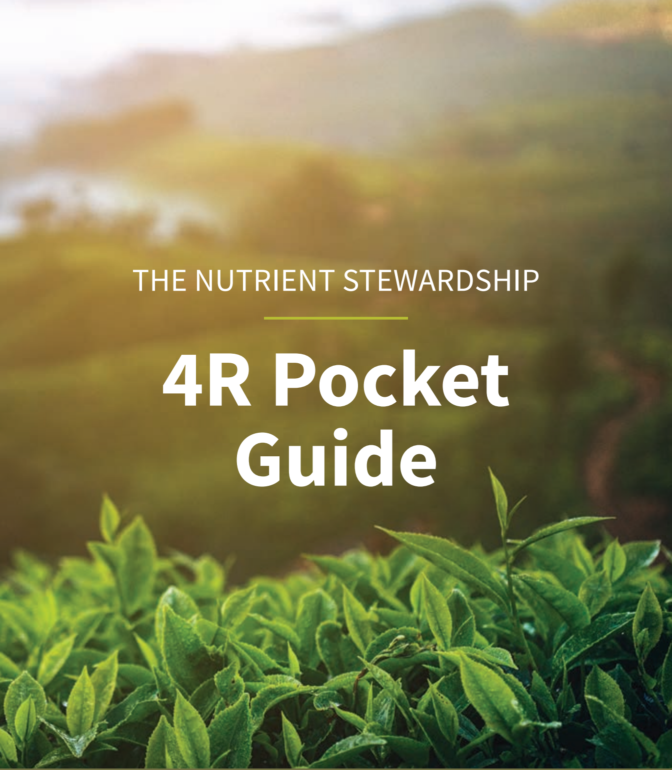
THE NUTRIENT STEWARDSHIP

4R Pocket Guide



nutrient stewardship

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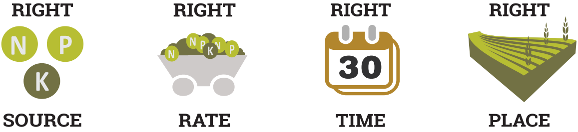
Foreword

4R Nutrient Stewardship is a new innovative approach for fertilizer best management practices adopted by the world's fertilizer industry. This approach considers economic, social and environmental dimensions of nutrient management and is essential to sustainability of agricultural systems. The concept is simple—apply the right source of nutrient, at the right rate, at the right time and in the right place—but the implementation is knowledge-intensive and site-specific.



While this pocket guide is a much-condensed version of the International Plant Nutrition Institute's *4R Plant Nutrition: A Manual for Improving the Management of Plant Nutrition*, it highlights the key points associated with 4R Nutrient Stewardship.

Details on obtaining a copy of the full length manual from IPNI can be found at **https://store.tfi.org/**.

Goal of Sustainable Agriculture

Increasing food production in an economically viable way while retaining the ecological integrity of food systems.

The 4R Nutrient Stewardship approach is an essential tool in the development of sustainable agricultural systems. Its application can have multiple positive impacts on the essential capital assets, required by the farmer, the farm family, and the community.

Applying the right nutrient source, at the right rate, right time, and right place has beneficial impacts on components of the natural capital. These benefits include better crop performance, improved soil health, decreased environmental pollution, and the protection of wildlife. Similarly, positive effects are expected on financial capital, as farmer profits improve, bringing about improvement in their quality of life and increased economic activity in their communities. These in turn can increase the social, human, and physical capital - such as improved access to education or equipment available to the farmer and the community.

CONCEPT

The 4R Nutrient Stewardship Concept

Applying the right source of plant nutrients at the right rate, at the right time, in the right place is the core concept of 4R Nutrient Stewardship.

These four “rights” are all necessary components of a cropping system where plant nutrients are managed sustainably. Fertilizer management practices, to be considered “right,” need to balance the economic, social and environmental dimensions of sustainability, as well as off-farm stakeholder’s goals for performance. However, the farmer is the final decision-maker in selecting the practices— suited to site-specific soil, weather, crop production conditions, and local regulations—that have the highest probability of meeting their sustainability goals.

Because these local conditions can influence the decision on the practice selected, right up to and including the day of implementation, local decision-making with the right support information tends to perform better than a centralized regulatory approach.

