Responses of soil carbon, nitrogen, and wheat and maize productivity to 10 years of decreased nitrogen fertilizer under contrasting tillage systems

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Introduction

Soil carbon (C) and nitrogen (N) stocks have become the subject of unprecedented focus for mitigating global atmospheric greenhouse gas emission. Increasing soil organic carbon (SOC) is beneficial to the sustainable development of agriculture, and store more SOC can decrease soil CO_2 release and slow the greenhouse effect (Bertora et al., 2009). Moreover, improving the fixed soil N can decrease both fertilizer application rates and fertilizer costs and can protect the environment from the negative effects of reactive N. In view of the dominant role of N nutrition in the growth of crops, it is very important to avoid N loss and to restore N nutrient concentrations during soil management (Giller et al., 1997; Zougmoré et al., 2004).

Considering N management under different tillage, we hypothesized that a certain extent of N fertilizer application decrease under straw returned could still maintain soil carbon (C) and N stocks and yields of wheat and maize at relatively high levels, however, the effects under different tillage systems may be different. Therefore, a 10-year long-term field experiment was conducted that involved different tillage methods and N levels under straw return; the SOC and STN storage as well as crop yields were thencomprehensively analysed. This study has the following objectives: (1) to study the accumulation and dynamics of soil C and N and yield change of wheat and maize in long-term tillage and fertilization experiment; (2) to find a suitable N application rate and tillage method to keep higher crop yields.

Materials and Methods

This experiment was established in 2006 at Qianzhuliu Village, Longkou City, Shandong Province.

Ten treatments (CT-100, CT-75, CT-50, CT-25, CT-0, NT-100, NT-75, NT-50, NT-25, and NT-0), including 2 tillage systems and 5 fertilization rates, were tested in triplicate (treatment size: 15 × 15 m^2) via a randomized block design.

The soil SOC and STN were determined using an Elementar Vario TOC analyser (Elementar Analysensysteme, Hanau, Germany) and the semi-micro Kjeldahl method, respectively.

Results

The annual wheat and maize yields of 100% N, 75% N and 50% N under CT and NT treatments were significantly higher than those of 25% and 0 N on the studied period ($P < 0.05$). The 75% and 50% N application promoted higher yield stability of the wheat and maize ecosystems and the yield, the mean annual wheat and maize yields of 75% N application were increased by 1.6% than that of 100% N application. However, the yield stability of wheat was lower than that of maize.

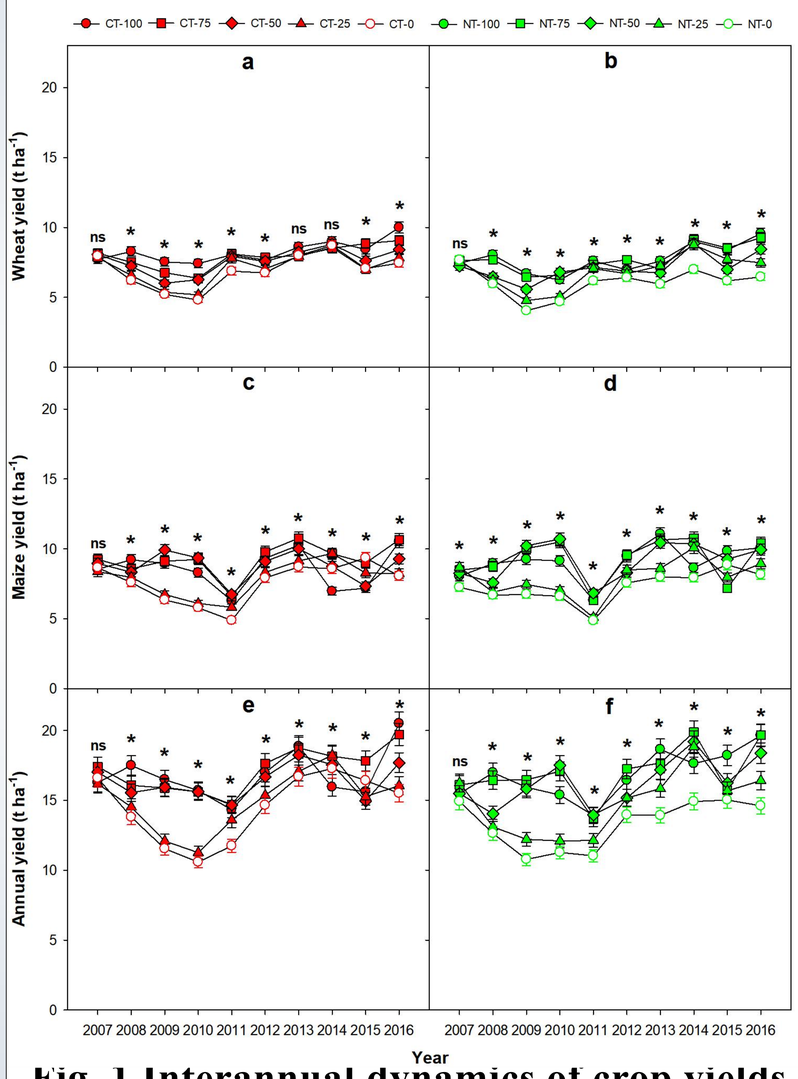

Fig. 1 Interannual dynamics of crop yields under different tillage practices and nitrogen application rates.

