Editor's note: This is the first article in a five-part series from the International Plant Nutrition Institute titled "Know Your Fertilizer Rights," sponsored by The Fertilizer Institute and the Canadian Fertilizer Institute. The series is based on fertilizer best management practices structured around the "4R" nutrient stewardship concept. For more information, visit www.ipni.net.

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Know your fertilizer rights

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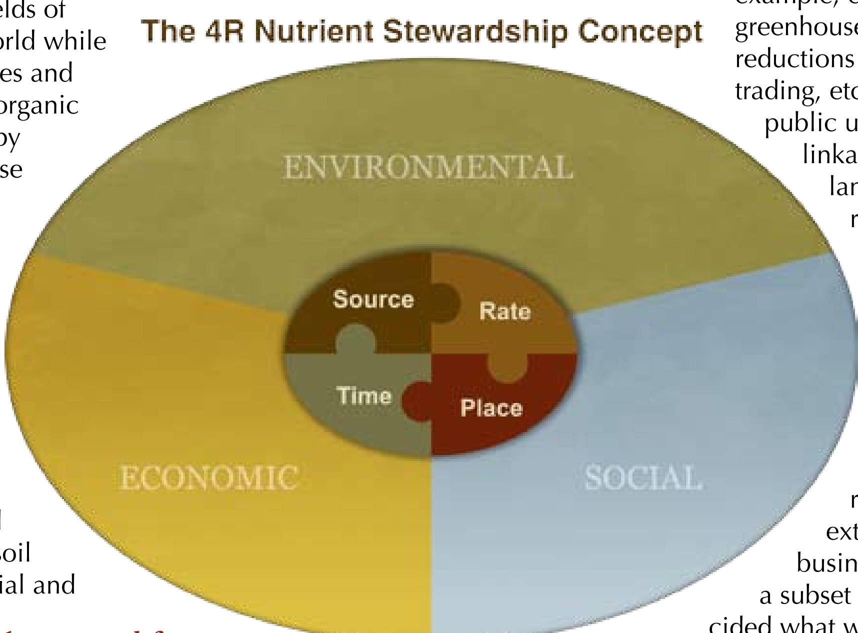
This article describes a new, innovative approach to best management practices (BMPs) for fertilizer known as 4R nutrient stewardship. It ensures that the right source (or product) is applied at the right rate, right time, and right place. This simple concept can help farmers and the public understand how the right management practices for fertilizer contribute to sustainability for agriculture. Getting practices "right" depends on important roles played by many partners including farmers, crop advisers, scientists, policymakers, consumers, and the general public.

Sustainability

The increasing number and importance of issues surrounding the management of crop nutrients makes it necessary to have an approach that clearly describes the practices and their impacts. On the one hand, nutrient applications increase yields of crops, nourishing the world while sparing land for other uses and increasing the return of organic carbon to the soil, thereby sequestering a greenhouse gas. On the other hand, unmanaged nutrient applications may increase nutrient losses, potentially degrading water and air quality in a number of ways and possibly increasing greenhouse gases. Fertilizer use also has longer-term and larger-scale impacts on soil productivity and the social and economic structure of rural areas. These issues are all part of sustainable development.

The 4R nutrient stewardship concept is being developed because sustainable agricultural production is important, and we need to ensure that fertilizer use contributes to it. The fertilizer rights—source, rate, time, and place—are connected to the goals of sustainable development. Internationally, sustainable development is recognized to consist of three nonnegotiable elements: economic, social, and environmental. Progress in each of those three areas is essential to sustainability. How the progress will be achieved requires input from stakeholders. For fertilizer use to be sustainable, it must support cropping systems that provide economic, social, and environmental benefits.

The connection between the practices and the benefits must be understood well, not only by crop producers and their advisers, but also by those who purchase the products of cropping systems and those who live in the environment impacted by those systems. Programs involving payments to farmers for ecological goods and services—for example, carbon offsets related to greenhouse gas mitigation, loading reductions for water quality credit trading, etc.—depend on a clear public understanding of these linkages and a common language and vocabulary relating to fertilizer management.



The 4R nutrient stewardship concept defines the right source, rate, time, and place for fertilizer application as those producing the economic, social, and environmental outcomes desired by all stakeholders to the plant ecosystem.

Who decides what's right?

Traditionally, a team of farmers, researchers, natural resource managers, extension staff, and agribusiness professionals—or a subset of this team—has decided what would qualify as a best management practice. Today there is still no doubt that the expertise of all these people is important to determining the right management on a practical basis. A sustainability-focused approach, however, is more comprehensive and includes input from all stakeholders in determining the indicators, measures, benchmarks, and targets for performance of the management practices implemented. So what's right is determined by how these people want the cropping system to perform.

