Balanced Fertilization for China's Cotton Production

By Jason Wang, Jin Ji-yun and Sam Portch

In 1984, China's cotton production reached its peak of 6.25 million tonnes (Lin, 1995). Since then, production has fluctuated between 3.54 and 4.50 million tonnes, with the exception of 1991 when it reached 5.68 million. Most production goes to the domestic textile industry, which annually consumes between 4.82 and 4.95 million tonnes of cotton. Any shortfall is made up with imports. In 1995, cotton imports cost China US$13.74 billion. Large scale imports not only dampen China's foreign exchange reserves, but also have significant negative impact on local economies in major cotton producing provinces.

Imbalanced nutrient supply has been identified in China by PPI/PPIC as one of the most important factors limiting cotton yields and quality. Among the essential plant nutrients required in high-yielding cotton production systems, potassium (K) is most often found deficient in almost all areas. The brown colored leaf rust symptom, a sign of K deficiency, is commonly seen during mid and late growing season.

Cotton plots in a demonstration field at Siyang, north Jiangsu province, contrast cotton fertilized with and without K in 1996. Cotton at left received N-P_2O_5-K_2O rates of 210-54-180 kg/ha (yield = 1,700 kg/ha). Cotton at right received 210-54-0 kg/ha (yield = 987 kg/ha).

In support of China's efforts to implement scientific farming technologies and to reduce foreign exchange expenditures on imported cotton, PPI/PPIC and cooperating Chinese scientists initiated a project in six provinces. The fundamental concept was to use soil test based balanced fertilization practices to obtain higher yields of high quality cotton with greater fertilizer use efficiency. This would provide larger profits for farmers and stimulate local economies. Six of the largest traditional cotton producing provinces...Anhui, Hebei, Henan, Hubei, Jiangsu, and Shandong...were included in this special project. In 1994, the total area planted to cotton among these provinces was 3.89 million ha, accounting for 70.44 percent of the national total. Lint yield was 2.74 million tonnes or 63.2 percent of the total, (*China Agriculture Yearbook*, 1995). While Xinjiang province is an important cotton producer, it was not included in this study since it is in the early stages of cotton expansion and native soil nutrient levels are higher than in traditional cotton producing provinces where nutrients have been depleted.

Table 1. Relative crop yield in absence of K.

Crop	Relative yield, %
Cotton	45
Corn	81
Soybean	73
Wheat	93

Source: Auburn University, Alabama, U.S.A.

Table 2. General treatment design for cotton trials in China 1995-96.

	Fertilizer rate, kg/ha			
Treatment	N	P_2O_5	K_2O	Other nutrients
1	150-300	60-180	0	added
2	150-300	60-180	low	added
3	150-300	60-180	high	added
4	150-300	60-180	highest	added
5[1]	150-300	40-135	high	added
Farmer[2]	N+ manure	low or none	low or none	–

[1]Different P rate and high K rate.

[2]Farmer practice: Up to 1.5 tonnes organic manure and low K were applied in the provinces of Jiangsu, Anhui, Hubei; no K was applied in the provinces of Henan, Hebei and Shandong.

Justification

With recent, rapid development in farming technology and management skills in China, cotton yields have continuously increased. This has resulted in greater plant nutrient removal from the soil. Results of China's National Soil Survey II (1990) indicate soil K levels have decreased considerably since 1980 in all major agricultural regions. In addition to K, phosphorus (P), sulphur (S), calcium (Ca), magnesium (Mg), and some micronutrients were also found deficient because of the implementation of intensive cultivation and high yield production systems.

The amount of plant nutrient removal by 1,000 kg/ha of cotton lint is calculated as N, 120; P_2O_5, 45; K_2O, 90; MgO, 40; and S, 20 kg/ha (PPI, 1993). To maintain soil productivity, these nutrients must be replenished. Cotton is a K sensitive crop, making it highly responsive to K fertilizer additions. Table 1 indicates relative crop yields without K.

When K supply is inadequate, lint yield and quality are affected because the cotton plant is likely to suffer a greater severity of leaf diseases and premature defoliation. Adequate supplies of K increase seed weight, percent lint, and lint yield. Fiber micronaire and its uniformity of strength and length are improved, as is the plant's resistance to wilt and nematodes.

Research in the 1950s and 1960s in the U.S.A. demonstrated both lint yield and quality improvements with K fertilization. Research in China, India, and other countries also shows significant yield increases with K fertilization (*Better Crops International*, 1993, 1989).

Table 3. Cotton yield response to K fertilizer rates in major cotton producing provinces of China.