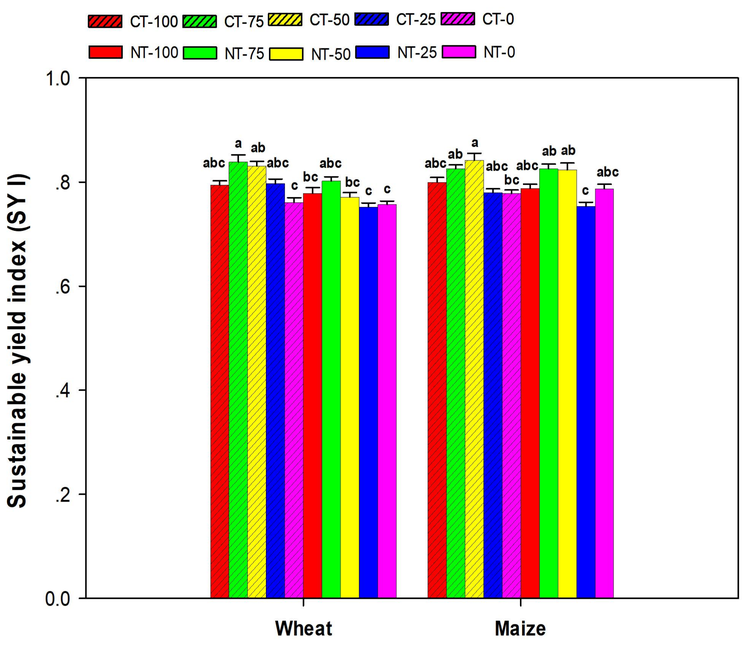

Fig. 2 Yield stability of wheat and maize under different tillage practices and nitrogen application rates.

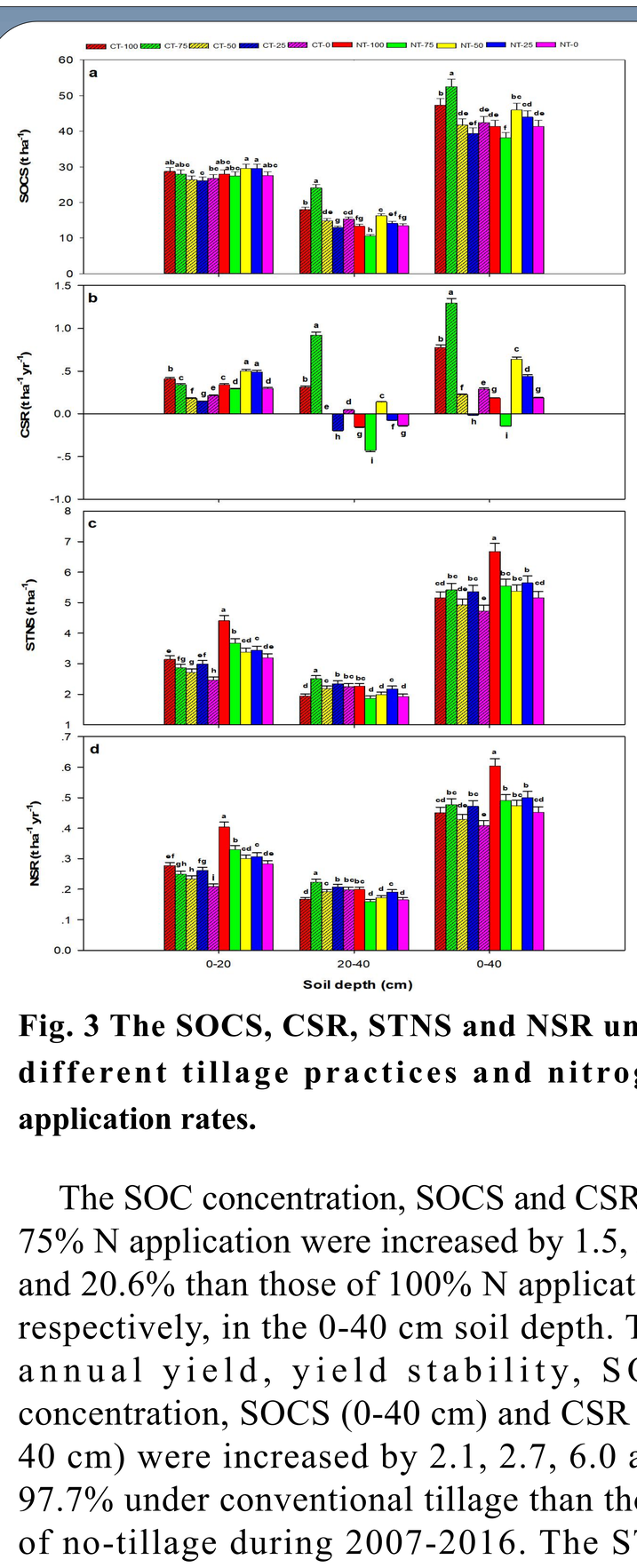

Fig. 3 The SOCS, CSR, STNS and NSR under different tillage practices and nitrogen application rates.

The SOC concentration, SOCS and CSR of 75% N application were increased by 1.5, 2.2 and 20.6% than those of 100% N application respectively, in the 0-40 cm soil depth. The annual yield, yield stability, SOC concentration, SOCS (0-40 cm) and CSR (0-40 cm) were increased by 2.1, 2.7, 6.0 and 97.7% under conventional tillage than those of no-tillage during 2007-2016. The STN concentrations of NT-100 and NT-75 was significantly higher than that of other treatments ($P < 0.05$). The STN concentration, STNS and NSR in the NT-100 treatment stayed high most of the years, which were greater under no-tillage than those of conventional tillage, and no-tillage could lead to more accumulation of SOC in the surface soil depth (0-20 cm) during 2007-2016.

Conclusions

75% N application rate not only decreased the application rate of N fertilizer, but also keep the yield of wheat and maize and soil quality from decreasing, so 75% N was recommended for use, i.e., 157.5 kg ha^{-1} of N during the wheat season and 202.5 kg ha^{-1} of N during the maize season.