Potassium Changes in Soils Managed for Cash or Grain Crops

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Analysis of soil test K from soil samples collected over 23 years, and yield responses from over 2,000 field experiments, indicate that any increase in average soil K in China were most attributable to high K fertilizer use on cash crops. Little change in grain crop field soil K was observed over the same period.

Urgent site-specific K nutrient management is needed in China to address the great variation in soil available K across its different regions and cropping systems.

Understanding soil K status is important when developing appropriate K nutrient management. Potassium deficiency is a serious problem for many regions in China; however, with the development of agricultural mechanization, implementation of policies by the Chinese central government promoting the return of crop straw to fields after harvest, and increased use of organic (compost) fertilizers, some soils are showing an increase in plant-available K. Contradictory reports on changes in soil available K have also raised concerns of scientists and the fertilizer industry. These contradictory results may be attributed to differences in soil sampling points, number of samples, time of sampling, and analytical methods. Up to now, the effects of K fertilizer use have not attracted concerns like those seen with N and P.

The historic national soil survey conducted in the early 1980s in China does not reflect current soil K status. The current soil K balance in China is influenced by the imbalance of K relative to N and P fertilizers, and crop K removal by new and high-yielding genotypes. The objectives of this study were to evaluate the temporal and spatial variation of soil available K and crop yield response to K fertilizer in China from 1990 to 2012.

Datasets for soil available K and crop yield were compiled from published and unpublished data sources between 1990 and 2012 from IPNI China Program. In total, 58,559 soil available K records and 2,055 yield records were collected (**Figure 1**). These experiments were conducted in farmers' fields, where yield data was obtained from first season harvests from N, P and K application plots. The rates of N, P and K fertilizers were recommended based on soil testing. The NP treatment rates were based upon those used in the NPK treatment.

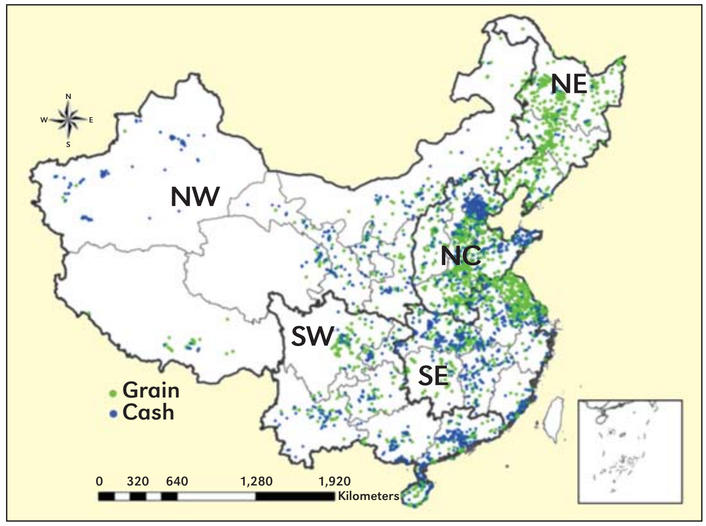

Figure 1. Distribution of experimental sites for five production regions of China from 1990 to 2012. The green and blue dots represent grain and cash crops, respectively.

To evaluate spatial variation of soil available K, five agricultural regions were grouped based on geographic location and China's administrative divisions (i.e., northeast, north central, northwest, southeast, and southwest). Each agricultural region was further divided into two sub-groups based on soil utilization pattern (i.e., grain or cash crop system). In the grain crop

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; IPNI = International Plant Nutrition Institute.

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Soils under grain or under cash crops show distinctly different K availability over the past two decades.