CONCEPT

The 4R Nutrient Stewardship Concept

Specific scientific principles guide the development of right source, rate, time and place practices. The principles are the same globally, but how they are put into practice locally varies depending on specific characteristics of the cropping environment including:

- Climate
- Policies
- Land tenure
- Technologies
- Financing
- Prices
- Logistics
- Management
- Weather
- Soil
- Crop demand
- Potential losses
- Ecosystem vulnerability

Farmers and crop advisers make sure the practices they select and apply locally are in accord with 4R principles. The four "rights" provide a simple checklist to assess whether a given crop has been fertilized properly. To help farmers and advisers identify opportunities for improvement in fertilizing each specific crop in each specific field, they can ask:

"Was the crop given the right source of nutrients at the right rate, time and place?"

The sciences of physics, chemistry and biology provide the fundamental principles governing the mineral nutrition of plants growing in soils. The practical application of these principles to crop management is through the scientific disciplines of soil fertility and plant nutrition.

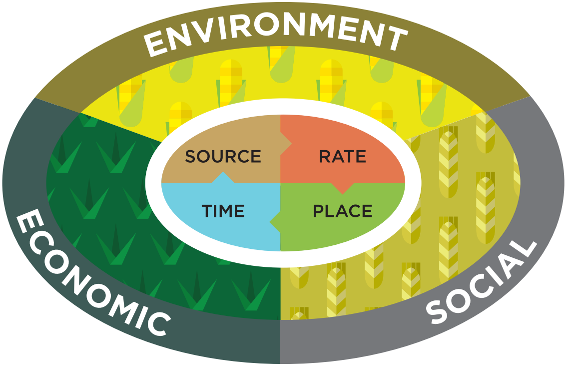


FIGURE 1 The 4R Nutrient Stewardship concept defines the right source, rate, time and place for fertilizer application as those producing the economic, social and environmental outcomes desired by all stakeholders to the cropping ecosystem.

The four “rights” are interconnected. They must work in synchrony with each other and with the cropping system factors of plant, soil, climate, and management. A balance of effort among the four “rights” is appropriate. It helps avoid too much emphasis on one “right” at the expense of overlooking the others. Rate may sometimes be overemphasized, owing to its simplicity and direct relation to cost.

CONCEPT

The 4R Nutrient Stewardship Concept

Source, time and place are frequently overlooked and may hold more opportunity for improving performance.

The performance of the cropping system is influenced not only by the 4Rs, but also by how they interact with other management practices such as tillage, drainage, cultivar selection, plant protection, weed control, etc. All of the factors shown below will influence management decisions and need to be considered in selecting 4R consistent practices.

Genetic yield potential and rotation	Drainage
Weeds	Compaction
Insects	Salinity
Diseases	Temperature
Soil Biota (Mycorrhizae, Rhizobium etc.)	Precipitation
Soil texture and structure	Solar radiation

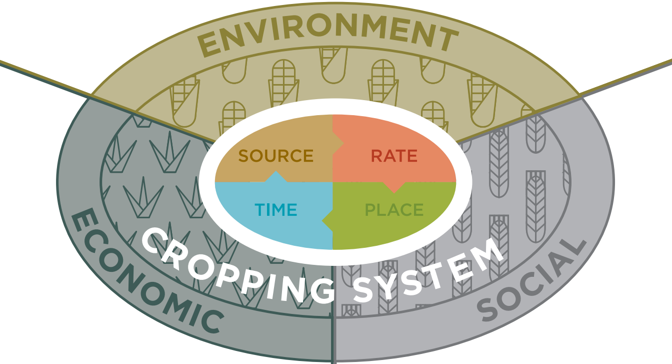
For fertilizer use to be sustainable, it must enhance the performance of the cropping system (Figure 2). To determine if changes lead to actual improvements, appropriate performance indicators need to be developed and applied.

Environment

Air Quality
Biodiversity
Nutrient Loss

Resource Use Efficiencies:
Energy, Labor, Nutrients and Water

Soil Erosion
Water Quality



Economic

Net Profit
Nutrient Balance
Return on Investment
Quality
Yield
Yield Stability

Social

Affordable and Accessible Food
Ecosystem Services
Farm Income

FIGURE 2 Performance indicators reflect the social, economic and environmental aspects of the performance of the plant-soil-climate system. Their selection and priority depends on stakeholder values.

