Practical Nutrient Management (II)

NUTRIENT "AVAILABILITY"

Vague term which depends on:

1. **Conc. 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)**

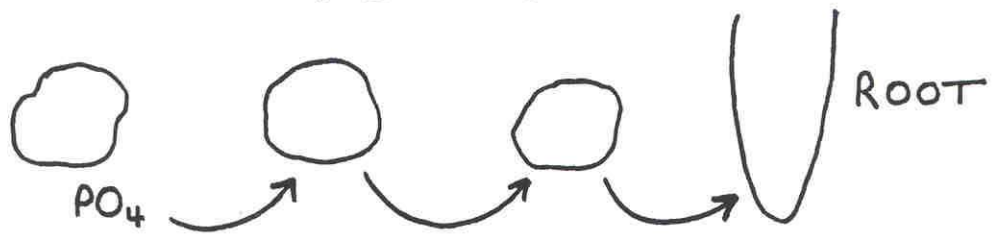
- **builds up reserves**

Availability may vary from soil to soil even when the same <u>amount</u> of nutrient is present because:

1. **Some nutrients are replenished by organic decomposition (eg. NO_3^-, 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 (eg. P,K)**



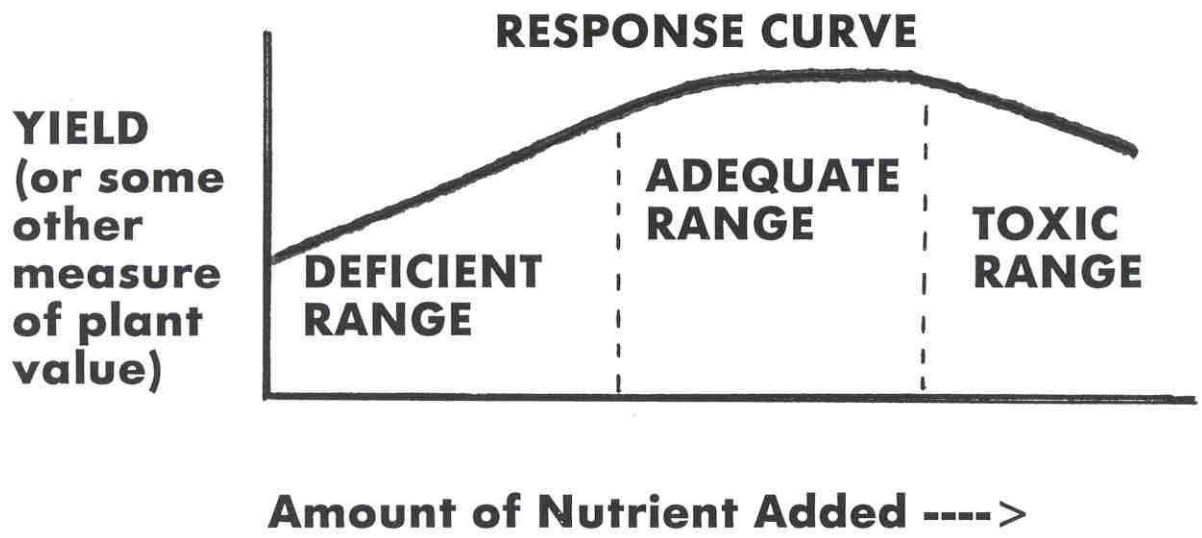
(slows TRANSPORT)

MOST RELIABLE MEASURES OF NUTRIENT AVAILABILITY

1. **SOIL TESTS (?)**

   (See 3 factors that control availability)

2. **PLANT RESPONSE**



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^-, $SO_4^=$ reduction (wet)
- burning --> N & S escape (N_2O, NO_2, SO_2)

LEACHING
- possible loss of <u>all</u> soluble nutrients
- most significant - NO_3^-, $SO_4^=$, K^+
- phosphate lost only in sandy soil
- minimized by fertilizing at right <u>time</u> in right <u>amount</u>

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: N_2 fixation (biological & chemical)

BUT Large energy cost

NUTRIENTS:

NITROGEN

Most extensively used, in greatest amounts

N deficiency is <u>normal</u>
(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
<u>But</u> in excess, Ca suppresses problems with
- **Soil acidity**
- **Sodicity**
- **Salinity**

Nutrients Removed by Crops

Crop	Yield (tonnes/ha)	Nutrients Removed (kg/ha/crop)					
		N	P	K	Ca	Mg	S
wheat grain	6	120	30	30	25	15	5
alfalfa hay	20	500	45	350	250	50	50
tomatoes (fresh)	20	150	25	200	10	15	20

Typical (California) Fertilizer Application Rates

	Rates Applied (kg/ha/yr)		
Crop	N	P	K
field crops	100	7	4
vegetables	150	35	40
alfalfa	0	30	15

FERTILIZERS

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

Manufactured

Nitrogen Fertilizers -

N in soil, plants, animals
ultimately comes from atmospheric N_2.