Province	Year	K_2O rate, kg/ha	Lint yield, kg/ha	Yield increase[1], kg/ha	Percent increase, %	Province average yield, kg/ha
Anhui	1995	270	1,517	160	11.8	562
	1996	300	1,411	388	37.9	679
Hubei	1995	165	1,231	196	19.0	904
	1996	180	1,302	99	8.2	1,167
Jiangsu, South	1995	225	1,123	161	16.6	855
	1996	270	1,061	98	10.1	994
Jiangsu, North	1995	270	1,517	621	69.4	855
	1996	270	1,157	617	114.2	994
Hebei	1995	113	1,256	83	10.2	569
	1996	135	1,290	130	11.2	528
Henan	1995	135	1,519	201	15.0	649
	1996	135	1,432	197	16.0	769
Shandong	1995	180	1,548	233	17.0	705
	1996	180	1,088	259	31.0	706

[1]Lint yield compared to the yield of local farmers.

PPI/PPIC publications state that K deficiency of cotton is a widespread production problem. Both mid-season K deficiency on older leaves and late season deficiency on young leaves reduce cotton yield and lint quality (*Better Crops International*, 1989). University research and grower experience show that higher yields can be produced with K fertilizer, giving economic returns of US$4 to $9 for each $1 invested in K fertilizer. This was true for fields already producing high lint yields in Arkansas and Mississippi, U.S.A.

Experimental Design

Experimental trials (30 m^2 plots, four replications) and demonstration plots (300 to 600 m^2) were established in two or more counties of each of the six provinces. Recommended fertilizer rates for all nutrients other than K were based according to soil test results, yield targets and local soil characteristics. In 1995 and 1996, four levels of K were used to test yield response to applied fertilizer. These rates were slightly adjusted in 1996 based on 1995 results. Two additional treatments were: (1) a lower rate of fertilizer P to evaluate possible response to P, and (2) the local farmers' practice (which varied at each location). The range in treatments is described in Table 2.

Results

Lint yields greater than 1,000 kg/ha were obtained at all locations when soil test based fertilizer recommendations were applied. When other essential plant nutrients were adequate, based on a scientifically derived recommendation, cotton yields increased sharply with high K rates in both 1995 and 1996 (Table 3). Yield increases were calculated as the differences between yield obtained from the recommended fertilizer treatment and local farmer practice.

Table 4. Estimation of yield increase potentials and economic analysis when soil test based fertilizer rates are applied to cotton in China.

Province	Year	Yield increase by K, kg/ha	Total yield increase estimated, tonnes	Cost of K, million yuan	Net return for K, million yuan[1]	VCR
Anhui	1995	160	42,600	133	630	4.7
	1996	388	103,000	122	1,519	12.5
Hubei	1995	196	39,000	50	577	11.5
	1996	99	19,800	55	293	5.3
Jiangsu, South	1995	160	25,600	72	379	5.3
	1996	98	16,600	76	246	3.2
Jiangsu, North	1995	621	99,400	54	1,471	27.2
	1996	616	104,400	85	1,539	18.1
Hebei	1995	116	27,800	68	411	6.0
	1996	130	31,800	83	471	5.7
Henan	1995	201	68,000	114	1,006	8.8
	1996	197	69,000	118	1,021	8.6
Shandong	1995	233	73,900	143	1,094	7.6
	1996	259	68,900	120	1,020	8.5

[1]Market prices in 1995 and 1996: MOP (KCl) fertilizer, RMB1,500/tonne; lint cotton, RMB14,800/tonne (14.8/kg).

Average yield increase over the six provinces was 27.7 percent, with all being above 10 percent, except for Hubei province in 1996. Flooding in Hubei and the higher use of inputs by the farmer in south Jiangsu contributed to relatively small yield increases in 1996. In north Jiangsu, a combination of high K rates and split K application was necessary to obtain high yields on these sandy soils, showing potential to increase yields is very high when scientific farming methods are applied. Serious rust symptoms resulting from K deficiency were commonly seen in mid and late season if K was not properly managed on these low cation exchange capacity soils.

Dr. Jason Wang compares cotton with balanced fertilization including 300 kg K_2O/ha (at left) and with 75 kg K_2O or less (at right). Field is in Siyang, north Jiangsu province.

Among these six provinces, soil test K levels are relatively higher in Hebei and Henan [74 to 90 parts per million (ppm)] and lowest in Anhui and Jiangsu (35 to 70 ppm), with Hubei and Shandong in between. It is reasonable to assume that similar yield responses to recommended K rates used in these trials would occur on 35 percent of the cotton growing soils in Henan and Hebei, 40 percent in Hubei and Shandong, and 60 percent in Anhui and Jiangsu. Thus, the potential economic benefit from adequate and balanced fertilization can be determined for each province (Table 4). These data are conservative estimates. Higher yields may be obtained as farmers continue to improve nutrient input and management practices.

