

# Pack # 118

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**Backgrounder: 4R approach to applying fertilizer**

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**Introduction**

This backgrounder discusses aspects of wheat and teff production with a specific focus on the 4R approach to applying fertilizer \*. It also includes information on gender-sensitive and climate-smart practices.

**Why is this subject important to listeners?**

This material aims to inform listeners on:

* The benefits of fertilizer application in crop production.
* The best ways to applying fertilizers to improve crop production.
* Gender aspects of using fertilizers.
* The challenges of using fertilizers.
* Climate change and fertilizer application.
* The types of fertilizers (organic, inorganic).

**Benefits of fertilizer application**

* Fertilizers supply growing crops with the nutrients they need for good growth and development. While soils often contain most of the nutrients that crops require, most soils only contain small quantities of these nutrients, especially if the soil has been cultivated for a long time with minimal application of organic and inorganic fertilizers.
* Fertilizer application ensures that more and better-quality food is produced.
* Fertilizer application allows high yields on small farms, therefore reducing the need for farmers to cut down forests in search of new land for cultivation.

**What are the big challenges with using fertilizers?**

* Nutrient runoff from farms which use synthetic and organic fertilizers can negatively affect land and water ecosystems. Because inorganic fertilizers are easily and quickly absorbed by plants, they can also be quickly washed away into ground or surface water during application or during irrigation or heavy rains, especially if they are not applied in the right way. (16)
* Improper application of nitrogen-based fertilizers such as urea can result in increased emissions of ammonia gas and greenhouse gases (GHGs) such as nitrous oxide.
* Lack of awareness of how to use fertilizers correctly.
* High fertilizer prices in Africa, mainly because the high cost of transporting fertilizers from shipping ports to farmlands, limits the ability of most African framers to use the recommended rate of fertilizers.

**Gender aspects of crop production and fertilizer use**

Women play a significant role in crop and livestock production, storage, and marketing. However, women’s work in the agricultural sector has often been mistakenly considered as marginal and they have been viewed more as consumers than producers. (19) Also, women’s relative access to and control over resources is limited.

* While women contribute a large share of the agricultural workforce, their ability to successfully participate in crop production is often constrained by cultural and social factors that limit their decision-making power and access to the land and financial resources required for successful crop production. For example, in the majority of communities in sub-Saharan Africa, husbands and male family members and relatives usually have the upper hand in decisions regarding land use.
* Land ownership is often vested in male members of the household and land ownership rights often pass from farther to son. Within households, land ownership documents are often in the name of the husband even when women who is more involved in day-to-day farming activities.
* Women’s rights, including their legal rights, to use and manage land are commonly violated, usually by their parents and relatives and by their husbands and husbands’ relatives. As a result, female farmers are usually at a disadvantage when it comes to crop production in small-scale farming systems as their success is often hindered by:
* Lower capacity to purchase farm inputs such as fertilizer and improved seeds due to their weaker socio-economic status.
* The lack of collateral such as title deeds for accessing the credit required to purchase inputs.
* The lack of access to funds from selling farm produce as this is often managed by male members of the household.
* Poorer access to extension information, including how to improve crop productivity, in part due to generally lower literacy levels.
* Limited time to fully commit to farming activities due to household responsibilities such as cooking and caring for children and other family members.
* Weaker access to markets.
* Poorer access to agricultural technologies and machinery.

As a result of the unequal access to extension information, agricultural technologies and lower purchasing power, women often use less fertilizer (12), resulting in lower crop productivity in female-managed farms.

**Climate change and fertilizer**

Climate change refers to significant, long-term changes in the global climate.

Effective use of fertilizers can play two major roles in the fight against climate change:

1. It can prevent deforestation, as using fertilizers efficiently enables increased productivity, which reduces the need to clear forest land and maintains forests as important carbon sinks.
2. Fertilizer use can also reduce emissions of greenhouse gases such as CO2 through increased carbon sequestration. Higher crop yields as a result of fertilizer use can result in increased soil organic matter from several sources: crop residues which can be retained on the farm after harvest, plant roots, and organic manure applied to the farm. Increased soil organic matter improves the ability of agricultural soils to sequester carbon, thereby limiting CO2 emissions (13).

