Nutrient Balance of Nitrogen, Phosphorus and Potassium under Triple Cropping Systems Based on Rice

By Wang De-ren and Lu Wan-fang

Applications of organic and inorganic fertilizers in rice-based triple cropping systems produce high, sustainable yields and increase economic efficiency while maintaining soil nutrient balance.

The north of Zhejiang province in China is an intensively cultivated area under triple cropping systems that are based on rice. Water supply is adequate to support this level of crop production. The region has a large population dependent on a limited land base. One solution to this problem is to increase the cropping index. With an increasing cropping index and popularization of regionally adapted, high yielding varieties, plant nutrient requirements will increase.

It is recognized that sustainable high yield systems require both adequate nutrient supplies to growing crops as well as continual improvements to the soil's nutrient status and quality. To compensate for chemical fertilizer shortages, especially potassium (K), it was determined that rational applications of both organic and inorganic fertilizers were required. This has become a main approach to plant nutrient management and conservation of paddy soils under triple cropping systems.

To identify the correct proportions of organic and inorganic fertilizers to apply for nutrient balance and high yields in this system, a 4-year field experiment was conducted.

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Brazil grows more than 11 million hectares of soybeans. No-till practices are gaining popularity. In the cerrado region, with improved varieties such as the Uirapurú cultivar shown in the close-up, yields up to 6 tonnes/ha are reported. **BCI**

Treatments were comprised of 2-year cycles of six cropping patterns that were replicated twice. Each plot of 1,000 m^2 was randomly arranged. The total trial area equaled 12,000 m^2. Soil analysis revealed the initial content of organic matter, total nitrogen (N), P_2O_5, and K_2O to be 3.71, 0.23, 0.14, and 1.81 percent, respectively. Available phosphorus (P) was 14.3 mg/kg and available K 61.3 mg/kg.

Results

Grain yields for the six individual treatments ranged from 22.2 to 31.6 t/ha/2 years and the overall average equaled 25.3 t/ha/2 years (**Table 1**). The 2-year yields from 4 years of continuous cropping in a "barley-rice-rice" system were 13.2, 17.2, 16.2, and 17.0 t/ha. Results show that rational applications of organic and inorganic fertilizer not only increase yield, but can also sustain a stable production level.

Table 1. Rate of fertilizer application and average yield in different periods under various multiple cropping rotation patterns.

	Yield, t/ha						Total	Fertilizer application			
	First year			Second year			grain	Organic	Inorganic, kg/ha/2 yrs.		
	1st season	2nd season	3rd season	1st season	2nd season	3rd season	output	t/ha/2 yrs.	N	P_2O_5	K_2O
Crop	Barley	Soybean	Late hybrid rice	Field pea	Corn	Late rice					
Yield	1.7	1.3	6.1	2.0	5.6	6.9	23.6	62	681	345	461
Crop	Rapeseed	Early rice	Soybean	Barley	Early rice	Corn					
Yield	2.1	6.9	0.8	3.5	7.4	4.7	25.4	82	672	245	320
Crop	Barley	Corn	Late rice	Rapeseed	Early rice	Soybean					
Yield	1.5	4.2	5.6	2.1	7.3	1.5	22.2	79	842	242	294
Crop	Green manure	Early rice	Late hybrid	Barley	Soybean	Late hybrid					
Yield	37.5	6.3	6.1	2.4	1.5	6.4	22.7	68	592	216	525
Crop	Barley	Early rice	Corn	Green manure	Early rice	Late rice					
Yield	3.4	6.6	3.6	37.5	6.8	6.1	26.5	59	914	207	642
Crop	Barley	Early rice	Late rice	Barley	Early rice	Late rice					
Yield	2.7	6.6	5.3	3.3	7.3	6.4	31.6	68	1,252	413	621
Average							25.3	70	826	278	478

For all treatments, average offtake (output) of N, P_2O_5 and K_2O from harvestable portions was calculated to be 736, 282 and 419 kg/ha/2 years, respectively. Average organic fertilizer application was 70 t/ha/2 years (**Table 1**), which was calculated to supply approximately 29.6 percent, 50 percent and 39.6 percent of the total N, P_2O_5 and K_2O, respectively. Therefore, the 2-year supply totals from the respective inorganic and organic fertilizers were approximately 826 + 348 (N); 278 + 278 (P_2O_5); and 478 + 314 (K_2O) kg/ha. Based on this, the output to input ratios for the N, P_2O_5 and K_2O were 0.63, 0.51 and 0.53, respectively. It is apparent that continued use of this type of practice should result in a build up of soil fertility and increased soil productivity.

Rate of Fertilization and Soil Nutrient Balances

After 4 years, 33 of the 36 indicators of soil fertility increased. The average increase in organic matter, total N, and available P and K was 0.36 percent, 0.12 percent, and 4 mg/kg and 5.1 mg/kg, respectively (**Table 2**). This points toward a positive nutrient balance and improved soil fertility and quality. This evidence clearly shows the consequence of mining soil nutrients and the benefits of fertilizer requirements needed to re-establish adequate fertility levels. In particular, the low initial levels for K suggest that the process of soil fertility remediation must be a long-term objective. Less fertile, highly buffered soil systems are less efficient at supplying nutrients to the crop. In such cases, fertility programs designed to compensate only for crop removal fall short of meeting crop demand.

Table 2. Increases (+) in soil nutrient levels after 4 years of six different crop rotations.

Treatment number	Organic matter, %	N	P_2O_5	K_2O	Available P, mg/kg	Available K, mg/kg
			%			
1	+0.45	+0.26	+0.15	+0.29	+7.2	+11.2
2	+0.19	+0.01	+0.03	+0.33	+1.2	+2.7
3	+0.15	+0.06	+0.03	+0.28	+3.7	+4.2
4	+0.29	+0.12	+0.04	+0.31	+3.7	+3.2
5	+0.62	+0.25	+0.02	+0.25	+4.7	+2.7
6	+0.45	+0.14	+0.09	+0.26	+3.7	+6.7
Average	+0.36	+0.14	+0.05	+0.29	+4.0	+5.1

Effect of Organic Plus Inorganic Fertilizer on Nutrient Utilization and Efficiency

Nutrient utilization rates of N, P_2O_5 and K_2O from organic manure were estimated based on ^{15}N uptake. Approximately 16 percent of the N, 10 percent of the P_2O_5, and 16 percent of the K_2O from manure was used by the crop, or about half the amount contributed by inorganic fertilizer. Compared to inorganic fertilizer alone, the combination of organic and inorganic fertilizers reduced the cost of nutrients and increased net income by 11 percent.

This fertilization strategy is the principal recommendation for sustainable agricultural development in triple cropping systems based on rice. As shown, this recommendation sustains high yields economically and provides the opportunity to either build or maintain plant nutrients in the soil. Organic fertilizer when used in sufficient quantity can effectively complement inorganic nutrient input. **BCI**

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