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Effects of straw mulch on growth and yield of durum wheat during transition to Conservation Agriculture in Mediterranean environment

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ABSTRACT

In Mediterranean environment, the transition to Conservation Agriculture (CA) poses as major issue the scarce accumulation of residues on soil surface; covering the soil with additional straw mulch could be a proven strategy for soil and water conservation, especially where durum wheat is the main crop, until reaching a layer of adequate thickness, typical of the stabilized CA systems.

Two field trials were carried out from 2010 to 2012 in a representative area of Southern Italy during the first two years of transition to CA. Durum wheat was grown under three increasing levels of straw added as soil mulching: 5.0 t ha^{-1} (100% mulch cover (100%MC)), 2.5 t ha^{-1} (50%MC) and 1.5 t ha^{-1} (30%MC), plus a CONTROL. The influence of such additional straw on soil water and nutrient availability, physiological traits, growth and yield of durum wheat was assessed, as well as the necessary amount of additional straw was estimated.

Both years of study indicated that root-zone moisture contents, monitored at 5 cm depth starting from the beginning of head emergence, were significantly improved by mulching, with the highest differences detected between 100%MC and CONTROL (36 and 41% higher in 2011 and 2012, respectively). 100%MC exhibited also the significant lowest concentration of nitrate-N (9 mg L^{-1} on average), K, Ca and Mg in soil solution. Additional straw at higher rates improved crop physiology: leaf water content (LWC) was highest in 100%MC (48.3%) and lowest in CONTROL (38.2%); SPAD and NDVI values (chlorophyll content) were respectively increased by 25% and 22% in 100%MC and by 15% and 17% in 50%MC, with respect to CONTROL. Nitrogen Nutrition Index (NNI) at anthesis was highest in 100%MC (0.97 vs. 0.50 in CONTROL). Significant high correlations were found between yield components and water as well as NO_3^- availability in soil solution (number of grains m^{-2} vs. NO_3^- in soil solution R^2 0.89; number of grains m^{-2} vs. soil water R^2 0.96). Yield was significantly affected by crop dry weight and N status at anthesis (0.49 kg m^{-2} in 100%MC vs. 0.27 kg m^{-2} in CONTROL, averaged over years). Moreover, the plots with higher amount of additional straw (100%MC and 50%MC) promoted significantly the accumulation of nitrogen in grains (0.56 mg N $grain^{-1}$ in 2011 and 0.51 mg N $grain^{-1}$ in 2012 in 50%MC).

Under our experimental conditions, 1.5 t ha^{-1} of straw added as mulching are enough to significantly produce higher yields, although to exert significant positive effects both on soil and on crop physiological indicators, 2.5 t ha^{-1} of wheat straw are necessary. However, increasing the amount of crop residues until 5 t ha^{-1}, crop performances and soil characteristics continue to significantly improve.

1. Introduction

Southern Europe's environment is characterized by cool and wet winters and hot and dry summers, with frequent drought spells in the spring due to low and erratic rainfall distribution. Here, not-irrigated agricultural systems depend mainly on winter crops; with limited alternatives, farmers rely on short rotations of wheat and barley, and occasionally sunflower, and very rarely on fallow. Soil is conventionally managed; ploughing and harrowing are normally applied for seedbed preparation with crop residues which are either removed or incorporated and diluted into the soil. In these durum wheat-based agricultural systems soil fertility decreases over time and crop productivity is seriously curtailed by water shortage and nutrient deficiency, as a result of severe water loss (i.e. evaporation, surface runoff, and downward movement), soil erosion and organic matter depletion (Anderson and Impiglia, 2002).

