ESSENTIALS NITROGEN

NO. 1

Nitrogen (N) has a central and essential role as part of the structural core of the photosynthetic molecule—chlorophyll. Nitrogen also has fundamental roles in the building and composition of all plant (and animal) proteins. The nutritive value of the food we eat begins with providing crops with an adequate supply of N.

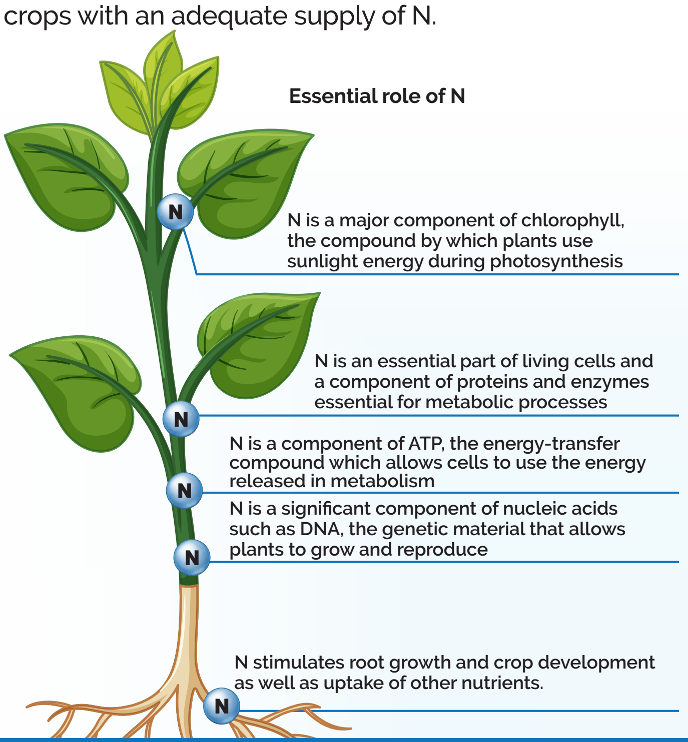


Figure 1. Some essential roles of nitrogen in plants.

About 80 percent of the air we breathe is nitrogen gas (N_2), but most crops can't access atmospheric N until it is changed through a process called "fixation". Through either biological, industrial or natural processes, atmospheric N_2 is fixed to ammonium (NH_4^+) or nitrate (NO_3^-), which are the major forms of plant-available N.

Biological N fixation involves special microorganisms (rhizobacteria) that function in the soil and within nodule sites found on the roots of legume crops. This symbiotic relationship allows the crop to fix carbon (C) for the benefit of the bacteria that, in exchange, provide fixed N to the crop. Legume crops are less reliant on soil N reserves, or N inputs, as a result.

The Haber-Bosch process of industrial N fixation (named after its early 20th century inventors) works by fixing N from the air with hydrogen (H) from a source such as natural gas to produce ammonia gas (NH_3). This N product is the source of the millions of tons of commercially produced N fertilizers around the world.

Lightning activity also fixes smaller amounts of N that are transported to the earth's surface with rainfall.

NITROGEN IN PLANTS

Nitrogen is required in large quantities by crops. It is common for the majority of crop N to be removed from the field with each harvest (**Table 1**). Legume crops have high N demands, but the majority is derived from biological fixation. Adequate N provides plants with the capacity for vigorous growth through to maturity, with harvests of abundant and high-quality crops.

Table 1. Nitrogen uptake and removal by common crops.

Crop	Uptake in above ground biomass, kg N per t	Removal in harvested product, kg N per t
Maize	18	12 (67%)
Rice	16	13 (81%)
Wheat	37	25 (67%)
Sorghum/Millet	22	13 (59%)
Beans	65	50 (77%)
Groundnuts	70	35 (50%)

APNI data. Legumes obtain most of their N from the air. Numbers inside parentheses indicate the % of total N uptake removed in harvested product.

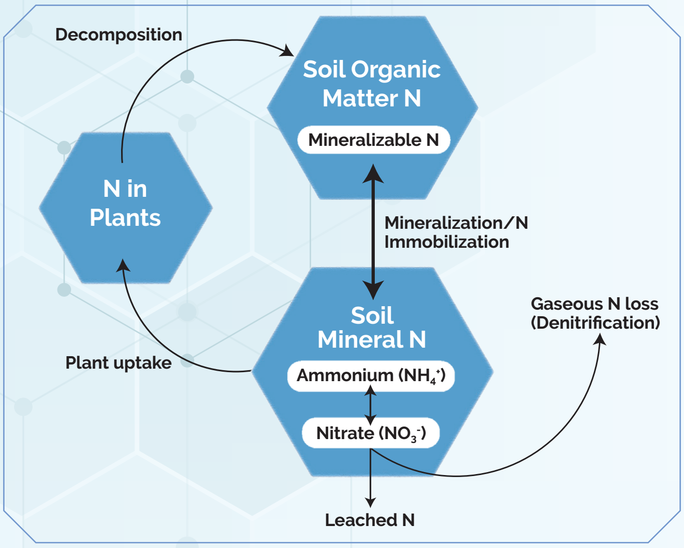
NITROGEN IN SOIL

Soil organic matter is a fundamental source of plant-available N. Generally, every 1% of soil organic matter contained within the top 15 cm of soil can release up to 20 to 30 kg N/ha annually. Often, this amount of N is inadequate to meet the full needs of a crop and its release is typically not synchronized with the important periods of crop demand.