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

e.g. Haber process

$$N_2 + H_2 \xrightarrow[\text{catalyst}]{\Delta} NH_3(g)$$

from coal, petroleum, natural gas

$$NH_3(g) \xrightarrow[\text{low T}]{\text{pressure}} \text{liquid anhydrous ammonia (80\% N)}$$

Ammonia is injected into soil.

Other N fertilizers:

$$NH_3 \xrightarrow[O_2]{\text{-----}>} HNO_3$$

$HNO_3 + NH_3$ ----> NH_4NO_3 ammonium nitrate

HNO_3 + lime ----> $Ca(NO_3)_2$

$NH_3 + C + \text{steam}$ ----> $CO(NH_2)_2$ urea

$NH_3 + H_3PO_4$ ----> $(NH_4)_3PO_4$ ammonium phosphate

} easier to handle than NH_3

PHOSPHORUS FERTILIZERS-

main industrial source is "rock phosphate"

$Ca_5(PO_4)_3(OH,F,Cl)$

phosphate rock (mostly apatite)

grinding → ROCK PHOSPHATE

+ H_2SO_4 → SUPERPHOSPHATE (9%) Ca phosphate/ Ca sulfate

+ H_3PO_4 → TRIPLE SUPERPHOSPHATE (20% P) Ca phosphate

POTASSIUM FERTILIZERS -

mined from sedimentary deposits of KCl and K_2SO_4

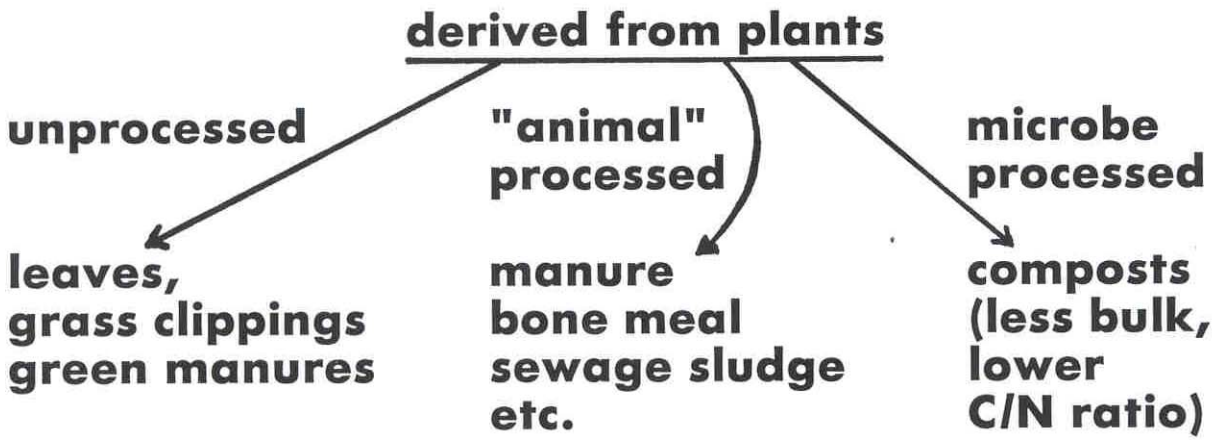
SULFUR FERTILIZERS -

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

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

superphosphoate (9% P) - contains $CaSO_4$

ORGANIC FERTILIZERS -



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 <u>fast</u> 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_4NO_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)

