Effects of Pig Manure Composts on Lettuces Quality and Nitrogen/Phosphorus Utilization Efficiency in Huang-Huai Plain

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Abstract. The prevailing problems in countryside, such as excessive use of chemical fertilizer and large amounts of livestock manure, need to be addressed urgently. In order to optimize the amount of applied organic fertilizer, the experiment was carried out in the planting-breeding combined circular agricultural area of Huang-Huai plain and the effects of pig manure fertilizer amounts on lettuces yields, quality and nitrate/phosphorus utilization efficiency were investigated. It was found that the replacement of chemical fertilizer with organic fertilizer had no significant effects on the N and P content of lettuces when treated with the same amounts of fertilizer. However, it could improve its yield, quality, and nitrogen/phosphorus utilization efficiency. When the ratio of organic fertilizer replacement was 25%~75%, the nitrate and nitrite content of lettuces were reduced by 19.41% and 73.33% compared with the chemical fertilizer treatment. The nitrogen and phosphorus utilization efficiency in the 75% organic fertilizer replacement were highest, which were 30.4%/44.9% higher than that of chemical fertilizer respectively. Above all, the 75% organic fertilizer with 25% fertilizer group had the best effect on the yield of lettuces, improving the quality and utilization efficiency of nitrogen and phosphorus fertilizer. The results could provide an important scientific basis for determination of regional vegetable planting fertilizer and reduce the non-point source pollution risk.

1. Introduction
With the rapid development of agriculture and rural economy, high inputs of chemical fertilizer have been used to increase crop yields in China. They could not only cause the decline of crop quality and yields, but also impact the quality of soil and groundwater. Attempts to enhance yields by adding excessive fertilizer have become increasingly uneconomical, resource-wasting and polluting issues[1]. Meanwhile, the pollution caused by large amount of livestock manure has become severe ecological environment destruction. Livestock manure could be used as high quality organic fertilizer containing large amounts of nutrients necessary for crop growth, such as nitrogen (N), phosphorus (P), and
microelement [2]. Therefore, rational use of organic fertilizer is an important way to achieve zero growth of chemical fertilizer and drive circular agriculture development.

Vegetables are the main crop type in the suburbs of the city, and have shallow root system and short growth period features. High fertilization and frequent irrigation could lead to easier migration and leach of nutrients in environment [3]. Importantly, the effects of manure composts on the vegetables are vital to optimize fertilizer management. Huang-huai plain is one of the main vegetables producing areas in China, and planting and livestock are well established. Therefore, promoting the application of manure compost and reducing chemical fertilizer would have significant economic and environmental benefits in this area. This study selected the local typical planting and breeding combination area (Huang-huai plain) as the research base, to analyze the effects of manure compost instead of chemical fertilizer on vegetable yield, quality, and N/P utilization efficiency under different proportions. The research objective was to determine the optimum application proportion of manure compost, and provide practical basis for establishing sustainable consumption of organic fertilizer in this area and reducing non-point source pollution.

2. Materials and Method

2.1. Site Location and Description
The study site (34.80°N 114.48°E) was located near Kaifeng City, Huanghuai plain in China. This area located in a temperate monsoon climate with an annual average temperature of 14.5 °C, an annual precipitation of 627.5 mm, and a frost-free period of 221 d. The soil, classified as wet regosol, was formed by sedimentation. And the soil between the test plots was uniform and the physical and chemical properties were similar.

The organic fertilizer was derived from pig manure composite after moderate temperature digestion, and the contents of N, P2O5 and K in the compost were 2.2%, 1.0% and 1.6%, respectively. The used chemical N, P and K fertilizers were urea, calcium superphosphate, and potassium chloride, respectively.

2.2. Fertilizer Treatments
Eight treatments, including organic fertilizer (henceforth, H1), 100% chemical fertilizer (H2), 75% organic fertilizer plus 25% chemical fertilizer (H3), 50% organic fertilizer plus 50% chemical fertilizer (H4), 25% organic fertilizer plus 75% chemical fertilizer (H5), and without fertilizer (Control), were laid out in a randomized block design with three replications. The size of each plot was 1.0 m × 9.0 m for each treatment, and isolated by 0.5 m earth baffle plates. The applied amounts of N, P, and K were 200.0 kg N·ha⁻¹, 96.8 kg P2O5·ha⁻¹, and 150.0 kg K·ha⁻¹ respectively, and the same for all fertilizer treatments. The lettuces are widely cultivated in Huang-huai plain, and selected as the test vegetable. The lettuces were planted on September 2017, then thinned, and harvested on November.

