Practical Nutrient Management (II)

**NUTRIENT "AVAILABILITY"**

Vague term which depends on:

1. Concentration of nutrient in solution
2. Speed of nutrient replenishment to solution
3. Mobility of nutrient in soil
DEFINITION:

AVAILABILITY IS THE SOIL'S ABILITY TO MAINTAIN "HIGH" CONCENTRATIONS IN SOLUTION (in vicinity of root)

Fertilizer - a material (natural or synthetic, inorganic or organic) that provides useful quantities of a plant nutrient in forms that can become soluble in soil.

- increases availability (3 factors above)
- builds up reserves
Availability may vary from soil to soil even when the same amount of nutrient is present because:

1. Some nutrients are replenished by organic decomposition (e.g. $\text{NO}_3^-$, $\text{NH}_4^+$)
   
   Depends on - kind of organic matter  
   - soil water content  
   - temperature

2. Nutrients may be retained more tightly if the soil has a high capacity to adsorb that nutrient (e.g. P,K)

   \[ \text{PO}_4 \rightarrow \text{Root} \]

   (slows TRANSPORT)
MOST RELIABLE MEASURES OF NUTRIENT AVAILABILITY

1. SOIL TESTS (?)
   (See 3 factors that control availability)

2. PLANT RESPONSE

   ![Graph showing response curve with YIELD on the y-axis and Amount of Nutrient Added on the x-axis. The graph is divided into three ranges: DEFICIENT RANGE, ADEQUATE RANGE, and TOXIC RANGE.](image)
NUTRIENT CYCLING & LOSSES

Nutrient cycles in soils are "leaky", especially in highly fertile soils.

Nutrient losses by:

SOIL EROSION
CROP REMOVAL
VOLATILIZATION OF GASES
LEACHING
EROSION - removes P & N (in solids)
- enhanced on bare soil
- promotes algal growth in lakes

CROP REMOVAL - necessary result of agriculture
- N & K removed most
- minimized by returning crop residues to soil

GASEOUS LOSSES - NH$_3$ volatilization (esp. alkaline soil)
- NO$_3^-$, SO$_4^{\text{2-}}$ reduction (wet)
- burning --> N & S escape (N$_2$O, NO$_2$, SO$_2$)

LEACHING - possible loss of all soluble nutrients
- most significant - NO$_3^-$, SO$_4^{\text{2-}}$, K$^+$
- phosphate lost only in sandy soil
- minimized by fertilizing at right time in right amount

HYPOTHESIS:
"HEALTHY CROPS USE NUTRIENTS BETTER"
Managing Plant Nutrients

Fertilizer manufacture and use does not create nutrients:

(a) animal manure, green manure, composts ---> contain nutrients taken from soil.

(b) inorganic fertilizers ---> mined from enriched deposits.

Therefore, fertilizers are a non-renewable resource.

Exception: $\text{N}_2$ fixation (biological & chemical)

BUT Large energy cost
NUTRIENTS:

NITROGEN

Most extensively used, in greatest amounts

N deficiency is normal
(few soils can sustain repeated cropping without N supplements).

PHOSPHORUS

Deficiency occurs on ≈ 70% of agricultural soils.

POTASSIUM, SULFUR, ZINC

Deficiency is common
NUTRIENTS:

IRON, BORON, MOLYBDENUM, MAGNESIUM, COPPER, MANGANESE

Deficiency less common

CHLORINE, COBALT, SODIUM

Deficiency rare

CALCIUM

Deficiency rare
But in excess, Ca suppresses problems with
- Soil acidity
- Sodicity
- Salinity
### Nutrients Removed by Crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (tonnes/ha)</th>
<th>Nutrients Removed (kg/ha/crop)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>wheat grain</td>
<td>6</td>
<td>120</td>
</tr>
<tr>
<td>alfalfa hay</td>
<td>20</td>
<td>500</td>
</tr>
<tr>
<td>tomatoes (fresh)</td>
<td>20</td>
<td>150</td>
</tr>
</tbody>
</table>

### Typical (California) Fertilizer Application Rates

<table>
<thead>
<tr>
<th>Crop</th>
<th>Rates Applied (kg/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>field crops</td>
<td>100</td>
</tr>
<tr>
<td>vegetables</td>
<td>150</td>
</tr>
<tr>
<td>alfalfa</td>
<td>0</td>
</tr>
</tbody>
</table>
FERTILIZERS

Natural - organic (manures, compost, etc.)
- inorganic (rock phosphate, etc.)

Manufactured

Nitrogen Fertilizers -

N in soil, plants, animals
ultimately comes from atmospheric N₂.

Worldwide - 50% from biological fixation
- 50% from industrial process

e.g. Haber process

\[
\Delta \quad N₂ + H₂ \quad \text{catalyst} \quad \rightarrow \quad NH₃(g)
\]

from coal, petroleum, natural gas

\[
\text{pressure} \quad NH₃(g) \quad \rightarrow \quad \text{liquid anhydrous}
\]
low T \quad ammonia (80% N)

Ammonia is injected into soil.
Other N fertilizers:

\[
\begin{align*}
\text{NH}_3 + \text{O}_2 & \rightarrow \text{HNO}_3 \\
\text{HNO}_3 + \text{NH}_3 & \rightarrow \text{NH}_4\text{NO}_3 \quad \text{ammonium nitrate} \\
\text{HNO}_3 + \text{lime} & \rightarrow \text{Ca(NO}_3)_2 \\
\text{NH}_3 + \text{C} + \text{steam} & \rightarrow \text{CO(NH}_2)_2 \quad \text{urea} \\
\text{NH}_3 + \text{H}_3\text{PO}_4 & \rightarrow (\text{NH}_4)_3\text{PO}_4 \quad \text{ammonium phosphate}
\end{align*}
\]

