AVRDC
The World Vegetable Center

Soil Health and Soil Fertility Management

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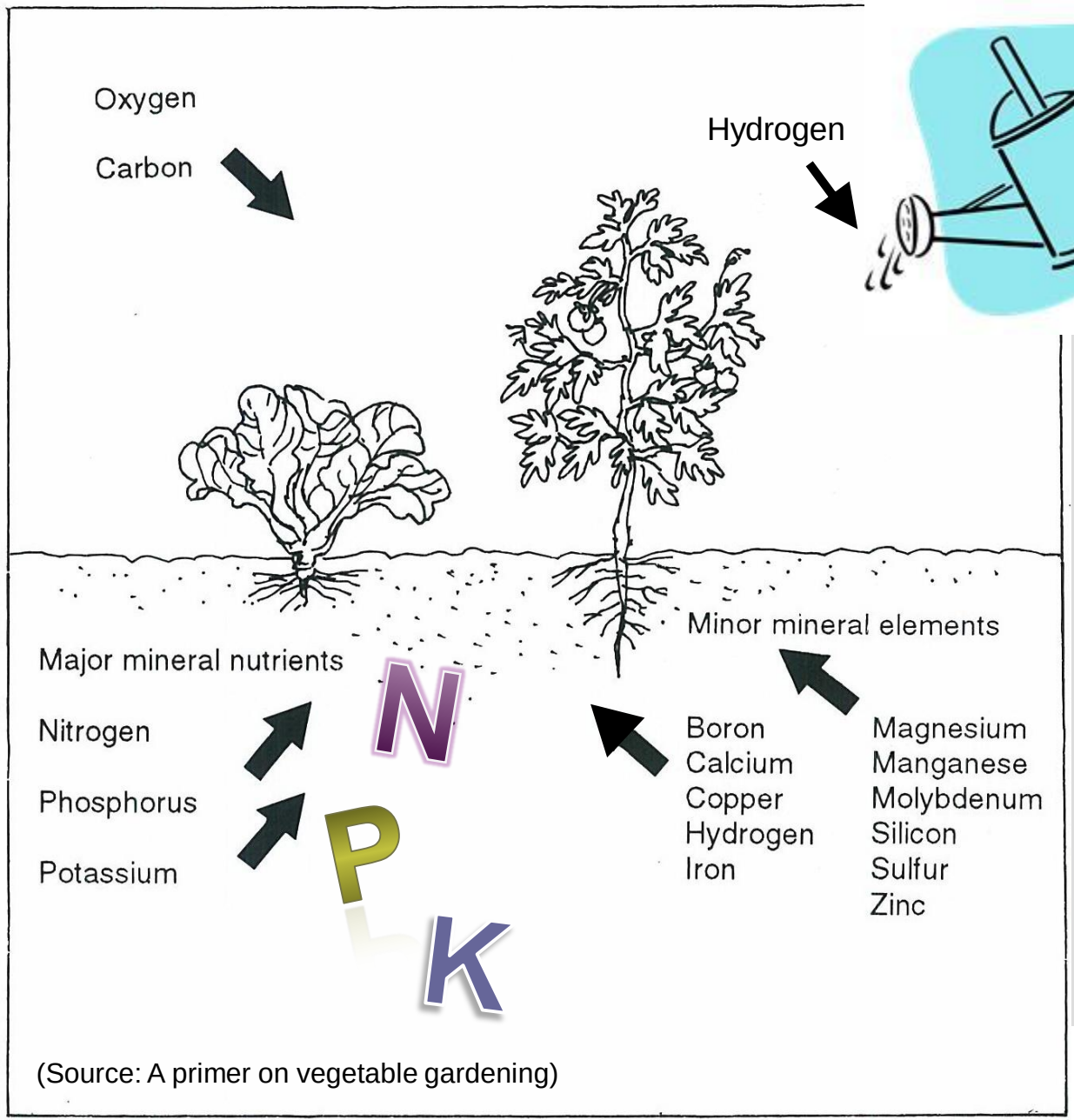
Outline

- What is Fertilization?
- Composting
- Starter Solution Technology & Balanced Fertilization

Fertilization

- Vegetables need nutrients, they are:
  - Carbon and oxygen from the air, hydrogen from water, and mineral nutrients from the soil.
  - Major nutrients (nitrogen=N, phosphorus=P, and potassium=K) in large amounts.
  - Minor nutrients in small amounts.