Stakeholders of cropping systems include the people who consume its products and the people living in the environment it impacts. The perspectives of all of these stakeholders must be reflected in the economic, social, and environmental goals that are set for the cropping system. Fertilizer management, to be considered "right," must support those goals. All stakeholders have input to the goals. However, the farmer—the manager of the land—is the final decision maker in selecting the practices—suited to the local site-specific soil, weather, and crop production conditions—that have the highest probability of meeting the goals. Because all these conditions can influence the decision on the practice selected, right up to and including the day of implementation, local decision making with the right decision support information performs better than a centralized regulatory approach.

For example, a recent BMP guide for dairy-based cropping systems in the Northeast was developed using the input of farmers, agribusiness professionals, land grant university extension, and staff of the USDA-NRCS. Performance goals for farm profitability and off-farm impact on water quality were the foremost considerations of this body of experts, based on input from experience with environmental agencies, public interest groups, and policymakers. The BMP guide they developed listed 20 general practices under the categories of right source, rate, time, and place (Bruulsema and Ketterings, 2008).

What does it mean to apply the 'right source at the right rate, right time, and right place?'

The phrase "right source at the right rate, right time, and right place" implies that each fertilizer management practice or group of practices is right—i.e., effective—in terms of the goals of sustainable production. It also implies that there are four aspects to every fertilizer application and provides a simple checklist to assess whether a given crop has been fertilized properly. Asking "Was the crop given the right source at the right rate, time, and place?" helps farmers and advisers to identify opportunities for improvement in fertilizing each specific crop in each specific field.

A balance of effort among the four rights is appropriate. It helps avoid too much emphasis on one at the expense of overlooking the others. Rate may sometimes be overemphasized, owing to its direct relation to cost. Source, time, and place are more frequently overlooked and hold opportunity for improving performance.

The phrase also clearly describes to the fertilizer industry that farmers have specific requirements for the delivery and distribution of the right nutrient forms suited to their application equipment in the right amounts to support the right rate at the right time and to the right place. Meeting these logistical challenges is the fertilizer industry's role in delivery and distribution.

Grouping specific practices associated with fertilizer management under the headings of source, rate, time, and place helps ensure that no critical steps in fertilizer management are overlooked. In that way, they are valuable to the farmer and the crop adviser. To ensure sound agronomy, the manager asks, "Am I using every tool available to choose the right product, to predict its right rate, to apply it at the right time, and to place it where it's most effective for my crop, soil conditions, and weather?"

The four headings also help farmers, crop advisers, and agronomic scientists to clearly communicate with stakeholders less familiar with agriculture.

Are the four 'rights' independent or interconnected?

The four aspects of fertilizer management—source, rate, time, and place—are completely interconnected and also linked to the full set of management practices for the cropping system.

None of the four can be right when any one of them is wrong. It is possible that for a given situation, there is more than one right combination of source, rate, timing, or placement, but when one of the four changes, the others may as well. For example, it may be true for certain farms in a certain region that a single application of a controlled-release source of nitrogen (N) is equal in costs and benefits to a split application of a soluble N source. The two sources would obviously differ in the "right" time of application. They would be equally right if they achieved the same performance from the cropping system at the same cost. However, in many practical situations, one combination may be preferred over another because of a better fit with the logistics of the operation or with the range of weather risks to which each might be susceptible.

The four "rights" must work in synchrony with each other and with the surrounding plant-soil-climate and management environment. One change of step or direction may cause the entire system of nutrient management to fall short of its intended goal.

The combination of source, rate, time, and place changes depending on the crop management system as well. For example, a broadcast fertilizer application incorporated before planting may suit a corn–soybean rotation with tillage, but a band application and injection may be needed under no-till management. So the right source, rate, time, and place are interconnected, not independent, and are linked strongly to crop management and to local site-specific soil, weather, and climate conditions.

What scientific principles apply?

The sciences of physics, chemistry, and biology are fundamental to the mineral nutrition of plants growing in soils.

▶ Table 1. Key scientific principles used in developing practices for determining right source, rate, time, and place.

Category	Examples of key scientific principles
Source	Ensure a balanced supply of essential nutrients, considering both naturally available sources and characteristics of specific products, in plant-available forms.
Rate	Assess soil nutrient supply and plant demand.
Time	Assess dynamics of crop uptake, soil supply, and logistics of field operations. Determine timing of nutrient loss risks.
Place	Recognize root-soil dynamics. Manage spatial variability within the field to meet site-specific crop needs and to limit potential losses from the field.

The application of these sciences to practical management of plant nutrition has led to the development of the scientific disciplines of soil fertility and plant nutrition. Each of the four management components of source, rate, time, and place has unique science describing fundamental processes. Science also studies and describes whole systems. Both levels of science are relevant because there are gaps in the knowledge of the fundamental processes and crop production systems or plant ecosystems are complex and can respond in unanticipated ways to the application of nutrients. So the science backing a particular practice needs to include both that which documents how the practice works at the basic level and that which measures the outcome in terms of changes in performance of the cropping system in which fertilizers are applied.

