Improving Productivity and Profitability of the Maize-Wheat System in Jharkhand

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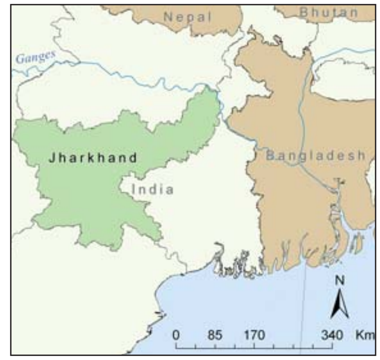

Field experiments within the maize-wheat crop sequence grown on the relatively low fertility red and lateritic soils achieved a yield target of 5 t/ha of maize and 4 t/ha of wheat with site-specific nutrient management (SSNM). This research provides a path towards the possibility of doubling current crop production on such soils.

The maize-wheat crop rotation is an important cropping system in the northeastern province of Jharkhand. Yet average maize and wheat productivity in Jharkhand is 1.4 t/ha and 1.6 t/ha, respectively; and are much lower than the national averages of 2.5 t/ha and 3.1 t/ha. Increased productivity of cereal crops can be addressed with proper attention to the introduction of high yielding varieties and suitable nutrient management practices. Red and lateritic soils of eastern India, especially in Jharkhand, have poor fertility because of coarse texture, low organic matter content, soil pH, and availability of N, P and K. Farmers use inadequate amounts of fertilizer and apply them in unbalanced proportions.

Omission plot trial site visit by Dr. Rakesh Kumar (left) and Dr. Sudarshan Dutta (right).

It was hypothesized that maize and wheat yields could be improved by two to three-fold using better quality seed and balanced fertilization. The approach combined an estimation of soil nutrient supply through nutrient omission plots, followed by adequate and balanced application of all yield-limiting nutrients based on attainable yield targets that would also bring about the necessary change in the regional food security scenario.

A field experiment was conducted at the Birsa Agricultural University Farm in Ranchi, Jharkhand to assess the effect of nutrient use and nutrient omission on crop yields, nutrient uptake, soil health, and the economics of the maize-wheat cropping system for two consecutive years (2009-10 and 2010-11). The experiments were carried out with hybrid maize (var. Pioneer 30V 92) grown during the rainy season as a rainfed crop (June to October) and wheat (var. DBW 17) grown in winter as an irrigated crop. The experimental area comes under the Eastern Plateau and Hill region (Agro-Climatic Region 7). The climate is sub-tropical—total rainfalls were 1247 and 1443 mm during 2009-10 and 2010-11, respectively. The soil was sandy loam in texture with pH 5.2, 4.9 g/kg of organic carbon, 272 kg/ha available N, 32 kg P_2O_5/ha, 139 kg K_2O/ha, and 14 kg S/ha. Five treatments comprising ample NPK (250-120-110 kg N-P_2O_5-K_2O/ha for maize and 150-110-100 kg N-P_2O_5-K_2O/ha for wheat), three treatments with successive omission of N, P and K from the ample treatment and a prototype SSNM treatment of 200-90-100 kg N-P_2O_5-K_2O/ha for maize and 120-70-60 kg N-P_2O_5-K_2O/ha for wheat was laid out in a randomized block design with four replications. The nutrient rate in the ample NPK treatment was chosen to avoid any nutrient limitation while the rates in the SSNM treatment was based on published nutrient uptake values for maize and nutrient use efficiencies in the soil (Setiyono et al., 2010; IPNI personal communication).

Abbreviations and Notes: N = nitrogen; P = phosphorus; K = potassium; ₹ = Indian rupee (US$1 = ₹62); CD = critical difference.

For calculation of the system yield, grain yield of wheat was converted to maize equivalent yield (MEY) by multiplying the wheat yield with wheat minimum support price (MSP) and divided by MSP of maize. Composite surface soil samples (0 to 15 cm) were collected after two crop cycles for available N, P and K analysis. Agronomic efficiency (AE) of N, P and K by the cropping system was calculated as described by Cassman et al. (1998).

Crop Yield and Plant Nutrient Uptake by the System

Maize grain yields > 5 t/ha were obtained with the SSNM treatment as well as with the ample NPK treatment (**Table 1**). Wheat yield in the ample NPK treatment was significantly (p

Table 1. Effect of nutrient omission on yield and nutrient use efficiency in maize-wheat sequence.

