INTEGRATED NUTRIENT MANAGEMENT, SOIL FERTILITY, AND SUSTAINABLE AGRICULTURE: CURRENT ISSUES AND FUTURE CHALLENGES

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Limited availability of additional land for crop production, along with declining yield growth for major food crops, have heightened concerns about agriculture's ability to feed a world population expected to exceed 7.5 billion by the year 2020. Decreasing soil fertility has also raised concerns about the sustainability of agricultural production at current levels. Future strategies for increasing agricultural productivity will have to focus on using available nutrient resources more efficiently, effectively, and sustainably than in the past. Integrated management of the nutrients needed for proper plant growth, together with effective crop, water, soil, and land management, will be critical for sustaining agriculture over the long term.

Integrated nutrient management (INM) is an approach that seeks to both increase agricultural production and safeguard the environment for future generations. It is a strategy that incorporates both organic and inorganic plant nutrients to attain higher crop productivity, prevent soil degradation, and thereby help meet future food supply needs. It relies on nutrient application and conservation, new technologies to increase nutrient availability to plants, and the dissemination of knowledge between farmers and researchers. The success of INM will depend upon the combined efforts of farmers, researchers, extension agents, governments, and nongovernmental organizations (NGOs).

NUTRIENTS AND BALANCE

In crop production, plants synthesize nutrients in the soil such as nitrogen, phosphorus, and potassium (NPK) with air, sunlight, and water. Without proper management, continuous crop production can reduce nutrient reserves in the soil. In Sub-Saharan Africa, for example, more than 30 net kilograms of NPK per hectare are removed from soils each year. As reserves get depleted, crop growth and productivity can be compromised. Over time, cumulative depletion can decrease agricultural production, crop yields, and soil fertility, and lead to soil degradation.

Techniques to conserve and add nutrients to the soil through the application of organic or inorganic fertilizers can help to maintain and increase the nutrient reserves of the soil. But oversupply of nutrients can also be a problem, causing economic inefficiency, damage to the environment, and, in certain situations, harm to the plants themselves, and to the animals and humans that consume them or products made from them.

Whereas soil mining is primarily a problem in developing countries, overapplication of nutrients occurs chiefly in the developed world, where the relatively low cost of fertilizer leads some farmers to use it in amounts far in excess of plant needs and the capacity of soils to hold nutrients. Balance in the absolute and relative application of nutrients is a part of INM.

Achieving Balance: Nutrient Application

Achieving balance between the nutrient requirements of plants and the nutrient reserves in soils is essential for maintaining high yields and soil fertility, preventing environmental contamination and degradation, and sustaining agricultural production over the long term. In many cases, imbalances can be corrected through the application of appropriate inorganic and organic fertilizers. In Kenya, the application of nitrogenous fertilizer on nitrogen-poor soils increased maize yields from 4.5 to 6.3 metric tons per hectare, while application of a less-appropriate fertilizer increased yields to only 4.7 tons per hectare. Correcting nutrient imbalances not only leads to sustainable high crop yields, but it reduces the need to cultivate unsustainable marginal lands.

The use of manmade inorganic fertilizer is a fundamental component of INM, yet it is often not available to farmers in developing nations. In Sub-Saharan Africa, in particular, fertilizer use is extremely low compared to the rest of the world. In 1996, Sub-Saharan Africa consumed 8.9 kilograms of fertilizer per hectare of arable land. Global fertilizer use in the same year was 97.7 kilograms per hectare. Failure to use fertilizer in Africa results from a number of factors, including high import prices, extra costs of tailored mixes needed for African conditions, and high transportation costs due to poor infrastructure. These factors dramatically increase the price of fertilizer for farmers in underdeveloped areas. Governments and NGOs supporting INM can address some of these problems by funding development programs and enacting policies and programs that reduce marketing costs and make organic and inorganic fertilizers easily available and affordable.

In addition to inorganic fertilizers, a largely untapped nutrient source is urban waste. Although a relatively poor substitute for commercial fertilizers, urban sludge improves soil structure, contains secondary and micronutrients as well as NPK, and has the potential to be a good source of nutrients for agricultural lands near urban centers. From an economic perspective, the use of urban waste as fertilizer has an added benefit: it puts to good use material that would otherwise be costly to dispose of.

There are some problems with the use of urban waste, however. Since it may contain heavy metals, parasites, and other pathogens that would not be beneficial to soils and plants, or the consuming public, urban waste needs to be treated and its application on agricultural land managed appropriately. Urban waste's effective use also has to overcome problems such as bulkiness and high handling costs, but its abundance and usefulness should make it a good alternative in areas where fertilizers, particularly inorganic fertilizers, are unavailable to farmers.