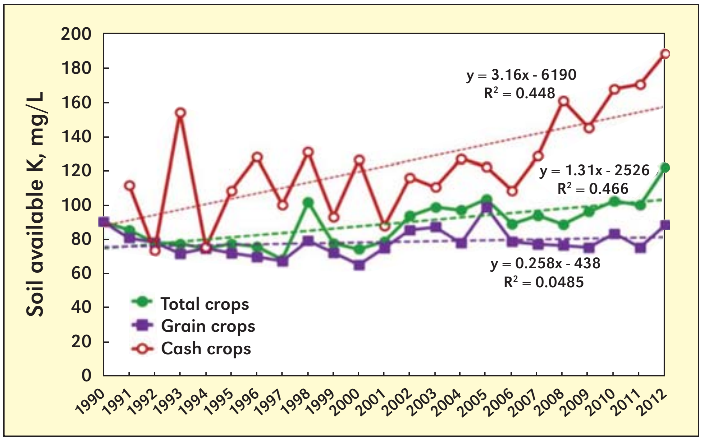

Figure 2. Trends in mean soil available K in China from 1990 to 2012.

systems, fields grew wheat, maize, rice, potato, and soybean. In the cash crop systems, vegetables, fruit trees, rapeseed, sunflower, cotton, and sugar crops, with higher fertilizer rates and higher economic returns, were planted. The geographical distribution of the data is shown in **Figure 1**.

Changes in Soil Available K

Soil available K from all experiments showed an increasing trend from 1990 to 2012 (**Figure 2**). Soil K under cash crops increased steadily from 1990 to 2012, while in grain crops, soil K fluctuated annually and did not show an obvious increase over this period of time. Fertilizer application for grains averaged 110 kg K_2O/ha (ranging from 30 to 360 kg K_2O/ha), while in cash crops the average was 255 kg K_2O/ha (ranging from 15 to 1,867 kg K_2O/ha) (data not shown). These results demonstrate the strong influence that high fertilizer K input in cash crops has on soil K concentrations, which is driving the increasing trend of soil available K in China.

Spatial and Temporal Variation of Soil Available K

Balanced fertilization was introduced to China in the 1980s, and there has been a major focus on the balanced use of K fertilizers in China since the 1990s. However, great variation in soil test K has existed across different regions, with mean values for ASI soil test K (Portch and Hunter, 2002) being 77, 100, 118, 84, and 81 mg/L for northeast, north central, northwest, southeast, and southwest China, respectively. A comparison of soil available K across the 1990s (1990 to 1999) and 2000s (2000 to 2012) shows that mean values increased from 80 mg/L in the 1990s to 93 mg/L in the 2000s. Soil available K showed no difference in the northeast between the 1990s and 2000s. However, soil available K increased by 35% (76 to 103 mg/L), 18% (72 to 84 mg/L) and 30% (69 to 83 mg/L) from the 1990s to 2000s for north central, southeast, and southwest China, respectively. Mean values decreased by 76% (154 to 116 mg/L) from the 1990s to 2000s for northwest China (**Figure 3A**).

Soil available K in grain crop fields followed the same trends as those shown for the average for all crops, but the results varied across regions (**Figure 3B**). For the north central, southeast and southwest regions, the soil K increased by 9%, 21% and 9%, respectively in the 2000s from baselines of 72, 65 and 66 mg/L in the 1990s. However, for the northwest, soil available K in the 2000s decreased by 74% compared with the 1990s (**Figure 3B**).

