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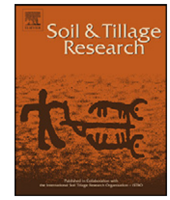

Effects of mulching and catch cropping on soil temperature, soil moisture and wheat yield on the Loess Plateau of China

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ABSTRACT

Soil management can notably influence crop production under dryland farming in semiarid areas. Field experiments were conducted, from October 2001 to September 2004, with an attempt to evaluate the effects of field management regimes on thermal status at an upland site; and soil water and wheat production in a winter wheat (*Triticum aestivum* L.) system at upland, terrace land and bottom land sites on the Loess Plateau, China. The field management regimes tested were: (i) the conventional practice (winter wheat followed by a ploughed summer bare fallow); (ii) conventional management, but a catch crop growing for certain time during fallow period used as green manure (after the wheat harvest, a catch crop were directly sown, instead of ploughing, and then incorporated into the soil roughly one month before wheat sowing); and (iii) wheat straw mulch (0.8 kg m^{-2}), covering the soil throughout the year during the experimental period (no summer ploughing, straw was removed during wheat sowing). Soil temperature under catch cropping was lower during certain period of its growing by about 2 °C, slightly higher for short spells after incorporation and before wheat harvest, no observed effects during the rest time of a year relative to conventional practice at the upland site. Moreover, soil water storage levels under catch cropping were comparable with those of the conventional practice for all three years, but wheat yield substantially declined in the last year. Mulching showed different responses for the three land sites. At the upland site, daily mean soil temperatures under mulching at 10 cm depth were decreased in the warmer period by 0–4 °C, and increased in the colder period by 0–2 °C when compared to those of non-mulched soil. At upland and bottom land sites, mulching conserved an average of 28 and 20 mm more water in the upper 100 cm soil layer at the time of wheat sowing, respectively, than conventional practice. However, at the terrace, mulching had little effect on soil water storage, nor on wheat grain yield, relative to conventional practice. Therefore, considering the limited availability of mulch material in this region and the economic benefits, it is recommended that mulching may be beneficial to upland or bottom land, but not to terraced land. In addition, the application of catch cropping in this study did not show positive effects, the more comprehensive evaluation of this approach would be further needed.

1. Introduction

Water is the most limiting factor for crop production under dryland farming in semiarid areas. In China, dryland farming is practised on about one third of the arable land, of which about 40% is situated on the Chinese Loess Plateau (Li, 2004). The Loess Plateau covers an area of 623,800 km^2 and has a population of about 90 million. Its climate is mostly semiarid, with annual precipitation ranging from 150–300 mm in the north to 500–700 mm in the south (Li and Xiao, 1992). Most of the annual precipitation (50–60%) falls as rain from June to September. Groundwater resources are sparse and deep, so most of the agriculture on the Loess Plateau is dryland farming, relying solely on rainfall (Li and Xiao, 1992). Sustaining agricultural production on the Loess Plateau is very important to ensure a sufficient food supply for the growing population.

It has been suggested that, by optimizing the management of soil water and nutrients, agricultural production on the Loess Plateau could be increased substantially, perhaps as much as threefold (Fan and Zhang, 2000). Winter wheat, the main crop on a large part of the Loess Plateau, is conventionally cultivated as a

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single crop per year followed by more than three months of summer bare fallow. The fallow period coincides with the rainy season and it is believed that water, stored in the soil during this period, is utilised by the subsequent wheat crop. However, fallow efficiency under bare fallow is low, accounting for 28% of fallow rainfall on average (Zhang et al., 2007a). Furthermore, during the past 20 years, wheat yield has been increased by fertilizer applications, but this practice has resulted in increasing soil water depletion (Huang et al., 2003). Consequently, soil water is no longer fully replenished during the fallow season and, where a dry subsoil layer has formed, especially, in the table land/high land region (Huang et al., 2002), crop yield varies greatly with rainfall within a growing season (Li, 2001). Hence, it is crucial to seek ways of improving water use efficiency (WUE) and of maintaining sustainable wheat production.

Soil management regimes can influence conservation and efficiency of stored water. Wheat straw mulching is regarded as one of the best ways of improving water retention in the soil and reducing soil evaporation (Steiner, 1989; Li and Xiao, 1992; Baumhardt and Jones, 2002). It also proved to be an effective approach for sustainable wheat production in upland ecosystems on the Loess Plateau region, both in short-term experiments (Huang et al., 2005; Zhang et al., 2007b) and a long-term simulation study (Zhang et al., 2007a). However, information on how the effectiveness of mulching may vary in different landscape positions is limited.

