# Long-term fertilization effects on grain yield and soil fertility in the paddy soil of Yangtse Delta in China

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**Abstract**
A long-term field experiment under different fertilizer N rates has been conducted to explore the optimal N application rates for a rice-wheat system and soil fertility change in the Yangtse Delta region where excessive applications of N fertilizer have resulted in reduced N recovery rate and environment pollution. Results of 11-years experiment showed that fertilizer N application rate had a significant effect on crop yield and soil fertility. Rice yield varied over time from 6.0 to 8.3 t/ha for the fertilization N and from 4.1 to 6.5 t/ha for nil N, and wheat yield varied from 2.3 to 6.5 t/ha for the fertilization N and 0.7 to 3.4 t/ha for nil N and control. The optimal N application rate of high grain yield ranged from 185 to 225 kgN/ha for rice and was about 180 kgN/ha for wheat. SOM and total soil nitrogen (TN) increased with the increase of N application rate, but there were no significant difference ($P<0.05$) under different N application rates. Soil available N had a slight increase with N application rate, but soil Olsen-P and available potassium was declined with the increase of N application rate. These show that this paddy soil has a strong buffer capacity.

**Key Words**
Rice-wheat system; long-term fertilization; N-Fertilizer: grain yield; soil fertility.

**Introduction**
The rice-wheat rotation is one of largest agricultural production system of the word, occupying 70~80% productive land in Yangtse Delta region in China. Some few reports, however, indicate that the system is under production fatigue as yields have started declining due to continuous rice-wheat cultivation(Yadav, 2000). farmers have resorted to using higher (550-600 kgN/ha/year) than the recommended doses of N fertilisers to maintain previously attained yield levels (Wang, 2004), which has resulted in reduced N recovery rate and environment pollution. Monitoring long-term fertilization effect on crop yield and soil fertility changes is important for maintaining the system productivity (Ladaha 2003). Although there have been many field trials on fertilizer yield responses in China, most of these studies have been carried out within a short period of time and can provide only preliminary fertilizer recommendations, which need further calibration through multi-year field experiments(Fan 2005). However, most of long-term experiments are too simple to provide fertilizer recommendations. Although there have been some long-term experiments in nutrient gradient (KBS LTER 2009), few of the results are well documented in China. The experiment reported here was begun in 1998 with different fertilizer-N rates at Changshu, central place of the Yangtse Delta region, China. The study aimed to (1) examine long term yield variation for different N application rates, and (2) monitor soil fertility changes.

**Methods**
*Experimental site*
A long-term field experiment has been conducted since June 1998 at the Changshu National Agro-ecological Experimental Station (31°32.93′N, 120°41.88′E), situated in Changshu Municipal, Jiangsu Province, China. The current agricultural practice in this region is an intensive double-cropping system consisting of irrigated summer rice and upland winter wheat. Gleyed paddy soil is Eqiaquepts(US Taxonomy) with an average SOM 35.0 g $kg^{-1}$ and clay loam texture over 0–30 cm depth. The top 15 cm of soil taken from the experiment starting had the following characteristics: pH 7.4, SOM 36.5 g/kg, total N (TN) 2.05 g/kg, total P (TP) 0.71 g/kg, total K (TK) 22.1 g/kg, available P (AP) 7.7 g/kg, and available K (AK) 121 g/kg.

*Experimental design and treatments*
The field experiment had 6 treatments of N0, N1, N2, N3, N4 and control(CK), with fertilizer N rate being 0(0), 180 (135), 225 (180), 270 (225), 315 (270) and 0 (0) kgN/ha, respectively for rice crops(wheat), and P application rate 26 (39) kg/ha and K application rate 94 (94) kg/ha for all the treatments except for CK,

which received nil fertilization. The experiment had four replicates with plots, 32.5 $m^2$ each, arranged randomly in rows. For both rice and wheat crops, the urea application was 40%-50% basal, 20% topdressed at tillering, and 30%-40% topdressed at panicle initiation(PI) stage. The P fertilizer, as superphosphate, was applied totally as basal. The K fertilizer, as potassium chloride, was applied 50% basal, and 50% topdressed at PI stage. Generally, two or three rice seedlings (25-30 days old) were translated to puddled field at 25 cm*20 cm spacing and wheat (100~120 kg seed/ha) was sown by broadcasting. Crops were harvested manually close to the ground and all harvested biomass was removed from the plots. Grain yields were determined by harvesting half area at centers of the plots and were adjusted to 14% moisture.