(Source: A primer on vegetable gardening)

Fertilization

VEGETABLES
NEED
NUTRIENTS

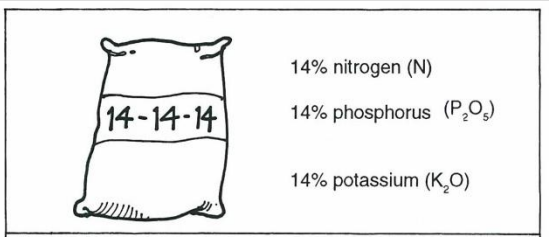
Fertilization – Different vegetables

- Nutrient requirements for vegetables:
  - Root, fruit and seed vegetables:
    - Require large quantities of **Phosphorus** and **Potassium** to stimulate root, flower, fruit and seed formation and development

  - Leaf and stem vegetables:
    - Require fertilizers high in **Nitrogen** to stimulates leaf formation and growth

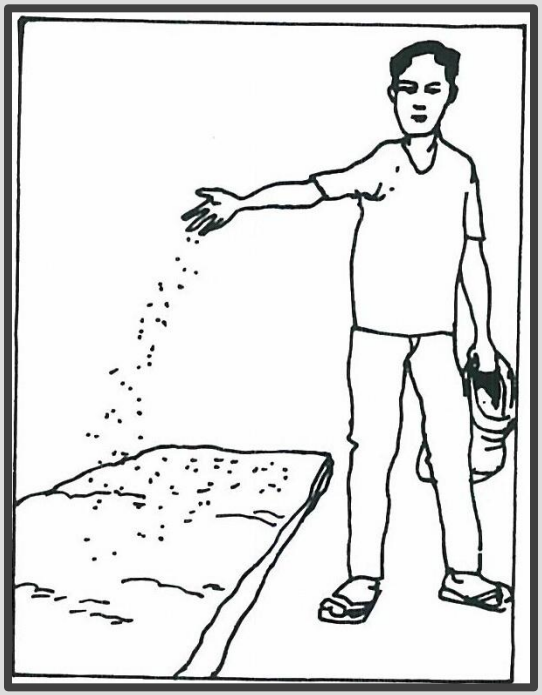
Fertilization - Sources

- **To have a sustainable soil fertility and healthy plant growth, fertilizer applications from organic and inorganic sources are needed:**
  - **Organic fertilizers:**
    - Derived from natural sources, such as compost, manure, agricultural wastes, etc.
    - Nutrients are in small concentration
    - Reaction is slow and takes time before nutrient released to plants
    - Improve soil texture and biological property, retain water and nutrients
  - **Inorganic fertilizers**
    - Commercially manufactured mineral nutrients
    - Available in different combinations of mineral nutrients
    - Numbers on the bag refer to the percentage by weight of mineral nutrients

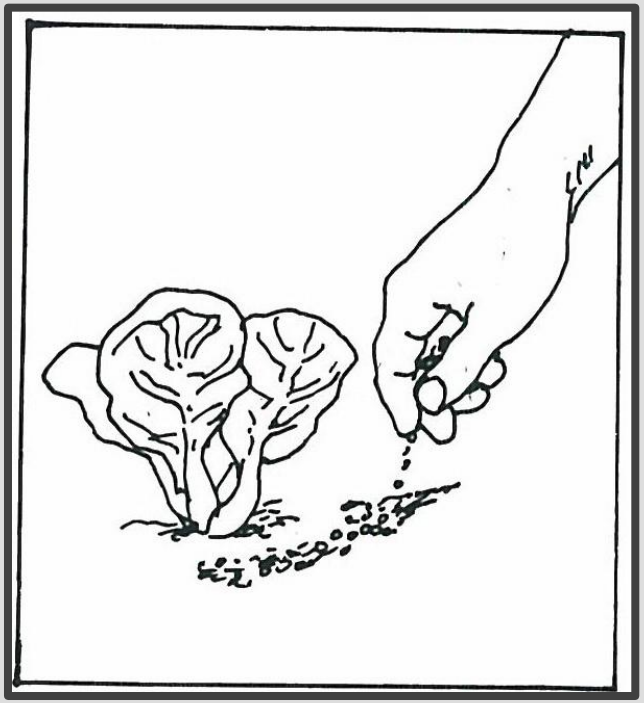


Fertilization - Methods

- How to apply fertilizers?



Broadcast/ soil incorporation (before planting)



Localized-spot application (as side-dressing)

Foliar application

Fertilization – Timing (examples)

- NPK fertilizers generally provide a quick release of nutrients for plant growth

Frequency and time of fertilizer application		
Kangkong 	**Tomato** 	**Yard-long bean** 
• Incorporate compost/manure into soil before planting	• Incorporate compost/manure into soil at planting time	• Incorporate compost/manure into soil before seeding
• Apply P, K, and ½ N in band at planting	• Apply P, ½ K, and ½ N in band at planting	• During dry season apply all required fertilizer at seeding
• Side-dress the remaining N 10 days after germination	• Apply remaining N and K one month and two months after transplanting	• During wet season apply ½ N and all P and K in band at seeding and side-dress the remaining half of N three weeks after seeding

Fertilization – Amounts

- Plant need a good balanced diet to grow well
- All the nutrients are found in plants in different amounts
- You need to apply fertilizers to replace what the plants has used and what has leached away in soils

Some examples of fertilizer recommendations:

- Apply organic fertilizers 0.5-1 kg/m^2 (5-10 t/ha) yearly or before every cropping
- You need to apply inorganic fertilizers based on the recommendation rates on fertilizer bags. If recommendation rate is in kg/ha, divide by 10 that will give the rate in g/m^2
- Different fertilizer has different nutrient %, e.g. 100 kg Urea contains only 46 kg of N. Care should be taken for fertilizer calculation.

What Make Soil Alive?

