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The role of improved regional cultural practices in the implementation of conservation agriculture in Arab countries

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Abstract. The key problem of agricultural production in arid and semi-arid environments is the steady decline in water availability and soil fertility, which are closely correlated to duration of soil use. Implementing agricultural practices that reduce soil degradation has the potential to increase agricultural sustainability and soil conservation. Managing the frequency and type of tillage can stop soil degradation and improve soil quality. Formation and stabilization of macro aggregates are important for protecting and maintaining soil organic matter. Tillage disrupts soil aggregates exposing organic matter to microbial degradation. These changes in structure can affect soil water temperature, aeration, equilibrium of reactions, and increase soil erosion. Implementing improved agricultural practices (crop rotation, tillage system, improved varieties, mulching, seeding rate, weed control, etc.) can change soil habitat by affecting nutrient status, depth of rooting, amount and quality of residues aggregation/microbial habitat and can stimulate soil microbial diversity and activity. Soil disturbance can cause significant modifications of soil habitat, which affect the microbial community. An experiment was conducted to determine the effect of three tillage systems on crop yield in a winter wheat-vetch rotation during three year growing seasons. The highest grain yield was obtained with shallow tillage treatment compared with double disk and conventional tillage. Heads density and head length increased significantly with shallow tillage, but tillage practices had no significant influence on thousand kernel weight. In another experiment, soil moisture content was significantly higher under no-tillage compared with minimum and conventional tillage systems. However, this increased quantity of water did not denote increased wheat production.

Keywords. No-tillage – Conventional tillage – Shallow tillage – Minimum tillage – Crop rotation.

Rôle des pratiques culturales améliorées sur la mise en œuvre de l'agriculture de conservation dans les pays arabes

Résumé. *Le problème clé de la production agricole dans les milieux arides et semi-arides est la baisse constante de la disponibilité de l'eau et la fertilité des sols, qui sont étroitement corrélées à la durée d'utilisation du sol. La mise en œuvre de pratiques agricoles qui réduisent la dégradation des sols, a le potentiel d'accroître la durabilité agricole et la conservation du sol. Gérer la fréquence et le type de travail du sol peut arrêter la dégradation du sol et améliorer sa qualité. La formation et la stabilisation des macro-agrégats sont importantes pour protéger et maintenir la matière organique du sol. Le travail du sol perturbe l'agrégation du sol exposant la matière organique à la dégradation microbienne. Ces changements de la structure affectent la température de l'eau du sol, l'aération, l'équilibre des réactions, et augmentent l'érosion du sol. La mise en œuvre des pratiques agricoles améliorées (rotation des cultures, travail du sol, variétés améliorées, paillage, densité de semis, désherbage, etc.) peut modifier le milieu sol en agissant sur le statut des éléments nutritifs, la profondeur d'enracinement, la quantité et la qualité des résidus support de la vie microbienne et peut stimuler la diversité et l'activité microbienne. Les perturbations du sol peuvent causer d'importantes modifications du milieu sol, qui influe la communauté microbienne. Une expérience a été menée afin de déterminer les effets de trois systèmes de travail du sol sur le rendement des cultures dans une rotation blé d'hiver-vesce pendant trois campagnes agricoles. Le rendement le plus élevé a été obtenu sous labour superficiel relativement au* cover crop *et au labour conventionnel. Le nombre d'épis et la longueur de l'épi augmentent significativement sous labour superficiel, par contre le travail du sol n'a aucun effet significatif sur le poids de mille grains. Dans une autre expérience, l'humidité du sol était significativement plus élevée sous semis direct, avec cependant aucun effet significatif sur la production de blé.*

Mots-clés. *Non labour – Travail conventionnel – Travail superficiel – Rotation.*

