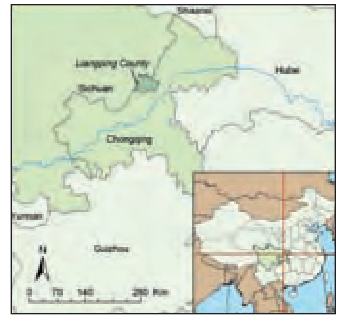
Effect of Long-Term Fertilization on Wheat-Corn-Sweet Potato Rotation in the Sichuan Basin



By Wei Li, Guoxue Cai, Henglin Dai, and Shihua Tu

A multi-year study was used to develop a nutrient management scheme capable of improving yields within a prominent cropping system for the Sichuan Basin.

The Sichuan Basin is an area in southwest China which encompasses the province of Sichuan and the region surrounding the autonomous city of Chongqing. The typical farming system in the uplands of the Basin involves a rotation of wheat followed by corn and sweet potato. Wheat grows from the winter to spring, and corn and sweet potato are usually inter-planted in alleys during the summer and fall. Crop yields vary within this rotation due to weather, landscapes, soil type and fertility, crop variety, and management practices. Yields generally range between 2,250 to 4,500 kg/ha for wheat, 4,500 to 7,500 kg/ha for corn, and 3,750 to 5,000 kg/ha for sweet potato (sweet potato yield is usually converted from its fresh yield to an equivalent grain yield using a 5:1 ratio).

The two summer crops have traditionally outweighed winter wheat production in terms of economic importance. But the need for increasing amounts of animal feedstuffs is placing an ever-increasing importance on corn in the rotation. In turn, a high demand for corn grain has raised its market price and stimulated farmers' interest in corn production. The ultimate response within the region has been interest in both the expansion of area planted and enhanced yield per unit area. These circumstances have made it more important than ever to acquire science-based nutrient management which is economically sustainable and environmentally responsible.

A fixed-site experiment was established in 2001 within Liangping County, Chongqing, to document the potential for improvement in productivity and nutrient use efficiency within this crop rotation. The study site had an elevation of 450 m, annual temperatures of 17 to 18 °C, and annual precipitation of 1,100 to 1,200 mm. Soil at the site was developed from sedimentary rock, and is classified as a purple soil under the Chinese soil classification system – a prevailing soil-type throughout the Chongqing region. Soil pH, OM, ammonium-N (NH_4-N), available P, available K, extractable Ca, extractable Mg, available S, and available Zn were determined as described by Lu (2000). Results indicated that the soil was acidic with very low organic matter content, available N, P, and K (**Table 1**).

Table 1. Characteristics of tested soil.

	pH	OM	NH_4-N	P	K	Ca	Mg	S	Zn
		g/kg	---------------			mg/kg			---------------
Purple soil	5.4	4.4	20	3	62	3,818	403	75	2

The experiment, managed from 2001 to 2005, was designed as a randomized block design with 10 treatments comprised of three rates of N (two rates for wheat) and four rates of P and K (**Table 2**). Each plot had an area of 13.3 m^2.

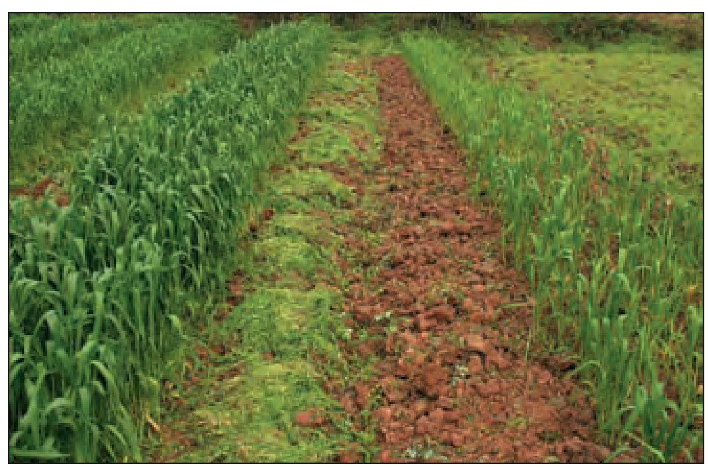
Table 2. Fertilizer treatments (N-P_2O_5-K_2O kg/ha) for wheat, corn, and sweet potato.

