تأثير نظم الفلاحة في إنتاجية محصول القمح وكفاءة استعمال مياه الأمطار تحت نظم الزراعة الجافة في شمال شرقي سورية

Effect of Tillage Systems on Wheat Productivity and Precipitation Use Efficiency Under Dry Farming System in the North East of Syria

Received 16 January 2011 / Accepted 21 February 2011

A. AL-Ouda

Leader of Conservation Agriculture Program, Plant Resources Dept., The Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD), Damascus, Syria. P.O. Box: 2440. Email: aymanalouda@ymail.com

المُلَخَّص

يُعد التراجع المستمر في معدل الهطول المطري، وخصوبة التربة من أهم مشاكل الإنتاج الزراعي في البيئات الجافة وشبه الجافة، ولاسيما تحت ظروف الزراعة المطرية. ويساعد تطبيق الممارسات الزراعية المناسبة في تحسين كفاءة استعمال الموارد الطبيعية، وإنتاجية الأنواع المحصولية، ومن ثمّ استدامة الإنتاج الزراعي واستقراره.

يُعد نظام الزراعة الحافظة من أهم السبل التكيفية (Adaptive approaches) للتخفيف من حساسية النظم البيئية الزراعية للتغير المناخي، وزيادة مقدرة هذه النظم على التكيف مع الجفاف الناجم عن التغير المناخي، حيث يساعد في زيادة إنتاجية مياه الأمطار الثمينة، وتحويل كل قطرة ماء إلى مادة جافة، الأمر الذي يُسهم في زيادة غلة الأنواع المحصولية المزروعة، وثباتيتها (Yield stability)، ومن ثمّ تقليل الفجوة الإنتاجية والغذائية، وتحقيق الأمن الغذائي والمائي. وتُسهم عملية إدارة فلاحة التربة، في وقف تدهور الأراضي الزراعية وتحسين نوعية التربة، حيث تعمل الفلاحة على تحطيم الكتل الترابية وزيادة وتيرة أكسدة المادة العضوية.

نُفذت تجربة حقلية في المنطقة الشمالية الشرقية من سورية، خلال ثلاثة مواسم زراعية متتالية (2008/2007 و 2009/2008 و 2010/2009)، بهدف دراسة تأثير ثلاثة نظم فلاحة مختلفة (الفلاحة التقليدية، والفلاحة بالديسك مرتين، والزراعة بدون فلاحة) في غلة محصول القمح الحبية المزروع في دورة زراعية مع البيقية. وضعت التجربة وفق تصميم القطاعات العشوائية الكاملة، وبثلاثة مكررات.

تمّ الحصول على أعلى غلة حبية عند استخدام نظام الزراعة بدون فلاحة (5057 كغ . هكتار$^{-1}$)، مقارنةً مع نظامي الفلاحة الآخرين (الفلاحة بالديسك مرتين، والفلاحة التقليدية) (4821، و 4683 كغ . هكتار$^{-1}$. على التوالي). وازداد عدد السنابل في وحدة المساحة، وعدد الحبوب في السنبلة بشكلٍ معنوي تحت ظروف الزراعة بدون فلاحة (841 سنبلة . م$^{-2}$، 48 حبة . سنبلة$^{-1}$)، ولكن لم يكن لنظام الفلاحة تأثير معنوي في وزن 1000 حبة. وكانت كفاءة استعمال مياه الأمطار الأعلى معنوياً تحت ظروف الزراعة بدون فلاحة (7.6 كغ . مم$^{-1}$. هكتار$^{-1}$)، بالمقارنة مع نظامي الفلاحة الآخرين (7.4، و 7.2 كغ . مم$^{-1}$.

هكتار-1 على التوالي).
ولوحظ أنّ محتوى التربة المائي كان الأعلى معنوياً تحت ظروف الزراعة بدون فلاحة بالمقارنة مع نظامي الفلاحة الآخرين، خلال مختلف مراحل النمو.

