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No-tillage technology: Research review of impacts on soil quality and wheat production in semiarid Morocco

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SUMMARY – Morocco, an agriculture-dependent country, is facing various challenges: soil deterioration, productivity decline, and structural drought. The main causes of these threats are unnecessary tillage and over-grazing. In fact, these practices have induced desertification and a recession of the harmony between soils and crops. Hence, it is of paramount importance to revitalise this harmony and reverse this decline in order to encourage a transition towards sustainable agricultural development. This paper aims at providing up-to-date information on various impacts of no-tillage (NT) technology on soil and crop attributes from on-going long-term experiments. Two decades of research have shown improved yielding of wheat without need of tillage and seedbed preparation. NT was also found to positively affect and hence ameliorate soil quality, particularly soil organic matter, aggregation, water and nutrient availability.

Key words: No-tillage, sustainability, soil quality, wheat.

RÉSUMÉ – *"La technologie de non labour : Résultats des recherches concernant les impacts sur la qualité du sol et la production de blé dans les zones semi-arides du Maroc". L'agriculture marocaine subit des défis majeurs, la détérioration des sols, le déclin de la production et la sécheresse. Les causes principales de ces menaces sont le labour et le surpâturage. En fait, ces pratiques ont induit la désertification et une récession de l'harmonie entre les sols et les cultures. Par conséquent, il est d'importance primordiale de revitaliser cette harmonie et de renverser ce déclin afin d'encourager une transition vers un développement agricole durable. Cet article vise à fournir des informations sur certains impacts de la technologie du semis direct ou non-labour sur certains attributs du sol et sur la culture du blé à partir d'expériences à long terme. Deux décennies de recherche ont montré que le rendement du blé est amélioré sans besoin de labour ou de préparation du lit de semences. Cette technologie a aussi amélioré la qualité du sol, particulièrement la matière organique, l'agrégation et la disponibilité en eau et en éléments nutritifs.*

Mots-clés : *Semis direct, durabilité, qualité du sol, blé.*

Introduction

In Morocco, tillage, straw exportation and grazing are major causes of soil quality deterioration and declining wheat yields. Hence, new alternatives are needed to curb these trends. No-tillage system (NT) represents the most dramatic change in soil management in modern history of agriculture (Bradford and Peterson, 2000). It is recognised that NT has a great economic value and wheat production can be achieved with minimum erosion risk. NT was introduced in North America and is now widely used in Latin America and Australia. NT system continues to escalate as an issue of wide public concern and debate in the Mediterranean basin (Boisgontier, 1991; Carvalho and Basch, 1994; López-Bellido *et al.*, 1996; Pala *et al.*, 2000; Hernanz *et al.*, 2002). In semiarid Morocco, NT research started in 1983 (Bouzza, 1990). Much of the research that forms the foundation for understanding the influence of NT on soil quality, water conservation and wheat productivity has been conducted in two experimental stations (Sidi El Aydi, with an average rainfall of 358 mm and a Vertic Calcixeroll, and Jemaat Shaim, with an average rainfall of 270 mm and a Typic Chromoxerert). In this paper, NT impacts on wheat yield and selected soil quality parameters are reviewed from these long-term trials.

Water conservation

Mrabet (1997) found that residues on the soil surface reduced evaporation. To reach soil moisture at wilting point, a non-tilled surface needed on average 32 days, while moldboard plow, chisel plow, rotavator and disking needed only 8, 21, 17 and 18 days, respectively. Bouzza (1990) found that water storage efficiency is 1.5 times higher under chemical fallow than under clean fallow (Table 1). With chemical fallow, an additional 80 to 100 mm (an average of 84 mm) were stored in the soil profile.

Table 1. Storage efficiency and amount of stored water for different types of fallow in semiarid Morocco (Bouzza, 1990)

Type of fallow	Fallow storage efficiency† (%)	Amount of stored water†† (mm)
Chemical	28	84
Clean	18	54
Stubble mulch	21	63
Weedy	10	30

†Calculated as the ratio of stored water and the rainfall received during fallow period.
††Amount of water stored in 1.2 m profile.