Treatment	Wheat[1]	Corn	Sweet potato
$N_0P_0K_0$ (CK)	0-0-0	0-0-0	0-0-0
$N_1P_2K_2$	150-90-90	150-120-150	38-60-120
$N_2P_0K_2$ (OPT-P)	150-0-90	225-0-150	75-0-120
$N_2P_1K_2$	150-45-90	225-60-150	75-30-120
$N_2P_2K_2$ (OPT)	150-90-90	225-120-150	75-60-120
$N_2P_3K_2$	150-135-90	225-180-150	75-90-120
$N_2P_2K_0$ (OPT-K)	150-90-0	225-120-0	75-60-0
$N_2P_2K_1$	150-90-45	225-120-75	75-60-60
$N_2P_2K_3$	150-90-135	225-120-225	75-60-180
$N_3P_2K_2$	225-90-90	300-120-150	112-60-120

[1]For wheat, only two rates of N were compared. Thus, N_1 and N_2 are both shown as 150 kg/ha.

In the winter season, half of the field is used to grow wheat while the other half was reserved to grow corn during the spring. Sweet potato was transplanted onto the wheat stubble soon after harvest. Fertilizers included urea, single superphosphate, potassium chloride, and ammonium molybdate.

All P and K fertilizers were applied at seeding. Urea was split between a basal application (i.e., 60% of the total for wheat and sweet potato, and 30% for corn) and topdressings



Wheat plots in rotation. The fertilizer treatments (N-P_2O_5-K_2O) are 150-45-90 on the left and 150-0-90 on the right.

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; Ca =calcium; Mg = magnesium; S = sulfur; Zn = zinc; OM = organic matter.

Corn plots in rotation.

(i.e., 40% for wheat at tillering stage, 30% and 40% for corn at the seedling and pre-silking stages, and 40% for sweet potato at tuber expansion stage, respectively). Ammonium molybdate powder was applied as a thoroughly mixed wheat seed coating. A zero fertilizer treatment was used as check (CK) to evaluate the basic soil fertility. Wheat and corn were seeded manually by hoeing and sweet potato was transplanted in alleys placed 1 m apart. Plant density was 380,000 plants per ha (30 cm × 15 cm) for wheat, 10,500 plants per ha (85 cm × 55 cm) for corn, and 23,000 plants per ha (85 cm × 25 cm) for sweet potato. Other field management was performed according to local farmer practices. Yields were calculated after each crop harvest.

The yield data suggest that both wheat and corn responded better to P than to K if compared with sweet potato (**Table 3**). Conversely, sweet potato showed a larger response to K which is not surprising given the large K requirements of tuber crops. Wheat showed a much larger response to P than did corn, which is most likely an effect of the crop season since wheat is grown during the winter season, and as such, is exposed to conditions of lower soil P availability compared to the summer. Given this response, farmers need to be aware of the importance of maintaining adequate soil P fertility in order to support the winter wheat season.

Table 3. Crop yield response to fertilizer treatment.

	Four year yield average, t/ha		
Treatment	Wheat	Corn	S. Potato[1]
$N_0P_0K_0$(CK)	1.6	4.2	3.7
$N_1P_2K_2$	2.9	7.2	4.8
$N_2P_0K_2$ (OPT-P)	2.2	6.5	4.4
$N_2P_1K_2$	2.7	7.2	4.7
$N_2P_2K_2$(OPT)	3.2	7.7	5.1
$N_2P_3K_2$	3.1	7.3	4.7
$N_2P_2K_0$ (OPT-K)	2.8	6.6	4.1
$N_2P_2K_1$	3.0	7.3	4.5
$N_2P_2K_3$	3.2	7.2	4.8
$N_3P_2K_2$	3.0	7.4	4.8

[1]Sweet potato yield is usually converted from its fresh yield to an equivalent grain yield using a 5:1 ratio.

