Balancing Short-Term and Long-Term Goals in Nutrient Management

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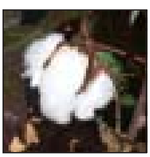
Four case studies are presented on cumulative crop response to repeated fertilizer additions. Greatest benefits in terms of yield, nutrient use efficiency, and soil fertility accrued over time in those systems that were managed with repeated, balanced nutrient additions that also led to improvements in soil fertility. Fertilizer recommendations must consider short-term as well as long-term crop response to applied fertilizer. Changes in soil nutrient pools need to be accounted for in evaluating nutrient management strategies by estimating the system level nutrient use efficiency.

Fertilizer recommendations are often derived from agronomic trials that focus on optimizing nutrient inputs with regard to achieving high net return in the crop to which the nutrient was applied. When a field experiment results in a small yield increase due to nutrient addition that is not statistically significant, the conclusion is often made that there is no need to apply that nutrient. This concept may lead to imbalanced fertilizer use and negative nutrient balances that threaten soil fertility and crop productivity over the longer term.



Case study 1: Cotton response to potassium (K)

Cassman et al. (1989) studied the response of irrigated cotton to K applications on a vermiculitic soil (**Figure 1**). Cotton yield was closely related to plant and soil K status and declined without K addition due to depletion of soil K, but a yield increase occurred in each successive year at the highest K rate. Annual rates of 129 or 257 lb K_2O/A resulted in increased cumulative seed yield by 13 to 21%, but 514 lb K_2O/A produced an increase of 42%. Soil K and soil organic matter contents declined in the control treatment, which shifted the K equilibrium towards fixation at interlayer clay sites. With high levels of K input, partial saturation of K fixation sites was achieved, resulting in increasing plant availability of added K and a 50% increase in the crop recovery efficiency of fertilizer-K. Those benefits were not achieved with small K applications or they would have been masked if the study had been conducted for a short time only.

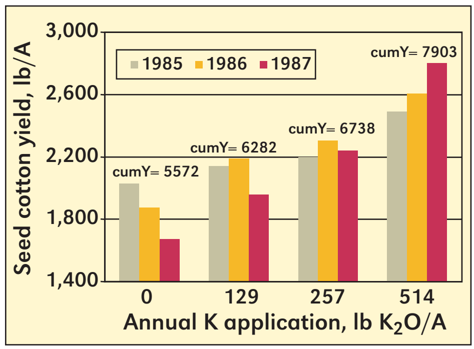


Figure 1. Response of annual and cumulative (cumY) seed cotton yield to annual K applications on a Vertisol.

Case study 2: Soybean response to phosphorus (P)

Key management decisions on acid, tropical soils include whether to invest in fertilizer P and how to apply it over time. On an Ultisol in Hawaii, P recovery by soybeans and agronomic efficiencies of applied P increased over time in two cropping seasons with different yield potential and at all levels of P input (Cassman et al., 1993). Cumulative P uptake and seed yield of all four crops grown were closely related to the level of P input (**Table 1**). The net P budget was positive in all +P treatments and resulted in an increase in extractable soil P, a reduction in the proportion of P fixed from subsequent P additions, greater P use efficiency, and an increase in nitrogen (N) uptake by soybeans. Cumulative yield response increased over time, which also means that the marginal return from investment in P fertilizer will increase with time.

Table 1. Cumulative soybean yield (cumY, bu/A) and P uptake (cumP, lb P/A), crop recovery efficiency (RE_P), and agronomic efficiency (AE_P) of annual P applications on an acid Ultisol. F=fall soybean; S=summer soybean.

Annual P input		1988 F	1989 F	1989 S	1990 S
lb P_2O_5/A	cumP	RE_P (ΔP uptake/P applied, lb/lb)			
0	27	–	–	–	–
72-102	50	0.08	0.14	0.2	0.29
143-205	67	0.08	0.13	0.19	0.22
429-614	78	0.04	0.05	0.08	0.09
lb P_2O_5/A	cumY	AE_P (ΔSeed yield/P applied, lb/lb)			
0	103	–	–	–	–
72-102	155	12.7	18.2	22.5	44.1
143-205	177	10.9	15.0	14.7	25.6
429-614	183	4.1	5.5	6.1	8.9

Note: The delta symbol (Δ) indicates "change in"

Case study 3: Rice response to P and K

Many P and K recommendations in irrigated rice systems of Asia are based on field trials that emphasize single-season yield response to nutrient applications. When no significant yield increase is measured, the recommendation is often not to apply that nutrient, which can lead to depletion of soil P and K (Dobermann et al., 1998). Although the initial yield response of lowland rice to P or K applications is often small, large cumulative yield increases accrue over time (Witt et al., 2004).

