage system as compared with other treatments, while the treatment (C) pointed out to the maximum value obtained that is because less bulk density and increase water retention into soil profile. The same trend seemed to be obvious in energy ratio; these data are in agreed with (Blevins et al., 1984).

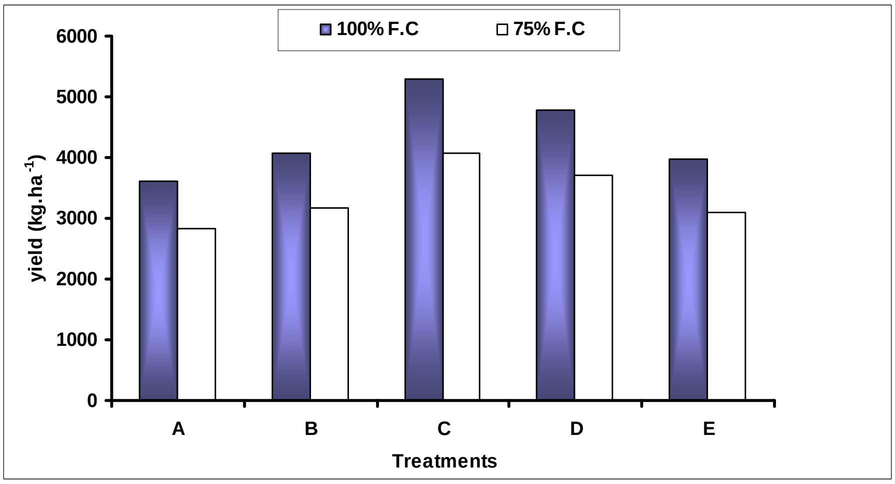

Figure 2. Effect of tillage treatments on yield.

Table 5. Effect of mechanical traetments on water use efficiency (WUE) and energy ratio.

Treatments	100 % F.C		75 % F.C	
	WUE (kg/m^3)	Energy Ratio (%)	WUE (kg/m^3)	Energy Ratio (%)
(A)	0.86	1.03	0.90	1.07
(B)	0.97	1.15	1.01	1.19
(C)	1.26	1.40	1.30	1.50
(D)	1.14	1.30	1.18	1.40
(E)	0.95	1.12	0.98	1.16

CONCLUSION

The results obtained of this investigation showed that through tillage both soil moisture content and bulk density are subjected to changes in their values resulting in having a yield production of values exceeding those where no tillage treatments were practiced. The tillage treatments conducted under 100% F.C were higher in their yield than that of the 75% F.C irrigation regime. Regarding the energy consumption and its corresponding cost, the data show that both vary with the variation in the type and number of operation included within each tillage treatment. This means that under soil management we have two options, the first where no tillage is practiced and thereby minimizing the energy cost, but negatively affecting the yield production. The second through soil tillage practiced with gradual important in the yield as well as a function of the number and type of tillage operations under practice. Accordingly the question of cropping with tillage and/or without tillage is a matter of the prevailing socio-economic conditions of the country and in particular availability of the energy sources and their corresponding cost.

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