Carbon sequestration

By changing the soil tillage from a plowing system to a NT system, nearly all physical, chemical, biological and biochemical properties of the soil are affected. Soil organic carbon (SOC) is the most reported soil attribute from tillage experiments since it is the keystone soil quality indicator, being inextricably linked to other soil properties. Generally, there is a trend towards a stratification of SOC at the surface under NT, without any effect on lower horizons (Mrabet, 2002c). At 0-25 mm, SOC increased from 5.62 to 7.21 t/ha under NT, after 4 and 11 years. At the same horizon, SOC level did not change under conventional tillage after the same periods (Bessam and Mrabet, 2003). These authors reported that NT soil has sequestered 3.5 and 3.4 t/ha of SOC more than conventional tillage in the 0-200 mm horizon, after 4 and 11 years, respectively. These findings are illustrated in Fig. 1. Over the 11 years, the 0-200 mm horizon gained 13.6 and 3.3% of its original SOC under no-till and conventional till, respectively (Mrabet *et al.*, 2001b). The NT improvement of SOC is also proportional to residue level (Fig. 2). Figure 2 shows that the increase in residue level helped sequester the greatest amount of C in the top 50 mm of soil, a lesser amount in the 50-100 mm depth and no significant amount in the 100-200 mm.

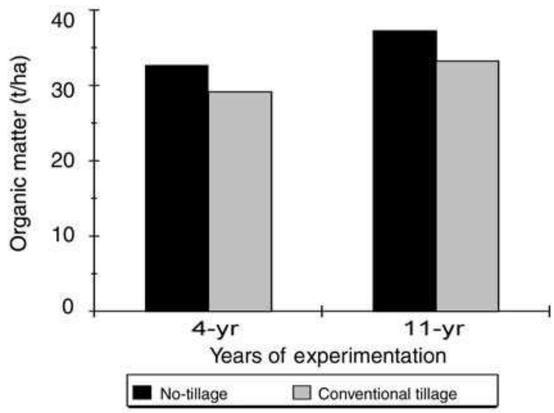

Fig. 1. Soil organic carbon in the 0-200 mm horizon as affected by tillage system and time (Bessam and Mrabet, 2003).

Nutrient availability

Retention of crop residues and lack of soil disturbance under NT affect nutrient cycling and availability. Consequently, fertilizer requirements of wheat grown with NT have also received attention (Mrabet *et al.*, 2001a). These authors found that NT helped to conserve more nitrogen, and resulted in increased extractable phosphorus and exchangeable potassium concentrations in the upper root-zone. There is also a slight acidification of the soil at the surface, which can increase availability of nutrients to wheat. Saber and Mrabet (2002) reported an increase in the labile fraction of soil organic matter (particulate organic matter) under NT compared to conventional tillage. This soil organic matter fraction also contributes to nutrient cycling and availability.

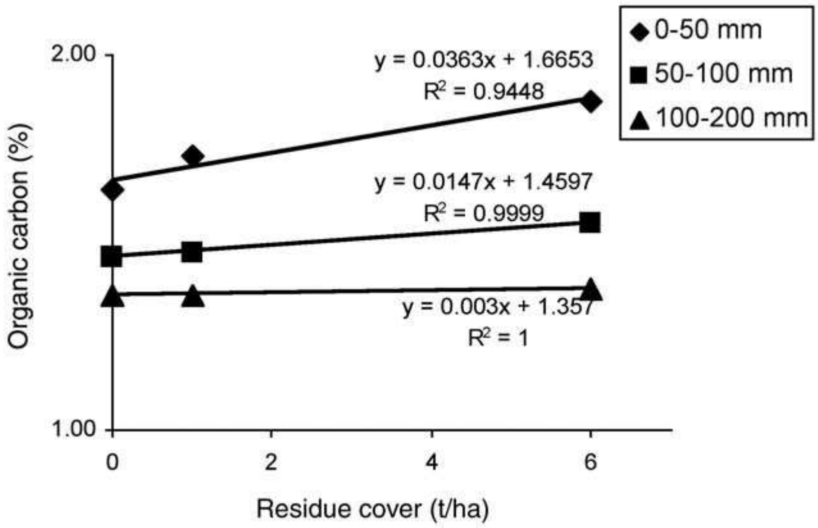

Fig. 2. No-tillage residue cover effect on organic carbon content in three horizons of a Calcixeroll soil (unpublished data).

Soil aggregate stability

The surface of Moroccan soils is vulnerable to erosion by water and wind due to its low aggregation and organic matter content. Independently of the season, results showed that the proportion of more stable aggregates in the soil surface (seed-zone) is greater in NT than conventional tillage (Fig. 3). It was also found that aggregate stability increases with depth as residue cover increases in NT (Fig. 4). The development of a good structure at the surface improves water entry, movement and distribution and has positive effects on evaporation and erosion control. The aggregation also reflects that SOC is conserved and protected and allows soil organic matter to function as a reservoir of plant nutrients and energy.