*Soil sampling and analysis*

Composite soil samples (5 soil core samples/plot, 0-15 cm depth) were collected after rice harvested each year. The samples were air-dried, sieved (<2 mm ) and stored for analysis of general soil properties. Representative samples were used to determine SOM, TN, TP, and available NPK， 1M NaOH hydrolyzed nitrogen (AN) , 0.5M $NaHCO_3$ extractable P (AP) and 1 N $NH_4OAc$ extractable K (AK), following the methods of Lu (2000)

*Data analyses*

Data were statistically analyzed by one-way ANOVA and significant differences were distinguished by LSD test at P < 0.05 level (SPSS 11.5).

## Results

*Effect of N application rate on yield of rice and wheat*

Rice yield varied over time from 6.0 to 8.3 t/ha for N fertilization (as N1-N4 hereafter) and from 4.1 to 6.5 t/ha for nil N. Yields was lower during 1999~2001 and 2003~2005, mostly resulting from excess rain and lower temperature (Figure 1a). The results of 11 years of experimentation indicated that the rice yield is related to N application. Among four treatments of fertilization N, rice yield of treatment N3 (270 kgN/ha) was close to the highest value, but the increase in yield was very limited when N application rate went beyond treatment N1(180 kgN/ha) and yields for only 2 of 11 years had significant differences (P<0.05) with N1 and N2(225 kgN/ha). So the optimal N application rate for rice on this paddy soil may range between 185 and 225 kg/ha. Rice yield for treatment N0 followed a trend of increase from 4.1(1999) to 6.2 t/ha (2008), which showed that there was a nitrogen contribution from an environment source. Monitoring indicated that the experiment field received about 35.3 kg N/ha/year from rain and irrigation during the 2005~2006. In addition, no significant difference was observed between CK and N0 in the first three years, showing that among the three macronutrients, NPK, N fertilizer has the most effect on yield of rice. For the wheat (Figure 1b), yield fluctuated much more than for rice, it varied from 2.3 to 6.5 t/ha for treatment of N application and 0.7 to 3.4 t/ha for treatment of N0 and CK. The yields of treatment N1-N4 were significantly higher than treatments N0 and CK, but most of the yields had no significant difference among fertilization N treatments, and between N0 and CK. Optimal fertilizer N rate for high yield wheat also fluctuated from 180 to 225 kgN/ha, but mostly was 180 kgN/ha.