الكلمات المفتاحية: الزراعة الحافظة، إنتاجية المياه، مكونات الغلة الحبية، التغير المناخي، القمح.

Abstract

The key problem of agricultural production in arid and semi-arid environments is the steady decline in the annual precipitation and soil fertility, especially under rainfed conditions. Implementing of the suitable agricultural practices help in improvement the utilization efficiency of the natural resources, and crops productivity, and as consequence the stabilization and sustainability of the agricultural production.

Conservation agriculture (CA) system is considered as one of the most important adaptive approaches mitigating the vulnerability of the agro-ecosystems to climate change, and increasing the capability of the cropping systems to adapt with drought, where it helps to improve rainwater productivity (Precipitation use efficiency). This will help increasing the productivity of the precious rainwater by converting each rain drop into dry matter "More crop per drop", thereby increasing field crops' yield and yield stability, which are very important prerequisites for water and food security.

Management of the frequency and type of tillage can stop soil degradation and improve soil quality, where tillage disrupts soil aggregates and enhances the oxidation of soil organic matter.

A field experiment was conducted in the North East of Syria, during three consecutive growing seasons (2007/2008 – 2008/2009 – 2009/2010), to study the effect of three different tillage systems [No tillage (NT), double disc tillage (MT) and conventional tillage (CT)] on wheat crop yield, grown in a rotation with vetch. The experiment was laid in randomized complete block design (RCBD), with three replications.

The highest grain yield was obtained with no- tillage system (5057 Kg . ha^{-1}) compared with double disk and conventional tillage (4821, 4683 Kg . ha^{-1} respectively).

Heads density and number of kernels per head increased significantly with no-tillage (841 heads . m^{-2}, 48 Kernel . $Head^{-1}$), but tillage practices had no significant effect on thousand kernel weight. Precipitation use efficiency was significantly higher under no-till (7.6 $Kg.mm^{-1}$. ha^{-1}) compared with the other tillage systems (7.4 and 7.2 $Kg.mm^{-1}$. ha^{-1} respectively).

Soil moisture content was significantly higher under no-tillage compared with minimum and conventional tillage systems, at different growth stages.

Keywords: Conservation agriculture, Water productivity, Yield components, Climate change, Wheat.

Introduction

The Mediterranean region encompasses a wide variety of agricultural systems where water is one of the main keys to productivity. Yield of Mediterranean dry land crops is usually low and widely variable due to high seasonal variability of rainfall, with 85% of annual rainfall occurring during the months of October to April. This variation in rain causes 75% of the variation in wheat yield (Kun, 1988).

The response of cereals to conservation tillage practices is variable. Higher yields are usually attributed to increased water retention or utilization by the crop, especially in arid and semi-arid regions, while lower yields are attributed to greater disease, weed spreading and nitrogen (N), immobilization (McMaster et *al*., 2002).

It has been found that when soil moisture limited plant growth, grain yield was always equal or greater in conservation tillage than in mouldboard ploughing, and positively correlated with earlier/greater seedling emergence and autumn growth (López-Bellido et *al*., 1996). Some authors found that conservation tillage might reduce yield through decreased N availability (Rao and Dao, 1996). However, residue retention by conservation tillage such as shallow or reduced tillage practices can over the long term, improve soil structure and nutrients cycling.

Tillage is responsible for most soil degradation in the Mediterranean basin (Six et *al*., 1999). No-tillage (NT) accompanied with suitable crop rotation causes an increase in the microbial biomass carbon (MBC) compared to conventional tillage (CT) (Dick, 1992). This could be attributed to several factors (Smith and Elliott, 1990). Plant residues lower soil temperature, and increase water content, soil aggregation and C content compared to CT systems, whereas removal of crop residues exposes soil surface to direct sun light, increasing the rate of water loss by evaporation (Roman and Agnes, 2005). The accumulation of crop residues at the soil surface provides substrates for soil microorganisms, which accounts for higher microbial biomass carbon at the surface under no-till system. Soil microorganisms mediate mineralization of soil organic matter (SOM) and nutrients (Mrabet, 2000).

