Asia 8: 11-13.

FAI. 2014. Fertiliser Statistics. The Fertiliser Association of India, New Delhi, India.

Majumdar, K., Dey, P. and Tewatia, R. K. 2014. Current nutrient management approaches: Issues and strategies. Indian Journal of Fertilizer 10(5): 14-27.

Majumdar, K., Kumar, A., Shahi, V., Satyanarayana, T., Jat, M. L., Kumar, D., Pampolino, M., Gupta, N., Singh, V., Dwivedi, B. S., Meena, M. C., Singh, V. K., Kamboj, B. R., Sidhu, H. S. and Johnston, A. 2012. Economics of potassium fertiliser application in rice, wheat and maize grown in the Indo-Gangetic Plains. Indian Journal of Fertilizer 8(5): 44-53.

Pampolino, M. F., Witt, C., Pasuquin, J. M., Johnston, A., Fisher, M. J. 2012. Development approach and evaluation of the Nutrient Expert software for nutrient management in cereal crops. Computer and Electronics in Agriculture 88: 103-110.

Sapkota, T. B., Majumdar, K., Jat, M. L., Kumar, A., Bishnoi, D. K., Mcdonald, A. J. and Pampolino, M. 2014. Precision nutrient management in conservation agriculture based wheat production of Northwest India : Profitability, nutrient use efficiency and environmental footprint. Field Crops Research 155: 233-244.

Setiyono, T. D., Walters, D. T., Cassman, K.G., Witt, C., Dobermann, A. (2010) Estimating the nutrient uptake requirements of maize. Field Crops Research, 118 (2): 158–168

Singh, V. K., Dwivedi, B. S., Buresh, R. J., Jat, M. L., Majumdar, K., Gangwar, B., Govil, V. and Singh, S. K. (2013) Potassium fertilization in rice–wheat system across Northern India: Crop performance and soil nutrients. Agronomy Journal 105, 471-481.

Singh, V. K., Dwivedi, B. S., Tiwari, K.N., Majumdar, K., Rani, M., Singh, S. K. and J. Timsina (2014) Optimizing nutrient management strategies for rice–wheat system in the Indo-Gangetic Plains of India and adjacent region for higher productivity, nutrient use efficiency and profits. Field Crops Research 164, 30–44.

Timsina, J., Singh V. K., Majumdar K. J. (2013) Potassium management in rice–maize systems in South Asia. Plant Nutrition and Soil Science 176, 317–330.

Witt, C., Dobermann, A., Abdulrachman, S., Gines, H. C., Wang, G. H., Nagarajan, R., Satawathananont, S., Son, T. T., Tan, P. S., Tiem, L. V., Simbahan, G. C. and Olk, D. C. (1999) Internal nutrient efficiencies of irrigated lowland rice in tropical and subtropical Asia. Field Crops Research 63, 113-138.

Soil K increases from cash crops in China

Ping He, Fang Chen, Shutian Li, Shihua Tu, Adrian M. Johnston

Understanding soil K status is important when developing appropriate K nutrient management. Reports have indicated that K deficiency is a worldwide problem. However, with the development of agricultural mechanization and 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, soils have been shown to have increased soil K levels. However, some contradictory reports on soil available K changes have 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 N and P. The historic national soil survey conducted in the early 1980s in China could not reflect current soil K status in reality. 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. This lack of understanding needs to be evaluated.

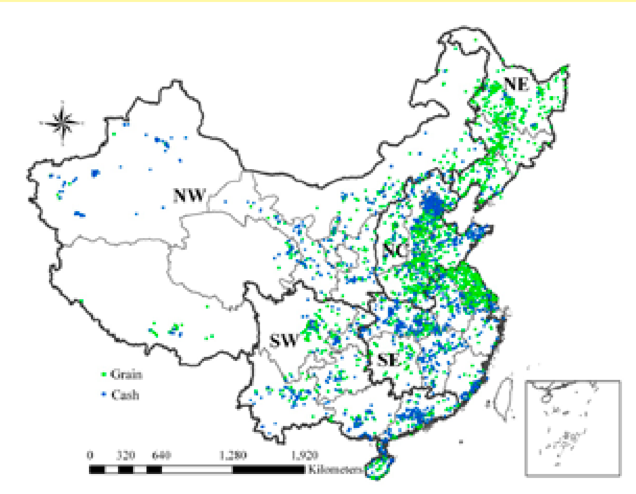

Fig. 1. Distribution of experimental sites for five production regions of China from 1990 to 2002. The green and blue dots represent grain and cash crops, respectively.