In the example shown in **Figure 2** (Witt et al., 2004), initial yield increases due to P or K application were not significant (<0.22 tons/A). However, yield increases were consistent and became larger over time because plant available soil P and K pools became exhausted. Over 9 years (18 crops), neglecting P or K application caused a grain production loss of 7.4 or 4.9 tons/A, respectively. Similar patterns were observed at other sites in Asia. Fertilizer requirements would be underestimated if they were based on the short-term yield response without considering nutrient removal with grain and straw. Therefore, in a new site-specific nutrient management concept, P and K maintenance rates are calculated based on a nutrient input-output model (Dobermann et al., 2004).

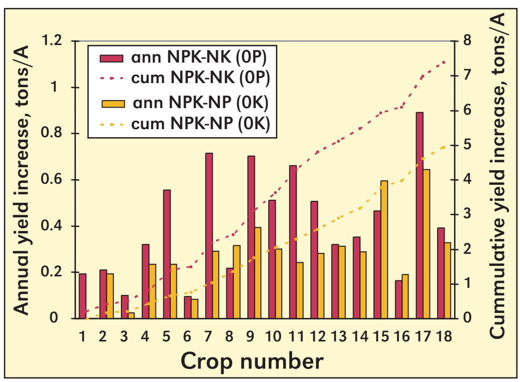


Figure 2. Annual and cumulative yield increases of irrigated rice due to P or K applied to each crop on a Vertisol at Maligaya, Philippines, 1968-76.

Case study 4: Nitrogen in irrigated corn systems

Maintenance of soil organic matter (SOM) is an important goal in agriculture, both in terms of soil fertility and increasing the sequestration of atmospheric carbon dioxide (CO_2) in soil. Because of the tight C:N ratio in SOM, sequestration of C requires sufficient N. This role of N should also be considered in assessing fertilizer N use efficiency and designing long-term N management strategies.

In the example shown in **Table 2**, the recommended continuous corn system represented management for yields of approximately 80% of yield potential. In the intensive system, management was intensified to achieve 90 to 95% of yield potential and an extra amount of N was applied in fall to support crop residue decomposition and humification. In a 4-year period the cumulative crop residue C input was 22% larger in the intensive system than with recommended management, but there was no difference in C respiration from the soil. Intensive management resulted in significant C *and* N sequestration in SOM, whereas a net loss of soil C and N occurred in the recommended system. Based on the annual partial factor productivity (PFP) of applied N, the recommended system appeared to be more N-efficient because it produced 1.29 bu grain/lb N applied (0.86 lb grain N/lb N) as opposed to 0.93 bu grain/lb N (0.65 lb grain N/lb N) in the intensive system. However, when the net change in soil N was included, the intensive system had a higher *system level* N use efficiency (0.83) than the recommended system (0.56, **Table 2**) because extra N fertilizer contributed to build-up of SOM. Over time, this will increase the indigenous soil N supply and lead to an increase in annual PFP, which cannot be achieved in the more conservatively managed recommended system.

Dr. Dobermann discusses high yield corn research at the recent Ecological Intensification Field Day.

Table 2. Nitrogen use efficiency in irrigated corn systems with recommended (Rec) or intensive (Int) management on a Mollisol at Lincoln, Nebraska, 2000-2004.

	Rec[1]	Int[2]
Average corn (maize) yield, bu/A	223	252
Average fertilizer-N rate, lb/A	174	272
4-year C & N budget (May 2000 to May 2004)		
Crop residue input, tons C/A, aboveground	9.6	11.8
Soil+root respiration, tons CO_2-C/A	12	11.6
Measured change in soil C, tons/A	-0.5	2
Fertilizer-N input, lb/A	697	1090
N removal with grain, lb/A	598	705
Measured change in soil N, lb/A	-205	196
Nitrogen use efficiency		
bu grain/lb N applied, PFP	1.29	0.93
lb grain N/lb N applied	0.86	0.65
lb grain N+change in soil N/lb N applied	0.56	0.83

[1] 18,500 plants/A; soil-test based fertilizer rates, 2 N splits

[2] 26,000 plants/A; increased fertilizer rates, 4 N splits+45 lb N A applied in fall on crop residue before plowing

Conclusions

Fertilizer management strategies should be balanced with regard to achieving high short-term efficiency as well as maximizing the cumulative crop yield response over time. Although the cost of fertilization is usually charged to a single crop, long-term benefits accruing from residual fertilizer availability (P, K) or increases in soil C and N storage should be included in evaluating fertilizer economics. Contributions of added nutrients to both crop uptake and soil nutrient supply must be accounted for in assessing the *system level efficiency* of applied nutrients. BC

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