Nutrients and Environmental Quality

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Scientists have long stated that there is no scientific basis for claims that organic nutrients are superior to inorganic nutrients. Still, there is widespread public perception that organic agricultural systems are more environmentally friendly and more sustainable than high-yielding conventional farming systems. In fact, long-term studies from around the world indicate that sustained yields and soil productivity can be achieved with balanced nutrition, using either or both organic and mineral fertilizer nutrient sources.

Regardless of the source, plant nutrients are absorbed primarily as inorganic ions. For example, N is taken up as either ammonium (NH_4^+) or nitrate (NO_3^-), phosphorus as HPO_4^{2-} or $H_2PO_4^-$, and potassium (K) as K^+. Thus, even if the nutrient source is organic, it must undergo transformation so the nutrients it contains can be released in the inorganic form before crop plants can use them.

Organic matter (OM) has long been known to have positive influences on soil structure, tilth, bulk density, and moisture-holding characteristics. Among its other benefits are increases in the soil's cation exchange capacity (CEC) and reduced soil runoff and erosion losses. The humus fraction of OM, along with certain cations, is able to retain significant amounts of P, and OM can reduce P fixation under some acid soil conditions. However, continued heavy applications of animal manure can result in P movement into groundwater as the manure is mineralized. It should be noted that groundwater NO_3^--N levels are likely to be elevated long before P because NO_3^- is far more mobile in the soil than is P.

> When properly managed, mineral fertilizers and animal manure can increase soil productivity, enhance sustainability, and increase carbon (C) sequestration. There are, however, management challenges and risks associated with both nutrient sources relative to 1) nitrogen (N) and phosphorus (P) losses to surface and groundwater; 2) heavy metal accumulation; 3) pathogen accumulation; and 4) greenhouse gas production.

Micronutrients and heavy metals occur naturally in varying amounts in rocks, soils, and water. Several heavy metals are essential or beneficial to both plants and animals, but can become toxic if accumulated in excessive amounts (**Table 1**). Proper management can reduce or eliminate the buildup of toxic levels in agricultural soils.

More than 97 percent of mineral fertilizers manufactured in North America are made from natural sources such as atmospheric gases or mineral deposits rather than industrial by-products. Cadmium (Cd) is the heavy metal of most concern because of the levels found naturally in phosphate rock, the principal ore from which phosphate fertilizers are made. While the long-term use of phosphate fertilizers can result in a gradual buildup of Cd in the soil, it would take hundreds or even thousands of years at normal application rates to reach critical levels. Micronutrient and heavy metal concentrations in animal manure and sewage sludge are highly variable. At typical use rates, loadings are generally higher from biosolids than from fertilizers.

As with successful crop production,

nutrient input is essential for sustained aquatic productivity, but an excess of nutrients such as N and P can over-stimulate aquatic growth, creating algal blooms. As the plants die, bacteria begin to decompose them, using dissolved oxygen (O_2) in the water. When the O_2 levels become too low, some aquatic plants and animal life can suffer, and less mobile organisms may die. Concern over this situation has been well publicized for the U.S Chesapeake Bay area and the Gulf of Mexico. Nitrogen and P from commercial fertilizers have been blamed as a primary cause of increased nutrient flux in such surface water bodies.

TABLE 1. Reaction of plants and animals to trace elements.

	Essential or beneficial to:		Potentially toxic to:	
Element	Plants	Animals	Plants	Animals
Arsenic	No	Yes		Yes
Cadmium	No	No	Yes	Yes
Chromium	No	Yes	Yes	DU
Cobalt	Yes[3]	Yes	Yes	Yes
Copper	Yes	Yes	Yes	Yes[2]
Lead	No	No	Yes	Yes
Mercury	No	No	DU[1]	Yes
Molybdenum	Yes	Yes	DU	Yes[2]
Nickel	No[3]	Yes	Yes	Yes
Selenium	Yes	Yes	Yes	Yes (4 ppm)
Zinc	Yes	Yes	DU	DU

Source: Webber and Singh, 1995.

[1]DU = Data on critical limits unavailable.

[2]Toxic to ruminants (cattle and sheep) at 5 to 20 parts per million (ppm).

[3]Other sources consider Cobalt to be nonessential and Nickel to be essential (PPI Soil Fertility Manual).

Scientists recognize that under current crop rotations and management in the U.S. Midwest, there is no way to keep N and P out of drainage waters and, ultimately, rivers and streams that feed the Mississippi River. However, practices that improve N use efficiency, such as placement, timing, source, and application rate, can minimize the impact of nutrient enrichment in surface and groundwater. Also, P management, as well as other practices such as tillage systems, can reduce the impact of P (and N) on water quality. For example, research in Arkansas showed that vegetative filter strips can be quite effective in reducing runoff P losses. Other studies have shown that properly designed vegetative filter strips have decreased N and P losses by 40 to 90 percent.