I – Introduction

The Mediterranean region encompasses a wide variety of agricultural systems where water is probably one of the main keys to productivity. Yield of dry land Mediterranean 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). Cereal grain response to conservation tillage practices is variable (Rao and Dao, 1996). 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 infestations, 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 mould board ploughing, and positively correlated with earlier/greater seedling emergence and autumn growth (López Bellido *et al.,* 1996). Some authors found that conservation tillage might diminish 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. Soil erosion is a perennial concern in many semi-arid regions with conventional tillage-based systems. Tillage is responsible for most soil degradation in the Mediterranean basin (López Bellido, 1996). No-tillage (NT) accompanied with suitable crop rotation causes an increase in the microbial biomass carbon (MBC) compared to conventional tillage (CT). This could be attributed to several factors. 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. The accumulation of crop residues at the soil surface provides substrates for soil microorganisms, which accounts for higher MBC at the surface under NT.

Soil microorganisms mediate mineralization of soil organic matter (SOM) and nutrients. The microbial biomass is a small but important reservoir of nutrients (C, N, P and S) and many transformations of theses nutrients occur in the biomass (Dick, 1992). Currently, there is a strong interest in sequestration of carbon in soils as a means to help decrease atmosphere CO_2 and a side benefit is the improvement of soil quality and plant productivity (Burras *et al.,* 2001; Sa *et al.*, 2001). 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, 2002a,b). Erodibility of soils is directly related to aggregate stability. 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 (Carpenedo and Mielniczuk, 1990). Annual grain legumes, grown in rotation with cereal crops, can contribute to the total pool of N in the soil and improved yields of the 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). It is well accepted that a rotation or cropping system helps in diversifying crops, maintaining higher yields, reducing disease severity and increasing diversity of pools and microbial communities. 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 (Fisher *et al.,* 2002; Halvorson *et al.,* 2000). Straw mulch can affect nodulation and N_2-fixation indirectly by affecting the soil physical chemical, and biological environment, although Horn *et al.* (1996a) indicated that N_2 fixation is not significantly affected by the tillage system.

When maintaining a sufficient level of residues at the surface, the soil is protected against erosion and its organic carbon may significantly increase (Mrabet and Bouzza, 2000). In order to reduce soil surface drying significantly, Mrabet (1997) recommended the maintenance of 60-80% of the produced residues at the soil surface. 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 water content in soil 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 whilst at the same time enjoying savings in supplies (Davis and Payne, 1992). Different tillage systems use specific tools at different intensities, which affect the structural characteristics of the profile in different ways, at both a superficial and a deeper level.

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 crops 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 sub soiling ploughs, a pan develops below the worked horizon, which alters both the hydrological and mechanical proprieties 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 will occur 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 mould board 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 ecological constraining factors for spreading no tillage in the arid and semiarid region are: low precipitation with low biomass production, short growing seasons, sandy soils with tendency to compaction, and soils at risk of water logging. The socio-economic-limiting factors are: strong demand for crop residues as forage for livestock, poorly developed infrastructure (market, credit extension services), distinct market preference for one crop (e.g. wheat, cotton). If a region is not suitable for implementing no-tillage the second best choice is minimum tillage. The objective of this study is to determine the effect of three tillage systems on crop yield in a winter wheat-vetch rotation during three year growing seasons.

II – Materials and methods

Two experiments were conducted to determine the effects of three tillage systems on crop yield and yield components in a winter wheat alternated with vetch or lentil as a crop rotation during 3 years growing seasons on a clay-loam soil in the North East region, Syria. The 10-yr average precipitation, temperature and relative humidity values for the experimental sites were 510 mm, 17℃, and 75% respectively for the first exper iment, while for the second experiment, 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 disk 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 rotated by vetch for the first experiment, and by lentil for the second one. Wheat was drilled at a rate of 200 kg ha^{-1} on 15 November, while vetch and lentil were drilled at a rate of 120 and 80 kg ha^{-1} respectively on 13 November, and 25 November respectively. Fertilizer applications were based on the recommended regional guidelines. Only a small amount of residues was left on the soil surface. 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.

