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Grain yield and water use in a long-term fertilization trial in Northwest China

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Abstract

The wheat- (*Triticum aestivum* L.) and corn- (*Zea mays* L.) rotation system is important for food security in Northwest China. Grain yield and water-use efficiency [WUE: grain yield/estimated evapotranspiration (ET)] were recorded during a 24-year fertilization trial in Pingliang (Gansu, China). Mean yields of wheat for the 16 years, starting in 1981, ranged from 1.29 Mg ha^{-1} for unfertilized plots (CK) to 4.71 Mg ha^{-1} for plots that received manure (M) annually with nitrogen (N) and phosphorus (P) fertilizers (MNP). Corn yields for the 6 years, starting in 1979, averaged 2.29 and 5.61 Mg ha^{-1} for the same respective treatments. Whether the years were dry, normal or wet, average grain yields and WUEs for both crops were consistently highest in the MNP and lowest in the CK treatment, and were always lower in the N than in the M treatment and in all others treatments that received N along with P fertilizers. More importantly, WUEs for MNP and for straw along with N annually and P every second year (SNP) were always higher than the other fertilized treatments in dry years. Compared to yield data, coefficients of variance (CV) for WUEs were consistently low for all treatments, suggesting that WUEs were relatively stable from year to year. Yields and WUEs declined over time, except in the CK and MNP treatments for wheat. Declined yields of wheat for the N and M treatments were comparable, and the decline for the NP treatment was similar to that for the SNP treatment. Likewise, corn yields and WUEs declined for all treatments. Grain yields were significantly correlated with ET, with slopes ranging from 0.5 to 1.27 kg m^{-3} for wheat and from 1.15 to 2.03 kg m^{-3} for corn. Balanced fertilization and long-term addition of organic material to soil should

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be encouraged in this region to maximize the use of stored soil water, arrest grain yields decline, and ensure sustainable productivity using this intensive cereal cropping system.

Keywords: Analysis of variance; Corn; Crop water stress index; Grain yield; Long-term fertilization; Estimated evapotranspiration; Water-use efficiency; Wheat

1. Introduction

Northwest China is a vast, semi-arid region with an average annual precipitation ranging from 300 to 600 mm. More than 90% of the cropland in this area receives no irrigation. The main crops are wheat (*Triticum aestivum* L.) and corn (*Zea mays* L.), which are periodically rotated. There are about 1.3×10^{-6} ha of wheat and corn rotations in the Loess Plateau region of Northwest China. These lands are mostly in the highland plateaus of East Gansu, North Shaanxi and West Shanxi and produce about 40% of local food needs (Fan and Song, 2002), and have emerged as the most important for food security in this dryland region (Xing et al., 2001). Generally, three or more years of continuous wheat are followed by two or more years of continuous corn. In a typical system, where winter wheat follows corn, wheat is planted immediately following corn harvest. In all other combinations, land is fallowed between crops to store water in the soil for the subsequent crop. Shangguan et al. (2002) reported that fallow efficiencies (FE) for the area, expressed as soil water accumulation divided by precipitation received during fallow periods, was about 35–40%. The importance of storing soil water during fallow periods for increasing grain yields of subsequent crops has been supported by many dryland studies, including those in the Southern Great Plains of the United States by Johnson (1964) and Musick et al. (1994), and in the China Loess Plateau by Shangguan et al. (2002).

Of all farming practices, rational fertilization is among the most important measures to improve grain yield and water-use efficiency (WUE: grain yield per unit of seasonal evapotranspiration (ET), in kg ha^{-1} m^{-3}) and aspires toward sustainable crop production that will be required to meet the food demands of the region's growing population. The importance of fertilization to maximize the use of stored water in the root zone has long been recognized (Power et al., 1961; Viets, 1962; Stewart, 1989; Cai et al., 2002). Lu et al. (1998) and Fan et al. (2004) reported that nitrogen and phosphorus fertilization increased grain yields and WUE in China by 50–60%. Farmyard manure (not pure manure, but a mixture with soil) and inorganic fertilizers are widely applied as a fundamental approach to improve both grain yield and efficient water-use for crop production (He and Lin, 1992). However, the challenges for Northwest China are low WUE, resulting from low and erratic precipitation, unbalanced fertilization, and removal of crop residue from fields for feed or fuel (Zhang et al., 1997; Zhu, 1984).

Long-term experiments are invaluable for the assessment of the effects of cropping system on grain yield and WUE, and risk management (Regmi et al., 2002; Dawe et al., 2000; Camara et al., 2003). Many long-term experiments have been used to measure the effect of fertilization on grain yield (Jenkinson, 1991; Mitchell et al., 1991; Sandor and Eash, 1991; Brown, 1991; Bhandari et al., 2002; Zhu, 1997; Wang et al., 2002), but few continuous long-term studies are