Field Crops Research 126 (2012) 181–188

Contents lists available at SciVerse ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Ridge-furrow and plastic-mulching tillage enhances maize–soil interactions: Opportunities and challenges in a semiarid agroecosystem

Li-Min Zhou[a], Sheng-Li Jin[b], Chang-An Liu[a], You-Cai Xiong[a], Jian-Ting Si[a], Xiao-Gang Li[a], Yan-Tai Gan[c], Feng-Min Li[a,*]

[a] Ministry of Education Key Laboratory of Arid and Grassland Ecology, School of Life Sciences, Lanzhou University, Lanzhou 730000, China
[b] Agriculture Extension Service Center of Yuzhong County, Lanzhou 730100, China
[c] Agriculture and Agri-Food Canada, Swift Current, SK S9H 3X2, Canada

ARTICLE INFO

Article history:
Received 4 May 2011
Received in revised form 17 October 2011
Accepted 18 October 2011

Keywords:
Soil microbial biomass C
Soil organic C
Soil nutrients
Semiarid Loess Plateau
Plastic film mulch
Double ridges and furrows

ABSTRACT

Understanding plant–soil relationships may help maximize crop productivity while maintaining and improving soil quality. Field experiments were conducted in 2006 and 2007 at the Dryland Agricultural Experimental Station of the Loess Plateau, Lanzhou University, China, to determine the effects of various ridge-furrow and plastic-mulching techniques on the growth and yield of maize (*Zea mays* L.) and soil biochemical properties.

Five treatments were designed: (1) flat-plot sowing without ridge-furrow mulching (CK), (2) large (80 cm) and small (40 cm) ridges alternated and fully mulched with plastic (DRM), (3) on-furrow sowing with plastic mulch applied only on the ridge at a row spacing of 60 cm and 40 cm alternatively (RM), (4) flat-plot sowing with plastic mulch at a row spacing of 60 cm and 40 cm alternatively (NM), and (5) flat-plot sowing with plastic mulch at a row spacing of 80 cm and 40 cm alternatively (WM).

The results showed that film mulching enhanced soil microbial biomass; where microbial biomass carbon (MBC) in the DRM treatment reached 633 mg kg^{-1} at harvest in 2007, three times the MBC of the CK. The MBC:SOC ratios were 8.8%, 7.1%, 5.7% and 5.4% in DRM, RM, NM and WM, respectively. The ridge-furrow with plastic-mulching increased soil light fraction carbon (LFOC) in both years, averaging up to 1.04 g kg^{-1} at harvest. Underground plant biomass increased substantially in the mulching treatments, especially in DRM. Positive correlations were found between total biomass and LFOC, between MBC and LFOC, and between MBC and available phosphorus (AP), but a negative correlation between SOC and soil mineral nitrogen (MN). The carbon to phosphorus (C/P) ratio was highest in DRM among treatments, but the content of SOC, MN, and C/N ratio in DRM was lowest, suggesting that the DRM treatment strengthened the interactions between maize and soil, and that the increased content of LFOC with time provides a basis for increasing productivity in future years.

In conclusion, the ridge-furrow and plastic-mulching technique brought about a challenge in maintaining soil fertility, but this technology provides a potential opportunity of substantially increasing crop yields in semiarid rainfed regions.

1. Introduction

Low temperature, limited water availability and poor soil fertility are the major factors limiting agricultural productivity in the semiarid Loess Plateau of Northwestern China (Zhao et al., 1995). The low crop productivity is largely related to soil degradation, inefficient water use, and drought and low-temperature stresses (Bonde et al., 1988; Liang et al., 2010). In recent years, some new technologies have been developed and adopted to improve the productivity of the region, including rainwater harvesting, timely fertilization, manure application, and use of terraces in the agro-ecosystem (Li et al., 1999; Liu et al., 2009). Studies have shown that tillage influences both biotic and abiotic processes of the soil, and impacts soil aeration, temperature, moisture, and nutrients (Huwe, 2003). These changes in soil environments have an ultimate effect on crop root growth, because the ability of roots to grow and explore the soil for water and nutrients is the key determinant of plant growth rates (Clark et al., 2003).

Plastic film mulch has been used for harvesting rainwater, and it is now becoming a well-evolved technique for agriculture in arid, semiarid and sub-humid areas, especially where irrigation is not

Abbreviations: SOC, soil organic carbon; LFOC, soil light fraction carbon; MBC, microbial biomass carbon; MN, mineral nitrogen; TN, total soil nitrogen content; AP, available phosphorus; TP, total soil phosphorus.

* Corresponding author. Tel.: +86 931 8912848; fax: +86 931 8912848.
E-mail address: fmli@lzu.edu.cn (F.-M. Li).

0378-4290/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.fcr.2011.10.010

available and spring temperatures are low (Liu et al., 2001; Zhang et al., 2005). This technology has proven to be highly effective in improving soil moisture and increasing topsoil temperature (Li and Lan, 1995; Li et al., 2001; Song et al., 2002; Wang et al., 2003).

