



Long-term response of soil Olsen P and organic C to the depletion or addition of chemical and organic fertilizers



Pu Shen^{a,b}, Minggang Xu^{a,*}, Huimin Zhang^a, Xueyun Yang^c, Shaomin Huang^d,
Shuxiang Zhang^a, Xinhua He^{b,*}

^a Ministry of Agriculture Key Laboratory of Crop Nutrition and Fertilization, Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China

^b School of Plant Biology, University of Western Australia, Crawley, WA 6009, Australia

^c College of Natural Resources and Environment, Northwest A&F University, Yangling, Shaanxi 712100, China

^d Institute of Plant Nutrition, Resources and Environment, Henan Academy of Agricultural Sciences, Zhengzhou, Henan 450002, China

ARTICLE INFO

Article history:

Received 28 July 2013

Received in revised form 17 January 2014

Accepted 26 January 2014

Available online 26 February 2014

Keywords:

Apparent P balance

Long-term fertilization

Maize–wheat rotation

Organic carbon

Phosphorus deficit or surplus

ABSTRACT

Soil degradation and water pollution could have resulted from inappropriate phosphorus (P) supply. Soil Olsen P is generally a good indicator to estimate bio-availability of P and environmental risk in alkaline soil. The change in Olsen P is always strongly affected by soil organic carbon (SOC) when different forms of inorganic and/or organic P are applied to farmlands with chemical fertilizer and/or manure. We related soil Olsen P to apparent P balance (APB) and SOC in alkaline soils at three 15-year (1991–2005) fertilization sites of northern China. Six treatments were examined: unfertilized control, chemical nitrogen (N), chemical NP, chemical N plus potassium (NK), chemical NPK, and chemical NPK plus animal manure (NPKM, same total N but 20–80% more P). Compared to the initial Olsen P in 1990, after 15 years Olsen P was increased under P fertilization but decreased under no-P fertilization. At the three 15-year fertilization sites, annual mean Olsen P was 4.9–12.3 times higher under NPKM, 1.9–2.8 times higher under NP and NPK, but only 28.3–84.8% under Control, N and NK. Annual mean percentage of Olsen P to total P was higher under NPKM (4.6–8.1%) than under other five fertilizations (0.4–2.9%). Change in Olsen P significantly positively correlated with accumulated APB under all fertilizations ($r^2 = 0.10–0.31$, $P < 0.05$). At these three sites, Olsen P could be increased by 5.2, 5.8 and 12.1% respectively under NP, NPK and NPKM when 1 kg P/ha was in surplus, meanwhile Olsen P was decreased by 2.1, 4.0 and 6.4% under Control, N and NK when 1 kg P/ha was in deficit. Significantly higher SOC accumulation was under NPKM than under other five fertilizations when calculated by the same unit of P input. The combination of chemical P and manure P with organic C input is a better strategy to increase soil Olsen P and SOC accumulation on farmland with maize–wheat rotation in northern China.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

A rational phosphorus (P) management in farmland is vital for an optimal crop production and environmental protection. Olsen P is generally a good indicator to estimate bio-availability of P and environmental risk in alkaline soil (Bai et al., 2013; Fu et al., 2009). Results from four long-term grazed fertilizer experiments (three in New Zealand and one in Australia) indicated that Olsen P accumulated with external application of P fertilizers while decreasing in soil P with the cessation of P fertilizer inputs (Cayley and Kearney, 1999; Dodd et al., 2013; McCaskill and Cayley, 2000). As regards to regulating the Olsen P in farmland,

one key practice is to increase the apparent P balance (APB, P input into soil minus P harvested from crops) (Cao et al., 2012; Messiga et al., 2010). Numerous studies in Canada, Europe and USA have also showed that soil Olsen P was increasing with P surplus while decreasing with P deficit (MacDonald and Bennett, 2009; Olson et al., 2010). In ~80% farmland soils in China, mean Olsen P was almost three times higher in 2006 (20.7 mg/kg) than in 1980 (7.4 mg/kg) after 26-year external P input (Li et al., 2011). This may be attributed to a doubled P fertilizer application in 2006 (7.70×10^6 mg) than in 1980 (2.73×10^6 mg), but P use efficiency was still as low as 10–33% in a given season in China (National Bureau of Statistics of China, 2012; Wang, 2007; Zhang, 2007). As a consequence, more P has been built up and hence more Olsen P might also be accumulated in soil.

Traditional farmyard organic manures are still important P sources for crop production, while the combined application of chemical P

* Corresponding authors. Tel.: +86 10 82105636; fax: +86 10 82106225.
E-mail addresses: mgxu@caas.ac.cn (M. Xu), xinhua.he@uwa.edu.au (X. He).

fertilizer and animal manure has been a traditional P management strategy in China (Duan et al., 2011; Zhang et al., 2009, 2010). Except for P nutrient, organic carbon and other nutrients were also simultaneously supplied from animal manures, while soil P accumulation or depletion was always affected by the organic carbon sources (Ramos and Martínez-Casasnovas, 2006; Shafiqat and Pierzynski, 2013). For example, Kang et al. (2009) found a strongly positive correlation between soil organic carbon (SOC) and maximum P saturation. Meanwhile, soil P was always activated by low-molecular-weight organic acids including citric, oxalic, and tartaric acids, and soil Olsen P was hence significantly increased by SOC (Kpombekou-A and Tabatabai, 2003; Siddique and Robinson, 2003). However, there might be difference in the accumulation and effect of SOC on soil Olsen P between the sole application of chemical P and the combination of chemical P and animal manure.