III – Results and discussion

1. Experiment I

A. 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. In general, grain yield was significantly higher in the shallow tillage treatment compared to the double disk and conventional tillage treatments. The grain yield ranking from the highest to the lowest was NT > MT > CT, indicating that grain production increased as tillage decreased (Fig. 1). The lower grain yield with CT compared to the other two treatments might have been partly due to the greater water loss, or 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.

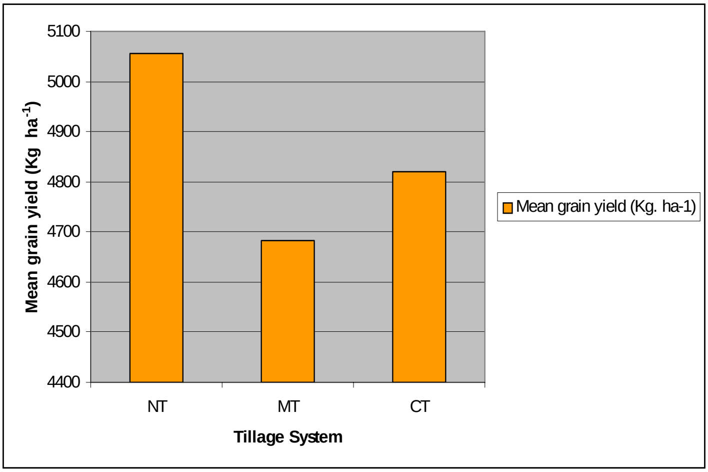

Fig. 1. Effect of different tillage systems on wheat grain yield.

B. Effect of tillage system on yield components

There was significant effect of tillage on head density (Fig. 2) and kernels per head (Fig. 3) when averaged across years. But tillage system did not significantly affect 1000-kernel weight (Fig. 4). Head density was higher in the no tillage treatment than in the other treatments. This large number of heads might be attributed to better seedling establishment, increased tiller production, and tiller survival. Lower yields following disk and conventional tillage were mainly due to fewer heads m^{-2} (Fig. 2). Tanaka (1989) concluded that more heads were produced as tillage was reduced.

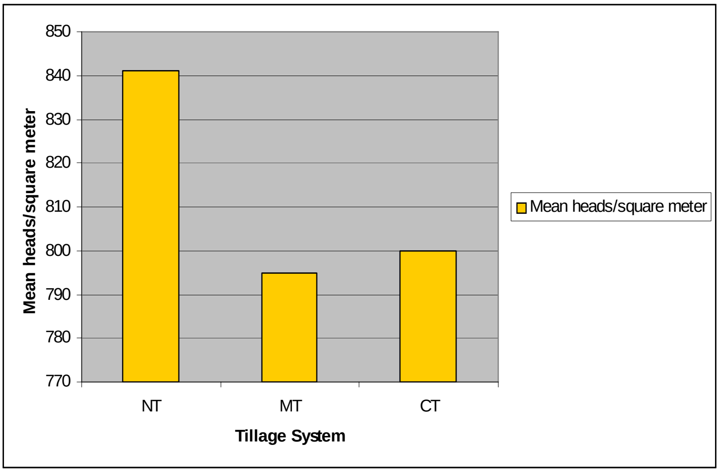

Fig. 2. Effect of different tillage systems on heads per square meter.

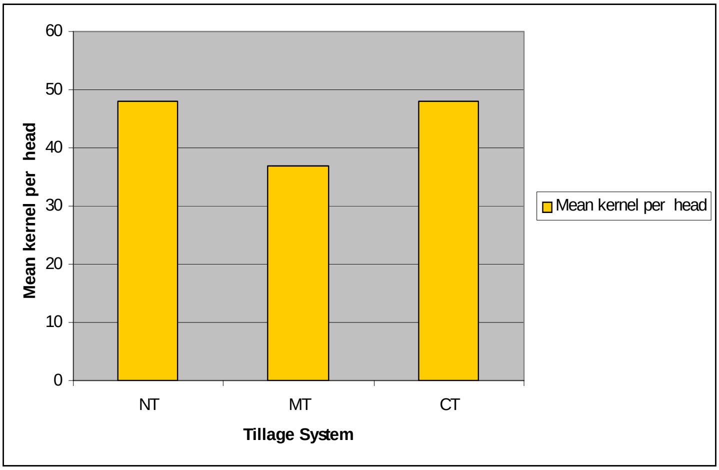

Fig. 3. Effect of different tillage systems on kernels per head.

