THE IMPACTS OF NO-TILLAGE ON GRAIN YIELD OF DURUM WHEAT AND ENERGY REQUIREMENT IN THE MEDITERRANEAN CLIMATE

Khaledian, M.R.[1]- Mailhol, J.C. [2]- Ruelle, P.[2]-Forest, F.[3]-Rollin, D.[2]- Mubarak, I[2, 4]- Mirzaei, M.R.[5]

[1]UMR G-EAU Cemagref-Cirad-Engref-IRD, BP 5095, 34196 Montpellier Cedex 05 France, and Guilan University of Iran. Tel.: 334-671-66412; fax: 334-671-66440; E-mail: mohammad.khaledian@cemagref.fr
[2]UMR G-EAU Cemagref-Cirad-Engref-IRD
[3]Direct seeding research unit, Cirad, Montpellier, France.
[4]LTHE, Grenoble, France and AECS, Agriculture Department, Damascus, Syria
[5]UMR EMMAH, INRA, Avignon, France and Yasuj University, Iran

1. Abstract

A key principle of no-tillage (NT) system is the retention of crop residues on the soil surface to preserve soil water for crop growth. In response to the negative impact of soil degradation processes under conventional tillage (CT) systems that are based on soil tillage, NT system without tillage practice and with protective cover of crop residue are being developed in many parts of the world. Apart from the positive effects on soil conservation and sustained land productivity, another major impact of NT is decreasing labor costs, generally leading to a higher income and a better standard of living for the farmers. However NT is a successful system especially in the South of America, but the impacts of this system in the Mediterranean climate especially in the south of France is less well known; so that this study has been carried out within the scope of a European project. Durum wheat was sown for two years in two tillage treatments i.e. CT and NT. Time requirement and fuel consumption in these two systems were measured. The results showed that the crop production is higher in CT system, while work duration and energy requirement are lower in NT system.
Keywords: No-tillage, conventional tillage, durum wheat, energy requirement

2. Introduction

NT system is becoming increasingly attractive to farmers because it clearly reduces production costs relative to CT system. NT provides feasible soil management with fewer disturbances to soil agroecosystems compared to CT. The main objective of soil cultivation, i.e. the proper sowing and raising of crops, can be achieved at lower costs and labor hours. In France, the estimation is that the surface under conservation agriculture techniques is 17% of total arable land (3×10^6 ha) with an increase of 1 million ha in comparison with the situation in 1999. The surface under NT has increased from 50×10^3 to 150×10^3 ha (0.3% of total arable land) in the same period (ECAF). Different authors (Lal (1989); Blevins and Frye (1993); Fischer et al., (2002); Bueno et al., (2006)) assessed and confirmed ecological and economical advantages of direct seeding. Despite of the potential benefits of this system from an environmental and economical point of view and the possibility of its application in most of the European country; the evolution of conservation agriculture has been slower in European Union than in other parts of the world, especially when talking about NT.

NT has considerable potential for stabilizing production in semiarid zones, but can have contrasting consequences on water conservation and yield. Lal et al., (1978) and Osuji (1984) demonstrated positive effects, whereas Chopart and Kone (1985) found negative effects. NT systems are characterized by high levels of previous crop residues on soil surface. The presence of residues can conserve soil moisture and decrease evaporation. But sometimes residues hinder correct seed placement and appropriate row closure in NT. The presence of residue may delay plant emergence and reduce crop yield mainly because of cooler soil temperatures. Delayed crop emergence and reduced plant population are problems sometimes associated with durum wheat under NT. Poor crop establishment, low plant populations, and delayed early plant growth due to higher mechanical resistance of soil were the primary cause of low durum wheat yields on NT.

The long term effects of CT and NT, under Mediterranean conditions have hardly been studied. Furthermore there is little information in the literature concerning the effects of tillage systems on durum wheat in Mediterranean condition. Yield responses to tillage systems can differ widely with respect to soil type, crop species, precipitation, and region. In this region most rain falls during autumn and winter, and so that water deficit emerges in the spring resulting in a moderate stress for wheat around anthesis, which increases in severity throughout grain filling (Edmeades et al., (1989)). In the Mediterranean region, low and erratic distributions of rainfall explain as much as 75% of the variation in wheat yield (Blum and Pnuel, (1990)).

NT has been widely used in the last decades as an attractive alternative to CT because of their potential to reduce production costs. Besides lower operation costs, NT can save significantly the time with seedbed preparation compared with CT. However, yield variably with NT still remains a major concern among farmers. In general, greater economic returns and lower production cost of reduced tillage systems result in reduced energy and operator time requirements compared with CT (Smart and Bradford (1999)). Moving away from plowing could lead us to a reduction of approximately 50 to 70% in power and energy use. Depending on soil type and the exact method of cultivating stubble and seeding operations, corresponding fuel saving would range from 20 to 50 $l.ha^{-1}$ (El Titi (2003)).The objective of this research was to determine the effects of NT and CT systems on durum wheat yield, and to compare the energy and time requirement of these two tillage systems.