Application of organic matter is another way of improving soil properties and thus increasing WUE (Unger and Stewart, 1974; Edmeades, 2003). Growing a crop of green manure during the fallow period, and ploughing it in at a certain time before the next wheat sowing, might be a viable method of increasing soil organic matter contents and thus increasing precipitation storage efficiency. After testing different crop rotation systems in the middle-west Loess Plateau, Li et al. (2000) reported that the use of a 'fallow crop' does not greatly influence the quantity of water stored in the soil at sowing time of subsequent winter wheat. In their study, however, the fallow crop was harvested as forage. Vigil and Nielsen (1998) found, in a two-year study, that wheat yields were reduced after growing legume, a green manure as a catch crop, in comparison to traditional summer fallow due to less water stored at wheat sowing time.

Soil management regimes could change the characteristics of the soil surface, and hence influence the soil thermal properties. Several investigators have reported that the soil thermal regime under mulching is different from that of bare soil, with soil temperatures often being lower under mulched surfaces than in non-mulched soils (Bristow, 1988; Sarkar et al., 2007). Others have documented mulch increasing soil temperatures (Ramakrishna et al., 2006). These conflicting reports may be related to the timing of soil temperature measurements.

The objectives of this study were to evaluate how mulching and catch cropping influence soil temperature, soil water storage and wheat yield on three land types (viz. upland, terrace land and bottom land). Soil temperatures were only measured at the upland site. The results from this study will be used to guide soil management strategies for local and other related regions.

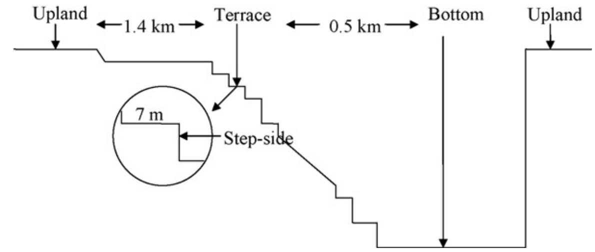

Fig. 1. A sketch of experimental sites, i.e. upland, terrace and bottom.

2. Materials and methods

2.1. Site description and experimental design

The land types were upland (N35°19′37″; E110°4′57″; 910 m a.s.l.), terrace (N35°18′39″; E110°4′16″; 833 m a.s.l.) and bottom land (N35°18′26″; E110°4′4″; 752 m a.s.l.), located at Ganjin village, Heyang County, Shaanxi province in the southeast part of the Loess Plateau, China (Fig. 1). The terrace land in this study orientates southward and is located on the upper part of the slope. During the period 1981–2000, the mean annual precipitation was 582 mm and the mean annual temperature was 10.5 °C. The experiment was carried out from October 2001 to September 2004. During these three years, the mean annual temperature was 11 °C, while the lowest temperatures (in December or January) were −7, −15.3, and −9.3 °C, in 2002, 2003, and 2004, respectively. According to the USDA textural classification system, soils at these locations are silt loams and according to the FAO-UNESCO soil map (FAO-UNESCO, 1974) soils are classified as Chromic Cambisols. The soil profile is deep (over 100 m for upland and terrace, over 20 m for bottom land) and generally homogeneous. The general soil properties of the plough layer (0–20 cm) are presented in Table 1.

The study included three treatments at each site. The first treatment was the conventional practice (C) in which wheat was sown in rows by hand at depth of about 4 cm and at a seed rate of 105 kg ha^{-1} in end of September or beginning of October and manually harvested in June of the following year, leaving stubble (5–10 cm) and roots. The soil was then tilled to about 20 cm deep by spade (i.e., summer ploughing) and remained bare until the next sowing season. Fertilizers were incorporated into the soil by manual harrowing, prior to wheat sowing. The second treatment differed from the first one in that a catch crop (legume) was grown as green manure for certain time of the fallow period instead of ploughed bare fallow (CC). The catch crop was directly sown after wheat harvest at a depth of about 5 cm and at a seed rate of 200 kg ha^{-1} by hand without applying any fertilizer, then was harvested and incorporated into soil by spade about one month before sowing wheat. The third treatment was mulching (M), more or less as no-till practice. The air-dried, unchopped wheat straw (0.8 kg m^{-2}) was evenly distributed over the soil surface following wheat sowing at the start of the experiment, and was thereafter kept at relatively constant levels over the soil surface throughout

Table 1
General properties of the tested soils (0–20 cm depth)

Site	Organic carbon (g kg^{-1})	Bulk density (g cm^{-3})	Sand 0.05–2 mm (g kg^{-1})	Silt 0.002–0.05 mm (g kg^{-1})	Clay <0.002 mm (g kg^{-1})
Upland	0.86 (0.05)	1.21 (0.02)	13	758	229
Terrace	0.49 (0.05)	1.26 (0.02)	63	712	225
Bottom	0.50 (0.10)	1.29 (0.08)	119	661	220

Means with standard deviations in parentheses (4 replicates for upland, and 3 for other two sites). Bulk density was measured at 10–15 cm depth. Particle size distribution was determined for a composite sample collected at the start of the experiment.