**What are fertilizers?**

Fertilizers are organic or mineral substances that increase the supply of nutrients in the soil, directly increasing plant growth, and are applied to crop fields to increase productivity. Fertilizers contain one, two, or several of the essential mineral nutrients required by plants, including the major nutrients nitrogen, potassium, and phosphorus. (1)

Commercial inorganic fertilizers contain at least one of the 14 essential mineral plant nutrients in chemical forms that are soluble in the soil when applied, and available for uptake by plant roots (20).

To ensure increased crop production and minimize the negative environmental effects of fertilizer use, fertilizers need to be applied in the right way. One way to ensure increased crop production and minimize environmental harm is to use fertilizers effectively and efficiently. The 4R approach to applying fertilizers (4R Nutrient Stewardship) specifies four essential principles: right source, right rate, right time, and right place.

**The importance of fertilizers for improved crop production (4)**

Just as humans require specific types and amounts of nutrients in our meals to grow and develop and stay healthy, plants too require specific types and amounts of essential nutrients for good growth and yields. Fertilizers provide crops with the essential nutrients they require for good growth and yields, and can therefore be thought of as a form of food for plants. Without applying fertilizers, crop yields, agricultural productivity, and soil fertility would be considerably reduced.

**The advantages and disadvantages of applying fertilizers**

*Advantages*

* Fertilizer application ensures that more and better-quality food is produced.
* Fertilizer application allows high yields on small farms, therefore reducing the need for farmers to cut down forests in search of new land for cultivation.
* Increase crop yields and improve poor quality soil.
* Manure improves soil texture, recycles nitrogen, introduces essential bacteria which improve soil structure and soil aggregation, and recycles soil nutrients and water. (11)
* Improves pasture so animals fatten up more quickly.
* Can help reclaim infertile, degraded, and unproductive soils.
* Helps crops grow faster, particularly when hybrid seeds are used.

*Disadvantages*

* Fertilizer application can stimulate faster weed growth.
* Excess nitrogen application from fertilizers can result in lodging (falling off) of plants such as wheat, teff, and rice.
* Excessive and inappropriate use of fertilizers can lead to leaching of nutrients such as nitrogen into surface and groundwater, reducing water quality and killing or harming fish and other aquatic creatures.
* Inappropriate use of fertilizers can result in increased emission of greenhouse gases such as methane and nitrous oxide into the atmosphere, contributing to global warming and climate change.
* Chemicals in some fertilizers can affect farmers’ health if not used with caution.

**Detailed information on the 4R approach to applying fertilizer**

Studies show that farmers in Ethiopia often fail to use best practices when applying fertilizers, which makes efficient crop production more difficult. That is why it is essential to use the 4R approach to applying fertilizer, an approach that also protects the environment through efficient fertilizer use and responsible farming practices.

1. **The Right Source (6)**

***The Right Source*** refers to applying the correct fertilizer and/or organic resources that provide crops with all the nutrients they need for good growth and maturity. However, it’s important to note that there is no one “Right Source” for every soil and crop condition. Each soil and crop has different needs that need to be considered when selecting a source. Also, farmers’ goals, for example, high yields for sale in the market or moderate yields for home consumption, also need to be considered when selecting the “Right Source.”

To determine the “Right Source” for a specific cropping system, the following key factors need to be considered.

* The recommended fertilizer application rate for the crop planted.
* The nutrients already available in the soil. (7)
* Crops previously planted in the particular field.
* Other available sources of nutrients such as organic manure.
* Locally available fertilizers that are the most cost-effective source of the types and amounts of nutrients required by the crop.
* The nutrients in a particular fertilizer that are available for immediate or delayed crop uptake.
* Soil conditions such as acidity or salinity that might limit the effectiveness of applied fertilizers.
* The expected rate of fertilizer application. (Different sources release nutrients at different rates.)
* The recommended place of fertilizer application. (Depending on where nutrients are required, different sources may be correct. For example, if foliar (leaf) applications are required, fully soluble single-nutrient fertilizers are the right source.

**Selecting the right nutrient source (6)**

*Nitrogen (N)*

* All N fertilizer starts as ammonia. Ammonia can be pressurized and used directly or converted to various kinds of solid and liquid fertilizers.
* Nitrate, ammonium, and urea are the most common sources of N.

