Fertilizing Irrigated Cotton for High Yield and High Nitrogen Use Efficiency

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Nitrogen was the first limiting factor in a cotton production study in Xinjiang Province, followed by P and then K. Key considerations to maximum N recovery included a top-dress schedule able to sustain adequate N supply throughout flower initiation and boll formation as well as balanced quantities of P and K fertilizer.

Cotton production continues to be a leading industry for the northwestern province of Xinjiang and the crop remains a primary source of income for farmers. Most recent statistics indicate planted area at 1.7 million ha, accounting for 31% of China's total cotton area. Xinjiang's cotton yield and total production also ranks highest across all provinces in China. Nutrient management is an important consideration for cotton, but farmers typically overuse N fertilizer, while K application is not sufficient. Despite this knowledge, it has been unclear how imbalanced use of nutrients is affecting cotton production in Xinjiang.

Field experiments were conducted from 2001 to 2003 and 2006 to 2007 in Awati, Kuche, and Manasi counties of Xinjiang Province (**Table 1**). Plots were arranged in a randomized complete block design with three or four replicates. Awati and Kuche are located along the northern edge of the Takelamagan Desert, and Manasi is located to the north of Urumqi. These areas have abundant sunshine, intense evaporation, and little precipitation. Climatic conditions and the local infrastructure combine to make these areas well-suited to high quality cotton production.

All experiments tested an 'optimum' (OPT) treatment containing N, P, and K, as well as nutrient omission treatments including an OPT-N, OPT-P, OPT-K. Recommended N, P, and K rates in the OPT were based upon the Agro-Services International (ASI) method used by the National Laboratory of Soil Testing and Fertilizer Recommendations in Beijing (Portch and Hunter, 2002). From 2001 to 2003, experiments were located at Await and Kuche counties. Basal fertilization at these sites included all of the P and K recommendation plus 60% of the total N. The remaining N was applied at flower initiation stage before the first or second irrigation.

In 2006 and 2007, field experimentation at Awati and Manasi counties evolved to a more detailed investigation of the impacts of N, P, and K rates on yield, nutrient uptake, and N use efficiency. These experiments varied four rates of N, P, and K which were co-applied along with set rates for the other two nutrients. In 2006, basal fertilization included 30% of the total N recommendation plus all of the P and K. The remaining N was applied along with irrigation water in four topdressings applied at June 24 (15%), July 5 (25%), July 25 (20%), and August 12 (10%). In 2007, all of the P and K fertilizer was applied basally and N was applied along with irrigation as five topdressings at June 20 (15%), July 18 (35%), August 5 (25%), August 22 (20%), and September 2 (5%).

A plant biomass and N accumulation study was also initiated in 2006 at Awati. Cotton plant (Xinhai-20 cv.) samples were taken on May 11 (seedling), June 11 (budding), June 28 (flowering), August 4 (bolling), and September 9 (batting). Stalk, foliage, bud and flower, hull of boll, fiber, and seed were collected and analyzed. Results determined a relatively slow rate of accumulation for both plant biomass and N up until flowering, after which the majority of accumulation took place (data not shown).

The mean proportion of total biomass at stages of seedling, budding, flowering, bolling, and batting was 1%, 6%, 21%, 51%, and 21%, respectively. Plant biomass responded to increased rates of N, P, and K throughout early crop development. The impact of fertilizer treatment on N accumulation was consistent with results observed for biomass. The mean proportion of total N accumulation at stages of seedling, budding, flowering, bolling, and batting was 2%, 10%, 25%,

Table 1. Physical and chemical properties of tested soils by ASI procedure.

Year/Location	pH	O.M. %	Ca	Mg	K	N	P	S	B	Cu	Fe	Mn	Zn
			\- μg/ml \-										
2001 Awati	8.0	0.6	1,978	245	130	8	38	90	2	1	11	10	1
2002 Awati	7.8	0.5	7,621	141	104	7	9	124	0.1	1	3	6	1
2002 Kuche	8.5	0.3	1,305	257	278	16	32	39	2	2	15	12	1
2003 Awati	7.8	0.4	4,433	216	115	20	20	132	2	2	6	9	1
2006 Awati	8.6	0.3	782	549	172	1	31	184	3	3	34	10	2
2007 Manasi	8.6	0.7	2,005	499	114	70	17	69	1	3	16	6	1
Critical Values			401	122	78	–	12	12	0.2	1	12	2	1

Table 2. Effect of N, P, or K omission on cotton lint yield.

	2001 Awati	2002 Awati	2002 Kuche	2003 Awati	2006 Awati	2007 Manasi
	\- kg/ha \-					
OPT[1]	1,564a	1,503a	1,547a	1,462a	1,498a	1,687a
OPT-N	1,199b	1,092b	1,194d	1,092d	1,234c	1,435b
OPT-P	1,238b	1,233b	1,330c	1,239c	1,348b	1,454b
OPT-K	1,303b	1,274b	1,393b	1,345b	1,333b	1,539b

[1]OPT N-P_2O_5-K_2O rates were 207-138-50 for 2001, 207-138-72 for 2002 and 2003, 225-140-70 for 2006, and 180-105-60 for 2007.