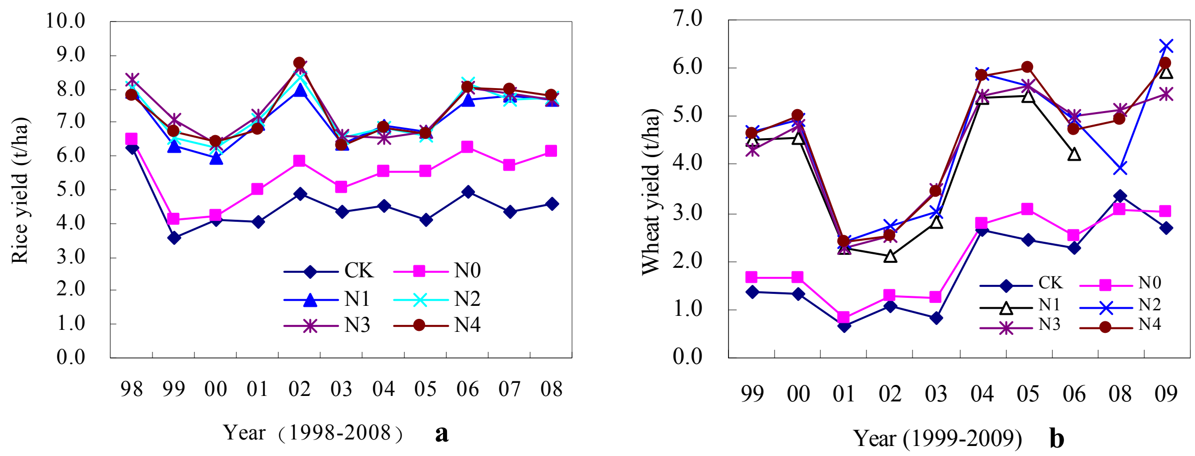


**Figure 1. Variation in yield of rice and wheat under the different N application rates from 1999 to 2009**

***Impact of N application rate on soil fertility***
The soil SOM and TN (taken in 2008 after rice harvesting, 0-15 cm depth) increased with increasing of N application rate after ten-year fertilization (Figure 2a) and highest values appeared in treatment N3 with 41.6 and 2.44 g/kg for SOM and TN, respectively. When the N rate went beyond the N3, both SOM and TN declined, but there were not significant differences among N fertilization treatments (N1-N4). A similar result was also reported for a calcareous paddy soil (Shena *et al.* 2004). For rapidly available soil NPK (Figure 2b), the AN had a slight increase with N application rate, but only the treatment N4 was a significantly higher than the other treatments. The content of AP and AK declined with increasing N application rate. Treatment N0 had a highest values of AP and AK with 36.1 and 199 mg/kg, respectively, which were significantly higher than for treatments of N fertilization and CK, however, there were not significant difference among N fertilization treatments. Compared to the initial soil, soil AP and AK increased about 140~200% and 19.0~24.3% for N treatments, respectively. Soil AP in control decreased 56%, however, AK changed little, being attributed to the soil being potassium rich.

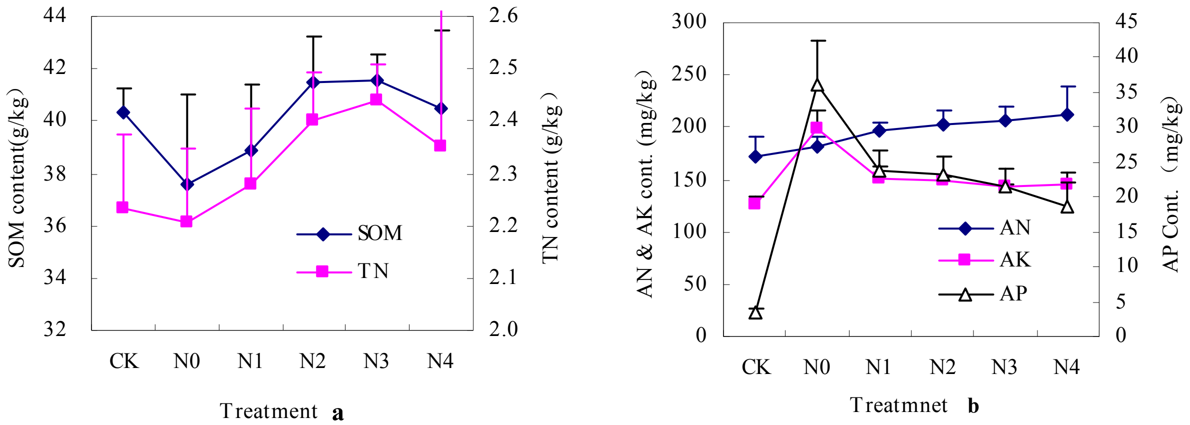


**Figure 2. Variation in soil nutrients for the different N application rates in 2008**

## Conclusion
Continuous (11 years) application of different N rates had a significant effect on crop yield and soil fertility. The rice yield was more stable than wheat yield over time, and the optimal N application rate for high yield ranged from 185 to 225 kgN/ha for rice and was about 180 kgN/ha for wheat in this area. The SOM and TN increased with the increase of N application rate, but there were not significant difference ($P<0.05$) among different N application rates. The AN showed a slight increase with N application rate, but soil AP and AK declined with increasing of N application rate. These data show that N fertilizer rate if reduced properly has no significant effect on grain yield and soil fertility in the rice-wheat system of this region.

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