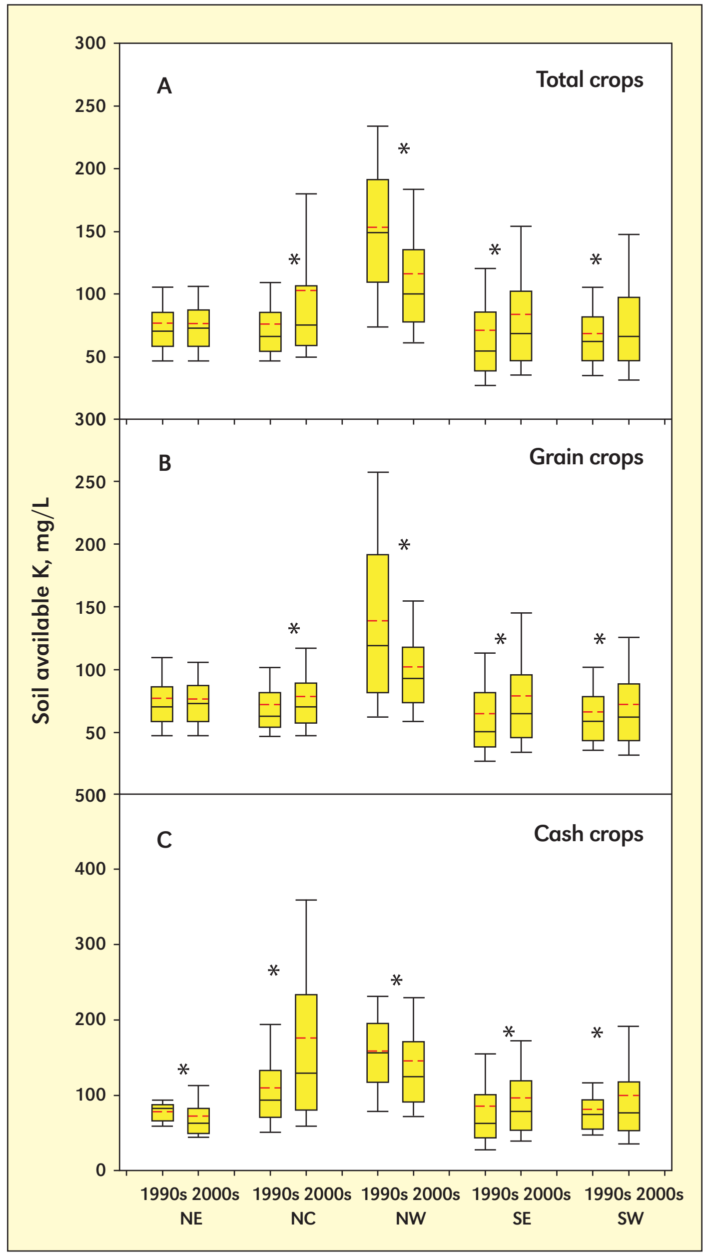

Figure 3. Comparison of soil available K between 1990s and 2000s. (A) Total crops; (B) Grain crops; (C) Cash crops. The star * between the two boxes indicates soil available K between 1990s (left box) and 2000s (right box) significant different at $p < 0.05$. The black and redlines, lower and upper edges, bars represent median and mean values, 25th and 75th, 5th and 95th percentiles of all data, respectively.

The soil available K in the 2000s for cash crops only increased by 60%, 12% and 22% for north central, southeast and southwest China, respectively, if compared to values in the 1990s, but declined to only 92% of 1990 values in the northeast and northwest. The increased soil available K in the north central and southwest regions were attributable to the large area of cash crops, while the increased mean values in the southeast was mainly attributed to larger increases in grain crops. The decrease in soil available K in the northwest was attributable to the large decline in soil available K in grain crop fields (**Figure 3C**).