Specific scientific principles guide the development of practices determining right source, rate, time, and place. A few of the key principles are shown in Table 1. These and other important principles of plant nutrition will be described in more detail in the next four articles in this series.

The principles are the same globally, but how they are put into practice locally varies depending on specific soil, crop, economic, climate, and weather conditions. Agronomists and crop advisers make sure the practices they select and apply locally are in accord with these principles.

What is performance and how is it assessed in implementing the four R's?

Performance is the outcome of implementing a practice. The impacts of fertilizer management are expressed in the performance of the cropping systems or soil–plant–air ecosystems in which they are applied. Performance includes the increase in yield, quality, and profit resulting from a fertilizer application and extends to long-term effects on soil fertility levels and on losses of nutrients to water and air. It also includes impacts on the regional economy and social conditions—for example, affordable food. Not all aspects of performance can be measured on each farm, but all should be assessed. Planning indexes and computer models may be used for these assessments but need to be acceptable to stakeholders.

Performance is assessed through measures and indicators. It relates to all outcomes considered important to stakeholders (farmers, agribusiness, consumers, and the general public).

Performance measures are detailed measurements of the actual outcome of the implementation of a particular management practice to a particular cropping system. They can be very expensive and difficult to do. Performance measurements are done primarily by research agronomists and are used to validate management practices, often in a controlled field context designed to extrapolate to a large number of practical farm crop situations. An example may be a field trial on an experiment station in which two or more practices are compared and where measurements include crop yields, nutrient uptake, losses of ammonia and nitrous oxide to the air, losses of nutrients in runoff and drainage water, etc. The 4R concept helps guide research and extension toward validation of practices most relevant to achieving the economic, social, and environmental outcomes that stakeholders consider important.

Performance indicators are simpler measures that can be done on actual farms. Stakeholders need to agree that they reflect their aspirations for performance and that the indicators correlate well to actual measurements. For example, where soil erosion is a major issue and a large source of nutrient loss, an indicator measuring crop residues covering the soil at critical times may be suitable.

Since fertilizer applications have multiple impacts, no single measure or indicator provides a complete reflection of performance. Neither can all possible impacts be measured. Stakeholders need to select the performance measures and indicators that relate to the issues of greatest concern. A partial list of indicators from which they can select follows in Table 2. It is important to recognize that none of these is affected by fertilizer management alone. All can be improved by applying 4R nutrient stewardship, but they also depend on sound management of all practices applied to the cropping system or plant ecosystem. For instance, a good fertilizer program for turfgrass will not assure erosion control if clipping management, or species selection, is inappropriate. ▶

Which are the most important performance indicators?

Crop managers or crop advisers cannot select the most important performance indicator on their own. Stakeholder input is required to select performance indicators representing progress on the goals considered important by all. It is often assumed that nutrient use efficiency is the most important indicator of performance for fertilizer use. This is not the case. Fertilizers are applied to increase the overall performance of the cropping system. Nutrient use efficiency is only one aspect of that performance, as indicated in Table 2. Nutrient use efficiency has many definitions, reflecting nutrient recovery, nutrient balance, or yield in relation to nutrients applied. Each provides unique indications of potential for improvement of fertilizer management, but none provides a full representation of the impact on overall performance.

In a nutshell, the 4R stewardship concept involves crop producers and their advisers selecting the right source–rate–time–place combination from practices validated by research conducted by agronomic scientists. Goals for economic, environmental, and social progress are set by—and are reflected in performance indicators chosen by—the stakeholders to crop production systems. ■

Reference

Bruulsema, T.W., and Q.M. Ketterings. 2008. Best management practices for fertilizers on Northeastern dairy farms. Fertilize BMP Item 30-3220; Ref. 08052. International Plant Nutrition Institute, Norcross, GA.

▶ Table 2. Performance measures and indicators for fertilizer management practices.†

Performance measure or indicator	Description
Yield	Amount of crop harvested per unit of cropland per unit of time.
Quality	Sugar, protein, minerals, vitamins or other attributes that add value to the harvested product.
Nutrient use efficiency	Yield produced or nutrient taken up per unit of nutrient applied.
Water use efficiency	Yield per unit of water applied or available.
Labor use efficiency	Labor productivity, linked to number and timing of field operations.
Energy use efficiency	Crop yield per unit of energy input.
Net profit	Volume and value of crop produced relative to all costs of production.
Return on investment	Profit in relation to capital investment.
Adoption	Proportion of producers using particular BMPs.
Soil productivity	Soil fertility levels, soil organic matter, and other soil quality indicators.
Yield stability	Resilience of crop yields to variations in weather and pests.
Farm income	Improvements in livelihood.
Working conditions	Quality-of-life issues, worker satisfaction, employee turnover.
Water and air quality	Nutrient concentration and loading in watersheds or airsheds.
Ecosystem services	Countryside aesthetics, natural predators and pollinators, outdoor recreation, hunting, fishing, etc.
Biodiversity	Difficult to quantify—can be descriptive.
Soil erosion	Degree of soil coverage by actively growing crops and crop residues.
Off-field nutrient losses	The combined total of nutrient losses from the agricultural management zone—edge of field, bottom of root zone, and top of crop canopy.
Nutrient budget	A total account of nutrient inputs and outputs, at the soil surface or farm gate.