Soil aggregation and aggregate dynamics are important in facilitating water infiltration, providing adequate habitat and protection for soil organisms, supplying oxygen to roots, and preventing soil erosion (Denef et *al*., 2001; Franzluebbers, $2002_{a,b}$). The continued existence of large pores in the soil that favor high infiltration rates and aeration depends on the stability of larger aggregates. Soil aggregation is also one of the principle processes responsible for carbon sequestration in soils (Lal et *al*., 1997) and in turn, structural degradation provokes soil organic matter loss (Six et *al*., 1999). Soil management systems that leave more plant residues on the soil surface generally allow improvements in soil aggregation and aggregate stability (Carpendo and Mielniczuk, 1990).

Annual grain legumes, grown in rotation with cereal crops, can contribute to the total pool of N in the soil and improve yields of cereals (Herridge et *al*., 1995). Legumes with a large harvested N index can only make a marginal contribution to the N-status of the soil, even when non-harvested residue is incorporated in the soil (Carranca et *al*., 1999).

No-till practices that maximize conservation of the legume residue and carry over residue from previous crops are necessary for sustainable production of legume crops on highly erodible soil landscapes (Miller et *al*., 2002).

Continuous conventional tillage reduced soil organic matter, independently of the rotation (Mrabet et *al*., 2001). The crop rotation with legumes breaks the soil pathogen cycles, and restores fertility (Halvorson et *al*., 2000; Fischer et *al*., 2002).

When maintaining a sufficient level of residues at the surface, the soil is protected against erosion and its organic carbon may significantly increase (Mrabet, 2000).

Restoration of soil organic carbon (SOC) in arable lands represents a potential sink for atmospheric CO_2

(Lal and Kimble, 1997). Strategies for SOC restoration by adoption of recommended management practices include conversion from conventional tillage to no-till, increasing cropping intensity by eliminating summer fallows, using highly diverse rotations, introducing forage legumes and grass mixtures in the rotation cycle increasing crop production and C input into the soil (Hao et *al*., 2002).

In dry farming areas, the soil moisturecontent varies during the growth cycle. This variability is due to the annual climatic cycle and to tillage operations, which drastically alter both the total pore space and relationship between macro- and micro pores. The water content can also be affected by the amount of water consumed by the crop (transpiration). One of the main objectives of using cropping systems in semi-arid climates is to improve the efficiency of water use (Nielsen, 2002). Conservation tillage systems allow farmers to employ sustainable agricultural practices and enjoying at the same time savings in supplies (Davis and Payne, 1992).

Several experiments have demonstrated that different tillage systems applied to clayey soils help retain varying amounts of water in dry areas (Goss et *al*., 1978). Plants and crop in particular need relatively deep soil. The roots of wheat for instance, are known to reach depth of more than 1 m, although the greatest root density is found in the first 0.6 m (Wulfsohn et *al*., 1996). In intensive tillage systems that don't make use of subsoiling ploughs, a pan develops below the worked horizon, which alters both the hydrological and mechanical properties of the soil profile. This limits the depth of the root system (Josa-March et *al*., 2002). For this reason, the water content in this ploughing layer is of particular importance when growing cereals, as most root development occurs above this depth.

Farmers in the east and northeast region of Syria grow wheat which is rotated with legumes, such as vetch, lentil, and chickpea. Conventional tillage with mouldboard ploughing is commonly used in this region, but conservation tillage (minimum and no-tillage) has not yet been introduced. Crop response to tillage systems is diverse due to the complex interactions between tillage-induced soil edaphic, crop requirements, and weather.

The objective of this research work is to evaluate the impact of different tillage systems on wheat yield and yield components under rainfed conditions, and to assess the role of no-till in the improvement of precipitation use efficiency and soil moisture content.