- **Clay minerals:**
  - carry negative charges, can attract cations with positive charges (NH_4^+ , K^+, Ca^{2+}, Mg^{2+}, etc.) and repel anions with negative charges (NO_3^-, $H_2PO_4^-$, $H_2PO_4^{2-}$,SO_4^{2-} , etc.)
- **Organic matter:**
  - carry negative charges and some positive charges. It have more positive positions than clay.

Clay and Organic Matter have greatest influence on CEC (cation exchange capacity)

Clay	Organic matter
10-150 cmol(+)/kg	200-400 cmol(+)/kg

Organic matter has a higher CEC

Note: cmol(+)/kg = meq/100g

Compost

- What is Compost?
  - Compost is **a form of organic matter** and can be made from a range of organic materials usually considered to be waste.
  - Ingredients: straw, cut grass, organic waste from the kitchen, weeds, plants, leaves, animal manure (except from dogs and cats), wood ash, animal and fish bones, feathers, cotton cloth, bits of leather or paper, soil.
  - Do not use cooked food, large pieces of wood, plastic, metal, glass, crockery, wire, nylon, synthetic fabrics, coal ash, seeding grass or very tough weeds.
  - Composting is a natural process that involves the decomposition of organic matter. Millions of microorganisms drive the compost process by breaking organic matter down to its original nutrient form.

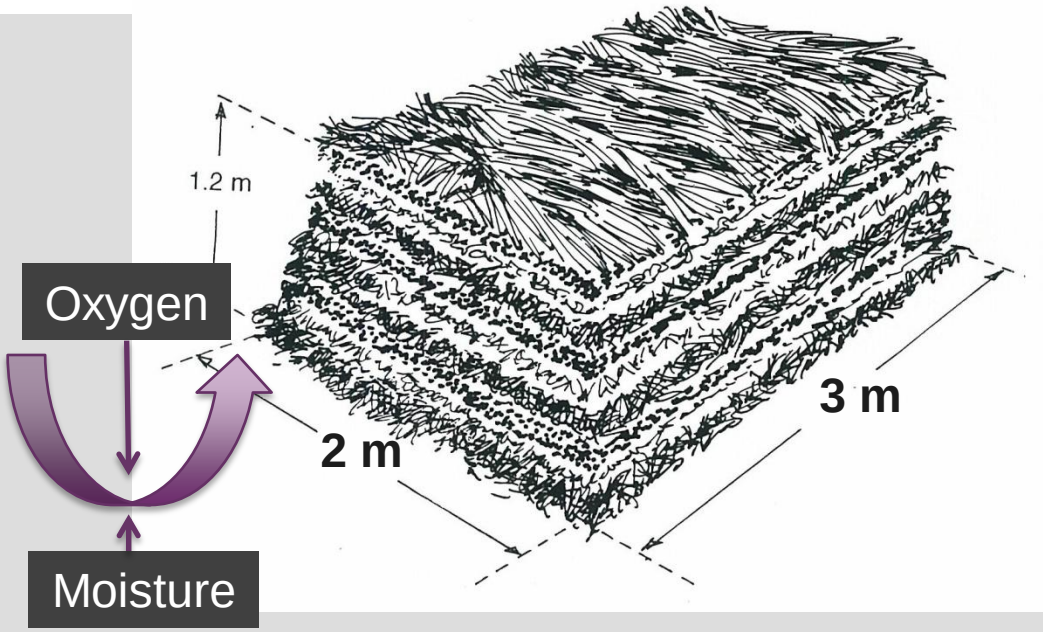
Benefits of applying composts

- Highly beneficial to soil sustainability and plant health
- Routine apply compost will optimize potential yields and quality
- Contain micronutrients, enzymes and microorganism that are not found in inorganic fertilizers
- Organic matter helps to retain water and nutrients in soils
- Act as excellent soil conditioner
- Improve soil physical and biological properties
- May reduce soil-borne diseases
- As bedding substitute and growing media