PHOSPHORUS FERTILIZERS -

main industrial source is "rock phosphate"
\[
\text{Ca}_5(\text{PO}_4)_3(\text{OH}, \text{F}, \text{Cl})
\]
phosphate rock (mostly apatite)

- grinding
- \( + \text{H}_2\text{SO}_4 \)
- \( + \text{H}_3\text{PO}_4 \)

ROCK PHOSPHATE

SUPERPHOSPHATE (9%)
Ca phosphate
Ca sulfate

TRIPLE SUPERPHOSPHATE (20% P)
Ca phosphate
POTASSIUM FERTILIZERS -

mined from sedimentary deposits of KCl and $K_2SO_4$

SULFUR FERTILIZERS -

gypsum ($CaSO_4$) - abundant
- mined from sedimentary rock
- fairly soluble

elemental sulfur ($S$) - mined insoluble, but oxidizes in soil:
$$S + O_2 \rightarrow SO_4^{2-} + H^+$$

superphosphoate (9% P) - contains $CaSO_4$
ORGANIC FERTILIZERS -

unprocessed leaves, grass clippings, green manures

"animal" processed manure, bone meal, sewage sludge, etc.

microbe processed composts (less bulk, lower C/N ratio)
GROWER Chooses Fertilizer based on:

1. Nutrient Content

"Complete fertilizers"
- multinutrient
- not cost-effective for commercial growers

"Simple fertilizers"
- one or two nutrients
- used by most commercial growers

2. Release Rates

A. Most inorganic fertilizers have fast release.
   EXCEPTIONS: ROCK PHOSPHATE
   ELEMENTAL S
   S-COATED UREA

B. Most organic fertilizers release nutrients slowly ---> "mineralization" of N, P, S, etc.

SLOW RELEASE  - advantages - reduced nutrient loss
                - disadvantages - release slower than demand
3. **AVAILABILITY and COST**

Cost is based on price per unit wt. of N, P, K, etc. (not fertilizer wt.).

High-analysis fertilizer may be preferred despite price because of lower bulk.

(Organic fertilizers usually have low analysis, bulky to handle)

4. **CONVENIENCE & EASE of USE**

Physical state, solubility, stability of material, determines labor & equipment needs.

Anhydrous NH$_3$ - needs injection equipment
Urea, NH$_4$NO$_3$ - do not
5. SIDE EFFECTS

Soluble salts damage plants, microbes

Organic materials (in excess)
  - clog soils
  - cause anoxic conditions
  - produce organic toxicities

Leached fertilizers pollute streams & groundwater

Soils are acidified by ammonium fertilizers or ammonium-releasing processes
(\(N_2\) fixation, organic fertilizers)

Secondary deficiencies are enhanced
  (eg. Zn by phosphate)
DETERMINING FERTILIZER NEEDS

Deficiency diagnosis can be done by:

1. Educated guess (i.e. experience)
2. Interpretation of visual symptoms (ambiguous)
3. Analysis of soil samples
4. Analysis of plant samples - tissue tests
5. Nutrient Response Trials (field or greenhouse) too slow & expensive
Rate of Nutrients to be Added determined by:

1. Educated guess
2. Measured response curves

"YIELD"

Deficient Soil

Nondeficient Soil

Amt. of Nutrient Added -->

3. Yield expectation (maximum yield is rarely economical).
SOIL TESTING

"Availability" of nutrient in soil is difficult to define or measure.

Diagnostic soil tests must be:

1. FAST!
2. CHEAP!
3. SIMPLE!
4. CORRELATED TO PLANT RESPONSE (deficiency and toxicity)
Successful soil tests exist for

PHOSPHATE
POTASSIUM
ZINC
ACIDITY (lime requirement)
SALINITY

Simple soil tests for N and S have not been successful.
All soil tests extract some part of the soil's total supply of an element.

Soil Sampling - heterogeneity requires mixing of "subsamples" to get a representative sample.

A = successful P extraction method

B = unsuccessful P extraction method
Soil test procedures vary regionally, are calibrated locally.
# Improving Fertilizer Efficiency

**Timing**
- add "slow-release" or "timed-release" fertilizer
- or add nutrient when needed

## Application Methods:

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcast</td>
<td>fast</td>
<td>poor nutrient accessibility</td>
</tr>
<tr>
<td></td>
<td>convenient</td>
<td>more soil contact</td>
</tr>
<tr>
<td></td>
<td></td>
<td>volatile gas loss</td>
</tr>
<tr>
<td>Injection &amp; Banding</td>
<td>reduced soil interaction</td>
<td>Root toxicity in band</td>
</tr>
<tr>
<td></td>
<td>reduce volatile loss</td>
<td></td>
</tr>
<tr>
<td>Soluble Form</td>
<td>convenient for irrigation</td>
<td>Cost of transporting bulk</td>
</tr>
<tr>
<td></td>
<td>controlled application rate</td>
<td></td>
</tr>
<tr>
<td>Foliar Spray</td>
<td>fast response</td>
<td>Needs repeated application --&gt; costly</td>
</tr>
<tr>
<td></td>
<td>accurate timing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>no soil immobilization</td>
<td></td>
</tr>
</tbody>
</table>