Yearly weather conditions exerted a prominent cause of year-to-year variability in yield for the three individual crops grown within the rotation. However, the schedule of selected treatments does outline a nutrient management strategy able to help minimize these gaps in productivity. Wheat, corn, and sweet potato yields showed annual responses to increased application of N, P, and K fertilizer, but they also showed a tendency to decrease, or level off, under the highest application rates (**Table 4**). The OPT produced the highest combined rotation yield, while zero fertilizer input produced 60% of the OPT. Omission of P or K decreased the average yield potential of the rotation by 17% and 15%, respectively. Total rotation yield varied considerably between years, but tended to decline over time regardless of treatment. Although this trend may imply that some other yield-limiting factor may have been induced by the experiment, this needs further study to confirm.

Table 4. Response of total crop yield (complete rotation) to fertilization, t/ha.

Treatment	2001/02	2003	2004	2005	Average
$N_0P_0K_0$(CK)	10.2**	9.8**	7.7**	10.0**	9.4
$N_1P_2K_2$	17.7	14.9	13.5	14.7	15.2
$N_2P_0K_2$ (OPT-P)	13.9**	14.0**	12.5**	12.3**	13.2
$N_2P_1K_2$	16.3	14.6*	13.6	13.7	14.5
$N_2P_2K_2$(OPT)	17.5	15.8	14.6	15.6	15.9
$N_2P_3K_2$	16.3	14.7*	14.0	15.2	15.0
$N_2P_2K_0$ (OPT-K)	14.1**	14.4**	12.5*	13.1**	13.5
$N_2P_2K_1$	15.6	15.2	13.6	14.5	14.7
$N_2P_2K_3$	17.3	13.8*	14.2	15.3	15.1
$N_3P_2K_2$	16.1	15.6	14.0	13.9	14.9

*, ** Denotes yields significantly different than the OPT at p = 0.05 and p = 0.01, respectively.

The cause of the decrease in total rotation yield over the course of the study can be isolated to steady yield declines in wheat, and to a greater extent sweet potato, since corn yields kept increasing over time. Taking the OPT treatments as ex-

Observing plots are Mr. Li (right) collaborator at Chongquing Ag-Tech Extension Center, and Ms. Guoling You, Head of the Soil and Fertilizer Station at Liangping County.

amples, the yield decrease from 2002 to 2005 was more severe for sweet potato (-50%) than for wheat (-9%), while corn yields increased from 6.3 t/ha in 2001 to 9.0 t/ha (+43%) in 2005. Thus, gains in corn productivity were received at the expense of declining sweet potato productivity.

Since corn and sweet potato were interplanted, this sharp contrast is most likely a reflection of the two crops' strong competition for sunlight, moisture, and nutrients. Given the importance of corn to the region, farmers will continue to explore their potential for making further gains in corn yields. Sweet potato carries a much lower market price and storage of this crop is more demanding, both in terms of space and ambient environment. Regardless, some balance in this productivity trade-off is required. In such intercropping systems, farmers are advised to manage crop competition through adjustments in plant density and/or planting date so that yields in both crops can be sustained at the desired, albeit compromised levels. BC

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Acknowledgment

The authors thank IPNI for financial support of this project.

Reference

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Recognizing Soybean Field Problems

Understanding how various nutrient imbalances, disease risks, and other factors threaten soybean plant health, production, and seed quality can be valuable in diagnosing and preventing field problems.

Shown on this page are a few examples illustrating symptoms from the IPNI publication titled *Be Your Own Soybean Doctor*. It is intended to help growers, consultants, and others in becoming more familiar with symptoms of nutrient deficiencies, toxicities, diseases, and other disorders in soybean production. While it does not substitute for diagnostic tools such as plant tissue analysis and soil testing, the guide can be useful in distinguishing and identifying various field problems. It features 40 color illustrations with brief discussion of each.

The full color publication is 8 pages, 8 ½ x 11 in., and patterned after the classic *Be Your Own Corn Doctor*, which has been widely used for many years. *Be Your Own Soybean Doctor* is available for 50 cents (US$0.50) per copy, plus shipping/handling. Discounts are available on quantity orders.

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