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Effect of Long-Term Fertilization on Soil Productivity and Nitrate Accumulation in Gansu Oasis

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Abstract

A long-term (1982-2001) field experiment was conducted in a calcareous soil under wheat (*Triticum aestivum* L.)-wheat (*Triticum aestivum* L.)-maize (*Zea mays* L.) rotation system at Zhangye, Gansu Province, China to determine the effects of long-term fertilization on crop yield, nutrients interactions, content and accumulation of nitrate-N in soil profiles. Twenty-four plots in a split-plot factorial with a combination of eight treatments (from nitrogen (N), phosphorus (P), potassium (K) and farmyard manure (M) applications) and 3 replications were selected. Main treatments were M and without M, and the sub-treatments were no-fertilizer (CK), N, NP and NPK. When P and K fertilizers were part of treatments, their ratio to N was 1N:0.22P:0.42K. All M, P and K fertilizers were applied as the basal dressing. The grain yield was harvested each experimental period and straw yield for the period from 1988 to 1997. After crop harvest in 2000, the soil was sampled from the 0-20, 20-60, 60-100, 100-140 and 140-180 cm depths to determine NO_3^--N content. Maize yield of CK in 2000 was only 28.2% of that in 1984, and wheat in 2001 was 25.7% of that observed in 1982. Average impact of fertilizers on grain yield decreased in the order of N>M>P>K. Yield response to N and P fertilizers increased with progress of the experiment. The impact of K fertilizer showed no increase in grain yield during the initial 6 years (1982-1987), moderate increase in the next 5 years (1988-1992), and considerable increase in the last 9 years (1993-2001). The straw yield trend was similar to grain yield. Accumulation and distribution of NO_3^--N in soil was significantly affected by annual fertilizations. Mineral fertilizers (NP and NPK) led to NO_3^--N accumulation in most subsoil layers, with major impact in the 20-140 cm depth. The combination of mineral fertilizers and farmyard manure (MNP and MNPK) reduced soil NO_3^--N accumulation in comparison to mineral fertilizers. It can be argued that long-term fertilization significantly enhanced grain and straw yield in this rotation scheme. The findings of this research suggest that it is important to balance application of mineral fertilizers and farmyard manure in order to protect soil and underground water from potential NO_3^--N pollution while sustaining high productivity in the oasis agro-ecosystem.

Key words: long-term fertilization, accumulation of nitrate-N, crop yields, nutrients interactions, farmyard manure, N balance sheet, Zhangye Oasis

INTRODUCTION

To succeed in feeding the growing world population continued increases in food production is a necessity and would depend on increased supply of irrigation water as well as plant nutrients obtained from the soil with mineral fertilizers. However, some studies have shown

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that the continued use of mineral fertilizers may result in decline of soil quality and productivity (Kumar *et al.* 2001; Cassman *et al.* 1995; Lu 1998; Schwab 1990; Lai *et al.* 1992), while other studies have indicated positive (Doran *et al.* 1996), and no noticeable (Aref and Wander 1998) effects on soil productivity. In most long-term experiments, combination of mineral fertilizers and farmyard manure has generally given the best crop yields and soil quality in many parts of the world (Lu *et al.* 2001; Wang *et al.* 2004; Lin *et al.* 1996; Christensen and Johnston 1997; Sommerfeldt *et al.* 1988; Chalk *et al.* 2003; Yang *et al.* 2004).

Statistical data showed that nitrogen fertilizer consumption is growing rapidly in the developing countries (Chalk *et al.* 2003). This has resulted in serious environmental consequences, such as nitrate (NO_3^--N) accumulation in ground water, leaching and eutrophication. The leaching of nitrates happens when excess nitrogen fertilizer is applied, resulting in increased NO_3^--N accumulation in soils when high amount of water is moved via soil pores and cracks, and reach beyond the effective absorption by root zone (Yuan *et al.* 2000; Di and Cameron 2002; Zhang *et al.* 1996; Legg and Meisinger 1982). A long-term experiment study at the Loess Plateau in Northwestern China showed that the NO_3^--N accumulation in soil is the result of interaction among the soil productivity; soil moisture status and nitrogen fertilizer use efficiency (Guo *et al.* 2005). The effective approach to minimize movement of NO_3^--N into groundwater is to develop site-specific improved N fertilization and irrigation management practices to increase N uptake efficiency, to decrease N loss, and to minimize leaching losses below the root zone.

The objective of this study was to determine the effects of mineral fertilizers and farmyard manure on grain and straw yield, the interaction of kinds of fertilizers and farmyard manure, N uptake in grain and straw, accumulation of nitrate-N (NO_3^--N) in the soil profile, and N balance sheet based on a long-term fertilization experiment conducted in Hexi Oasis of Gansu, China.

MATERIALS AND METHODS

Field experimental site description

A field experiment was conducted from 1982 to 2001 on a calcareous warped desert soil (sandy clay loam) near Zhangye (38.6°N, 100.3°E; 1 560 m altitude) in Hexi Corridor of Gansu Province, Northwestern China. The region is one of the main grain food production areas for human consumption in China. The mean annual precipitation is only 136 mm and mean annual temperature is 7.0°C. Annual potential evaporation is about 1 990 mm. Annual frost-free period is about 165 days and approximately 50% of the annual precipitation is received during July to September. At the experimental site, mean annual precipitation during the study period was 127 mm (range of 72 mm in 1985 to 214 mm in 1983), and on average 53% (range of 36% in 1987 to 85% in 1995) of the annual precipitation was received in July to September. The mean annual air temperature at this site ranged from 6.3 to 9.5°C. The mean monthly temperatures ranged from 19.8 to 23.2°C for July, 18.9 to 21.8°C for August and 13.3 to 17.5°C for September. Results from soil determinations indicated that in the experimental site in 1982 soil was 8.4 pH, 20.8 g kg^{-1} soil organic matter, 28.1 mg kg^{-1} available N, 21.7 mg kg^{-1} extractable P and 99.1 mg kg^{-1} exchangeable K. The prearrangement of experiment showed that nitrogen fertilization had a remarkable yield-increasing effect, phosphorous fertilization had a definite increased effect, and potassium had not significantly affected the yield.

Experimental design

The experiment was a split-plot factorial design and included eight treatments with three replications. Plot size was 33.3 m^2. All the adjacent plots were separated by ridges (50 cm width), and the blocks were separated by irrigation furrows (60 cm width) and two ridges (50 cm width). Main treatments were with farmyard manure (M) and without farmyard manure, and subplot treatments consisted of unfertilized check (CK), N, NP and NPK. The eight treatments were CK, N, NP, NPK, M, MN, MNP and MNPK.

Fertilization and agronomical practice

The mineral fertilizer sources of N, P and K, respectively, were ammonium nitrate or urea, single super-phosphate or di-ammonium phosphate and potassium chloride commercial fertilizers. The majority of farmyard ma-

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