There was also effect of tillage on wheat precipitation use efficiency. No tillage treatment reached a significantly higher precipitation use efficiency (PUE) level than CT, 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 (Fig. 5).

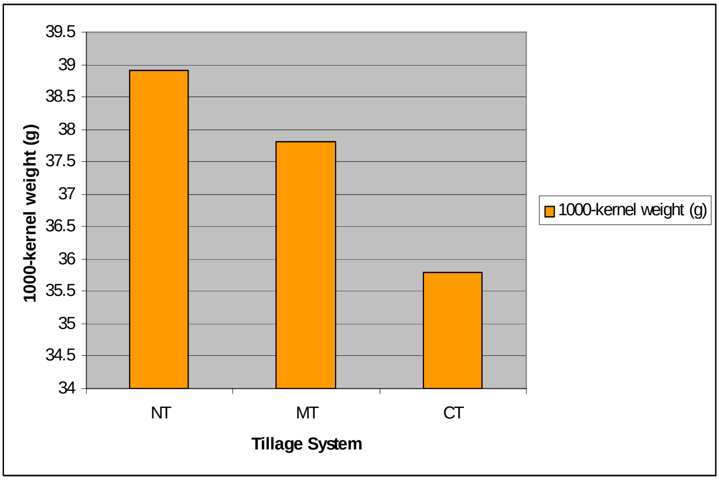

Fig. 4. Effect of different tillage systems on 1000-kernel weight.

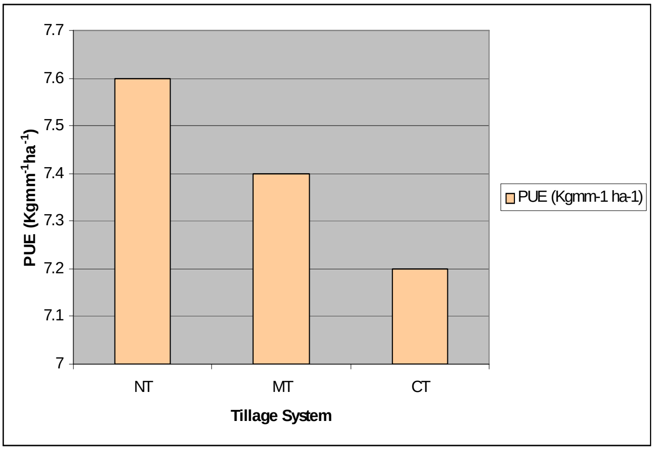

Fig. 5. Effect of different tillage systems on precipitation use efficiency (PUE).

C. Effect of tillage systems on wheat tiller per plant, head length and plant height and emergence

It was also found that plants of wheat were significantly taller on the NT plots than the CT and MT plots. It appears that wheat plants with an appropriate vegetative growth (source size) produce higher yields due to increasing number of developed heads, which led to larger heads with a higher number of grains (Fig. 6).