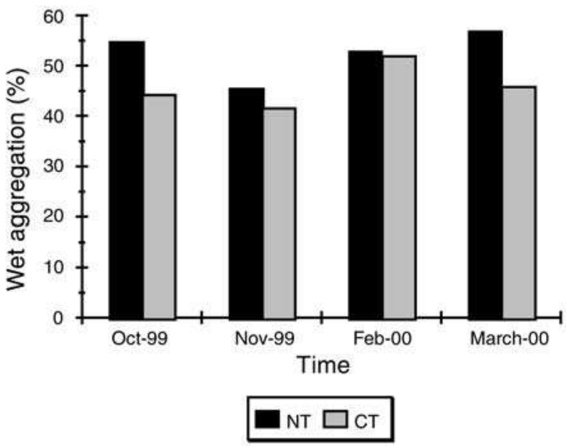

Fig. 3. Aggregate stability as a function of tillage and season (Mrabet, 2002c). NT = no-tillage and CT = off-set disking.

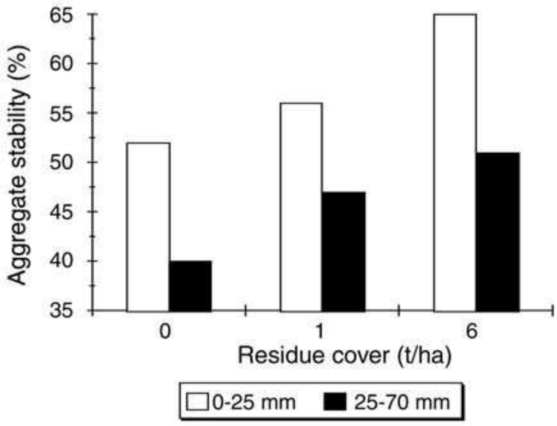

Fig. 4. No-tillage residue cover effect on aggregate stability at two surface horizons of a Calcixeroll soil (Lahlou and Mrabet, 2001).

The marked differences in soil organic matter, particulate organic matter and aggregate stability between NT and conventional tillage may be attributed to considerable biological activity (including the activities of fungus and fauna). These biological activities increase protection of soil organic matter and its particulate fraction, moderate moisture and temperature fluctuations and prevent the soil from adverse effects of external factors.

Wheat productivity

As a result of long-term trials at the research stations, It has been found that average wheat yields with use of no-tillage systems are higher than those observed with other tillage systems (Bouzza, 1990; Mrabet, 2000). Mrabet (2002a) stated that in spite of a somewhat slower rate of growth of wheat in the early growing season, final yields were higher under NT. These data were supported by those found in a farmer's field over a five-year period (Mrabet, 2002b; Fig. 5). Mrabet (2002a) reported that 30% of straw produced under no-tillage could be removed without jeopardising wheat performances. The importance of fallowing is also well shown from Table 2 in both research stations. Taking into account the potential savings in machinery, labour and fuel, NT will give a net economic benefit.

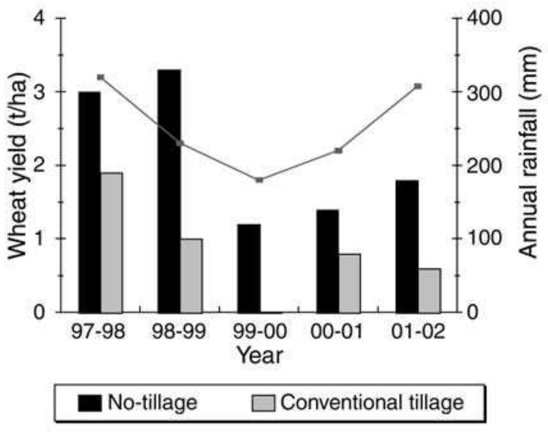

Fig. 5. Tillage effect on wheat production in a semiarid Moroccan farm (Mrabet, 2002b).

Table 2. Wheat grain yield (Mg/ha) as affected by tillage and cropping system (Mrabet, 2002b)

Tillage system	Continuous wheat	Wheat-fallow
Sidi El Aydi†		
No-tillage	1.9a	3.7a
Conventional tillage	1.4b	2.6b
Jemaa Shaim††		
No-tillage	1.6a	3.1a
Conventional tillage	1.6a	2.4b

†Average annual rainfall 358 mm, clay soil, flat topography; this experiment started in 1983 and ended in 1993.
††Average annual rainfall 270 mm, clay soil, flat topography; this experiment is at its 18th year.
[a,b]In a column, values with the same letter do not differ significantly.

Conclusion

To avoid further soil degradation, alternatives should be adopted to shift from degrading to conserving processes. By minimising erosion, increasing soil organic matter and reverting soil structure degradation, NT system provides sustainability in cropping systems. It is clear from Fig. 5, that NT is more durable and less risky than conventional tillage for Moroccan farmers. In this figure, wheat production under NT in a drought year like 1999 expresses the stabilising effects of favourable conditions of soil properties and microclimate when applying NT and residue cover. However, crop failure under conventional tillage means that conditions for degradation are prevalent.

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