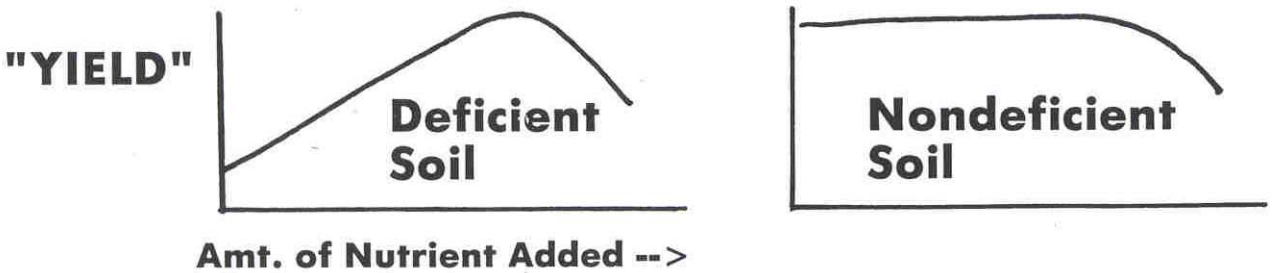
DETERMINING FERTILIZER NEEDS

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 <u>response curves</u>



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)**

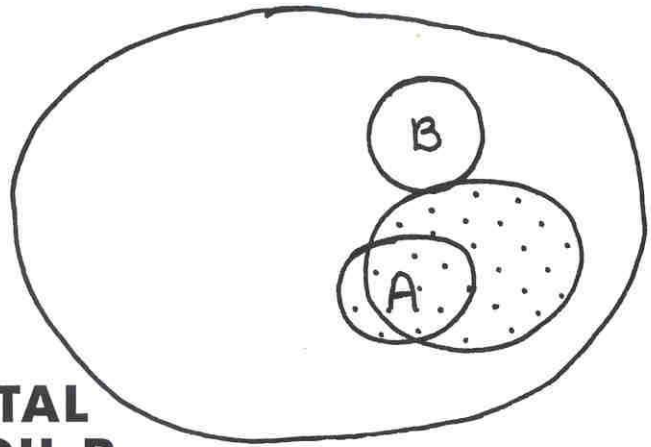
Successful soil tests exist for

PHOSPHATE
POTASSIUM
ZINC
ACIDITY (lime requirement)
SALINITY

Simple soil tests for N and S have <u>not</u> been successful.

All soil tests extract some <u>part</u> of the soil's total supply of an element.

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

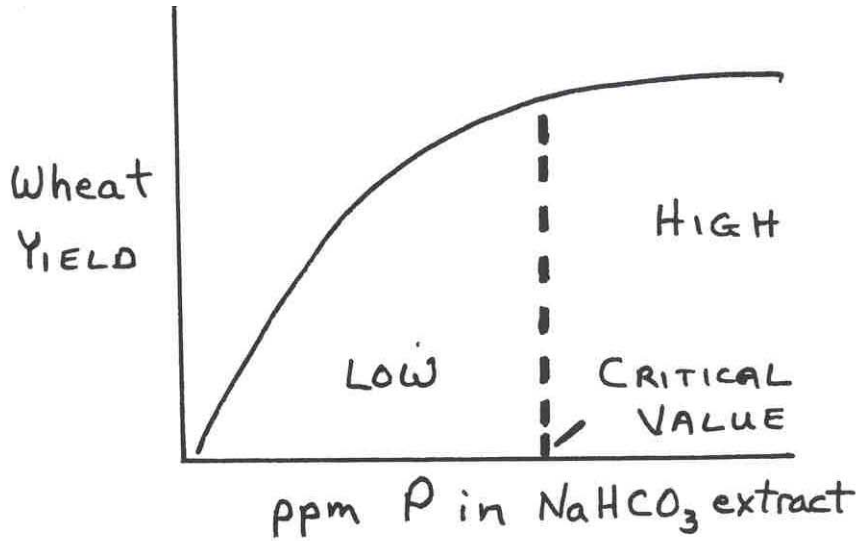


A = successful P extraction method

B = unsuccessful P extraction method

Soil test procedures vary regionally, are calibrated locally.