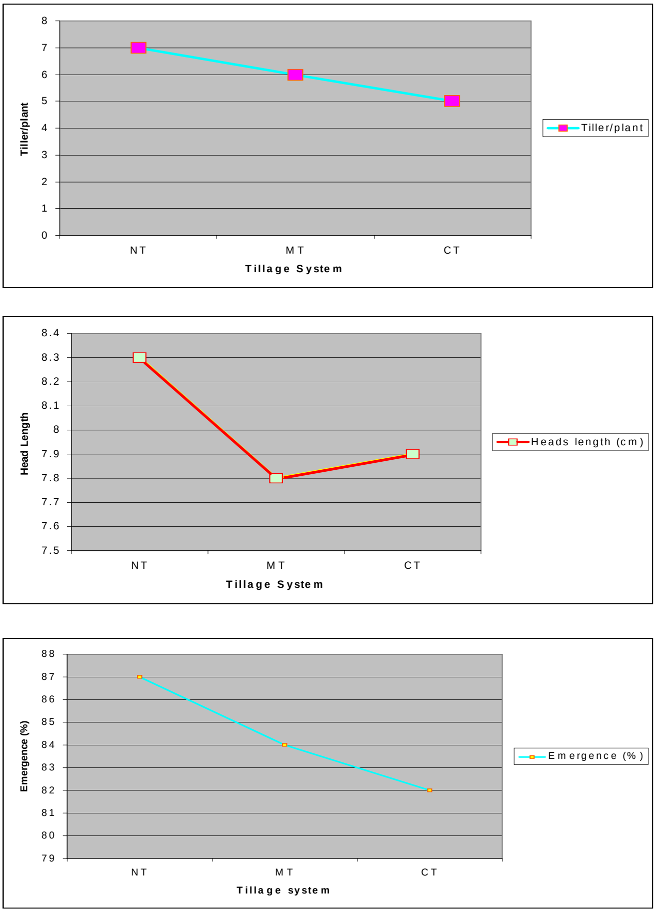

Fig. 6. Effect of three tillage systems on tiller/plant $^{-1}$, plant height, head length, and emergence.

2. Experiment II

A. Tillage system and crop yield

It has been found that NT crop (wheat) production was lower than for the other two treatments (Fig. 7). 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). Several authors describe 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 Mm 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 under CT and MT treatments.

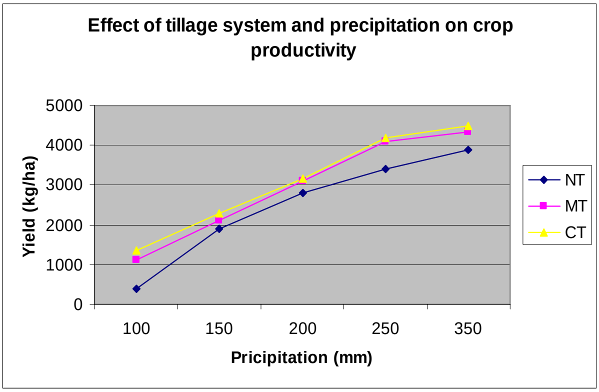

Fig. 7. Effects of different tillage systems and precipitation on wheat grain yield.

Lower wheat yields under reduced tillage systems (NT and MT) might be attributed to higher bulk density in soils under conservation tillage systems. Increased bulk density is associated with soil compaction and changes in total porosity and pore geometry. Soils under reduced tillage system appear to have higher proportion of small pores (<15 µm radii) in relation to conventional one. This will increase WRC and reduces the water availability, and plants are consequently submitted to water stress.

B. Tillage system and soil water content

It was found 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. 8). 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.

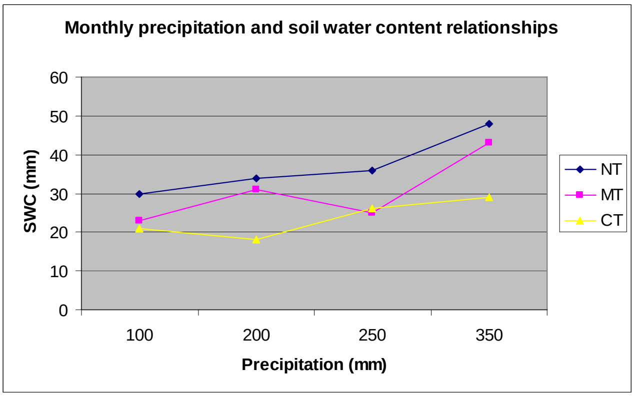

Fig. 8. Monthly precipitation and top soil water content under three different tillage systems.

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