Materials and Methods

A field experiment was conducted to determine the effects of three tillage systems on crop yield and yield components in durum wheat (*Triticum durum* var. *turgidum*) (Variety Acsad$_{1105}$), alternated with vetch (*Vicia sativa* L.) as a crop rotation during three growing seasons (2007 - 2010) on a clay–loam soil in the North East region, Syria (Amooda region, which belongs to Al-Khamishli city), in a farmer's field. The ten year average precipitation, temperature and relative humidity values for the experimental sites were 510 mm, 17 °C, and 75% respectively, the annual rainfall and the top soil's water content were monitored weekly using two permanent sets of TDR probes of 0.20 m in length, which were vertically installed in each plot.

The tillage treatments consisted of no- tillage (NT), double disc tillage (MT): two passes of disking; and conventional tillage (CT): mouldboard ploughing followed by two passes of tandem disk. All disc operations were performed to a depth of 8 - 10 cm.

All the tillage treatments were fixed and repeated on the same plot during the experiment period. Wheat was drilled at a rate of 200 kg ha^{-1} on 15 November. The distance between rows was 17 cm, and 10 cm between plants within the same row. The length of the raw was 10 m, where each plot (replicate) contained 40 rows), for the no-till treatment, while the same seeding rate was conventionally planted for the other tillage treatments. Vetch was drilled at a seeding rate of 120 kg ha^{-1} on 13 November. The distance between rows was 20 cm, and 10 cm between plants within the same row. The length of the raw was 10 m, where each plot (replicate) contained 40 rows), for the no-till treatment, while the same seeding rate was conventionally planted for the other tillage treatments. The planting was done by using a direct driller (Funkhouser), which is imported from Brazil.

Fertilizer applications were based on the recommended regional guidelines, and based on the soil analysis. Only a small amount of residues was left on the soil surface for the no-till treatment. In both tillage systems, crop residues were incorporated into the topsoil following the traditional practice in the area (in July or August). The crop residues remaining on the soil surface covered less than 30% of the soil surface.

Investigated traits

1. **Number of spikes per square meter:** Three random square meters from each plot/replicate, from each tillage treatment were harvested, and the total number of spikes was counted, and then divided by three to get the number of spike per m^2.
2. **Number of kernels per spike:** The fertile spikes were completely threshed, and the number of the grains was recorded by using an electric grain counter, then the resulting value was divided by the number of the spikes.
3. **1000-kernel weight (gm):** The 1000-kenel weight was computed based on the following equation:

   [(Grain weight) – (weight of impurities + weight of broken seeds)/ Total number of grains] × 1000

4. **Grain yield (Kg . ha^{-1}):** The average weight of grains per square meter was converted from gm. m^{-2} into Kg . ha^{-1}.
5. **Precipitation Use Efficiency (Kg . mm^{-1} . ha^{-1}):** Precipitation Use Efficiency (PUE) is defined as the ratio of grain weight to the total amount of water utilized by plant per land unit area. This trait is highly correlated with economic yield under dry farming system. It is calculated from the following formula:

   PUE = Grain weight per hectare / (annual precipitation – water lost by evaporation)

6. **Soil moisture content:** A compound soil sample was taken randomly from each plot, by means of a 4″ post hole auger, number of samples collected from each plot were representative of the plot area (5 samples). Ten gram of the air dry soil sample transferred to a weighed silica dish and put in an air oven at 105 ºC and dried for 16 hours. The soil sample then cooled in a desiccator and weighed. The loss in the weight represents the soil moisture content (Chopra and Anwar, 1991).

Experimental design and statistical analysis

The experiment was laid in a randomized complete block design (RCBD), and each treatment was repeated three times (replicates). The data were compiled, tabulated and statistically analyzed using M-Stat-C to compute the least significant difference (LSD) at 0.05 level of significance among the investigated tillage treatments.