	Grain yield, t/ha			kg grain increased/
Treatments	Maize	Wheat	System (MEY)	kg nutrient applied
NPK	5.38	4.63	12.26	17.93
(-N)	1.22	0.86	2.50	8.81
(-P)	3.48	2.98	7.88	13.51
(-K)	4.13	3.63	9.49	18.96
SSNM	5.67	3.78	11.26	22.38
CD (p = 0.05)	0.83	0.52	1.08	

Table 2. Effect of nutrient omission on uptake (kg/ha) of N, P and K by maize-wheat sequence.

	----- N uptake -----			----- P uptake -----			----- K uptake -----		
Treatments	Maize	Wheat	System (MEY)	Maize	Wheat	System (MEY)	Maize	Wheat	System (MEY)
NPK	145.0	99.4	244.4	25.6	18.6	44.2	97.2	117.1	214.3
(-N)	34.6	17.4	52.0	7.4	3.7	11.1	35.5	20.4	55.9
(-P)	92.0	70.0	161.9	16.3	7.1	23.3	67.8	62.9	130.8
(-K)	98.9	92.2	191.1	16.7	13.0	29.7	63.6	85.3	148.9
SSNM	132.0	79.4	211.4	22.9	10.6	33.5	108.2	89.4	197.7
CD (p = 0.05)	20.7	18.1	31.5	3.4	2.8	5.8	20.4	17.4	34.1

Table 3. Agronomic efficiency (%) in maize and wheat in ample NPK and SSNM plots.

Treatments	Maize	Wheat	System
AE of N (%)			
NPK	16.6	25.1	24.4
SSNM	22.2	24.3	27.4
AE of P (%)			
NPK	15.8	15.0	19.0
SSNM	24.3	11.4	21.1
AE of K (%)			
NPK	11.4	10.0	13.2
SSNM	14.0	2.5	10.4

Table 4. Effect of nutrient omission on economics in maize-wheat sequence.

Treatments	Cost of cultivation, ₹/ha	Gross return, ₹/ha	Net return, ₹/ha	Benefit-to-Cost ratio
NPK	60,316	116,470	56,154	1.93
(-N)	53,628	23,750	-29,878	0.44
(-P)	48,241	74,860	26,619	1.55
(-K)	55,057	90,155	35,098	1.64
SSNM	53,535	106,970	53,435	2.00

₹ = Indian rupee (US$1 = ₹62).
Values used for calculating economic data were: Wheat = ₹11.70/kg; Maize = ₹10.50/kg; N = ₹11.40/kg; P_2O_5 = ₹32.20/kg; K_2O = ₹18.33/kg.

≤ 0.05) higher than the SSNM treatment. Maize-wheat system yield, however, did not differ significantly between these two treatments. As expected, significant yield losses were observed in both maize and wheat due to omission of nutrients from fertilization schedules. The highest loss was observed in the case of N omission followed by P and K omissions. Omission of N, P and K in the treatment plots resulted in 77%, 30% and 15.7% lower yields respectively, compared to the ample NPK treatment.

Uptake of N, P and K were highest in the ample NPK treatment (**Table 2**). Omission of nutrients resulted in the reduction of the plant uptake and highlights the importance of balanced fertilization to optimize productivity of crops. Nutrient uptake was lowest in the N omission plots followed by those omitting P and K, and can be associated with biomass production.

Agronomic Efficiency

The AE was calculated by using the example equation for N: AE (for N) = (Yield in NPK plot – Yield in N omission plot) / N applied x 100. The AE of N for the maize-wheat sequence increased by 3% under SSNM compared to NPK treatment (**Table 3**). This was primarily due to higher N utilization efficiency of maize under SSNM management (22.2%) compared to that measured under NPK treatment (16.6%)—caused by excess application of nutrients in the ample NPK treatment following the omission plot experimental protocol. However, this information has considerable importance for farmers of the region as this suggests that optimized SSNM can improve AE of N without compromising crop yield. Similarly, AE of P and K were also increased under SSNM if compared to NPK plots for maize (**Table 3**). Increases in AE were highest for maize compared to wheat or the system as a whole.

Crop response to fertilizer (kg grain/kg NPK applied) was higher in SSNM plots (22.4) than in NPK plots (17.9). Omission of N, P or K from the fertilizer schedule resulted in much lower crop response, which followed the order of N followed by P and then K (**Table 1**).