Compost making

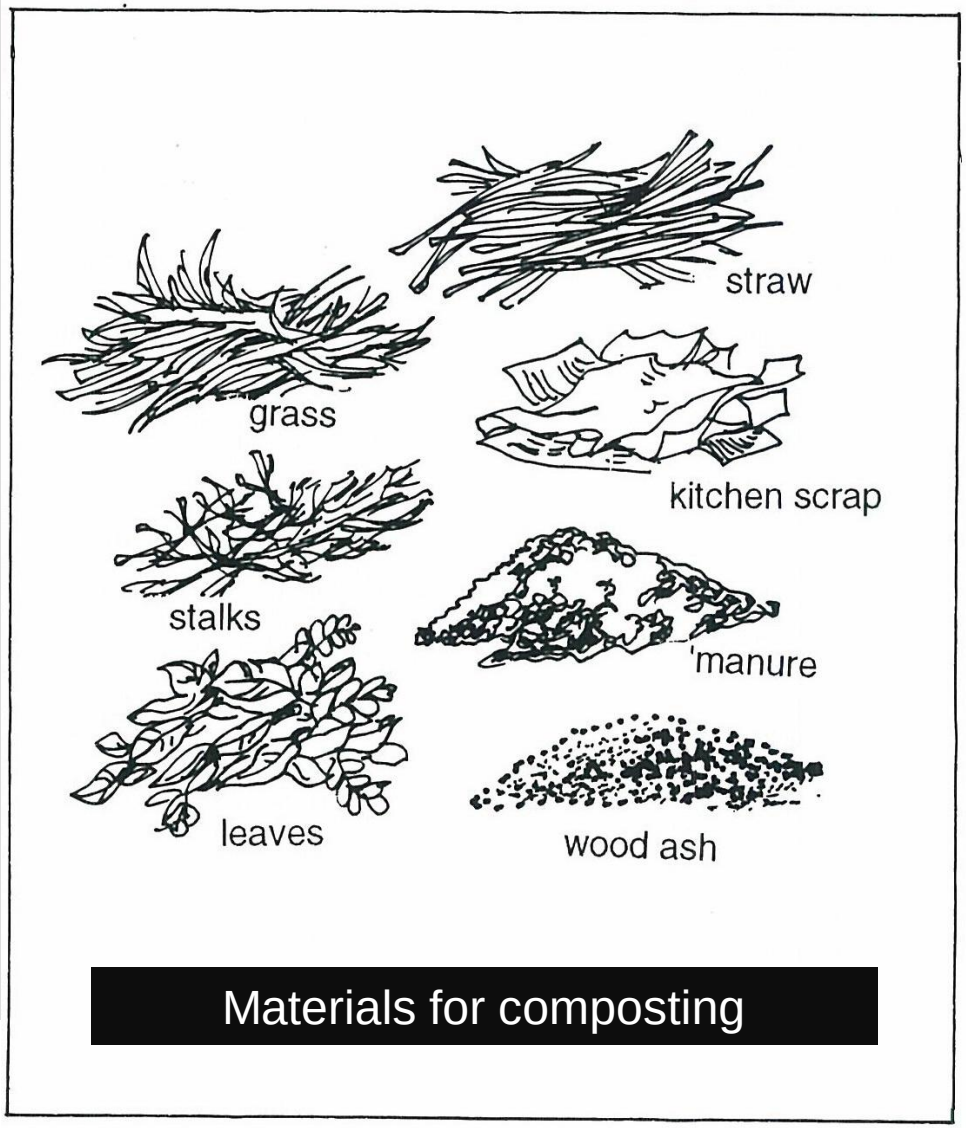
- **Step 1.** Collect all waste materials
- **Step 2 .** Choose a shady level area measuring 3 meter long and 2 meter wide; the height of compost pile must be higher than 1.2 meter
- **Step 3.** Pile by layers with one layer C-rich and one layer N-rich materials; do not pack the layers down to avoid slowing decomposition.

  Step 4. Water the pile evenly and avoid over watering. Adjust the moisture to 50-60 % of total weight.



- **Step 5.** Monitoring the temperature inside the pile.
- **Step 6 .** Turn the pile upside down when it has cooled down or every 2-3 weeks. After 2-4 months, the compost will be ready for use.

