Mulching and soil tillage influence on the thermal behaviour of a Luvisol surface layer

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Abstract. Important energy exchanges at soil surface regulate the thermal environment within top soil layer and the boundary layer above it. By this reason, the application of mulches or the modelling of micro relief by soil tillage are common practises to modify the thermal regime of a soil. The aim of this study is to compare the effect on thermal behaviour of a Luvisol resulting of soil tillage and the application of stubble mulch and, different amounts of straw mulch. For this purpose, experiments were performed from January to May 2007 in a field sowed with winter wheat. Temperatures were measured with copper-constantan (Type T) thermocouples placed over straw and over stubble, at soil surface and at 2, 4 and 8 cm depth. Temperatures above canopy were also recorded.

Daily mean temperatures and temperature amplitudes in the top soil layer covered by straw mulch were smaller than those verified either by stubble mulch or with soil tillage. Daily minimum temperatures in mobilized plots or covered by stubble mulch were smaller than those verified in plots covered by straw mulch, therefore being the former treatments more susceptible to frost than the later ones. Thermal differences between the four plots decreased significantly with wheat growth. Implications of these techniques of soil temperature control for crop growth are also discussed.

Introduction

Crop establishment is a major factor determining crop productivity in the field which is strongly controlled by soil temperature (Abreu, 1987). Important energy exchanges at soil surface regulate the thermal environment within top soil layer and the boundary layer above it (Arya, 1988). Therefore both the application of mulches and the modelling of micro relief by soil tillage are common practises to modify the soil thermal regime. All these practises affect the soil thermal regime by changes on surface net radiation and heat transfer by evaporation (De Vries, 1975). Thus, investigation into the influence of surface treatments on soil thermal regime is useful to evaluate differences of performance on crop growth.

The aim of this study is to compare the effect on thermal behaviour of a Haplic Luvisol (WRB, 2006) under different types of soil surface management: soil tillage, stubble mulch and different amounts of straw mulch.

Data and methods

Field experiments were performed at Herdade da Revilheira, Reguengos de Monsaraz (lat.: 38º28'N; long.: 7º28'W), from January to May 2007, in a field sowed with winter wheat (*Triticum aestivum* L.) in preceding December. The local climate is Csa, according to Köppen. According to climatic data recorded at the nearest station (Évora, about 40 Km away from the site) the mean annual temperature averages 15.6ºC, ranging from a monthly mean of 9.3ºC in January to 23.0ºC in August. Mean annual rainfall is 642.6 mm, 77% of which falls between October and March. The soil is a Haplic Luvisol (WRB, 2006) and its profile was Ah-AB-Bt-C. The clay-loamy Ah (0-8 cm) and AB (8-24 cm) horizons had a bulk density of 1.51±0.12 Mg m^{-3} and 1.58±0.07 Mg m^{-3}, respectively while the clayey Bt (24 - 53 cm) horizon had a bulk density of 1.63±0.04 Mg m^{-3}.

Soil temperatures were measured in four profiles with copper-constantan thermocouples connected to a data-logger (*data Taker* 600). One profile was subject to a surface soil tillage only (modality A), another was covered by stubble mulch (mod B) and the remainder were covered by different amounts of straws mulch (mod C - 2500 Kg ha^{-1} and mod D - 5000 Kg ha^{-1}). Thermocouples were placed in each profile at its surface, 2, 4 and 8 cm depth and over straw and stubble mulches. Hourly averaged temperatures were recorded anyway.

Effects on soil thermal regime were evaluated by daily mean temperatures and daily minimum temperatures at 2 cm depth as well as by thermal amplitudes at 2 cm, at 4 cm depth and at the surface of the mulch.

Results and discussion

Daily mean temperatures at 2 cm depth ranged from about 3-4ºC (end of January) to 23-28ºC (middle of May), following the annual course of net radiation at a soil surface in areas of Mediterranean climates (Fig. 1). From January to March, no significant differences were found between daily mean temperatures recorded in the four plots; in April and May, the plots covered by straw presented mean temperatures significantly lower than those covered by stubble mulch or subject to surface tillage. This means that

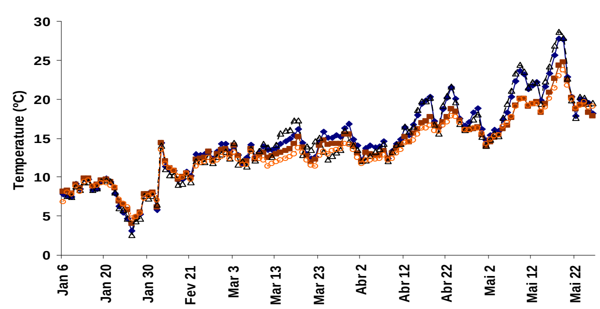

Figure 1. Daily mean temperatures recorded at 2 cm depth from Jan 6 to May 26: mod A (—♦—), mod B (---△---), mod C (—■—) and mod D (---o---).

the application of straw mulch can influence more the establishment of summer crops than that of winter crops. In April and May, the increase of mean temperatures in soil profiles covered by straw (mod C and mod D) follows, with same delay, the increase verified in the other profiles (mod A and B), probably due to the higher water holding capacity presented by straw mulch. Maintenance of stubble mulch over soil surface did not seem to benefit crop establishment when compared with tilled soil.