Numbers followed by the same letter in columns are not significantly different at p=0.05.

Cotton varieties by year and location: 2001-2003 in Awati, Xinhai-16 cv.; 2002 in Kuche, Xinluzhong-9 cv.; 2006 in Awati , Xinhai-20 cv.; and 2007 in Manasi, Zhongmian-297-5 cv.

Table 3. Effect of N rates on N use efficiency.

Year/location	N-P_2O_5-K_2O	Lint yield of cotton, kg/ha	Net returns, US$/ha	Total N uptake, kg/ha	AE, kg/kg N	Recovery efficiency, %
2006 Awati	0-140-70	1,234 c	—	131	—	—
	112-140-70	1,361 b	309	149	1.1	16
	225-140-70	1,498 a	647	211	1.2	35
	338-140-70	1,413 ab	340	191	0.5	18
2007 Manasi	0-105-60	1,435 c	—	149	—	—
	90-105-60	1,541 b	153	163	1.2	16
	180-105-60	1,687 a	383	215	1.4	37
	270-105-60	1,510 bc	-4	202	0.3	20

For Tables 3 to 5, in 2006, the price of cotton lint (Xinhai-20 cv.) is 22 RMB/kg, N is 4 RMB/kg, P_2O_5 is 4 RMB/kg, K_2O (K_2SO_4) is 7 RMB/kg. In 2007, the price of cotton lint (Zhongmian-297-5 cv.) is 14 RMB/kg, N is 4 RMB/kg, P_2O_5 is 5.4 RMB/kg, K_2O (KCl) is 4 RMB/kg. 1US$=7.5 RMB. In each year, numbers followed by the same letter are not significantly different at p=0.05.

Table 4. Effect of P rates on N use efficiency.

Year/location	N-P_2O_5-K_2O	Lint yield of cotton, kg/ha	Net returns US$/ha	Total N uptake, kg/ha	Increase of N recovery efficiency, %
2006 Awati	225-0-70	1,348 b	—	147	—
	225-70-70	1,395 b	97	157	4
	225-140-70	1,498 a	358	211	28
	225-210-70	1,405 ab	48	198	22
2007 Manasi	180-0-60	1,454 b	—	150	—
	180-52-60	1,538 b	122	154	2
	180-105-60	1,687 a	369	215	36
	180-158-60	1,485 b	-54	165	8

Table 5. Effect of K rates on N use efficiency.

Year/location	N-P_2O_5-K_2O	Lint yield of cotton, kg/ha	Net returns US$/ha	Total N uptake, kg/ha	Increase of N recovery efficiency, %
2006 Awati	225-140-0	1,333 c	—	166	—
	225-140-35	1,354 bc	28	177	5
	225-140-70	1,498 a	414	211	20
	225-140-105	1,466 ab	289	185	9
2007 Manasi	180-105-0	1,539 b	—	162	—
	180-105-30	1,584 b	69	165	2
	180-105-60	1,687 a	249	215	29
	180-105-90	1,578 ab	24	173	6

40%, and 23%, respectively.

Five years of omission plot study determined N to be the most limiting nutrient factor in cotton yield in Xinjiang followed by P and then K (**Table 2**). Over all years, balanced use of N, P, and K significantly increased cotton lint yield by an average of 28%, 18%, and 13%, compared with the OPT-N, OPT-P, and OPT-K treatments, respectively.

The highest cotton lint yield and economic return, as determined by the final 2 years of study at Awati and Manasi, were obtained when 225 kg N/ha was applied along with 140-70 kg/ha of P_2O_5-K_2O in Awati in 2006, and when 180 kg N/ha was combined with 105-60 kg/ha of P_2O_5-K_2O in Manasi in 2007 (**Table 3**). Agronomic efficiency (AE) —calculated as lint yield increase per unit N and apparent recovery efficiency (RE)—calculated as the increase in N uptake per unit N added—were also highest under these same treatments (**Table 3**). These balanced NPK combinations resulted in AE values of 1.2 and 1.4 kg N/kg N, while RE was 35% and 37% in 2006 and 2007, respectively. Under the optimal fixed rates of N and K fertilizer, recovery of N increased by 28% under optimal P at Awati, and by 36% at Manasi (**Table 4**). Similarly, optimal K application allowed for 20% more N recovery at Awati and 29% more N recovery at Manasi (**Table 5**).

Balanced use of fertilizer nutrients is important for improved cotton yield and N use efficiency in Xinjiang. Soil testing used to evaluate soil nutrient supply provided good direction with regards to fertilizer nutrient application. Profits were highest with the N rates recommended, and balanced use of P and K were effective in supporting improved farmer profit and N recovery. Soil testing also provided the necessary guidance to avoid over-application of nutrients, a critical management practice in the effort to achieve optimum fertilizer best management practices. BC

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