Compost making – Step 1

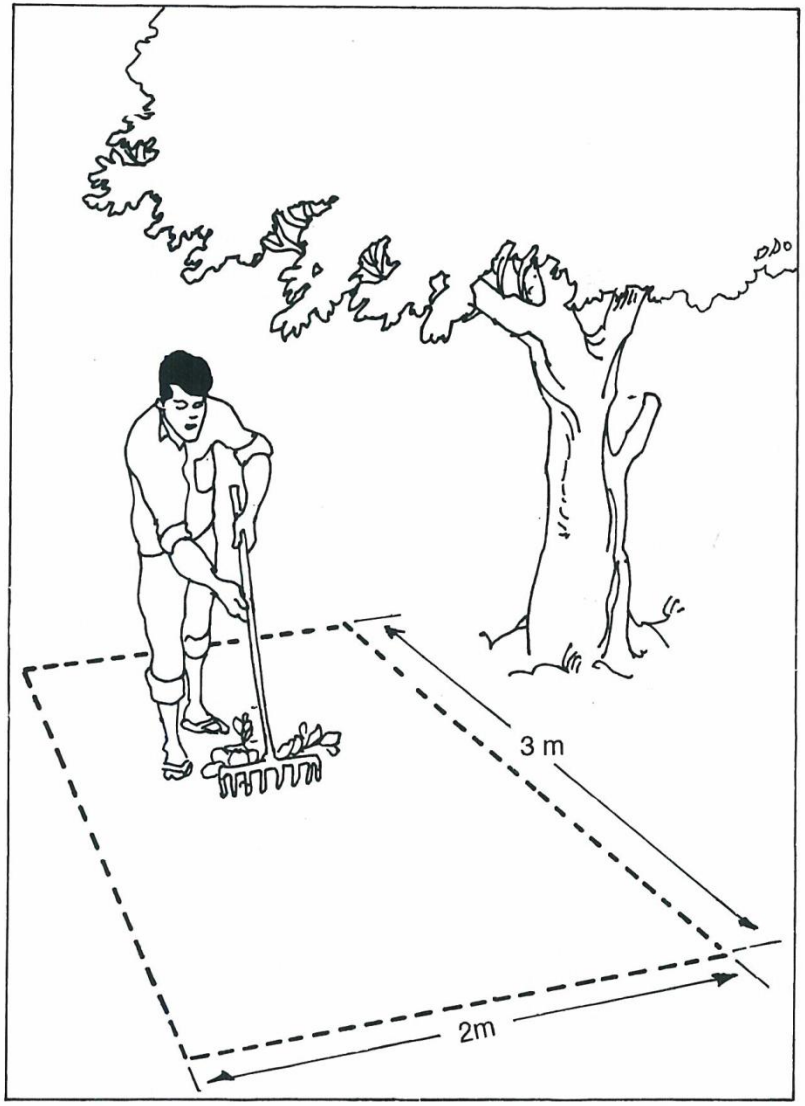


Materials for composting

- Step 1: collect all waste materials
- Anything that **was once alive** can be composted
- **Materials high in C (Brown)** - crop residues and stems, straw, sawdust, paper, wood ash, etc.
- **Materials high in N (Green)** – manures, vegetable/fruit wastes, grass clippings, fresh weeds, leaves, flowers, etc.
- The ideal mix is **25 parts of C-rich to 1 part of N-rich materials** by weight (C:N ratio=25:1)

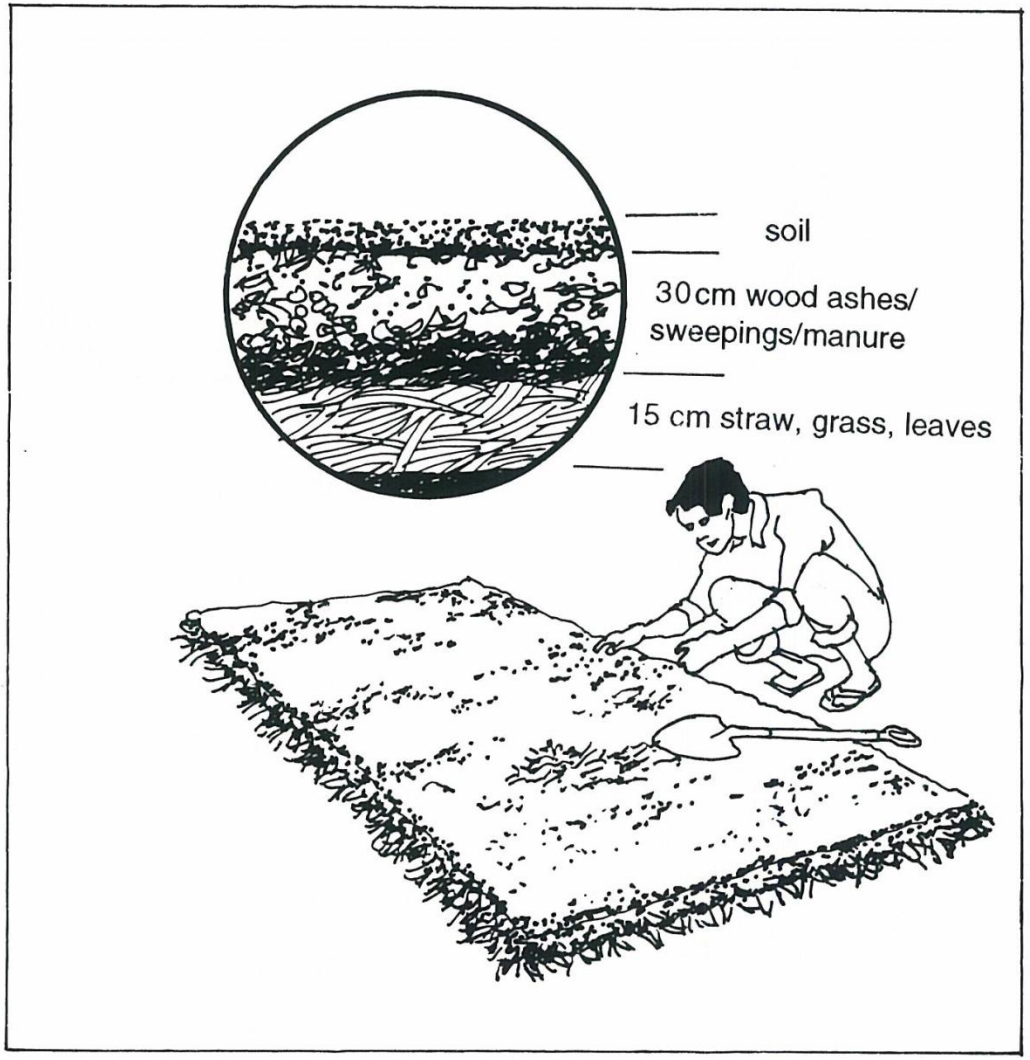
Compost making – Step 2

- Choose a shady level area measuring 3 meter long and 2 meter wide; the height of compost pile must be higher than 1.2 meter



Compost making – Step 3

- Pile by layers with one layer C-rich and one layer N-rich materials; do not pack the layers down to avoid slowing decomposition.