Calibration of Soil Test

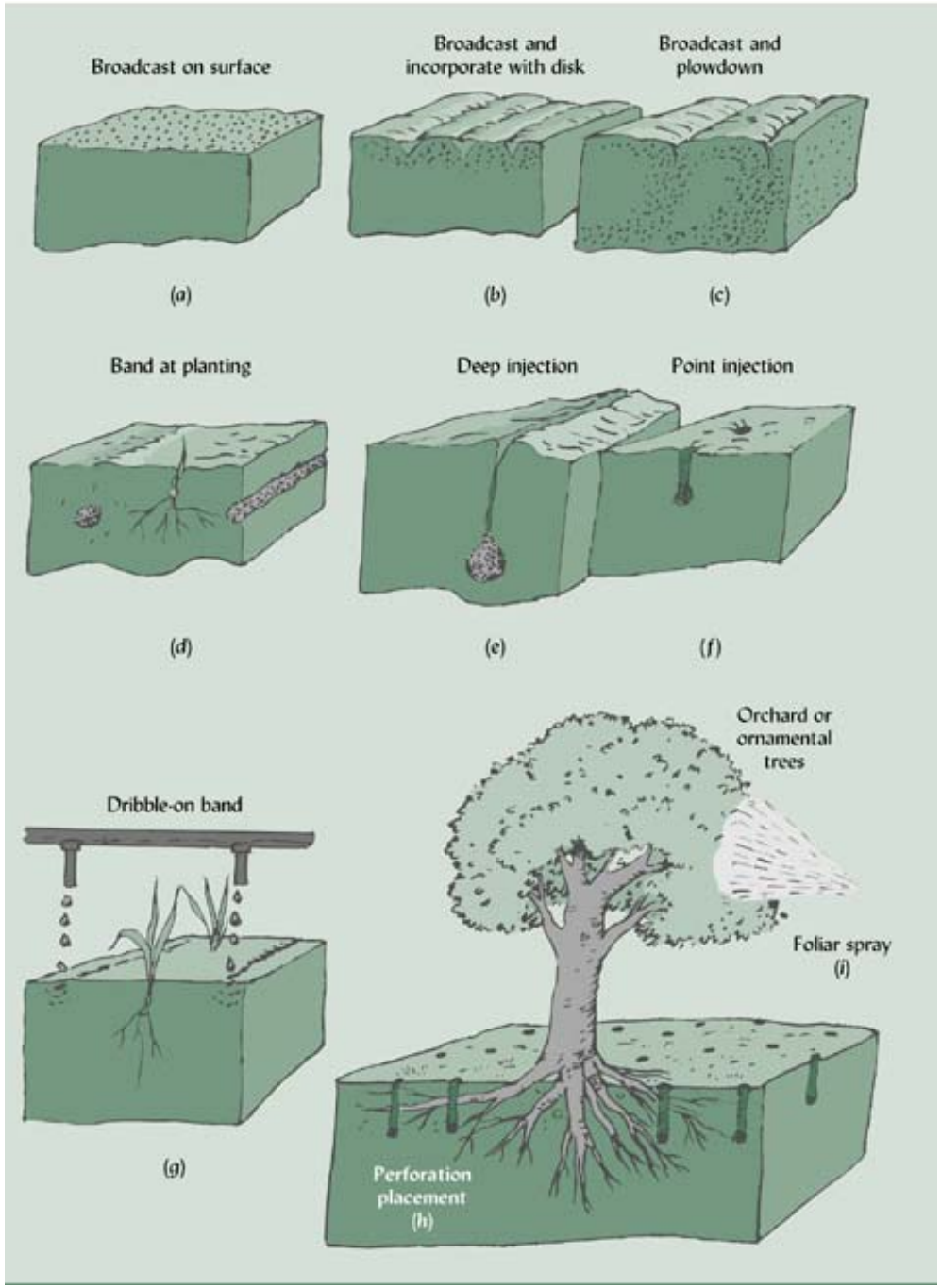


IMPROVING FERTILIZER EFFICIENCY

TIMING
- add "slow-release" or "timed-release" fertilizer
- or add nutrient when needed

APPLICATION METHODS:

METHOD	ADVANTAGES	DISADVANTAGES
BROADCAST	- fast - convenient	- poor nutrient accessibility - more soil contact - volatile gas loss
INJECTION & BANDING	- reduced soil interaction - reduce volatile loss	- root toxicity in band
SOLUBLE FORM	- convenient for irrigation - controlled application rate	- cost of transporting bulk
FOLIAR SPRAY	- fast response - accurate timing - no soil immobilization	- needs repeated application --> costly


Broadcast on surface
Broadcast and incorporate with disk
Broadcast and plowdown
(a)
(b)
(c)
Band at planting
Deep injection
Point injection
(d)
(e)
(f)
Dribble-on band
(g)
Orchard or ornamental trees
Foliar spray (i)
Perforation placement (h)