3. Methods

An experimental study under irrigation condition has been carried out at Lavalette experimental site of the Cemagref Institute (43° 40' N, 3° 50' E, altitude 30 m) in Montpellier in the South of France. The average annual rainfall is 823 $mm.year^{-1}$ (a 13-year average). Evapotranspiration calculated by Penman equation exceeds rainfall throughout the year under this Mediterranean climate (910 $mm.year^{-1}$). The tillage treatments consist of: conventional tillage (CT) and no-tillage (NT). For NT there were two plots, NT1 and NT2. According to the USDA soil classification CT and NT1 belong to the Loam class; whereas NT2 belongs to the sandy clay loam.

The crop rotation before 2004/2005 growing season was: (2000/2001) oat - corn, (2001/2002) oat - corn in CT and NT1 and oat - sunflower in NT2, (2002/2003) wheat - sorghum, (2003/2004) mixed of oat and vetch – sorghum. Each season, the first crop i.e. cover crop which was used to produce mulch in NT, was destroyed approximately 2 weeks before sowing the second crop i.e. main crop, by glyphosat. After a 4-year study on summer crops, durum wheat was sown for 2 crop seasons i.e. 2004/2005 and 2005/2006. For these two seasons there was not any cover crop in NT, but there were enough residues on the soil surface. At the beginning of 2004/2005 season, there was 2.8 and 1.5 $t.ha^{-1}$ in NT1 and NT2, respectively. For the 2005/2006 season, there was 1.12 and 2.14 $t.ha^{-1}$ in NT1 and NT2, respectively.

In CT plots, primary tillage for durum wheat with disc harrow was done to chop and bury the residues at the end of September. Secondary tillage with plough was performed later; Depth of the tillage was in average 25cm. By using a harrow, seedbed was prepared and sowing of durum wheat was performed. Durum wheat was sown in CT at the end of November. In NT plots sowing was performed with a specific seeder, namely Semeato. All agronomic practices were kept normal. Durum wheat was hand harvested at the end of June for yield and yield components from four 1-m rows per plot five times. Samples were dried and threshed and grain yields were calculated. Farm scale equipments were fixed and repeated on the same plot during the experiment period. Time requirement for each operation was recorded. The energy requirement for each tillage system was determined by measuring the tractor fuel consumption applying volumetric system. Energy equivalent of 38.7 $MJ.L^{-1}$ was taken for energy calculation (Cervinka (1980)). Statistical assessment of this experiment was performed by the analysis of variance (ANOVA). The Duncan's test was employed to compare the mean results, after a significant variation had been highlighted by ANOVA. The differences had been considered as significant if $P<0.05$.

4. Results

Yield of Mediterranean crops is widely variable due to the high seasonal variability of rainfall. There was a great variation in the total and monthly distribution of precipitation between two cropping seasons and the 13-year average. Total rainfall over the cropping season decreases 53 and 38% in 2004/2005 and 2005/2006, respectively, in comparison with the 13-year average. Rainfall during the pre- and post-anthesis growth period was lower too. Mean monthly temperature for the growing season was near the long-term average. However for 2004/2005, in the middle of the season, the air temperature decreases which can delay anthesis; and in June, air temperature was higher than the long-term average. In 2005/2006, the air temperature was lower than the long-term average which can delay and reduce crop emergence especially in NT where the soil temperature is lower than CT (Khaledian et al, (2006) [1]).

The amount of wheat grain yield and response to the tillage systems varied depending on the season. In the first growing season, grain yield was significantly higher in CT while no significant difference of grain yield was evident in both NT1 and NT2. In the second season, grain yield was lower in all treatments as compared with the first one. In CT, grain yield was significantly higher (Table 1). Similar to the first year of the experiment, no significant impact of soil texture was found in NT treatments.

The emerged plant number was significantly higher in CT than NT (results not showed here). The unfavorable effects of residues prevent proper seed placement and emergence. Better plant emergence in CT translated into higher grain yield. Lower yield under NT may have been associated with the development of cereal leaf beetle (Oulema melanopus L.); this pest can cause senescence during grain filling stage. The lower grain yield with NT might have been partly due to greater water loss or lower root development with NT (Khaledian et al., (2006) [2]).

Table 1 Average durum wheat yield of two growing seasons

Tillage system	Durum wheat 2004/2005 Mg.ha^{-1}	Durum wheat 2005/2006 Mg.ha^{-1}
Conventional tillage (CT)	6.65a	5.94a
No-tillage plot 1 (NT1)	3.06b	2.72b
No-tillage plot 2 (NT2)	3.44b	2.75b

Data within the same column followed by the same letter are not significantly different at $P<0.05$.