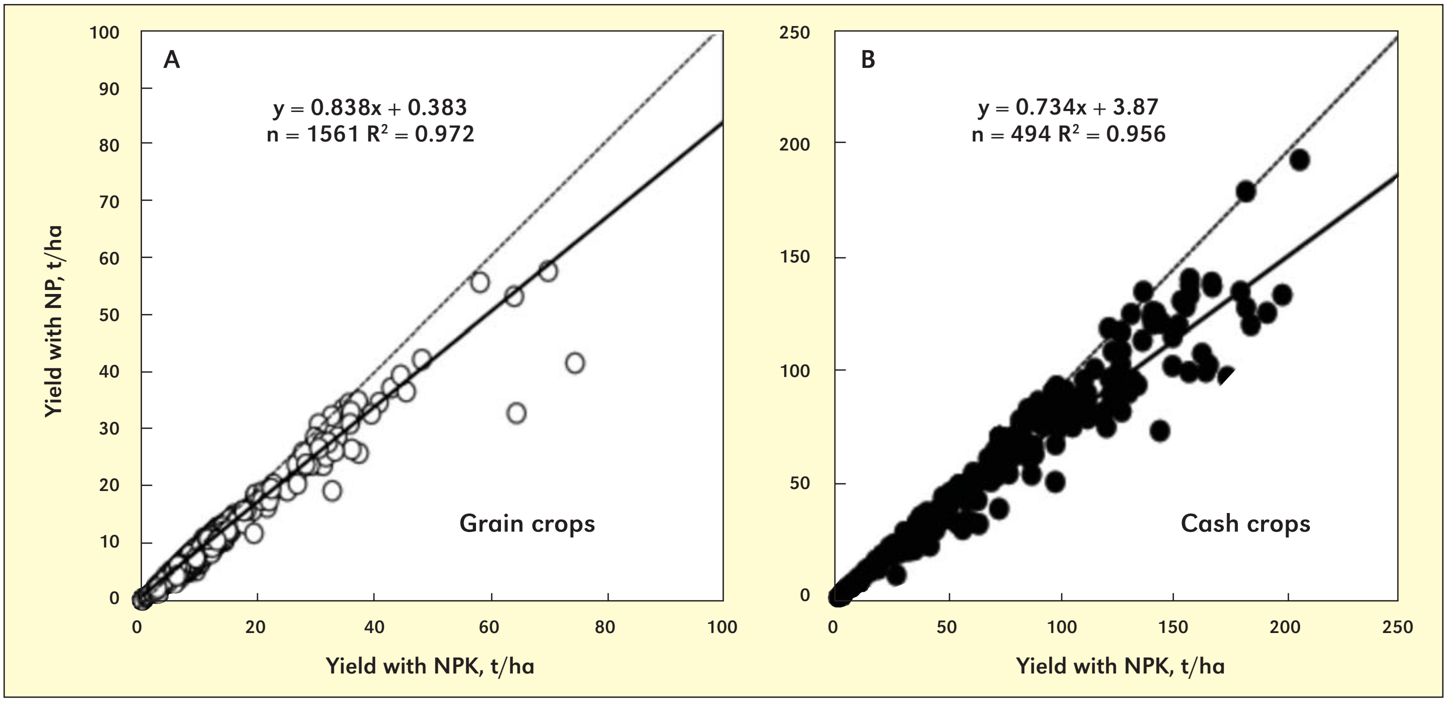

Figure 4. Yield with PK and yield with NPK for (A) Grain crops; (B) Cash crops. The dashed line is the1:1 line.

Results from this study indicate that soil available K showed a minor increase in soils planted to grain crops, but increased significantly in those soils planted to cash crops. The trends of increased soil K for cash crops is in accordance with the high fertilizer K application rates used by farmers. The K fertilizer application rates for cash crops averaged 164, 231, 205, 240, and 391 kg K_2O/ha, which were 1.7, 2.1, 1.7, 2.1, and 2.8 times those for grain crops for northeast, north central, northwest, southeast, and southwest China, respectively (data not shown). However, the soil available K for grain crops in 2000s were lower than 80 mg/L (the critical value for K deficiency) in all regions except the northwest. Therefore, more K fertilizer was needed for soils planted with grain crops and no increase in soil indigenous K supply has been measured. The results can be supported by relative yield and a great number of site-to-site reports as well. Although with the development of agricultural mechanization and more crop residues being returned back to soils, reports from grain crop fields indicated that the return of straw alone is not sufficient to maintain the soil K balance. Fertilizer K application is essential to maintain both high yield and soil K balance.

Although soil K values in cash crops were observed to be higher than those in grain crops, the relative yield of cash crops were lower than grain crops indicating that yield reduction with NP treatment, or without K application, was larger for cash crops than grain crops as compared with NPK treatment (data not shown). This observation was also supported by the larger response to K application for cash crops than that for grain crops (**Figure 4**). These results indicate that the contribution of soil indigenous K supply to yield was higher for grain crops than for cash crops. More K is needed to achieve the optimal yield of cash crops, with larger yield response to K, as compared with that for grain crops. In addition, the K nutrient removal by cash crops was larger than that for grain crops.

Summary

Soil available K in China has shown an increasing trend from 1990 to 2012 and these increases came from the increased soil K in cash crop fields due to higher K fertilizer application. Therefore, K fertilizer application is required not only for grain crops with lower soil K levels, but also for cash crops with large yield response to K application as well. The strategies used to address this challenge need to be regional and site specific. The information from the current study can also be used to guide future research activities, such as research on soil K critical values for individual cash crops, K nutrient cycling, and 4R nutrient management strategies under agricultural mechanization. BC

Acknowledgment

More detail on this research can be found in the original article published by He et al. in Field Crops Research (2015, 173: 49-56) http://dx.doi.org/10.1016/j.fcr.2015.01.003.

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References

Portch, S. and A. Hunter. 2002. PPI/PPIC China Program Special Publication No. 5.