Results and Discussion

Effect of tillage system on wheat grain yield

It has been found that the amount of wheat grain yield and response to the tillage systems varied depending on the amount and distribution of precipitation in each growing season. We have taken the average grain yield because the main purpose of the study was to compare the different tillage systems rather than the impact of the variation in the environmental factors. In general, grain yield was significantly higher (5057 Kg . ha^{-1}) in the no-tillage treatment compared to the double disc and conventional tillage treatments (4821 and 4683 Kg . ha^{-1} respectively). The grain yield ranking from the highest to the lowest was NT > MT > CT, indicating that grain production increased as tillage intensity decreased (Table 1). The lower grain yield with CT compared to the other two treatments might have been partly due to the greater water loss, due to exposure of the wet sub-soil layers to direct sunlight as a consequence of soil inversion, or due to lower root development.

Bradford and Peterson (2002) related wheat yield increase to improved physical, and moisture conditions. Campbell and Janzen (1995) related increased yields of wheat under NT to a reduction of soil moisture loss and increase of organic carbon at the surface horizons. Frequently, the literature shows that soils under a no-tillage system are more humid because of the accumulation of crop residues on the soils surface (Smith and Elliott, 1990) and that crop yield values are greater for no-tillage than for CT (Unger, 1990; Sakine, 2005). Rieger et *al*., (2008) showed that the wheat grain yield decreased by 3% under no-till compared to conventional and minimum tillage treatments, this was mainly attributed to fewer ears per unit land area and a significantly lower thousand-kernel weight.

Table 1. Average wheat grain yield and yield components under three tillage systems .

Tillage	Mean grain yield (Kg. ha^{-1})	Mean heads/square meter	Mean kernel per head	1000-kernel weight (g)
No tillage (NT)	5057 ^{a}	841 ^{a}	48 ^{a}	38.9 ^{a}
Double disk (MT)	4821 ^{b}	800 a ^{b}	48 ^{a}	35.8 ^{a}
Conventional tillage (CT)	4683 ^{c}	795 ^{b}	37 ^{b}	37.8 ^{a}
$L.S.D_{0.05}$	128	50	8.59	N.S

Several authors described a higher bulk density in soils under conservation tillage system (Moreno et *al*., 2000; Pelegrin et *al*., 1990; Hill et *al*., 1985) during the complete agricultural cycle. Increased bulk density is associated with soil compaction and changes in total porosity and pore geometry (Horton et *al*., 1989). Soils under conservation tillage systems appear to have a large properties of small pores (<15 µm radii) in relation to CT (Hill et *al*., 1985). This will increase the water retention capacity of the soil at any matric potential, and reduces the water availability for plants, and plants are consequently submitted to higher stress conditions under NT than these under CT and MT treatments.

Effect of tillage system on yield components

There was significant effect of tillage on head density (Table 1) and kernels per head when averaged across years. But tillage system did not significantly affect 1000-kernel weight (Table 1). Head density was significantly higher in the no tillage treatment (481 spikes . m^{-2}) than in the other treatments (800 and 795 spikes . m^{-2} respectively). This large number of heads under no-tillage might be attributed to better seedling establishment, increased tiller production, and tiller survival. Lower yields following disc and conventional tillage were mainly due to fewer heads .m^{-2} (Table 1).

Effect of tillage system on precipitation use efficiency

There was also an effect of tillage on wheat precipitation use efficiency. No tillage treatment reached a significantly higher precipitation use efficiency (PUE) level (8.6 Kg mm^{-1} ha^{-1}) than MT and CT (7.4 and 7.2 Kg mm^{-1} ha^{-1} respectively), as averaged across years, because of better water usage in the pre- anthesis period for semi-arid conditions, where plant usually suffer of drought and heat terminal stresses (Table 2).

Table 2. Mean precipitation use efficiency (PUE) of wheat under three tillage systems .