*Phosphorus (P) and Potassium (K)*

* P and K fertilizers are mined from mineral deposits of, respectively, phosphate and potash ore. After mining, phosphate and potash are transformed into soluble fertilizers.
* P is commonly taken up by plants in the form of phosphate.
* Potassium chloride, also known as muriate of potash, is the most commonly used K compound in fertilizer production. (18)
* Fertilizers that supply phosphorus include DAP, NPS, and TSP.
* Fertilizers that supply potassium include NPK and muriate of potash (MOP).
1. **The Right Rate**

***The Right Rate*** refers to supplying growing crops with the right amount of nutrients for healthy growth and development. Once the right source has been determined, the right rate should provide the nutrients in sufficient quantities, balanced proportions, available forms, and at the time when plants need them most.

Different crops require different amounts of nutrients. The quantity of nutrients required also depends on the desired yield and the capacity of the soil to supply nutrients. Selecting the right rate involves matching nutrient supply with expected plant nutrient demand.

**How to determine the right rate of fertilizer application:**

* *Consider the source, time, and place of nutrient application*:
	+ Different nutrient sources contain different quantities of nutrients. For example, organic fertilizers usually contain lower quantities of nutrients than inorganic fertilizers. Therefore, farmers need higher quantities of organic fertilizers to reach the targeted rate of nutrients.
	+ The timing of application also influences the right rate. For example, when several applications are required over the course of the growing season (as is common with nitrogen fertilizer in crops like wheat and teff), farmers can apply lower rates at planting and at top-dressing compared to when only one application is needed.
	+ The place of application also influences the right rate. (8) For example, spot applications require lower rates than broadcasting because spot applications concentrate nutrients close to plant roots more than broadcasting.
* *Assess plant demand for nutrients*:
	+ Different crops require different quantities of nutrients. For example, cereal crops like wheat generally require higher rates than legume crops such as chickpeas or lentils.
	+ The quantity of nutrients required also depends on the targeted yield. High yields require higher rates of application because plants need to take up more nutrients to produce a higher yield.
	+ The quantity of nutrients needed also depends on the type of nutrients. In general, the primary macronutrients (nitrogen, phosphorus, and potassium) are required by plants in greater amounts than secondary macronutrients such as sulphur and calcium, or micronutrients such as zinc and boron.
* *Assess the capacity of the soil to supply nutrients*:
	+ Some of the nutrients required for plant growth can be met by the soil, while the rest can be supplied by fertilizers. Highly fertile soils have a better ability to supply nutrients and therefore require lower application rates. Methods for quickly assessing soil fertility and the capacity of the soil to supply nutrients include:
		- Soil testing: Soil testing measures the amount of nutrients available for plants to take up. The higher the level of plant-available nutrients, the higher the soil fertility and the potential to supply nutrients.
		- Crop production history: Soils in which crops have been grown for many seasons with minimal application of fertilizer or manure can be expected to have a low capacity to supply nutrients.
		- Soil types: Soils that are very sandy usually have a lower capacity to supply nutrients than clay-rich soils.
		- Soil organic matter content: Soil organic matter contains most nutrients required for plant growth. Soils with high soil organic matter content have a higher capacity to supply nutrients.
		- Visible symptoms of nutrient deficiency: The growth, vigour, and colour of growing plants often indicates the capacity of the soil to supply nutrients. For example, in cereal crops like maize and wheat, plants with strong stems and dark green leaves indicate a sufficient supply of nutrients, while plants with weak stems and yellowish, small leaves indicate an insufficient supply of nutrients.
* *Consider all available nutrient sources*: When determining the right rate of fertilizer, consider the contribution of other available nutrient sources on a farm. Additional source of nutrients include:
	+ Compost and animal manure: When applied in large quantities, compost and animal manure can contribute some of the nutrients required by plants. Farmers with access to large quantities of compost or animal manure can therefore apply lower rates of fertilizer.
	+ Legume crops and green manures: Legume crops such as chickpea and lentil can contribute nitrogen to the soil. Nitrogen application rates for cereal crops such as wheat grown in rotation with legume crops can therefore be reduced.
	+ Crop residues: Crop residues such as leaves and stems contain nutrients. In fields where large quantities of crop residues are often recycled back to the soil, fertilizer application rates can be reduced.