Compost making – Step 4

- Water the pile evenly and avoid over watering. Adjust the moisture to 50-60 % of total weight.
- Keep good aeration of the heap, have a removable cover on top of pile to prevent too much rain

Compost making – Step 5

- Test if the pile is hot inside by inserting a stick all the way into the pile, or use thermometer.

Compost making – Step 6

- Turn the pile upside down when it has cooled down or every 2-3 weeks. After 2-4 months, the compost will be ready for use.

Compost making

- Compost making as part of AVRDC's Regional Training Course in Thailand.

Home compost

- Advantage of the home compost:
  - Can control what goes into the compost, reducing problems with salts, weed seeds, and plant diseases
- Compost made solely from plant residues (leaves and other yard wastes) is basically free of salt problems and higher application rates are safe
- Compost needs to be thoroughly mixed into the upper 15-20 cm of the soil profile

Problems in Vegetable Production System

- Improper fertilization:
  - overuse, nutrient imbalance, resulting in salinity, acidity, alkalinity and accumulation of toxic metal ions
- Insufficient fertilizer use, resulting in depletion of soil fertility
- Depletion of soil organic matter
- Poor sustainability, land degradation
- Environmental Pollution
- Lack of proper integrated soil fertility management (ISFM)

Starter Solution Technology (SST)

- Small amounts of very **concentrated inorganic fertilizer solution** (Starter Solution, ST) are applied in a small volume of **50 ml** to soils in the root vicinity immediately after **transplanting**, which build up high nutrient gradients in soil solution, provide young plants with readily available nutrients before their root systems are well established, thus **enhancing the plant's initial growth** significantly.
- After nutrient ions adsorbed on soil particles, the remaining nutrients in soil solution are directly available to the plants

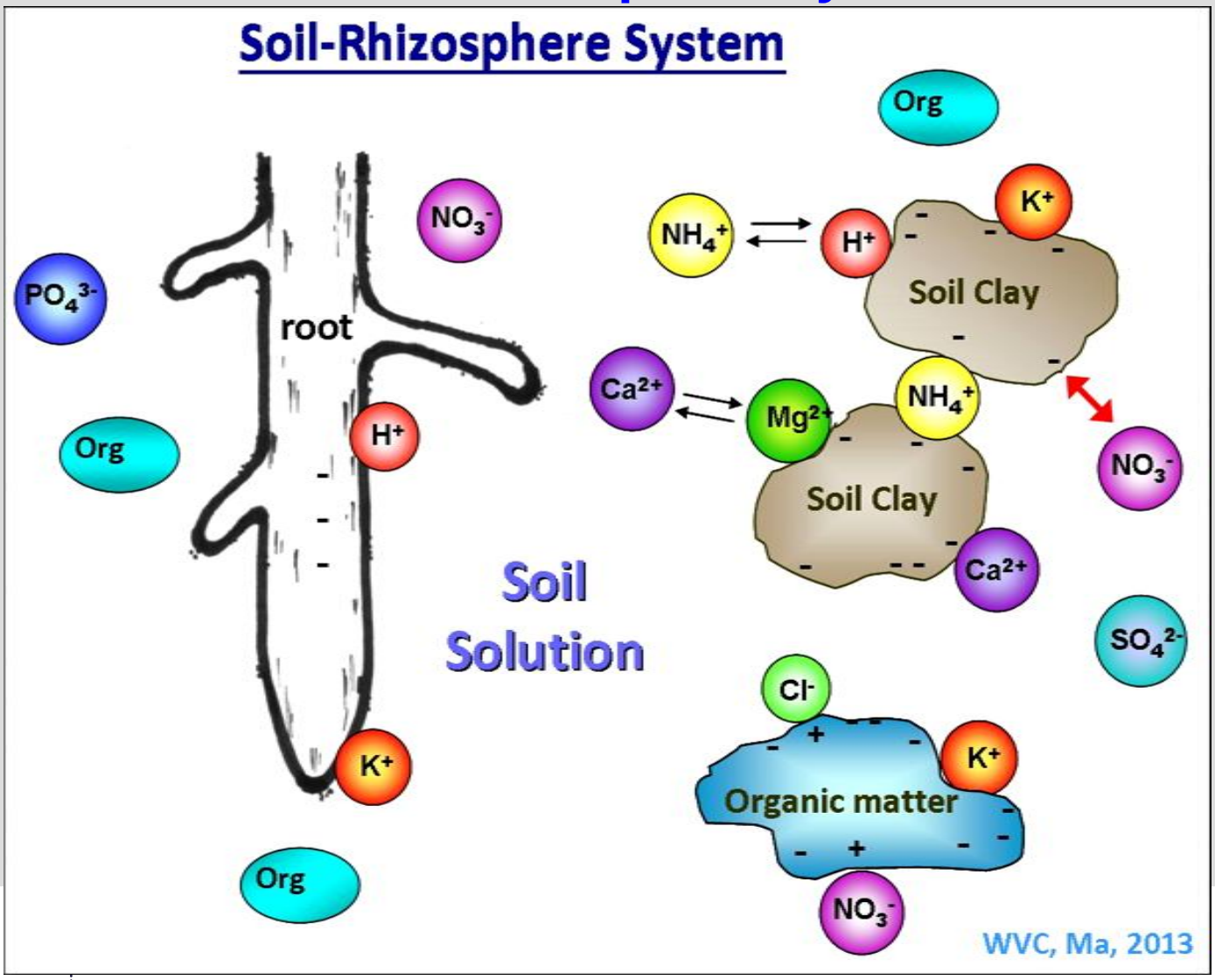
Time for Applying ST

- At transplanting (roots are not accessible to nutrients)
- During root injury (after disaster or heavy rain, diseases)
- At fruit setting or heading stage (productive stage)