Tillage system	PUE (Kg mm^{-1} ha^{-1})
No tillage (NT)	8.6 [a]
Double disk (MT)	7.4 [b]
Conventional tillage (CT)	7.2 [b]
L.S.D $_{0.05}$	1.4

Tillage system and soil water content

The results showed that the amount of water in the top 0.2 m of the soil decreased significantly from one tillage system to another in the following sequences: NT > MT > CT (Fig. 1). These results indicate that the water content in the soil is associated with crop residue management. Crop residues reduce runoff, increase water infiltration and reduce soil evaporation. But in dry land farming these effects may be reduced or may even disappear if the crops don't produce enough residues, or if the residues are not left on the soil surface for weed control.

The superior effect of no-till in comparison to conventional tillage system was due to lower water evaporation from soil, which is often combined with enhanced soil water availability for plants in the rihizosphere (De Vita et *al*., 2007).

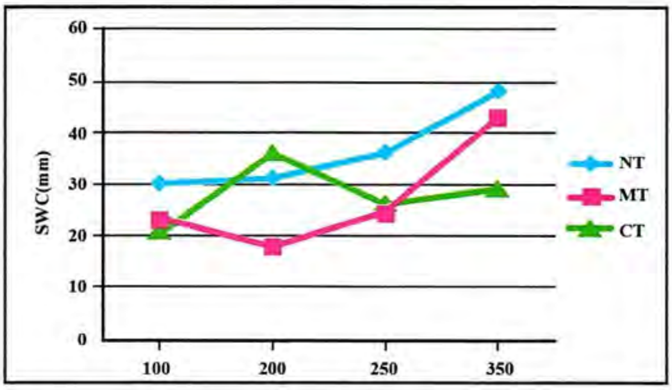

Figure 1. Monthly precipitation and top soil water content under three different tillage systems.

In general, increased yield and yield components under conservation tillage system compared to reduced and conventional tillage systems is highly attributable to improving the soil moisture content via reducing the rate of water loss by evaporation and thereby increasing the amount of water at the plant available tension, which will play a pivotal role in increasing precipitation use efficiency (Rainwater productivity) and reducing the resilience of the cultivated crops to terminal drought and heat stresses, indicating the relevance of conservation agriculture as a promising more productive, profitable and sustainable farming system.

References

Bradford, J.M. and G.A. Peterson. 2002. Conservation tillage. In: Summer, M.E. (Ed.), Handbook of Soil Science. CRC Press, Boca Raton, USA, : 247-269.

Campbell, C.A. and H.H. Janzen. 1995. Effect of tillage on soil organic matter. In: Farming for a Better Environment. SWCS, Ankeny, IA, USA : 9-11.

Carpendo, V. and J. Mielniczuk. 1990. Estado de agregacao e qualidade de agregadosde Latossolos Roxox, submetidos a diferentes sistemasde manejo. R. Bras. Ci. Solos 14: 99-105.

Carranca, C., A. de Narennes, and A. Rolston. 1999. Biological nitrogen fixation by faba bean, pea, and chickpea under field conditions, estimated by 15N isotop dilution technique. Eur. J. Agron. 10: 49-56.

Chopra, S.L. and J.S.K. Anwar 1991. Analytical Agricultural Chemistry, 4th edition, Kalyani Publishers, New Delhi-110 002.

Davis, D.B. and D. Payne. 1992. Exploitation of physical soil properties. In: Wild, A. (Ed.), Soil Conditions and Plant Development According to Russell, Ediciones Mundi-Prensa, Madrid, Spain :431-470.

Denef, K., J. Six, H. Bossuyt, S.D. Frey, E.T. Elliott, R. Merckx and K. Paustian. 2001. Influence of dry-wet cycles on the interrelationship between aggregate, particulate organic matter, and microbial community dynamics. Soil Biol. Biochm. 33: 1599-1611.