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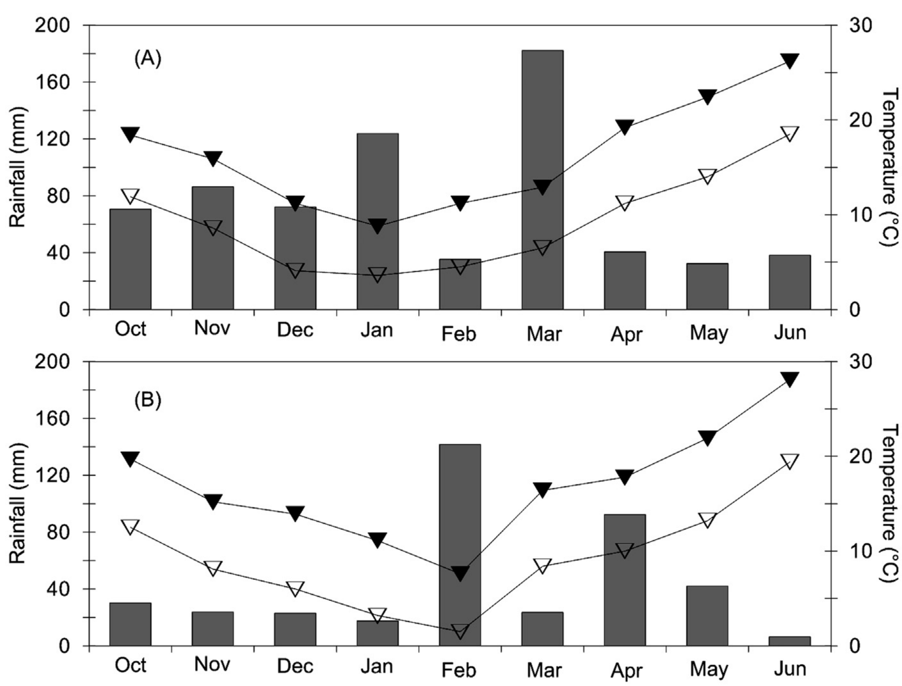
In such situations Conservation Agriculture (CA) could be a proven strategy for soil and water conservation and enhancement of soil biological processes (Kladivko et al., 1997; Blanco-Canqui et al., 2006), especially if combined with the management of crop residues. Through the application of its principles, i.e. minimum or no soil disturbance, maintenance of a permanent living or dead plant material as surface mulch and rotations or associations of different crops (FAO, 2002; Hobbs, 2007; Pisante, 2007; Stagnari et al., 2010; Pisante, 2013) higher and stable yields could be achieved (Stagnari et al., 2013).

CA has, indeed, considerable potential for stabilizing production in semiarid zones, although the consequences on water conservation and yield are sometimes contrasting. Several authors have demonstrated a positive effect on yield and water-use efficiency (Hargrove and Hardcastle, 1984; Lal, 1989; Bonfil et al., 1999), while others found negative effects (Wilhelm et al., 1987; Taa et al., 2004). In addition to a soil protection from runoff and erosion, crop residues on soil surface increase soil moisture in the soil profile (Moldenhauer et al., 1994; Knowles and Singh, 2003; Baker et al., 2007; Bationo et al., 2007). These effects have been reported in conventional tillage systems for maize (Zhang et al., 2004), wheat (Huang et al., 2005; Rahman et al., 2005), vegetables (Araki and Ito, 2004; Incalcaterra et al., 2003) and other crops (Haq, 2000; Kar and Singh, 2004). However, mulching from crop residues may not always improve water infiltration and hydraulic conductivity in all soils, because its positive effects depend on the amount and quality of applied residues, tillage system, site-specific soil properties and climate (Blanco-Canqui and Lal, 2007). In long-term experiments, Lentz and Bjorneberg (2003) reported that wheat straw application at rates as low as $1.5\,\mathrm{Mg\,ha^{-1}}$ increased water infiltration rates, while Baumhardt and Lascano (1996) suggested a rate of $0.7\,\mathrm{Mg\,ha^{-1}}$ on a clay loam. Under 10 consecutive years of no-tillage, Blanco-Canqui and Lal (2007) found a significant impact of additional straw mulch in soil water retention, mostly confined to the upper 3-cm layer.

Besides, mulching alters the soil microenvironment and has significant effects on many biochemical processes in the soil, leading to changes in nitrogen (N) availability, N-use efficiency, and accumulation of residual N in soil (Gao et al., 2009). The slow release of N from decomposing mulch residues is better synchronized with plant uptake than sources of inorganic N, and increases N uptake efficiency and crop yield while reducing N losses by leaching (Aulakh et al., 2000; Cline and Silvernail, 2001; Cherr et al., 2006; Stagnari and Pisante, 2010).

The transition phase from tillage-based agriculture (TA) to CA is crucial and delicate (Knowler and Bradshaw, 2007). Usually the full benefits of CA and the rehabilitation of soil-related ecosystem functions can take time (three to seven years may be needed for all the benefits to take hold) and, the initial transition years may pose issues which can influence farmers to leave the CA practices. Weeds require integrated management approach. The loss of pest and disease maintenance previously afforded by conventional tillage necessitates chemical inputs, which ideally are used in moderation as part of an integrated pest management system for ensuring a healthy biotic community (Knowler and Bradshaw, 2007). However, a major issue in semiarid environments is represented by the inadequate accumulation of residues on soil surface due to the constrained production of crops biomass; hence, covering the soil with additional straw mulch can be a temporary agronomic tool to build



	Average mean air temperature (°C)	Average max air temperature (°C)	Average min air temperature (°C)	Max air temperature (°C)	Min air temperature (°C)	Total Rainfall (mm)
2011	12.7	16.2	9.2	30.5	- 4.2	586.4
2012	13.0	16.9	9.1	32.9	- 3.4	362.2

Fig. 1. Rainfall (bars) and maximum (closed symbols) and minimum (open symbols) temperatures registered during the growing seasons of 2010/2011 (A) and 2011/2012 (B) at Mosciano S. Angelo (TE). Below, minimum, maximum and average temperatures and total rainfall as recorded during the whole durum wheat crop cycle.