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Achieving Balance: Conservation and Uptake of Nutrients

Boosting plant nutrient sources does not necessarily require the heavy application of inorganic fertilizer. Planting practices such as terracing, alley cropping, and low-till farming prevent nutrient loss. Other practices, including use of cover crops and intercropping and application of organic manures, can improve nutrient reserves and soil characteristics and structure. The rotation of cereals and leguminous plants has been shown to reduce chemical fertilizer use by up to 30 percent, as cereals absorb the nitrates released from the decaying roots and nodules of leguminous plants.

INM also includes making nutrient uptake more efficient. Most crops make inefficient use of nitrogen, often losing nitrogen into the atmosphere through volatilization. New techniques, such as deep placement of fertilizers and the use of inhibitors or urea coatings, have been developed to address this problem. With these innovations, and with better timing and more concentrated fertilizers, nutrient uptake efficiency can be expected to improve by as much as 30 percent in the developed world and 20 percent in developing countries by the year 2020.

Achieving Balance: Internal Supplies

Genetic engineering holds the promise of enabling plants themselves to generate some of the nutrients they require. By altering or creating microorganisms that can fix nitrogen in nonleguminous plants such as cereals, genetic engineering would reduce the amount of nitrogen farmers had to apply. While this strategy holds promise for the future, the process is quite complex and will be expensive to realize.

INSTITUTIONAL RESPONSES

The promotion of INM will require diverse actors to come together in research, extension, evaluation, and dissemination of technologies.

As one would expect, different climates, soil types, crops, farming practices, and technologies dictate that the correct balance of nutrients necessary for one farm may be quite different from that necessary for a farm somewhere else in the world. In parts of Asia, for example, research on the role of micronutrients is important because irrigated rice yields have leveled off despite increased NPK application. The research challenge in Africa is particularly daunting because of the severe climatic and soil conditions and the diversity of smallholder farmers. Determining the appropriate balance of nutrients to increase yields and improve soil fertility in any given location will require localized research, but will also benefit from the cooperation of both national and international agricultural research centers.

In addition to research differences mandated by diverse agricultural environments, the application of INM around the world depends on choices individual farmers make based on their own objectives. With the aid of researchers and extension agents, farmers have to be given access to the most appropriate and cost-effective technologies for their particular circumstances. Successful INM adoption programs thus must facilitate an exchange of information between farmers, extension programs, and researchers that helps these participants learn about what actually works on farms in their area. Adoption programs also require greater monitoring and testing of plants and soils to ensure that INM is establishing the best environment for plant growth.

Not only must farmers, researchers, and extension program personnel interact with one another, but NGOs and the private sector will also need to be involved in order to properly evaluate and disseminate traditional technologies and develop new ones. And the role of government will continue to change from one of supplying and distributing chemical fertilizers to one of regulating the market for plants and nutrients. Government also needs to provide better infrastructure so that farmers in remote locations can have access to information and technology and have the ability to reach markets with their crops.

CONCLUSIONS AND RECOMMENDATIONS

In order to meet the food demands of a rising population in the first decades of the 21st century, farmers must manage nutrients and soil fertility in an integrated way. Required yield increases of major crops cannot be attained without ensuring that plants have an adequate, balanced supply of nutrients. This balance will not be achieved until “nutrient cycles” are better understood, an issue that government should address by establishing testing and monitoring systems. Genetic engineering may also contribute to better nutrient balancing by helping plants provide some of their own nutrients for enhanced growth. Government and extension services will need to facilitate adoption of nitrogen-fixing species among farmers.

Government will also need to continue to facilitate the widespread and responsible use of organic and inorganic fertilizers. In developed countries and a few developing countries, this will require a reduction in overfertilization. But in most developing countries, where fertilizer use is low, greater application will help to improve crop production and benefit the environment by limiting soil mining and reducing land degradation.

Nutrient depletion through soil mining is an especially acute problem in parts of Africa and special steps to combat it are required there. These efforts include soil testing for nutrient depletion, cooperation between farmers and researchers, promotion of more productive use of organic nutrients, and encouragement of extension services and NGOs to pay attention to soil-related issues. Efforts may also include government and NGO-supported investments to enhance soil fertility.

Integrated nutrient management can address many of the problems besetting poor, smallholder farmers in Africa and elsewhere. But INM’s success ultimately depends upon the timely and concerted efforts of extension programs, government, NGOs, researchers, and the farmers themselves.

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2020 VISION

“A 2020 Vision for Food, Agriculture, and the Environment” is an initiative of the International Food Policy Research Institute (IFPRI) to develop a shared vision and a consensus for action on how to meet future world food needs while reducing poverty and protecting the environment. Through the 2020 Vision initiative, IFPRI is bringing together divergent schools of thought on these issues, generating research, and identifying recommendations. The *2020 Briefs* present information on various aspects of the issues. The 2020 Vision Initiative gratefully acknowledges support during 2000 from the following donors: CIDA, CTA, DANIDA, Spain, Rockefeller Foundation, SIDA, and SDC.