A number of mulching and planting arrangements have become available, including (1) alternating ridges and furrows with only the ridges mulched with plastic film (Liu et al., 1989; Zhang et al., 2004), (2) alternating mulched rows and bare rows without ridges (Liu et al., 1989), and (3) flat plots mulched with plastic film (Zhang et al., 2004). Since 2007, a new mulching pattern, ridge-furrow coupled with plastic-mulching, has been widely adopted and achieved a significant improvement in grain yield per unit area. This pattern has been shown to improve topsoil temperature, especially at the seedling stage, increase topsoil moisture, improve water use efficiency, and enhance crop maturity and yield in maize (Zhang et al., 2006; Liu et al., 2008; Zhou et al., 2009). The area of using this pattern had reached 193×10^3 ha in 2008 in Gansu Province, which occupied about 7% of the total cropland and contributed 20% to the total grain production (Wang, 2009). Studies have shown that the use of ridge-furrow and plastic-mulching tillage can significantly increase soil temperature, decrease evaporation, and enhance grain yield in maize (Zhou et al., 2009). However, little is known about the effect of this new planting pattern on crop–soil interactions in maize. It is unknown whether the increased grain yield was a consequence of mining the soil or causing soil nutrient imbalance. There is a need to determine the relationship between total biomass of maize and soil carbon (C) pool and other soil nutrients.

Microbial biomass carbon (MBC) is an important fraction of soil organic matter, and it is a general indicator of soil microbial activity (Wick et al., 1998). Also, MBC has been recognized as a sensitive indicator of changes in soil quality (Benintende et al., 2008). Soil organic carbon (SOC) is of great importance in maintaining the pool of soil nutrients and improving nutrient availability (Li et al., 2003; Zhao et al., 2009). The loss of SOC may reduce soil fertility (Jamalam et al., 1998). SOC is a heterogeneous material that can be separated into a light fraction (LFOC) and a heavy fraction (HFOC) by densitometry techniques (Janzen et al., 1992; Gregorich and Ellert, 1993). LFOC mainly consists of botanical relics and can respond to agricultural practices more rapidly and sensitively than SOC and HFOC (Janzen et al., 1992; Biederbeck et al., 1994; Gregorich et al., 1994). SOC, LFOC and MBC are frequently used to assess the influence of agricultural management practices on soil quality (Bremer et al., 1994; Gregorich et al., 1994). The objectives of this study were to (i) assess the effects of different ridge-furrow and plastic-mulching tillage treatments on maize productivity, (ii) explore the influence of different mulching patterns on SOC, LFOC, MBC, and (iii) determine the relationship between MBC and soil nutrients in a semiarid environment.

2. Materials and methods

2.1. Description of the experimental site

The experiment was conducted in 2006 and 2007 at the Semiarid Ecosystem Research Station of Lanzhou University at Zhonglianchuan village, a northern mountainous region of Yuzhong county (36°02′N, 104°25′E, 2400 m above sea level), Gansu, China. Long-term annual mean air temperature is 6.5 °C, monthly maximum temperature 19.0 °C (July) and monthly minimum temperature −8.0 °C (January). Annual precipitation is 320 mm, of which about 60% falls in the major part of the growing season (June–September). Rainfall during the experimental period was measured using an automatic weather station (WS-STD1, England). The field site has a Heima soil (Calcic Kastanozems, FAO Taxonomy), with field water holding capacity (FWHC) of 22.9% and permanent wilting coefficient (PWC) of 6.2% (Shi et al., 2003).

The rainfall during the growing season (April–September) was 213 mm in 2006, which was lower than the long-term (1970–2000) average (Fig. 1). The July rainfall in 2006 was about half of the long-term July average. The growing season rainfall in 2007 (287 mm) was slightly above the long-term average, largely due to June rainfall more than doubled the long-term June average.

2.2. Experimental design

In this experiment, three treatments were established in 2006: (1) a flat plot without mulch (CK); (2) alternating large (80 cm) and small (40 cm) ridges with the ridge heights being 10 and 15 cm, respectively (designated as DRM). These ridges were mulched with plastic film (0.14 kg plot^{-1}, equaling to 75 g ha^{-1}), 140 cm in width. The bottom of the two ridges was the furrow where the plastic film was joined to harvest rainwater and the film sealed at the base

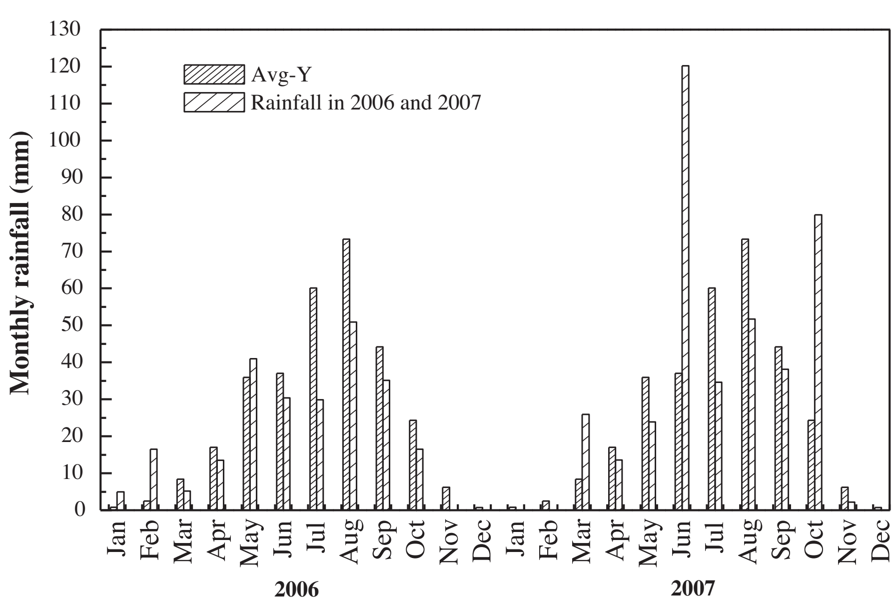

Fig. 1. Distribution of monthly rainfall (mm) at the experimental site during the 2006 and 2007 growing seasons and the average rainfall for the past 30 years at the site (Avg-Y).