After determining the right application rate for a particular crop, it is important to make sure that the equipment used to apply the fertilizer is well-calibrated to distribute equal quantities of fertilizer across the field.

**Why is the Right Rate important?**

Applying the Right Rate of fertilizer is essential because under- or over-application of a particular nutrient can affect crop production, income, and soil health. Under-applying nutrients can result in low yields, poor quality produce, and depletion of soil fertility \*. Over-application can result in reduced profits, pollution of soil and water systems, and lodging \* in crops such as rice, teff, and wheat.

1. **The Right Time**

***Right Time*** refers to applying nutrients when plant most need them. After determining the right source and rate of nutrient application, farmers should apply nutrients to match the time that plants uptake nutrients. This ensures that nutrients are used efficiently and results in good growth and high yields.

**How to determine the right time for nutrient application:**

* *Consider the source, rate, and place of nutrient application*:
	+ Different sources differ in how quickly their nutrients are released, which influences the right time for application. For example, organic sources like manure release nutrients more slowly than mineral sources like fertilizers. Therefore, organic sources need to be applied a few weeks before planting to ensure that nutrients are available when crops are planted, while mineral sources can be applied at planting.
	+ The application rate also influences the right time to apply fertilizers. For example, high application rates for nutrients like nitrogen that are easily lost from the soil require more than one application. Thus, the total amount to be applied is split into smaller amounts to reduce losses of applied nutrients and ensure more efficient use of nutrients.
	+ The place where nutrients are applied also influences the right time. For example, applying nutrients on plant leaves (foliar applications) allows rapid uptake of nutrients by plants. Farmers can therefore make foliar applications at the exact time when plants require nutrients. Applying fertilizer to soil, however, require more time for nutrients to be taken up and must therefore be conducted a few days in advance of the desired uptake period.
* *Match nutrient application time with plant nutrient demand:* Most crops take up nutrients slowly during early stages of growth, and nutrient uptake increases when the crop is growing rapidly, and declines when the crop matures. This is particularly important for cereal crops like maize, wheat, and teff where nitrogen applications should be matched with key growth stages. For instance, in wheat and teff, applying a nitrogen-rich top-dressing at the early tilling stage helps to enhance N uptake and increase yield. For rice, a split application consisting of a top-dressing of N-rich fertilizer at the early tilling stage and again at panicle initiation helps enhance N uptake and increase yield.
* *Minimize the risk of nutrient losses*: Fertilizer applications should be timed to reduce the risk of nutrient loss from the soil. For example, nutrients such as nitrogen are easily lost when applied during heavy rainfalls, so applications should be avoided during these periods.
* *Other key considerations*: The timing of nutrient application should also consider field and weather conditions. Issues to consider include:
	+ Labour availability: To use available labour most efficiently, fertilizer application should be conducted at the same time as other field operations that usually occur around the same time. For example, fertilizer required at planting can be applied when seeds are sown to use labour designated for planting most efficiently.
	+ Timely availability of fertilizer: To ensure that nutrients can be applied at the right time, purchase fertilizer well in advance of application.
	+ Weather: For example, top-dressing of nitrogen fertilizer should be conducted when soils are moist but not very wet. It should be avoided when soils are dry and during heavy rains to minimize losses and ensure efficient uptake.
1. **The Right Place**

***Right Place*** refers to adding nutrients to the soil at the place where crops can most easily access them. Proper placement of nutrients allows a plant to develop well and achieve high yields.

For most crops, the right place is the root zone or just ahead of the advancing root system. Most nutrient uptake occurs through the root system, so placing nutrients in the root zone maximizes the likelihood of absorption by the plant. (15)

Here are the factors to consider when deciding on the right place to apply fertilizers:

* *Source, rate, and time of nutrient application*:
	+ The source of the nutrient has implications for the right place. For example, manure is best applied through broadcasting and incorporation into the soil, while mineral fertilizers are best suited for spot applications close to planting holes.
	+ The rate of nutrient application also influences the right place. When large quantities of fertilizer are available, broadcasting can be conducted. But with small quantities, banding or spot application is best.
	+ The timing of nutrient application also influences the right place. For example, during basal application to maize at planting, fertilizer should be applied in the planting hole close to where seeds will be planted. But during top-dressing, fertilizer should be applied in small holes close to the plant.
* *Consider where plant roots are growing*: Different crops have different rooting systems. For example, maize has deep, narrow roots, while beans have short, widely-growing roots. Consider a plant’s roots during fertilizer application to ensure that roots can easily take up the applied nutrients.
* *Movement of nutrients in the soil*: The right method of applying fertilizer and the right place to apply it should consider the ease of movement (mobility) of nutrients in the soil. Nutrients with low mobility such as phosphorus should be concentrated in bands or holes close to the plant to improve availability for plants.