When soil organic matter slowly decomposes, a process also referred to as mineralization, NH_4^+ is produced and held by the soil, taken up by crop plants, or further converted to NO_3^-. This NO_3^- is also used by plants, but it is vulnerable to being leached from the soil profile, or converted to gaseous N and lost to the atmosphere through denitrification.

The rate of release of plant-available N is controlled by the activity of soil microorganisms, which is influenced by soil environmental factors such as temperature, moisture, pH, and texture. Given the right conditions soil microbes can also immobilize plant-available N back into organic

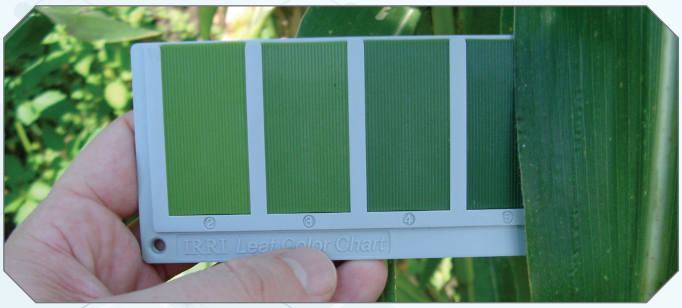
N. For example, the addition of farmyard manure or recycled crop residues can create either net mineralization or immobilization of N depending on its composition. Carbon-rich sources have relatively high C:N ratios (e.g., 40) that create a microbial demand for soil N and result in its net immobilization. Alternatively, organic sources having a lower C:N ratio (e.g., 15) would contribute to a net mineralization of soil N.



Transformation of soil organic matter N

NITROGEN DEFICIENCY SYMPTOMS

An adequate supply of N is usually seen in most plants as a dark green color in leaves, which is a good indicator of a healthy amount of chlorophyll. Nitrogen deficiency is therefore initially observed as a yellowing (chlorosis) of the leaves. Deficiency symptoms commonly appear first on older leaves since N is redistributed away from mature growth towards younger, more actively growing tissue if its supply is limiting. Over time these symptoms progress to younger plant tissue and chlorotic tissues become brown (necrotic) as the deficiency becomes more severe.



A calibrated leaf colour chart is a simple method of determining the N status of the crop.

Other symptoms of N deficiency may include:

- stunted, spindly plants
- less tillering in small grains
- low protein content...in seed and vegetative parts
- fewer leaves
- higher susceptibility to stress from weather, pests and diseases

NITROGEN MANAGEMENT

Most soils cannot provide sufficient quantities of N to support economically optimum crop growth and quality. The process of selecting the appropriate N source should be based on several factors including: availability, price, crop-type, timing and methods of application, tillage systems, and risks and pathways for N losses. A combination of fertilizers, animal manure, and recycled crop residue N should always be considered when supplementing a crop's need for N.

A N-deficient area of maize (foreground) has plants that are underdeveloped and pale compared to the healthier plants in the background.

Non-fertilizer N sources are more variable in their composition which makes it difficult to predict their ability to meet the seasonal demands of a growing crop. Transporting organic N sources to points located off-farm, or even to more distant on-farm locations, is often prevented by a lack of economic incentive or farmer capacity or is otherwise constrained by a lack of supply. If kept on-farm, organic sources provide an opportunity to recycle N (and other essential nutrients) back to the area it was harvested from.

For plant nutrition, a unit of soluble N is the same, regardless of whether its source was from bag of fertilizer or farmyard manure. All N sources require careful stewardship to use them effectively and efficiently. If not properly managed, all N sources can pose a potential source for environmental losses, including nitrate accumulation in groundwater and surface water, and gaseous loss to the atmosphere.

Nitrogen fertilization is most profitable and efficient when used with other best management practices. Constraints such as nutrient imbalances, soil acidity, drought, poor drainage, poor soil structure, pests and disease, crop variety, etc., all have local management interventions that have an incremental effect on improving N.

Table 2 shows an example of how maize yield and N use efficiency were increased over current practices in low, medium, and high fertility status fields in western Kenya. Balanced, site-specific recommendations for N, phosphorus (P), and potassium (K) increased yields across all fertility classes. In this case, high-yielding sites were most productive with less N (and P) combined with a moderate input of K. Agronomic efficiencies for N use were also consistently raised to acceptable values for the range of yields obtained.

Table 2. Effect of improved nutrient recommendations on maize yield and agronomic efficiency of N for smallholder farmers in western Kenya.

Soil fertility status	Fertilizer NPK application, kg/ha	Maize yield, t/ha	Agronomic efficiency of N, kg grain/kg N
Current practice			
Low	21-3-0	1.4	19
Medium	32-9-0	2.2	21
High	80-58-0	4.4	18
Nutrient Expert recommendation			
Low	100-25-15	3.5	25
Medium	100-40-25	4.5	30
High	50-33-20	5.0	40

Vanlauwe et al. 2015. doi:10.5194/soil-1-491-2015