Significantly linear correlations between APB and the change in soil Olsen P have been observed under the sole chemical P fertilization particularly over a comparative short-term period (Cao et al., 2012). For instance, such sole chemical P input studies were conducted over an 8-year (1992–2000) groundnut–rapeseed rotation in India (Aulakh et al., 2007), and an ~10-year (~1990 or 1991 to ~2000) crop rotation (rice–wheat and maize- or soybean–wheat) in seven field sites across China (Cao et al., 2012). However, limited studies have addressed the differences in the response of soil Olsen P to APB and the relationships between SOC accumulation and Olsen-P under the combination of applying chemical P and manure P and/or over 10-year long-term fertilization.

Maize (*Zea mays* L.) and wheat (*Triticum aestivum* L.) are two main crops in China, whereas P, either in a sole chemical P or a combination of chemical P plus manure P, is often applied to increase their productivity. Under six 15-year long-term (1991–2005) fertilizations (three no-P, two chemical P, and one chemical P plus manure P) at three contrasting alkaline soils with maize–wheat rotations in northern China, the objectives of this study are to address differences in (1) soil Olsen P accumulation patterns, (2) responses of soil Olsen P to APB and (3) relationships between change in soil Olsen P and organic C accumulation.

2. Materials and methods

2.1. Experimental sites and designs

The geographical locations of three 15-year (1991–2005) long-term fertilization experiments in alkaline soils (pH 8.2–8.6 at 0–20 cm depth) are located at Changping (E40°13', N116°14'), Yangling (E34°17', N108°00') and Zhengzhou (E34°47', N113°40') of northern China. Soil physicochemical properties in 1990 varied with sites (Table 1).

At the three sites the cropping system was an annual maize–wheat rotation but varied with crop cultivars. Wheat was annually seeded around 10 October and harvested around 1 June, while maize was sown around 10 June and harvested around 1 October. Irrigation was applied to the wheat crop before seeding (5 mm), during winter (4 mm) and at jointing (5 mm), and for the maize crop once before seeding (5 mm). Without replicates the size of experiment plots was 200 m² (20 by 10 m) at Changping, 196 m² (14 by 14 m) at Yangling and 400 m² (25 by 16 m) at Zhengzhou. Soil was plowed up to 20 cm depth twice a year, always in early June or October after wheat and maize harvesting. Herbicides and pesticides were applied during the wheat or maize growing season when needed.

Six fertilization treatments or plots were applied to these three sites: (1) unfertilized control (Control), (2) chemical nitrogen (N), (3) chemical NP, (4) chemical nitrogen plus potassium (NK), (5) chemical NPK and (6) chemical NPK plus animal manure (NPKM). Chemical urea, superphosphate and potassium chloride (KCl) or potassium sulfate (K₂SO₄) were applied to all three sites while farmyard manure to Changping, cattle manure to Yangling and horse manure to Zhengzhou (Table 2). Manure application rates under NPKM were matched for the same rate of N under NPK, but this resulted in annual P rates 1.2 to 1.8 times higher than where P was applied as synthetic fertilizers (Table 3).

2.2. Soil and plant sampling, and variable analysis

Soils (0–20 cm) from five random locations of each plot were annually collected by 5 cm diameter auger after ~15 days of maize harvest and then mixed as one composite sample. Soils were air-dried, sieved

Table 1
Basic parameters of geography and physicochemical properties of initial soils (0–20 cm, 1990) at the three fertilization sites.

Parameters	Changping	Yangling	Zhengzhou
<i>Geographic condition</i>			
Altitude (m)	44	523	59
Latitude (E)	40°13'	34°17'	34°47'
Longitude (N)	116°14'	108°00'	113°40'
<i>Weather condition</i>			
Precipitation (mm) ^a	605	574	641
Evaporation (mm) ^a	1850	1292	1808
Temperature (°C) ^a	12.7	13.5	14.7
<i>Soil condition</i>			
Soil classification (FAO system)	Haplic Luvisol	Calcaric Regosol	Calcaric Cambisol
Bulk density (g/cm)	1.58	1.30	1.49
Clay (<0.002 mm, %)	10.2	16.8	13.4
Soil pH	8.2	8.6	8.3
CaCO ₃ (%)	3.4	9.2	4.8
Organic C (g/kg)	7.1	6.3	6.7
CEC (cmol/kg) ^b	14.6	24.7	10.5
Total N (g/kg)	0.64	0.83	0.67
AN (mg/kg) ^c	49.7	61.3	76.6
Total P (g/kg)	0.69	0.61	0.64
Olsen P (mg/kg)	4.6	9.6	6.5
Total K (g/kg)	14.6	22.8	16.9
AK (mg/kg) ^d	65.3	191	74.0

^a Annual mean value.

^b CEC: cation exchange capacity.

^c AN: alkaline-hydrolyzable N.

^d AK: NH₄OAc-Extractable K.

Download English Version:

<https://daneshyari.com/en/article/6408112>

Download Persian Version:

<https://daneshyari.com/article/6408112>

[Daneshyari.com](https://daneshyari.com)