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.

Materials and Methods

Datasets for soil available K and crop yield were compiled from published and unpublished data sources in 1990-2012 from the Inational Plant Nutrition Institute (IPNI) China Program database. In total, 58,559 soil available K records (**Fig.1**) and 2055 yield records were collected from this database. These experiments were conducted in farmers' fields, and crop yield was obtained from the first season harvested crops from N, P and K application plots (NPK, the rates of N, P, and K fertilizers were recommended based on soil testing) and only N and P treatment (NP, no K fertilizer was applied based on NPK treatment).

To evaluate spatial variation of soil available K in China, five agricultural regions were grouped based on geographical locations and China's administrative

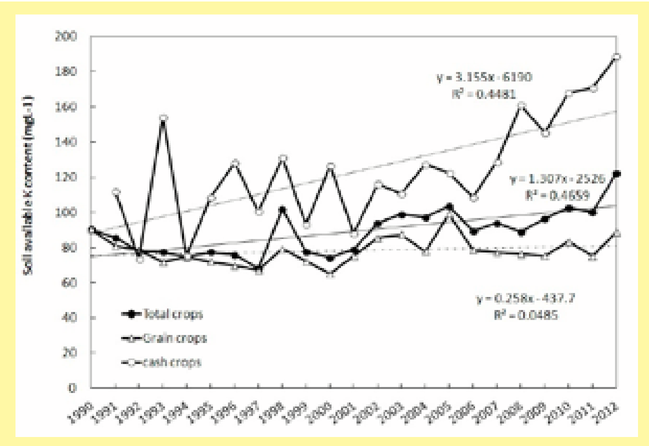

Fig. 2. Trends in soil available K in China from 1990 to 2012.

divisions, consisting of Northeast (NE), North Central (NC) Northwest (NW), Southeast (SE) and Southwest (SW).

In addition, each agricultural region was further divided into two sub-groups based on soil utilization pattern (grain crop and cash crop systems). In grain crop systems, soils were used for wheat, maize, rice, potato, and soybean. In cash crop systems, vegetables, fruit trees, rapeseed, sunflower, cotton, and sugar crops with higher fertilizer loadings and higher economic outputs were planted based on classification by China Agriculture Yearbook (2012). The geographical distribution of the data was shown in **Fig.1**.

Results

Changes of soil available K in farmland from 1990 to 2012

From 1990 to 2012, the soil available K content from experiments with all crops in China showed an increasing trend (**Fig.2**). For further analysis of the driving forces of this increasing trend of soil available K, we separated the soil samples into two categories based on crops planted: grain crops and cash crops. The soil K values for both grain crops and cash crops increased with the time going from 1990 to 2012. For grain crops, soil available K content fluctuated annually, but was found to show no obvious increase. However, for cash crops, the value increased dramatically over the period. Fertilizer application rate for grain crops averaged 110 kg K_2O ha^{-1} (ranging from 30 to 360 kg K_2O ha^{-1}), and that for cash crops averaged 255 kg K_2O ha^{-1} (ranging from 15 to 1867 kg K_2O ha^{-1}) (data not shown). These results indicated that high K concentrations in soils planted with cash crop from high fertilizer K input drove the increased trend of soil available K in China from 1990 to 2012.

Spatial and temporal variation of soil available K

Balanced fertilization was introduced to China in 1980s, with a major focus on use of K fertilization in China since the 1990s. However, great variation existed across different regions with mean values for soil test K of 76.8, 99.8, 118.0, 83.9 and 81.3 mg L^{-1} for Northeast (NE), North Central (NC), Northwest (NW), Southeast (SE) and Southwest (SW), respectively. To evaluate changes of soil available K in different regions of China