Excess NO_3^- in groundwater poses a potential threat to humans. In agricultural soils, contamination is most likely in humid or irrigated areas where sandy soils overlay shallow aquifers. In clay or clay loam soils that drain slowly, denitrification can significantly reduce NO_3^- and prevent its leaching to groundwater. Large applications of animal manure can increase the soil's total N and inorganic N contents. Nitrate is the primary end product of manure decomposition and may pose environmental risks when manure is applied to provide N rates above crop use. On well drained or tile drained soils, the potential for NO_3^- leaching goes up as manure rates increase.

Risks from Pathogens

Animal wastes contain intestinal bacteria, many of which present substantial human health risks if ingested through drinking water. One of the bacteria of most concern is *E. coli* O157:H7. The U.S. Centers for Disease Control (CDC) has estimated that there are about 70,000 cases of infection and more than 60 deaths each year caused by this particular bacterial strain. While animal manure is not the only source for this pathogen, it is a contributor.

Viruses have also been reported in manure. Those found in poultry litter may present a bigger environmental problem than bacteria. A number of antibiotics, growth hormones, and disinfectants are used to protect animal health and to improve production. The consequences and fate of these substances have not been thoroughly assessed.

Air Quality

Odors from ammonia (NH_3) and other gases are released from animal production facilities, in waste storage lagoons, stockpiles, composted wastes, and in excreta by grazing animals. Odor-causing gases can arise from

TABLE 2. Total organic C, corn-derived C, and native C found in fertilized and unfertilized corn plots, using ^{13}C

Fertilization N-P_2O_5-K_2O, lb/A	Total C	Corn-derived C	Native C
		tons/A	
0-0-0	36	5	31
115-70-30	40	9	31

Source: Gregorich and Drury, 1996.

the decay of organic substances in the absence of O_2. Besides the offensive odors from gases such as hydrogen sulfide (H_2S), some of the gases can cause health problems. High NH_3 concentrations can be detrimental to birds and to farm laborers as well. Atmospheric loss of NH_3 from N fertilizers is considerable. Such losses can be minimized by proper N management.

Increased emissions of greenhouse gases (GHGs) are thought to increase the potential for global warming. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the three most important GHGs associated with agriculture. Carbon dioxide emissions in agriculture come from the burning of fossil fuel and the decomposition of OM and crop residues. Methane comes primarily from ruminant animals, livestock manure, wetlands, and rice production. Any N source is subject to denitrification reactions in the soil, so all forms of N, organic and inorganic, contribute to N_2O emissions. Proper management minimizes the effect.

Agriculture has an opportunity to significantly reduce CO_2 emissions by sequestering more C in the soil. One 35-year study showed that fertilization increased the amount of corn-derived C while maintaining native soil C (**Table 2**). Fertilization and crop rotation increased both crop yields and soil organic matter levels.

Former U.S. Assistant Secretary of Agriculture, Dr. C.E. Hess, stated that agriculture has a great opportunity to help mitigate climate change by stashing CO_2 as C in soil and vegetation. Practices requiring good agricultural husbandry, which should be implemented anyway, can be quite effective for sequestering C. For cropland, these practices include building soil OM levels, improving soil fertility, and growing more food on less land.

Role of Nutrients in Stabilizing C in Soil OM

Sound nutrient management aids the capture of atmospheric CO_2, improves photosynthesis, enhances O_2 release to the atmosphere, and increases soil C. Several studies have shown the correlation between N fertilization and C sequestration. Long-term research has also shown that soil organic N and C levels are highest when conservation tillage is combined with rotations of high residue crops and adequate, balanced fertility to increase crop yields.

Summary

Mineral fertilizers and animal manure are valuable nutrient sources for crop production to meet the world's food and fiber demands. Fertilizers are more predictable and thus more manageable nutrient sources. Improperly managed, any source can potentially pollute the soil, water, and air.

The growing challenge for agriculture is to find ways to increase crop yields and improve nutrient use efficiency while stabilizing nutrients...not removed in harvested crops...in crop residues and, ultimately, OM in the soil. Nutrient management must be site-specific and cost effective to protect the viability of North American agriculture. At the same time it must also include considerations for the protection of our soil, water, and air resources. That means protection from surface runoff, leaching, and gaseous emissions.

There is no reason crop production systems based on sound nutrient management cannot sustain optimum yield production while also protecting the environment.

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