Dick, R.P. 1992. A review: long-term effects of agricultural systems on soil biochemical and microbial parameters. Agric. Ecosyst. Environ. 40: 25-36.

De Vita, P.; E. Di Paolo, G. Fecondo, N. Di Fonzo and M. Pisanta .2007. No-tillage and conventional tillage effects on durum wheat yield, grain quality and soil moisture content in Southern Italy. Soil and Tillage Research, Volume 92 (1-2): 69 – 78.

Fischer, R.A., F. Santiveri, and I.R. Vidal. 2002. Crop rotation, tillage and crop residue management for wheat and maize in the sub-humid tropical highland. I. Wheat and legume performance. Field Crops Res. 79: 107-122.

Franzluebbers, A.J. 2002a. Soil organic matter stratification ratio as an indicator of soil quality. Soil Till. Res. 66: 95-106.

Franzluebbers, A.J. 2002b. Water infiltration and soil structure related to organic matter and its stratification with depth. Soil Till. Res. 66: 197-205.

Goss, M.J., K.R. Howse, and W. Harris. 1978. Effect of cultivation on soil water retention and water use by cereals in clay soils. J. Soil Sci. 29: 475-488.

Hao, Y., R. Lal, L.B. Owens, R.C. Izaurralde, W.M. Post and D.L. Hotherm. 2002. Effect of cropland management and slop position on soil organic carbon pool at the Appalachian Experimental Watersheds. Soil Till. Res. 68:133-142.

Halvorson, A.D., A.L. Black, J.M. Krupinsky, S.D. Merill, B.J. Wienhold and D.L. Tanaka,. 2000. Spring wheat response to tillage system and nitrogen fertilization in rotation with sunflower and winter wheat. Agron. J. 92: 136-144.

Harridge, D.F., H. Marcellos, W.L. Felton, G.L. Turner and M.B.Peoples. 1995. Chickpea increase soil-N fertility in cereal systems through nitrate sparing and N2 fixation. Soil Biol. Biochem. 27: 545-551.

Hill, R.L., R. Horton, and R.M. Cruse. 1985. Tillage effect on soil water retention and pore-size distribution of two mollisols. Soil Sci. Soc. Am. J. 49: 1265-1270.

Horton, R., R.R. Allmaras and R.M. Cruse. 1989. Tillage and comparative effects on soil hydraulic properties and water flow. In: Larson, W.E. (Ed.), Mechanics and Related Processes in Structured Agricultureal Soils. Kluwer Academic Publications: 187-203.

Josa-March, R., A. Hereter-Quintana, I Queralt and A. Verdu-Gonzalez . 2002. Efectos de una precipitacion intense sobre los suelos compartaniento del horizonte Ap. In: Perez-Gnzalez, A.; Vegas, J and machado, M.J. (eds.), Aportaciones a la Geomorfologia de Espana en el Inocio del Tecer Milenio, vol. 1. Instituto Geologico de Espana, Serie Geologia, Madrid, Spain: 277-282.

Kun, E. 1988. Cool Climate Cereals, Textbook. University of Ankara, Turkey, Pub. No. 299.

Lal, R., and J.M. Kimble. 1997. Conservation tillage for carbon sequestration. Nutr. Cycl. Agroecosyst. 49: 243-253.

Lal, R., J.M. Kimble and R.F. Follett. 1997. Pedospheric processes and the carbon cycle. In: Lal, R.; Blum, W.H.; Valentine, C.; Stewart, B.A. (eds.), Methods for Assessment of Soil Degradation. CRC Press, Boca Raton: 1-8.

Lopez-Bellido, L., M. Fuenes, J.E. Castillo, F.J. Lopez-Garrido. and E.J. Fernandez. 1996. Long-term tillage, crop rotation, and nitrogen fertilizer effects on wheat yield under Mediterranean conditions. Agron. J. 88: 783-791.