CONCEPT

The 4R Nutrient Stewardship Concept

At the farm or crop production system level, producers and their advisers make decisions— based on local site factors—and implement them. They then evaluate the outcome of their decisions to determine what practice changes to make the next time through the cropping cycle. Ideally the assessment of practice performance would be done on the basis of all indicators considered important to stakeholders.

Essentially, this is the practice of adaptive management —an ongoing process of developing improved practices for efficient production and resource conservation through hands-on learning and continuous systematic assessment. To provide sound guidance in this process, crop advisers should have some level of professional certification backed by education and training as well as appropriate local experience.

SCIENTIFIC PRINCIPLES SUPPORTING

Right Source

The core scientific principles that define right source for a specific set of conditions are the following:

Consider rate, time, and place of application

Supply nutrients in plant-available forms

The nutrient applied is plant-available, or is in a form that converts timely into a plant-available form in the soil.

Suit soil's physical and chemical properties

Examples include avoiding nitrate application to flooded soils and surface applications of urea on high pH soils.

Recognize synergisms among nutrient elements and sources

Examples include the P-zinc interaction, N increasing P availability, and fertilizer complementing manure.

Recognize blend compatibility

Certain combinations of sources attract moisture when mixed, limiting uniformity of application of the blended material. Granule sizes should be similar to avoid product segregation.

Recognize benefits and sensitivities to associated elements

Most nutrients have an accompanying ion that may be beneficial, neutral or detrimental to the crop. For example, the chloride (Cl^-) accompanying K in muriate of potash is beneficial to corn, but can be detrimental to the quality of potatoes and some fruits. Some sources of P fertilizer may contain plant-available Ca and S, and small amounts of Mg and micronutrients.

Control effects of non-nutritive elements

For example, natural deposits of some phosphate rock contain non-nutritive trace elements. The level of addition of these elements should be kept within acceptable thresholds.

SCIENTIFIC PRINCIPLES SUPPORTING

Right Rate

The core scientific principles that define right rate for a specific set of conditions are the following:

Consider source, time, and place of application

Assess plant nutrient demand

Yield is directly related to the quantity of nutrients taken up by the crop until maturity. The selection of a meaningful yield target attainable with optimal crop and nutrient management and its variability within fields and season to season thus provides important guidance on the estimation of total crop nutrient demand.

Use adequate methods to assess soil nutrient supply

Practices used may include soil and plant analysis, response experiments, omission plots, crop sensors, etc.

Assess all available nutrient sources

Depending on the farm, this assessment may include quantity and plant availability of nutrients in manures, composts, biosolids, crop residues, atmospheric deposition and irrigation water, as well as commercial fertilizers.

Predict fertilizer use efficiency

Some loss is unavoidable, so to meet plant demand, the amount lost must be considered in setting the final rate.

Consider soil resource impacts

If the harvest removals and nutrient losses from a cropping system exceed inputs, soil fertility declines in the long term.

Consider rate-specific economics

For nutrients unlikely to be retained in the soil, the most economic rate of application is where the last unit of nutrient applied is equal in value to the increase in crop yield it generates (law of diminishing returns). For nutrients retained in the soil, their value to future crops should be considered. Assess probabilities of predicting economically optimum rates and the effect on net returns arising from error in prediction.

SCIENTIFIC PRINCIPLES SUPPORTING

Right Rate

Nutrient removal in the harvested portions of selected crops (lb nutrient/unit harvested*).

Crop**	Unit	N	P_2O_5	K_2O	S
Alfalfa† (DM)	ton	51	12	49	5.4
Barley	bu	0.99	0.40	0.32	0.09
Beans† (dry)	bu	3.0	0.79	0.92	0.52
Bromegrass (DM)	ton	32	10	46	5.0
Canola	bu	1.6	0.80	0.40	0.25
Corn grain	bu	0.67	0.35	0.25	0.08
Fababean†	bu	3.4	1.22	1.04	0.14
Flax	bu	2.5	0.70	0.60	0.19
Lentil†	bu	2.0	0.62	1.08	0.15
Oat	bu	0.77	0.28	0.19	0.07
Pea,field†	bu	2.3	0.69	0.71	0.13
Potato	ton	6.0	3.0	13	0.6
Red clover† (DM)	ton	45	12	42	3.0
Rye	bu	1.4	0.46	0.31	0.10
Silage, corn (DM)	ton	31	13	61	3
Silage, barley (DM)	bu	34	12	27	4
Soybean†	bu	3.3	0.73	1.2	0.18
Sugarbeet	ton	3.7	2.2	7.3	0.45
Wheat, Hard Red	bu	1.42	0.55	0.45	0.10
Wheat, Durum	bu	1.42	0.55	0.45	0.10
Wheat, Soft White	bu	1.25	0.50	0.30	0.15
Wheat, Winter	bu	1.2	0.48	0.29	0.10
Wheat, CPS	bu	1.25	0.50	0.30	0.15

*Nutrient removal coefficients may vary regionally depending on growing conditions and crop class. Use locally available data whenever possible. Values shown are for removal, total uptake values per unit of crop produced will be substantially higher particularly for K_2O.