† The relative importance among these and other indicators needs to be determined by stakeholder input.

March–April 2009 Self-Study Quiz

Know your fertilizer rights (no. SS 03853)

This quiz is worth 1 CEU in Nutrient Management. A score of 70% or higher will earn CEU credit. The International CCA program has approved self-study CEUs for 20 of the 40 CEUs required in the two-year cycle. An electronic version of this test is also available at www.certifiedcropadviser.org. Click on "Continuing Education" and then "Self-Study CEUs."

DIRECTIONS

1. After carefully reading the article, answer each question by clearly marking an "X" in the box next to the best answer.
2. Complete the self-study quiz registration form and evaluation form on the back of this page.
3. Clip out this page, place in envelope with a $20 check made payable to the American Society of Agronomy (or provide your credit card information on the form), and mail to: ASA c/o CCA Self-Study Quiz, 677 S. Segoe Road, Madison, WI 53711. You can also complete the quiz and pay online at www.certifiedcropadviser.org ($15 charge).

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1. According to principles of sustainability, stakeholders need to provide input into selection of
- ❑ a. performance indicators.
- ❑ b. site-specific practices.
- ❑ c. source, rate, time, and place.
- ❑ d. sustainability goals.

2. Scientific principles guide the development of
- ❑ a. stakeholder teams.
- ❑ b. site-specific combinations of source, rate, time, and place.
- ❑ c. nitrous oxide emissions.
- ❑ d. sustainability goals.

3. Right source, rate, time, and place are
- ❑ a. independent among themselves and of other practices.
- ❑ b. interconnected but independent of other crop management practices.
- ❑ c. interconnected and linked to other crop management practices.
- ❑ d. independent of fertilizer management.

4. Fertilizer management practices should be validated by evaluating
- ❑ a. crop yield increases on research plots.
- ❑ b. crop yield increases in on-farm plots.
- ❑ c. economic, social, and environmental impacts in both research and farm plots.
- ❑ d. environmental benefits in both research and farm plots.

5. The final decision on selection of a site-specific combination of source, rate, time, and place should be made by
- ❑ a. regulatory authorities.
- ❑ b. the crop manager.
- ❑ c. a qualified research scientist.
- ❑ d. stakeholder teams.

6. The most important aspect of sustainable development is
- ❑ a. economic.
- ❑ b. social.
- ❑ c. environmental.
- ❑ d. a balance of the three.

7. A science-based fertilizer management practice is one that is
- ❑ a. based on past local experience.
- ❑ b. consistent with scientific principles and validated through field testing.
- ❑ c. specifically described in regulations.
- ❑ d. environmentally neutral.

8. The right combination of fertilizer source, rate, time, and place ensures the
- ❑ a. highest possible crop yields.
- ❑ b. minimum loss of nutrients to water.
- ❑ c. minimum loss of nutrients to air.
- ❑ d. best chance of achieving sustainability goals.

Quiz Continues Next Page →

9. The most important performance indicator of fertilizer management is

- ❑ a. nutrient use efficiency.
- ❑ b. crop yield.
- ❑ c. crop quality.
- ❑ d. determined by stakeholders.

10. Performance indicators reflect the progress of fertilizer management in helping to improve

- ❑ a. water quality.
- ❑ b. air quality.
- ❑ c. crop yield.
- ❑ d. sustainability.

SELF-STUDY QUIZ REGISTRATION FORM

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❑ $20 check payable to the American Society of Agronomy enclosed. ❑ Please charge my credit card (see below)

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I certify that I alone completed this CEU quiz and recognize that an ethics violation may revoke my CCA status.

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SELF-STUDY QUIZ EVALUATION FORM

Rating Scale: 1 = Poor 5 = Excellent

Information presented will be useful in my daily crop-advising activities: 1 2 3 4 5

Information was organized and logical: 1 2 3 4 5

Graphics/tables (if applicable) were appropriate and enhanced my learning: 1 2 3 4 5

I was stimulated to think how to use and apply the information presented: 1 2 3 4 5

This article addressed the stated competency area and performance objective(s): 1 2 3 4 5

Briefly explain any "1" ratings: ______________________________

Topics you would like to see addressed in future self-study materials: ______________________________