Table 2 shows fuel consumption, energy requirement, and the work duration of machinery used for crop establishment in each treatment. According to data presented in this table, it is evident that CT system was the greatest fuel and energy consumer. The greatest part of the energy, almost 45% or 696.6 MJ.ha^{-1} spent to plow, while NT system required only 270.9 MJ.ha^{-1}. In comparing these data to other sources, wide variations can be expected due to soil types, field conditions, working depth, etc. NT involved time saving of 87% for crop establishment, as compared to CT. The time required per hectare was reduced from 7.55 h to 1 h. Work rate was better in NT system. That parameter can be interesting when we have not lots of time to prepare the soil for sowing or in some cases one or more tractors and one or more workers can be saved.

Table 2 Energy and time requirement of two tillage methods to seedbed preparation (two years average).

Tillage	Fuel consumption L.ha^{-1}	Energy requirement MJ.ha^{-1}	Work duration h	Work rate ha.h^{-1}
Conventional tillage (CT)				
Plough	18	696.6	2.55	0.39
Disc-harrow	8	309.6	1	1
Harrow	8	309.6	3	0.33
Seeder	6	232.2	1	1
Total	40	1548	7.55	
No-tillage (NT)				
No-tillage seeder	7	270.9	1	1

In table 3 total energy and total work duration in both tillage systems over the season were shown. According to data presented for both seasons, it is evident that CT system was the greatest fuel and energy consumer. CT required 2631.6 and 2476.8 MJ.ha^{-1} for the first and second season, respectively. The maximum energy requirement in NT is 1431.9 MJ.ha^{-1} enabling thus saving 46% of energy. NT can reduce work duration too. Substitution of CT with NT enables us to save approximately 64% of work duration over the season.

Table 3 Total energy and total time requirement of two tillage methods of durum wheat.

Tillage	Fuel consumption L.ha^{-1}	Energy requirement MJ.ha^{-1}	Work duration h
2004/2005 season			
Conventional tillage (CT)	68	2631.6	9.75
No-tillage plot 1 (NT1)	35	1354.5	3.2
No-tillage plot 2 (NT2)	37	1431.9	3.4
2005/2006 season			
Conventional tillage (CT)	64	2476.8	9.35
No-tillage plot 1 (NT1)	37	1431.9	3.14
No-tillage plot 2 (NT2)	37	1431.9	3.14

Further comparison of tillage systems was done to better understand the energy requirement to obtain grain yield (Figure 1). To prepare the soil for sowing in CT, we need 233 and 261 MJ to produce 1 Mg of grain yield in the first and second season, respectively. While the maximum energy requirement in NT is just 100 MJ.

The results of this study indicated that grain yield of durum wheat was higher in CT system. Lower yield under NT may have been associated with the development of cereal leaf beetle (Oulema melanopus L.) and lower emerged plant number compared with CT. While, NT provided a considerable saving in work duration, fuel consumption and energy required for either crop production or seed bed preparation.

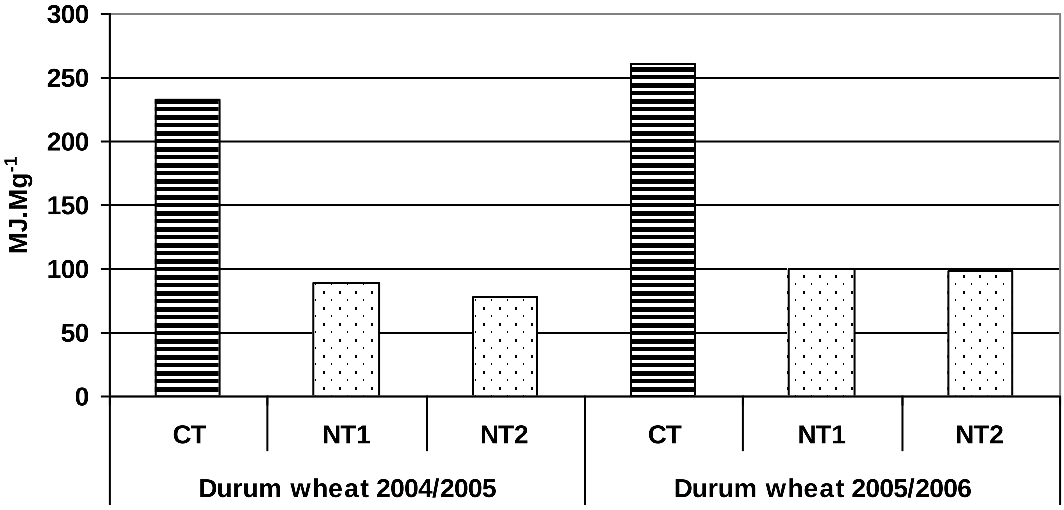

Figure 1: Energy requirement of two soil tillage methods to prepare the soil for sowing durum wheat with respect to energy requirement to obtain grain yield

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