Daily minimum temperatures recorded at 2 cm depth were lower in profiles covered by stubble or subject to a surface tillage than in profiles covered by straw mulches, irrespective of their densities (Fig. 2). Differences between minimum temperatures recorded in modalities B (stubble mulch) and D (straw mulch – 5000 Kg ha^{-1}) were about 2ºC, reaching to about 4ºC on some days of January and April. Differences between minimum temperatures in modalities C and D were generally lower than 0.5ºC, meaning that frost prevention does not seem to depend on densities of straw mulch.

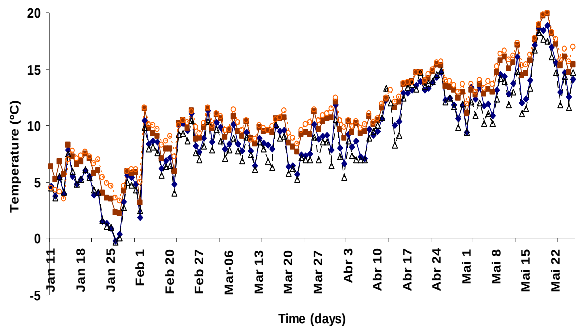

Figure 2. Daily minimum temperatures recorded at 2 cm depth: mod A (—♦—), mod B (---△---), mod C (—■—) and mod D (---o---).

Damping of thermal wave down to 4 cm depth was significantly higher with straw mulch (mod D) than with other modalities; in addition, the damping was the lowest when modality B is applied (Fig. 3). Ratio between

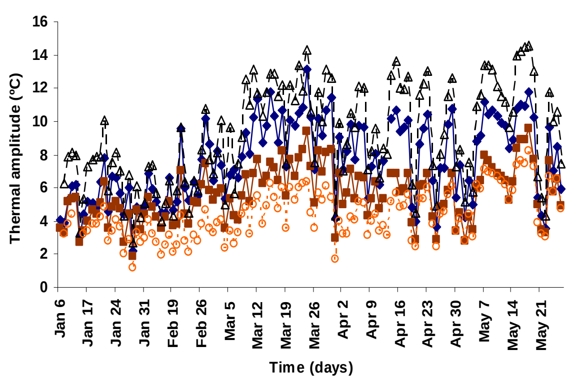

Figure 3. Temperature amplitudes at 4 cm depth recorded from Jan 6 to May 26: mod A (—♦—), mod B (---△---), mod C (—■—) and mod D (---o---).

thermal amplitudes verified at 4 cm depth in tilled soil and those verified in profile covered by stubble mulch ($\Delta T_{modA}/\Delta T_{modB}$) varied from 0.90 to 0.71 (0.81±0.04), while that verified in covered profiles by straw ($\Delta T_{modD}/\Delta T_{modC}$) ranged from 1.05 to 0.72 (0.77±0.13). Thermal amplitudes at 2 cm depth were 44±7% and 23±4% of those observed at the top of straw mulch layer, respectively in modalities C and D; on the contrary, stubble mulch damped the thermal wave in about 21 per cent only, i.e., the amplitudes at 2 cm depth are 79±10% of those observed at the surface (Fig.4). Relationship between amplitudes recorded in different modalities didn't seem to be affected by crop growth.

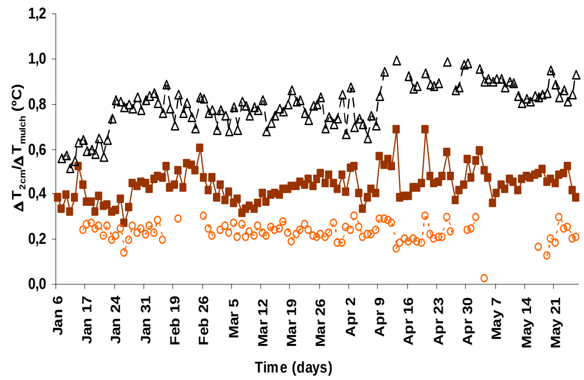

Figure 4. Ratio thermal amplitudes at 2 cm depth/ Thermal amplitudes over mulch: mod B (---△---), mod C (—■—) and mod D (---o---).

Conclusions

The more evident is the soil warming that reflects the annual course of net radiation, the more evident is the cooling resulting of the application of straw. The application of straw mulch at soil surface increases daily minimum temperatures in top soil layer by about 2ºC, avoiding often the occurrence of frost and consequent crop damages. In spite of no significant influence of the amount of straw mulch on daily mean and minimum temperatures, it affects significantly the damping of thermal wave into top soil layer. To keep the stubble mulch at soil surface is not an efficient practice on the thermal moderation in top soil layer or to prevent frosts.

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