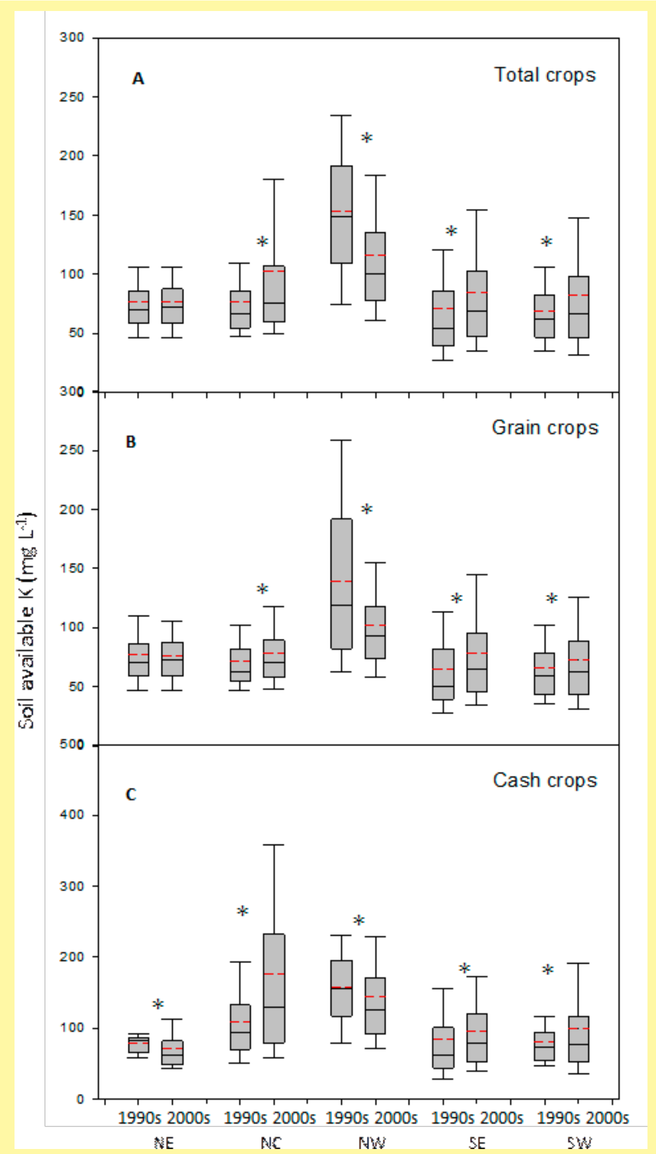

Fig. 3. Comparison of soil available K between 1990s and 2000s. (A) Total crops; (B) Grain crops; (C) Cash crops. The star * between the two boxes indicates soil available K between 1990s (left box) and 2000s (right box) significant different at P<0.05. The black and redlines, lower and upper edges,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

from 1990 to 2012, we compared the soil available K across different periods, the 1990s (1990-1999) and 2000s (2000-2012). Our data shows that on average, soil available K increased from 79.8 mg L-1 in the 1990s, to 93.4 mg L-1 in the 2000s. Soil available K showed no difference in the NE between the 1990s and 2000s. However, the soil available K increased by 34.8% (76.4 to 103.0 mg L^{-1}), 17.9% (71.5 to 84.3mg L^{-1}) and 30.2% (68.8 to 82.7 mg L^{-1}) from the 1990s to 2000s for NC, SE and SW respectively, and decreased by 75.9% (153.5 to 116.5 mg L^{-1}) from the 1990s to 2000s for NW (**Fig.3A**).

Further analysis demonstrated that soil available K in grain crops only followed the same trends as those shown in total crops, but the changes varied among regions (**Fig.3B**). For the NC, SE and SW regions, the soil available K increased by 8.7%, 21.0% and 8.7% respectively in the 2000s from baselines of 72.2, 65.1 and 66.4 mg L^{-1} in the 1990s. However, for the NW, soil