**DM = dry matter basis; otherwise moisture content is standard marketing convention or at the stated moisture content.

† Legume crops may meet the N demand in whole or in part through symbiotic nitrogen fixation.

Example: Using the table, a 60 bu/A canola crop removes 48 lb P_2O_5 from the field (60 bu/A x 0.80 lb P_2O_5/bu = 48 lb P_2O_5/A). So, the maintenance P_2O_5 application will be 48 lb P_2O_5/A.

SCIENTIFIC PRINCIPLES SUPPORTING

Right Time

RIGHT 30 TIME

The core scientific principles that define right time for a specific set of conditions are the following:

Consider source, rate, and place of application

Assess timing of plant uptake

Nutrients should be applied to match the seasonal crop nutrient demand, which depends on planting date, plant growth characteristics, sensitivity to deficiencies at particular growth stages, etc.

Assess dynamics of soil nutrient supply

Mineralization of soil organic matter supplies a large quantity of some nutrients, but if the crop's uptake need precedes its release, deficiencies may limit productivity.

Recognize dynamics of soil nutrient loss

For example, in regions where soil freeze, losses in drainage water or by leaching tend to be more frequent in late fall or early spring.

Evaluate logistics of field operations

For example, multiple applications of nutrients may or may not combine with those of crop protection products. Nutrient applications should not delay time-sensitive operations such as planting.

SCIENTIFIC PRINCIPLES SUPPORTING

Right Place

RIGHT PLACE

Right place means positioning added nutrients strategically so that a plant has access to them. Appropriate placement allows a plant to develop properly and realize its potential yield, given the environmental conditions in which it grows.

Right place is, in practice, continually evolving. A host of factors can affect proper fertilizer placement, including but not limited to the following:

Plant genetics	Plant spacing
Placement technologies	Crop rotation or intercropping
Tillage practices	Weather variability

Consequently, there is much yet to learn about what constitutes the “right” in right place and how well it can be predicted when management decisions need to be made.

The core scientific principles that define right place for a specific nutrient application are the following:

Consider source, rate and time of application

Consider where plant roots are growing

Nutrients need to be placed where they can be taken up by growing roots when needed.

Consider soil chemical reactions

Concentrating soil-retained nutrients like P in bands or smaller soil volumes can improve availability.

Suit the goals of the tillage system

Subsurface placement techniques that maintain crop residue cover on the soil can help conserve nutrients and water.

Manage spatial variability

Assess differences within and among fields in potential crop productivity, soil nutrient supply, and vulnerability to nutrient loss.

ADAPTIVE PRACTICES

The Whole Farm

As illustrated in Figure 3, nutrient management practices are always nested in cropping systems. Other management and site factors such as tillage, drainage, cultivar selection, etc. can greatly influence the effectiveness of a specific practice. Many factors interact with plant nutrition and nutrient management practice effectiveness, for example:

Genetic yield potential and rotation	pH
Weeds	Drainage
Insects	Compaction
Diseases	Salinity
Soil Biota (Mycorrhizae, Rhizobium etc.)	Temperature
Soil texture and structure	Precipitation and solar radiation

Best practices are dynamic and evolve as science and technology expands our understanding and opportunities, and practical experience teaches the astute observer what does or does not work under specific local conditions. In the end, there is no one right answer. Every 4R Plan will be unique based on the particular circumstances of the farm.

FIGURE 3 The role of adaptive management in practice refinement for 4R Nutrient Stewardship.

Example 1

Practices listed here are being utilized and evaluated by a grower with the assistance of an agronomic service provider. The farm is located on the Prairies and rotates among cereals, oilseeds and pulses. About one third of the acreage is irrigated and the rest is dryland.