Soil Available Nutrient Status

Available soil nutrient status after two years of cropping showed major depletion of available N in all treatment plots. Slight depletion of K was also observed across all plots except the N omission plots. A build-up of soil P was observed in all treatments except the P omission plots. Build-up of P and K was highest within the N omission plots, which is most attributed to lower biomass production in this treatment and lower uptake of P and K (**Figure 1**). Considering the widespread deficiency of P in Alfisols of eastern India, the study clearly suggests that P omission can result into extremely low available P status of soil. Soil available K also decreased significantly in the K

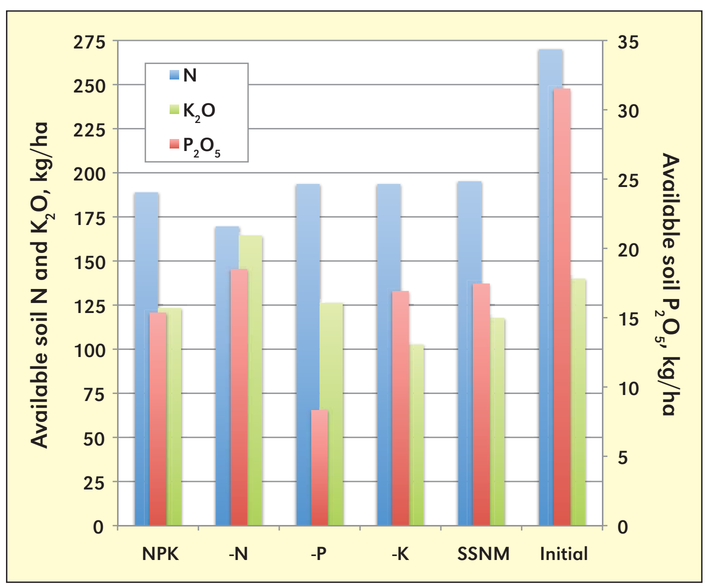

Figure 1. Available nutrient status in fertilized and nutrient omission plots after two crop cycles.

omission plot, but the effect was not as pronounced as the P depletion because of addition of K through irrigation water (data not shown). In P-treated plots, an increase in available P status of soil was observed in both SSNM and NPK plots.

Economics

Economic analysis of the nutrient management practices was determined through a benefit-to-cost (B:C) ratio analysis. The study revealed that the B:C ratio was highest with SSNM (2.00) with a system yield level of 11.3 t/ha followed by the NPK treatment plot (1.93) that yielded 12.3 t/ha (**Table 4**). A lower B:C value associated with the NPK treatment can be attributed to higher input cost associated with additional nutrients prescribed by the omission plot protocol. Omission of N generated a negative net return and lowest B:C ratio (0.44). Omission of P and K produced B:C values of 1.55 and 1.64, respectively. This indicates that production and profitability could be increased in maize-wheat system in Jharkhand with balanced nutrient management practices.

Summary

The study highlights that maize and wheat yields in Jharkhand could be increased two to three-fold to nearly 5 t/ha each with proper nutrient management. The response data obtained from the experiment could provide an alternate approach of estimating nutrient application rates to achieve targeted yields of maize and wheat. One of the advantages of the omission plot approach of estimating soil nutrient supply capacity is that it circumvents the infrastructural issues associated with soil testing and provides an alternate method of estimating site-specific nutrient rates for a crop sequence. This can help in disseminating SSNM strategies for farmers in eastern India for improved productivity, farm profit and environmental sustainability. BC

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Conversion Factors for U.S. System and Metric

Because of the diverse readership of *Better Crops with Plant Food*, units of measure are given in U.S. system standards in some articles and in metric units in others…depending on the method commonly used in the region where the information originates. For example, an article reporting on corn yields in Illinois would use units of pounds per acre (lb/A) for fertilizer rates and bushels (bu) for yields; an article on rice production in Southeast Asia would use kilograms (kg), hectares (ha), and other metric units.

Several factors are available to quickly convert units from either system to units more familiar to individual readers. Following are some examples which will be useful in relation to various articles in this issue of *Better Crops with Plant Food*.

To convert Col. 1 into Col. 2, multiply by:	Column 1	Column 2	To convert Col. 2 into Col. 1, multiply by:
	Length		
0.621	kilometer, km	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
0.394	centimeter, cm	inch, in.	2.54
	Area		
2.471	hectare, ha	acre, A	0.405
	Volume		
1.057	liter, L	quart (liquid), qt	0.946
	Mass		
1.102	tonne[1] (metric, 1,000 kg)	short ton (U.S. 2,000 lb)	0.9072
0.035	gram, g	ounce	28.35
	Yield or Rate		
0.446	tonne/ha	ton/A	2.242
0.891	kg/ha	lb/A	1.12
0.0159	kg/ha	bu/A, corn (grain)	62.7
0.0149	kg/ha	bu/A, wheat or soybeans	67.2

[1]The spelling as “tonne” indicates metric ton (1,000 kg). Spelling as “ton” indicates the U.S. short ton (2,000 lb). When used as a unit of measure, tonne or ton may be abbreviated, as in 9 t/ha. A metric expression assumes t=tonne; a U.S. expression assumes t=ton.