Mc-Master, G.S., D. B Palic and G.H. Dunn. 2002. Soil management alter seedling emergence and subsequent autumn growth and yield in dry land winter wheat-fallow systems in the central Great Plains on a clay loam soil. Soil Till. Res. 65: 193-206.

Miller, P.R., B.G. McConkey, J.A. Staricka, G.W. Clyton, S.A. Brandt, A.M. Johnson, G.P. Lanfond, B.G. Schatz, D.D. Baltensperger and K.A. Nelly. 2002. Pulse Crop Adaptation in the Northern Great Plains. Agron. J. 94:261-272.

Moreno, F., F. Pelegrin, J.E. Fernandez, J.M. Murillo and I.F. Giron. 2000. Influence of climate conditions on soil physical properties under traditional and conservation tillage. In: Horn, R.; van den Akker, J.J.H. and Arvidsson, J. (Eds.), Subsoil compaction. Distribution, Processes and consequences, Advances in Geology, vol. 32. Reiskirchen, : 295-304.

Mrabet, R. 2000. Long-term no-tillage influence on soil quality and wheat production in semi-arid Morocco. In: Morrison, J.E.(Ed.). Proceedings of the 15th ISTRO Conference: Tillage at the threshold of the 21st Century: Looking Ahead, Fort Worth, TX, USA, 2-7 July 2000.

Mrabet, R., N. Saber, A. El-Brahli, S. Lahlou and F. Bessam. 2001. Total, particulate organic matter and structural stability of a calcixeroll soil under different wheat rotations and tillage systems in a semi-arid area of Morocco. Soil and Tillage Research 57: 225-235.

Nielsen, D.C. 2002. Water use efficiency, enhancing. In: Lal, R. and Ahuja, L. (Eds.), Encyclopedia of Soil Science. Marcel Dekker Inc., New York: 1399-1402.

Pelegrin, F., F. Moreno, J. Martin-Aranda and M. Camps. 1990. The influence of tillage methods on soil physical properties and water balance for a typical crop rotation ISW Spain. Soil Till. Res. 16: 345- 358.

Ramon, J. and H. Agnès. 2005. Effect of tillage systems in dryland farming on near-surface water content during the late winter period. Soil and Tillage Research 82: 173-183.

Rao, S.C. and T.H. Dao. 1996. Nitrogen placement and tillage effect on dry matter and nitrogen accumulation and redistribution in winter wheat. Agron. J. 88: 365-371.

Rieger, S.; W. Richner; B. Streit; E. Frossard and M. Liedgens 2008. Growth, yield and yield components of winter wheat and the effects of tilling intensity, preceding crops and N fertilization. European Journal of Agronomy, Volum 28(3): 405 – 411.

Sakine, O. 2005. Effects of tillage on productivity of a winter wheat-vetch rotation under dryland Mediterranean conditions. Soil and Tillage Research 82: 1-8.

Six, J.; E.T. Elliott. and K. Paustian. 1999. Aggregate and soil organic matter dynamics under conventional and no-tillage systems. Soil Sci. Soc. Am. J. 63: 1350-1358.

Smith, J.L., G.H and L.F. Elliott. 1990. Tillage and residue management effects on soil organic matter dynamics in semi-arid regions. In: Sing, R.P.; Parr, J.F. and

Stewart, B.A. (Eds.), Dryland Agriculture: Strategies for Sustainability. Advances in Soil Sciences, vol. 13. Spring-Verlag, New York, USA: 69-88.

Unger, P.W. 1990. Conservation tillage systems. In: Sing, R.P.; Parr, J.F. and Stewart, B.A. (Eds.), Dryland Agriculture: Strategies for Sustainability. Advances in Soil Sciences, vol. 13. Spring-Verlag, New York, USA: 27-68.

Wulfsohn, D., Y. Gu, A. Wulfsohn and E.G. Mojlaj. 1996. Statistical analysis of wheat root growth patterns under conventional and no-till systems. Soil Till. Res. 38: 1-16.