There are four main methods of fertilizer application or placement:

1. *Broadcasting:* Uniform application of fertilizer to the surface of a field. Key facts related to broadcasting include:
* It is suitable for densely-sowed crops such as wheat and teff.
* It is also suitable for increasing the fertility level of the entire plough layer. \*
* It can be conducted by hand or by using fertilizer application equipment.
* Whether broadcast by hand or with equipment, spreading should be as uniform as possible.
* When basal applications are broadcast, fertilizer should be incorporated into the soil through tilling or ploughing-in.
* Broadcasting is easy to implement and has low labour requirements.
1. *Banding:* Placement of fertilizer in bands or furrows 5-8 cm below the soil surface. Key facts related to banding include:
* Banding is suitable when fertilizer placement near planting rows is required.
* Banding is also suitable for crops planted in relatively widely-spaced rows but small spaces between plants, for example, beans and lentils.
* Banding is an effective method for phosphorus-fixing soils. \*
* To ensure uniform distribution during banding, apply equal amounts of fertilizer in each banding row by dividing the number of planting rows into the total amount of fertilizer to be applied to determine the amount of fertilizer for each row.
* During banding, fertilizer should be placed under or beside seeds and covered with soil to avoid direct contact between seeds and fertilizer.
1. *Spot application:*Applying small amounts of fertilizer close to each planting hole at or after planting. Key facts related to spot application include:
* It is suitable for widely-spaced crops such as maize.
* It’s the most effective method for small quantities of fertilizer.
* To ensure uniform distribution of fertilizer during spot application, use small dollop cups of different sizes that facilitate equal quantities per planting hole.
* Where dollop cups are not available, use bottle tops or teaspoons.
1. *Deep placement:* Placing fertilizer granules 5-10 cm under the soil surface by hand or with specially-designed applicators. Key facts related to deep placement include:
* Deep placement is an effective method for applying nitrogen fertilizer to paddy rice.
* Urea fertilizers can be compressed into large granules ranging from 1- 4 g that are more suitable for application through deep placement than normal fertilizer granules.
* Fertilizer application through deep placement is more expensive than other placement methods due to:
* The higher cost of fertilizer granules.
* The higher demand for labour.
* The specialized equipment required.

**Key definitions**

*Fertility*: The ability of soil to sustain growing plants with the nutrients required for good growth and high yields.

*Fertilizers*: Organic or mineral nutrients that increase the supply of essential plant mineral nutrients in the soil, directly benefiting plant growth.

*Lodging:* The bending over of grain crop stems near the ground, which makes them very difficult to harvest and can dramatically reduce yield.

*Nutrient:* Substance used by an organism to survive, grow, and reproduce.

*Organic matter:* Matter composed of organic compounds derived from the remains of organisms such as plants and animals and their waste products. Soil organic matter is the organic matter component of soil.

*P Index (Phosphorous Index):* A risk assessment tool that helps to quantify the potential for phosphorous runoff from a field and helps to target critical areas of potential phosphorous loss for greater attention.

*Phosphorus-fixation:* A process whereby phosphorus applied to the soil reacts with other minerals to form insoluble compounds and becomes unavailable for crop uptake.

*Plough layer:* Upper layer of soil that is usually worked during plowing.

*Soil aggregates*: Soil is a combination of primary particles—sand, silt, and clay. These can be bound together in “aggregates,” which are clumps of soil of varying size.

*Soluble:* Able to be dissolved, especially in water.

*Volatilization*: Process whereby a substance dissolved in liquid is vaporized to become a gas.

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Interviews

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Shewaye Derib Woldeyohannes, Program director, Ethio-Wetlands, April 23, 2021 via telephone.

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**Where can I find other resources on this topic?**

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