Integrated nutrient management in crop systems for sustainable agriculture in China

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Abstract*:*

The paper summarizes the challenges in food security faced by China and presents the approach of integrated nutrient management (INM) for improving crop productivity with efficient resource utilization and environmental protection. In INM approach, strategy is to emphasize the integrated use of nutrients from fertilizers, wastes and soil and environmental sources; managing nutrient according to different nutrients' specific characteristic; nutrient management should also be integrated with sound soil management practices and other farming techniques.

Media summary

Present an integrated nutrient management approach in crop production systems for improving crop yield and efficient resources utilization.

Key words

Higher yield, efficient resource utilization, integrated nutrient management, crop systems

Accomplishments and Challenges of Nutrient Management in Crop production

Since 1949, especially when China initiated economic reforms and the open-door policy in the 1980's, China's economy has made great strides. In 2007, China's GDP was 24661.9 billon RMB，increased by 11.4% than that in 2006. The growth of agricultural production has been one of the main accomplishments of the country. By 1999 China was successfully feeding 22% of the global population with only 9% of the world's arable land, and per capita food availability reached the levels of developed countries. The use of fertilizers has played a crucial role, accounting for about 50% of the yield increase. However, the rapid economic growth has led to unprecedented resource exhaustion and environmental degradation.

China's "grain security" will face multiple pressures stemming from resource limitation, environmental pollution and population growth. To meet the demand for grain and to feed a growing population, food production has to increase by 150-200 Mt and crop yields to increase at an annual rate of 1.4% within the next 30 years. But annual growth rates are

gradually declining. For example, the growth rate of cereal yields decreased from 2.2% in the 1970s to 1.1% in the 1990s, and grain production showed almost zero growth between 1996 and 2000.

On the resource utilization side (e.g. fertilizers), Chinese farmers are using 35% of the world's total fertilizers on farm land that accounts for only 9% the total arable land in the world. Nutrient utilization efficiencies (e.g. partial factor productivity) in main crop systems in China were considerably lower. For instance, the partial factor productivity of fertilizer in maize cropping systems was 17 kg/kg in China, 27kg/kg in the USA, and 70 kg/kg in Argentina. The situation is further exacerbated by the loss of agricultural land at a rate of approximately one per cent annually through rapid industrialization and urbanization, by an increasing shortage of available water and by environmental deterioration. China is faced with low fertilizer manufacturing efficiency and shortages of raw materials for fertilizer production such as coal, natural gas and electricity, and P and K mines. In the case of P, current P resource use efficiency is only 39%, i.e. from every 10 kg P in the source rock only 4 kg of P fertilizer are produced (Zhang et al, 2007). China will exhaust its high grade P rock resources by 2014 if fertilizer use continues to increase at the current rate (Zhang et al, 2007).

On the environmental side, irrational fertilizer utilization has led to environmental pollution. For example, losses of N and P through leaching and run-off have led to drinking water pollution which affects 30% of the population, and result in eutrophication in 61% of lakes in the country. Agricultural production also produces considerable emissions of nitrogen oxides.

In order to meet increasing food demand with enhanced nutrient efficiency and sustaining the environment, China must undertake a new step toward rethinking and restructuring nutrient management approaches in the crop production systems.

Integrated nutrient management in crop production systems for improving crop yield and efficient resources utilization

Sustainable agricultural production incorporates the idea that natural resources should be used to generate increased output without depleting the natural resource base. However, despite past achievements in crop production in China, both over- and under-application of fertilizers, de-coupling between crop and animal production, and poor management of resources have led to low resource efficiency and damage to the environment. The overall strategy for further increasing crop yields to feed the growing population and maintaining them in a sustainable way should focus strongly on integrated nutrient management (INM).

In the integrated approach the strategy is to emphasize the following.

(1) The integrated use of nutrients from fertilizers, wastes (from both agriculture and industry), and soil and environmental sources such as atmospheric deposition and irrigation water. China is producing large amounts of organic wastes. This is especially true for livestock production and the amount of organic waste from this source reached about 4000 Mt in 2000. However, organic manures are applied to only 47% of the agricultural land area. Furthermore, other nutrient inputs have been ignored. For example, N inputs from rainfall were up to 60-90 kg/ha in the wheat-maize cropping system in Huiming and inputs from

irrigation reached 180-250 kg/ha in the tomato production system in Shouguang, Shandong province.