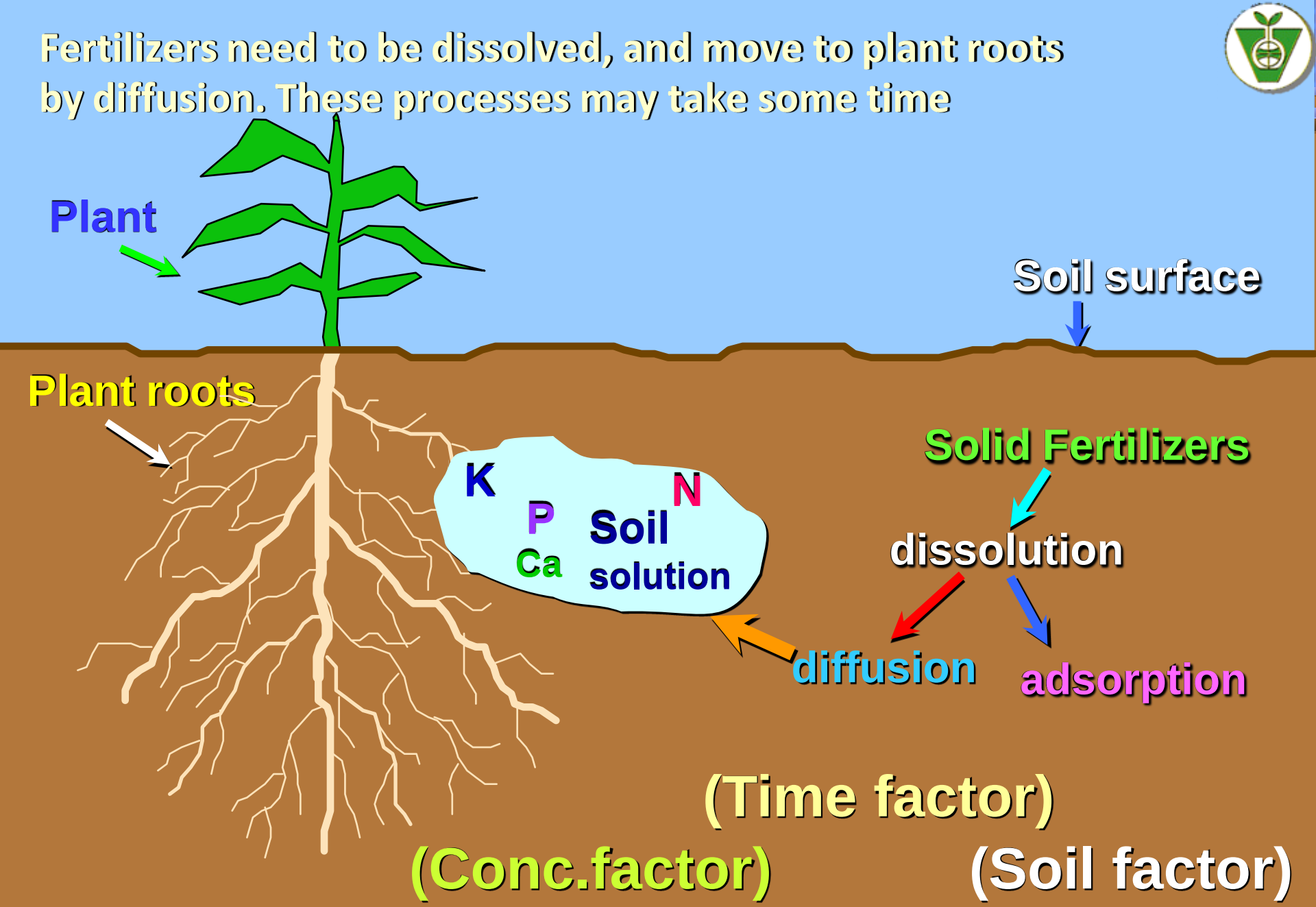
Effects of Starter Solution

- Enhance the initial growth of vegetables significantly
- Reduce fertilizer amounts
- Increase yield/fertilizer efficiency
- Shorten growth duration
- Enhance flower initiation
- Decrease nutrient residues in soil, reduce environmental pollution

Components that affect nutrient availability in the soil-rhizosphere system



Fertilizers need to be dissolved, and move to plant roots by diffusion. These processes may take some time



