Environmental Pollution 266 (2020) 115304

Contents lists available at ScienceDirect

Environmental Pollution

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

How long-term excessive manure application affects soil phosphorous species and risk of phosphorous loss in fluvo-aquic soil☆

Xuechao Qin [a], Shufang Guo [b], Limei Zhai [a, *], Junting Pan [a], Benyamin Khoshnevisan [a], Shuxia Wu [a], Hongyuan Wang [a], Bo Yang [a], Jinghong Ji [c], Hongbin Liu [a]

[a] Key Laboratory of Nonpoint Source Pollution Control, Ministry of Agriculture and Rural Affairs/Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing, 100081, PR China
[b] Institute of Agricultural Environment and Resources, Yunnan Academy of Agricultural Sciences, Kunming, 650201, PR China
[c] Institute of Soil Fertilizer and Environment Resources, Heilongjiang Academy of Agricultural Sciences, Harbin, 150086, China

ARTICLE INFO

Article history:
Received 25 March 2020
Received in revised form
18 June 2020
Accepted 22 July 2020
Available online 2 August 2020

Keywords:
Non-point source pollution
Manure
Phosphorus
Long-term fertilization

ABSTRACT

The excessive application of manure has caused a high load of phosphorus (P) in the North China Plain. Having an understanding of how manure application affects soil P changes and its transport between different soil layers is crucial to reasonably apply manure P and reduce the associated loss. Based on our 28-year field experiments, the compositions and changes of P species and the risk of P loss under excessive manure treatments were investigated, i.e., no fertilizer (CK), mineral fertilizer NPK (NPK), NPK plus 22.5 t ha^{-1} yr^{-1} swine manure (LMNPK), and NPK plus 33.75 t ha^{-1} yr^{-1} swine manure (HMNPK). Manure application increased the content of orthophosphate and myo-inositol hexaphosphate (*myo*-IHP), especially the orthophosphate content exceeded 95%. The amount of orthophosphate in manure and the conversion of organic P to inorganic P in soil were the main reasons for the increased soil orthophosphate. Compared with NPK treatment, soil microbial biomass phosphorus and alkaline phosphatase activity in LMNPK and HMNPK treatments significantly increased. Compared with NPK treatment, a high manure application rate under HMNPK treatment could increase the abundance of organic P-mineralization gene phoD by 60.0% and decrease the abundance of inorganic P-solubilization gene pqqC by 45.9%. Due to the continuous additional manure application, soil P stocks significantly increased under LMNPK and HMNPK treatments. Furthermore, part of the P has been leached to the 60–80 cm soil layer. Segmented regression analysis indicated that $CaCl_2$–P increased sharply when Olsen-P was higher than 25.1 mg kg^{-1}, however the content of Olsen-P did not exceed this value until 10 years after consecutive excessive manure application. In order to improve soil P availability and decrease the risk of P loss, the manure application rate should vary over time based on soil physicochemical conditions, plants requirements, and P stocks from previous years.

1. Introduction

Phosphorus (P) is an essential macro-element for crop production. Although soil P stock is abundant in the North China Plain, most of it is not available to the plants due to the strong adsorption capacity of soil (Wang et al., 2018a). The application of P fertilizers is the key to improve soil P availability, meet crop P demand, and consequently ensure an acceptable crop yield (Medinski et al., 2018; Guo et al., 2020). The P resources in the world are limited (Gilbert, 2009), but the abundant P in manure makes it possible to provide sufficient P for crops. However, in parallel with the rapid development of animal husbandry, a large amount of livestock manure has been recycled in arable lands, leading to extremely excessive P in agro-ecosystem (Bouwmana et al., 2012; MacDonald et al., 2011). Excessive manure has long been applied in crop cultivation in the North China Plain while ignoring its P content and its associated environmental problems (Li et al., 2015a, 2015b; Miao et al., 2010; Wang et al., 2018b), because manure nitrogen is always taken into account to determine the manure application rate. The high P input from manure and mineral fertilizers as well as the low P uptake by plants has caused the accumulation of more than

☆ This paper has been recommended for acceptance by Yong Sik Ok.

* Corresponding author.
E-mail address: zhailimei@caas.cn (L. Zhai).

https://doi.org/10.1016/j.envpol.2020.115304
0269-7491/