Effect of Balanced Fertilization on Rice Nutrient Uptake, Yield, and Profit

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Balanced fertilization is important in optimizing both rice yield and profit. In this study, balanced fertilization also accelerated rice nutrient uptake and maintained soil nutrient balance at the site.

Rice covers about 20% of the total cultivated area in the north central province of Liaoning in China. And rice contributes over 25% of the province's total grain production per year. Traditionally, N and P fertilizers have been the only nutrients applied in these crops, but they are applied without any real understanding of yield potential or the required amounts and ratios of fertilizer nutrients.

In recent years, with various new high yield varieties being developed and introduced to Liaoning, soil nutrient deficiency has become more severe than ever. Previous investigation and experiments agree that while K deficiency exists in many regions, this deficiency has been alleviated after sustained K application, and yields have been shown to increase (Lei, et al., 2002).

Thus balanced fertilization can play a significant role in sustained development of grain production in Liaoning. The objective of this study was to investigate the effect of balanced fertilization technology on rice nutrient uptake, yield, and profit. A field experiment was conducted in the northern rice production area of Changgouyan Village, in Tieling County, Liaoning. This is a temperate region that is influenced by a monsoon season. The annual rainfall is 700 mm, and the average annual temperature is 7.6 °C, with a frost-free period of about 150 days annually.

The site was located on a paddy soil whose properties are listed in **Table 1**. A randomized complete block design was used with six treatments and three replications (**Table 2**). Plot area was 20 m^2 (2.5m x 8m). An initial soil test-based 'optimum' (OPT) nutrient application was recommended in 2006 based on the ASI method (Portch and Hunter, 2002) used by the National Laboratory of Soil Testing and Fertilizer Recommendations in Beijing (Yang, et al., 2001). In 2007, application rates for N and K were adjusted according to 2007 soil test results and profits obtained in 2006. Treatments received a basal fertilizer application including one-quarter of the total N as urea plus all of the P as diammonium phosphate (DAP) and K as potassium chloride (KCl). The remaining urea-N was topdressed and split between the seedling, tillering, and boot stages. The rice variety was '265-11-1' planted at a density of 225,000 hills/ha in 2006. The rice seedlings were transplanted on May 27 and harvested on September 29, 2006. In 2007, the rice variety was 'Liaojing 9' planted at 225,000 hills/ha. Rice seedlings were transplanted on June 6 and harvested on October 11, 2007.

In both 2006 and 2007, the OPT supported the highest nutrient uptake in rice, followed by a group including farmer practice (FP), OPT-P, OPT-K, and then the check (CK) and

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; OM = organic matter.

Northern Liaoning has extensive tracts of large-scale rice production.

Table 1. Soil OM, available nutrients, and pH of tested soil.

Item	2006	2007	Critical value
pH	5.65	5.69	–
OM, %	1.65	1.57	–
NH_4^+-N,mg/l	19.66	20.8	50
P, mg/l	12.15	25.7	12
K, mg/l	54.75	54.5	78

Table 2. Nutrient rates of different fertilizer treatments.

	Rates of N- P_2O_5- K_2O, kg/ha	
Treatments	2006	2007
OPT	300-90-150	210-90-135
OPT-N	0-90-150	0-90-135
OPT-P	300-0-150	210-0-135
OPT-K	300-90-0	210-90-0
CK	0-0-0	0-0-0
FP	210-105-105	210-105-105

Table 3. Treatment effect on nutrient uptake of rice, kg/ha.

	2006			2007		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
OPT	191	87	262	183	84	197
OPT-N	153	69	217	70	46	81
OPT-P	155	73	240	163	79	161
OPT-K	164	77	228	143	68	118
CK	110	52	151	102	51	101
FP	166	79	238	152	72	171

Balanced fertilization research sites are valuable extension tools used to promote improved nutrient management.

Optimum fertilization and farmer practice plots in Liaoning.

OPT-N treatments (**Table 3**).

Trends for soil nutrient balance were similar between the 2 years of study (**Table 4**). All treatments, including the OPT, showed a severe K deficit. With the exception of the OPT-N and CK, all other treatments expressed an N surplus and indicates that N was being applied in excess of crop requirements. Lowering the N rate in 2007 helped to minimize this N surplus. Only the OPT-P and CK treatments demonstrated a P deficit in either year, while the all other treatments provided sufficient P or a minor P surplus. It is important to note that the P balance was closest to zero for the OPT treatment. A nutrient imbalance due to lack of N or K produced an even greater P surplus.

Table 4. Effect of balanced fertilization on nutrient balance, kg/ha.

	2006			2007		
Treatments	N	P_2O_5	K_2O	N	P_2O_5	K_2O
OPT	199	3	-112	27	6	-62
OPT-N	-153	21	-67	-70	44	54
OPT-P	145	-73	-90	47	-79	-26
OPT-K	136	13	-228	67	22	-118
CK	-110	-52	-151	-102	-51	-101
FP	44	26	-133	58	33	-66

The OPT treatment supported the highest yields in both years of study (**Table 5**). Compared to plots receiving CK, FP, and nutrient omission treatments, the balanced OPT returned 6 to 42% more grain yield in 2006 and 8 to 40% more grain in 2007.

Table 5. Effect of balanced fertilization on rice yield.

	2006		2007	
Treatments	Yield†, kg/ha	Decrease, %	Yield, kg/ha	Decrease, %
OPT	8,667a	–	8,700a	–
OPT-N	6,333d	27	5,267e	40
OPT-P	7,100c	18	8,000b	8
OPT-K	6,467d	25	6,633c	24
CK	5,067e	42	6,000d	31
FP	8,133b	6	7,567b	13

†Dried rice yields followed by a different letter are significantly different (p=0.05).

Table 6. Effect of balanced fertilization on profit, US$/ha.

	2006			2007		
Treatments	Output	Fertilizer input	Net income	Output	Fertilizer input	Net income
OPT	2,374	316	2,059	2,384	248	2,135
OPT-N	1,735	146	1,498	1,443	111	1,332
OPT-P	1,945	248	1,697	2,192	191	2,001
OPT-K	1,772	238	1,626	1,817	178	1,639
CK	1,388	0	1,388	1,644	0	1,644
FP	2,228	253	1,976	2,073	242	1,831

2006 Prices (US$): 0.61/kg N, 0.81/kg P_2O_5, 0.56/kg K_2O, 0.29/kg rice grain.
2007 Prices (US$): 0.62/kg N, 0.92/kg P_2O_5, 0.56/kg K_2O, 0.29/kg rice grain.

The significant yield gains did translate into high returns as the economic analysis of net income over fertilizer costs determined the OPT to be the most desirable option, followed by the FP, and then the OPT-P treatments (**Table 6**). Net income derived from the OPT was US$83/ha and US$305/ha above common farmer practice in 2006 and 2007, respectively.

Balanced fertilization not only accelerates rice nutrient uptake and maintain soil nutrient balance, but also increases grain yield and farmer income. It was demonstrated that N was the first nutrient limiting factor for yield, followed by K, and then P. The continued K deficit observed in this study, even when K was applied, indicates that K deficiencies will continue to limit rice yields in the future. Application of K fertilizer should be increased beyond the level prescribed in the 'optimum' treatment of this study, so that soil K balance can be maintained under high yields. The importance of balanced fertilization in maintaining soil fertility for sustainable yield production is highly evident. BC

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