Based on data from these six provinces, it is estimated that a total lint yield increase of 413,500 tonnes would result when soil test based recommendations are used. To achieve this potential yield, an additional 403,000 tonnes of potassium chloride (KCl) along with small amounts of some micronutrients would be needed. Estimated economic return and VCR to K fertilization indicate an enormous economic benefit at reasonable risk. Total economic return from cotton lint yield increases would be nearly 10-fold the cost invested in KCl, assuming market prices of RMB 1,500/tonne for KCl and 14,800/tonne for cotton lint (US$1 = 8.2 RMB).

Statistics from the General Administration of Customs indicated that 743,217 tonnes cotton were imported in 1995 at a value of US$13.77 billion (*China Agricultural Yearbook*, 1996). With adequate use of K in a balanced fertilization program, cotton imports could be

Table 5. Cotton lint yields respond to P fertilizer rates in major cotton producing provinces of China.

Province	Year	P rate, kg/ha	Lint yield, kg/ha	1.5 P rate, kg/ha	Lint yield, kg/ha	Yield increase kg/ha	Yield increase %
Anhui	1995	60	1,336	90	1,423	87	6.5
	1996	90	1,143	135	1,166	23	2.0
Hubei	1996	60	1,396	75	1,276	–	–
Jiangsu	1996	120	1,020	180	1,061	41	4.0
Hebei	1995	75	1,216	113	1,256	40	3.3
	1996	90	1,275	135	1,288	13	1.0
Henan	1995	75	1,404	113	1,432	31	2.2
	1996	90	1,370	120	1,432	62	4.5
Shandong	1995	135	1,253	180	1,315	62	4.9
	1996	135	907	180	928	21	2.3

reduced by 54 percent. This would save US$7.39 billion on imports, when cost of K is deducted. These funds would then be available for investment in other needy agricultural sectors.

Furthermore, while only a few participating provinces made measurements on the effect of K on cotton quality, it is well understood from the world literature that cotton quality would be higher where K fertilization was adequate.

Raising the P fertilizer rate to 1.5 times recommended levels resulted in small increases in cotton yields (Table 5). These results indicate that current recommended P levels are economically adequate for cotton production. However, data suggest that recommended P levels for cotton must be closely watched because they are not agronomically adequate. Future studies to determine the economic benefits of the residual effects of both P and K on the subsequent crop, a result of higher P and K fertilization of cotton, are likely to show additional economic benefits from application of these two nutrients.

Conclusions

Cotton yield is sensitive to K nutrition. Lint production could be increased by 413,500 tonnes by supplying an additional 403,000 tonnes of KCl in six of China's major cotton producing provinces. This would provide a net benefit of 13.3 RMB for each kg of lint produced ...or an annual saving of US$7.39 billion in foreign exchange after subtracting US$0.054 billion for cost of additional KCl. In other words, an investment in 403,000 tonnes KCl, for application on cotton would save China US$7.39 billion to spend on agricultural development and improvements in other areas.

The cotton produced would be of higher quality. As well, there would be an added benefit of residual K in the soil for the subsequent crop...two advantages not calculated in the net benefit of using additional K on cotton in these trials.

Higher than presently recommended P rates gave only marginally higher yields. Although not economically advantageous based on cotton yields alone, the residual effect resulting from additional P may be beneficial to following crops. This should be measured since current P recommendations are not biologically sufficient. BCI

Dr. Wang and Dr. Jin are Deputy Directors, PPI/PPIC China Program. Dr. Portch is Director, PPI/PPIC China Program, Hong Kong.

Acknowledgement: The authors wish to acknowledge the support given by the Soil and Fertilizer Institutes of the provincial academies of agricultural sciences of Anhui, Hebei, Henan, Hubei, Jiangsu and Shandong and the Institute of Soil Science, Chinese Academy of Sciences, for conducting the research reported in this paper.

References

Lin Bao, 1995. China's current fertilizer use and future development. In Fertilizer Development Strategy for China's Agriculture Workshop, Beijing, October, 1995.)

China Agricultural Yearbook, 1995. China Agriculture Publishing Ltd. Beijing.

China Agricultural Yearbook, 1996. China Agriculture Publishing Ltd. Beijing.

PPI, 1993. Potash & Phosphate Institute, China Program, leaflet No. 1.

Better Crops International, 1993. PPI/PPIC publication, December 1993. Atlanta, Georgia, U.S.A.

Better Crops International, 1989. PPI/PPIC publication, December 1989. Atlanta, Georgia, U.S.A.