(2) On the nutrient management side, managing nutrient according to different nutrients' specific characteristic. Due to N is easily move, N management emphasizes the synchronization of N supply and crop N demand. The N fertilizer applications can be split to match crop requirements at different growth stages based on the total fertilizer N rate required at the specific sites to minimize N losses from the soil-plant system. This requires dynamic monitoring of root zone nutrient concentrations at different growth stages of crops in order to realize the synchronization of crop nutrient uptake, soil nutrient supply and fertilizer input. Additional fine-tuning to top-dressing is achieved using N-kit and SPAD/LCC.

The fertilizer P or K management focuses on maintenance of adequate soil available P or K levels to ensure that neither P nor K supply limits crop growth and N-use efficiency. Therefore, maintenance fertilizer P or K rates are recommended through constant monitoring of soil nutrient supply capacity (Wang et al., 1995).

(3) In the integrated approach the strategy of nutrient management should also be integrated with sound soil management practices and other farming techniques such as high yielding cultivation systems (Zhang et al., 2007 a,b).

Current evidence indicates that integrated nutrient management offer benefits to farmers. As shown in Table 1 the INM techniques have realized the multiple objectives of reducing fertilizer use, improving grain yield and quality, and increasing resource use efficiency as well as amelioration of environmental pollution. Compared with farmers' traditional treatments, INM treatments on average have saved N by 20-40%, increase yields by 2-12%, increase N recovery rates by 10-15%, and decrease N losses by 10-50% over nine cropping systems across the country.

Table 1 The potential of N saving, yield increase, N recovery rate increase, and N loss decrease in INM compared with farmers' traditional treatments in different cropping systems in China (Zhang et al., 2007b)

Cropping system	N saving (%)	Yield increase (%)	N recovery increase (%)	N loss decrease (%)
Wheat/Maize rotation	41-59	5-10	12-15	43-69
Rice	22-32	8-12	10-15	40-50
Vegetable	30-50	2-10	5-15	40-65
Cotton	20-30	5-8	10-15	10-30
Oilseed rape	10-30	5-30	8-15	-
Rice/wheat rotation	30-50	8-20	8-30	30-50
Intercropping	20-50	0-10	8-13	20-45
Tobacco	10-30	0-10	7-20	40-50
Apple	10-50	5-15	2-12	-

Reference

Wang X. R., Cao Y. P., Zhang F. S., Chen X. P. 1995. Feasibility of a fertilizization method for keeping constant application rate of phosphorus by monitoring available phosphorus in the soil. Plant Nutrition and Fertilizer Sciences. 1(3-4), 58-63 (In Chinese).

Zhang F.S., Fan M.S., Chen X.P., Shen J.B., Li L, Cui Z. L. 2007a. Integrated nutrient management in cropping systems in China. In：Balanced Fertilization for Sustaining Crop Productivity Proceedings of the IPI-PAU International Symposium, Punjab Agricultural University, Ludhiana, India, 22-25 November, 2006. Volume I: Invited papers, Edited by D.K. Benbi, M.S. Brar and S.K. Bansal. ISBN 978-3-9523243-2-5. International Potash Institute, Horgen, Switzerland. pp, 193-201

Zhang F.S., Fan M.S., Zhang W.F. 2007b. Principles, dissemination, and performance of Fertilizer Best Management Practices developed in China.Fertilizer Best Management Practices, First edition, International Fertilizer Industry Association (IFA), Paris, France, August 2007, ISNB 2-9523139-2-X. pp,135-146

Zhang W. F., Gao L., Ma J., Ma W. Q., Xu X. C., Zhang F. S. Evaluation on the reform effectiveness of fertilizer industry policy in China. Phosphate & Compound Fertilizer, 2007, 22(1):5-9 (In Chinese)

Zhang W. F., Ma W. Q., Ji Y. X., Fan M. S., Zhang F. S., Oenema O. 2008. Efficiency, economics, and environmental implications of phosphorus resource use and the fertilizer industry in China. Nutrient Cycling in Agroecosystems. 80.131-144