This is not a template for nutrient management in a cropping system, rather it serves as an example of a suite of utilized practices that would support improved nutrient use efficiency.

Cropping System Objectives:

Employ emerging tools and technologies to better manage nutrients and ensure crop production system is sustainable.

Strategies and Key Performance Indicators:

- Utilize technology-driven data management to compare yields, costs and return on investment for fertilizer program by field and by crop.
- Track water use efficiency and reduce nitrogen losses caused by over watering.

Right Source

Use urease inhibitors with topdress applications of liquid UAN on cereals and oilseeds.

Inoculate pulse crops in rotation.

Right Rate

Zone soil sample all acres for variable rate application of nutrients.

Account for nutrient credits from the previous year’s pulse crop.

Test irrigation water for nitrogen and sulphur content.

Right Time

Utilizes split application of nitrogen; urea application at seeding followed by liquid UAN as a top dress to assure the right rate is available at critical growth stages for the crop and to minimize N loss to volatilization and leaching.

Use in season tools (weather data and growth staging models) to help determine application timing and evaluate effectiveness of the fertilizer program.

Right Place

Adopt variable rate technology to match nitrogen rate to variations in yield potential.

Place phosphate in side-band near seed to insure early season access.

Use Autosteer and GPS guidance on all field operations and spraying applications to reduce skips and overlaps.

Additional Practices

Adopt digital data management and decision support tools to assess practices, enhance profitability and improve environmental stewardship.

Adopt irrigation scheduling technology to track crop water needs and avoid over or under watering.

Example 2

Practices shown in this example are being implemented by a grower with the help of their Ag Retailer. The retailer is a participant in the 4R Certification Program. The farm is located in the Lake Erie drainage in S. Ontario. Rotational crops include soybean, corn, and winter wheat. Soybean fields are not fertilized. Phosphorus and potassium rates in corn and wheat are adjusted to account for removal by soybean. The farmer largely uses fluid fertilizers and also has access to liquid cattle manure.

Cropping System Objectives:

Make cropping decisions that result in higher nutrient use efficiency and increase farm profitability.

Strategies and Key Performance Indicators:

- Employ technology-driven data management to compare yields, costs and return on investment for fertilizer program by field and by crop.
- Perform on-farm research to compare nutrient management practices and estimate differences in nutrient use efficiency.

Right Source

Use custom liquid blend of ammoniacal nitrogen, phosphorus and potash at seeding.

Right Rate

Utilize soils sampling and soil maps to determine nutrient application needs.

Factor in nutrient release from previous manure application in determining N, P, K rates.

Tissue sample at critical crop stages to assess need for in-crop applications of nutrients.

Right Time

Utilize split application of nitrogen. For corn, apply custom blend at seeding followed by UAN as a top dress at appropriate crop stage. For wheat, use custom PK blend at seeding and UAN in spring before tillering.

Use in season tools (weather data and growth staging models) to help determine application timing and evaluate effectiveness of the fertilizer program.

Right Place

Use RTK guidance to improve implementation of precision practices.

Band liquid N, P and K blends a minimum of 4 inches underground to prevent runoff and volatilization.

Additional Practices

Assess use of strip tillage and cover crops to reduce soil erosion and compaction; retain residual nutrients; and improve soil health.

Summary

The process of relating source, rate, time and place practices to sustainability outcomes can be daunting.

Cropping systems are highly complex, site-specific and vary over time. Predicting outcomes from practice change may involve considerable uncertainty and improved sustainabilty may not be immediately obvious.

Nevertheless, practical common-sense thinking— guided by an appropriate science framework—can reduce the risk of changing practices and improve outcomes within both short-term and long-term time frames. Guiding nutrient management practices towards optimum crop productivity can help to resolve many of the current issues associated with plant nutrient use. Further research into nutrient behavior in cropping systems and the development of new management technologies will drive continuous science-based improvement of the theory and practice of 4R Nutrient Stewardship.

Using a 4R approach to balance the Economic, Social, and Environmental dimensions of nutrient use in crop production will help ensure that farms remain financially viable, food production meets the growing demands of the global population, and the ecosystem services that we all depend on are passed unimpaired to the next generation.

For more information on 4R programs and resources in Canada, visit

fertilizercanada.ca/nutrient-stewardship

4R nutrient stewardship

RIGHT SOURCE

RIGHT RATE

RIGHT TIME

RIGHT PLACE

FERTILIZER CANADA