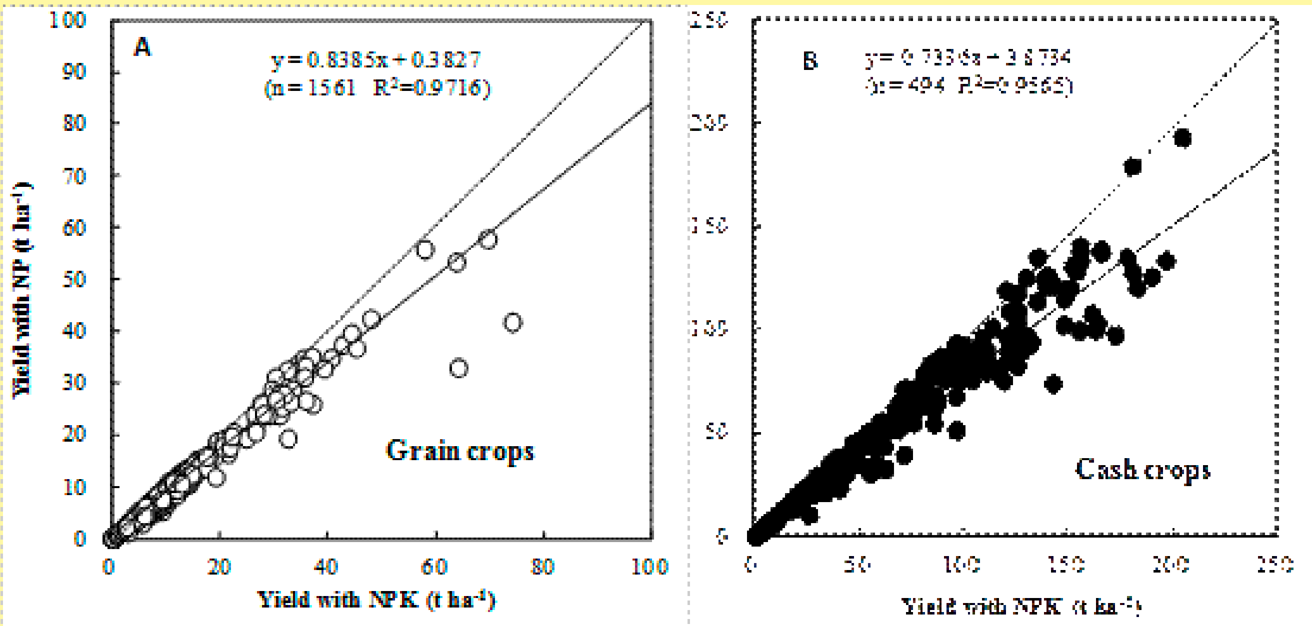

Fig. 4. Yield with NP and yield with NPK for cash crops and grain crops. (A) Grain crops; (B) Cash crops. The dash line is 1:1 line.

available K in the 2000s decreased by 73.5% compared with the 1990s (**Fig.3B**).

The soil available K in the 2000s for cash crops only increased by 59.7%, 12.4% and 22.2% for NC, SE and SW respectively, as compared with that in the 1990s, but declined to only 92.5% and 91.7% of that in the 1990s for NE and NW. It was indicated that the increased soil available K in the NC and SW mainly relied on the large increase in soil available K in cash crops, while the increased values in the SE was mainly attributed to larger increases in grain crops. The decrease in soil available K in the NW was mainly from the large decline in grain crops (**Fig.3C**).

Discussion and conclusion

Results in this study indicated that soil available K showed a minor increased in soils planted to grain crops, but increased significantly in those soils planted to cash crops between 1990 and 2012. The trends of increased soil K for cash crops was in accordance to the high fertilizer K application rate. The K fertilizer application rates for cash crops averaged 164, 231, 205, 240 and 391 kg K_2O ha^{-1}, 1.7, 2.1, 1.7, 2.1 and 2.8 times those for grain crops for NE, NC, NW, SE and SW, respectively (Data not shown). However, the soil K for grain crops in 2000s were lower than 80 mg L^{-1} (the critical value for K deficiency) except in NW China. Therefore, more K fertilizer was needed for soils planted with grain crops since soil K level for grain crops were below the critical levels 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 indicated that straw returning alone is not sufficient to maintain the soil K balance and chemical K fertilizer 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 (**Fig.4**). These results indicate that the contribution of soil indigenous K supply to the yield was higher for grain crops than for cash crops and 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.

In summary, soil available K in China kept increasing from 1990 to 2012 and these increases came from the increased soil K in cash crop soils 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 also guides the future research orientation, such as research on soil K critical values for individual cash crops, K nutrient cycling and 4R nutrient management strategies under agricultural mechanization.

References (Omitted)

More detail please refer to He et al published in Field Crops Research (2015, 173: 49-56) or http://dx.doi.org/10.1016/j.fcr.2015.01.003.