2.3. Sample Collection and Analysis
The aerial part of the lettuces was used as the test sample. The concentrations of soluble sugar, nitrate-N and nitrite-N were measured by colorimetry [4]. The samples were dried at 105 °C for 2 h and 85 °C over 24 h. Dry mass of the whole plant was recorded and the dry material was ground to a particle size of 1 mm. A prepared sample of 5 g was used for measurements of total N and other nutrients. Total N was measured by the Kjeldahl method. Total P was measured colorimetrically with an ammonium-vanadate-molybdate method [5].

2.4. Data Statistical Analysis
Data analyses were performed with SPSS 10.0 statistical software. Treatments were compared by variance (ANOVA) at P=0.05, and the different lowercase letters indicate significant differences among treatments (P<0.05). The formula for calculating the N/P absorption (Ai) and utilization efficiency (Ri) was as follows:

\[ A_i = Y_i \times C_i \]
\[ R_i = \frac{A_i - A_{ck}}{D_i} \]

Where \( Y_i \) is the yield of lettuces, \( C_i \) is N or P\(_2\)O\(_5\) content of lettuces, \( A_i \) is the N or P absorption amount of lettuces, and \( D_i \) is N or P application amount.

3. Results

3.1. Lettuces yields

The yields of lettuces in different fertilizer treatments are shown in Figure 1. The yields under fertilizer treatments were significantly increased by 30.7%-61.1%, compared with the control (\( P < 0.5 \)). The lettuces yields changed in an increasing order of CK < H1 < H5 < H4 < H2 < H3. The combination of chemical and organic fertilizer significantly increased yields of lettuces compared with H1. And the yields were similar for H2, H3, H4, and H5 treatments.

![Figure 1. Effects of different treatments on the yield of lettuces](image)

3.2. Quality of lettuces

The soluble sugar content is shown in Figure 2. The application of fertilizer could significantly lead to higher soluble sugar concentration than the control group (\( P < 0.05 \)). The complex of organic and inorganic fertilizers increased soluble sugar concentration by 56.9%-88.2%, compared to H2. And the soluble sugar concentration of H5 was the highest, which was 88.2% higher than that of the merely chemical fertilizer treatment.

![Figure 2. Effects of different treatments on the soluble sugar concentration of lettuces](image)
It can be found that the fertilizer types could affect the nitrate and nitrite contents of the *lettuc*es (Figure 3 a and b). The nitrate and nitrite concentration in chemical fertilizers (H2) was highest, which was 2.7 g·kg\(^{-1}\) and 12.0 mg·kg\(^{-1}\), respectively. However the application of organic fertilizer decreased the nitrate and nitrite content, their contents in H1 were 25.8% and 87.5% lower than that of the H4 treatment, respectively. The nitrate content in different fertilizer treatments was similar except H2. However, there were significant differences among nitrite content in all groups.

![Figure 3](image)

**Figure 3.** Nitrate content (a) and nitrite content (b) in lettuces

3.3. *N and P content in lettuces*

The N content (Figure 4 a) in different fertilizer treatments was significantly higher than that of the control (23.1 g·kg\(^{-1}\)), and the increase range was 55.6-129.5%. The difference of N content in H2-H5 groups was negligible (*P*>0.05). Furthermore, compared to the control, fertilization also could greatly increase the P content (Fig. 4 b). The H4 group exhibited the highest P content, which was similar to the content in H3 and H1 groups. Moreover, the P content in the H2 and H5 treatments was lower than the other fertilizer treatments.

![Figure 4](image)

**Figure 4.** The N accumulation (a) and P accumulation (b) in lettuces

3.4. *N and P utilization efficiency*

The N utilization efficiency in various fertilizer treatments was in the following order (Table 1): combined application of organic fertilizer and chemical fertilizer (H3-H5) > chemical fertilizer (H2) > organic fertilizer (H1). Among them, the N utilization efficiency of the H3 treatment was the highest (25% fertilizer plus 75% organic fertilizer), and reached to 29.6%. Generally, the change trend of P fertilizer utilization efficiency was consistent with N fertilizer basically. Additionally, the P accumulations in different fertilizer treatments were in the order: H3>H4>H5>H2>H1. Notably, the P utilization efficiency of H3 was 44.8% higher than that of chemical fertilizer treatment (*P*<0.05).
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