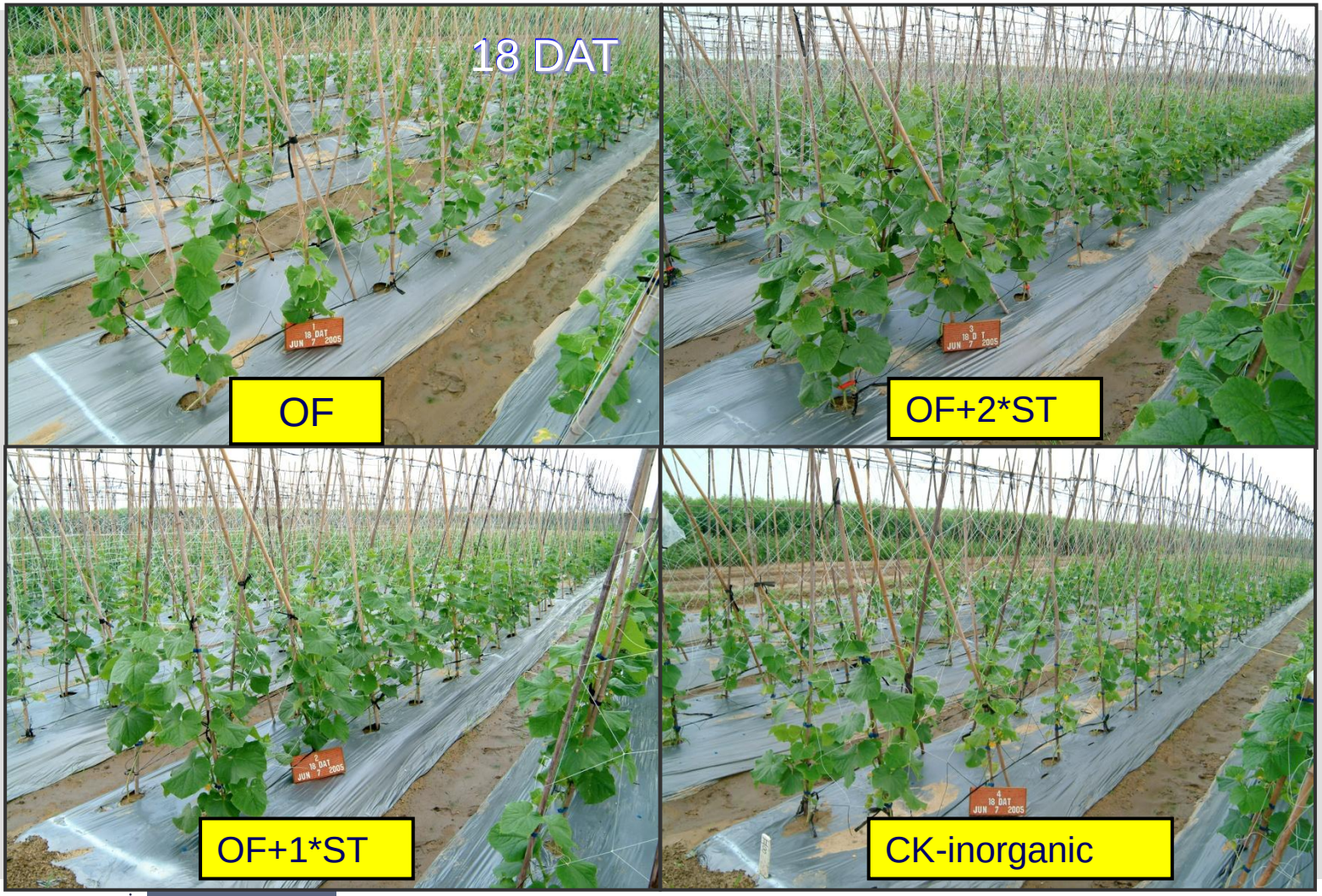
Source: modified from one slide in ISFM05S.ppt, ISFM-82-7500/CD published by PPI/PPIC.

Effects of ST on Cabbage

CM + ST

Chicken manure

Effect of ST on Cucumber



Method for SST

- Form: Concentrated liquid fertilizer solution
- Nutrients: include N,P and K
- Forms of N: need both NH_4-N and NO_3-N (in 1:4 ratio), the best ratio is dependent on crops
- Concentration: very high, 240 mg N/plant in 50 ml water (4800-9600-4800 ppm of N-P_2O_5-K_2O)
- Volume: 50 ml/plant, less than 1% soil max. water holding capacity (MWHC)
- Application method: near root vicinity
- Time: after transplanting, and at critical time
- Soil moisture when apply: dry

How to apply SST – Step 1

- Step 1: Apply manures and inorganic basal fertilizers in central band of beds or beside each plant.

How to apply SST – Step 2

- Step 2: Transplant seedlings when soil is dry.

How to apply SST – Step 3

- Step 3: Apply 50 ml concentrated Starter Solution near root vicinity in between plants and basal fertilizers immediately after transplanting.

How to apply SST – Step 4

- Step 4: Follow by **furrow irrigation** (80% full), allow water moving upward to sustain the nutrients near root zones. If furrow irrigation is not available, let starter solution be adsorbed on soil particle surfaces, stand at least **30 minutes** after application. Then, irrigate plants from other side of the plants using watering can.

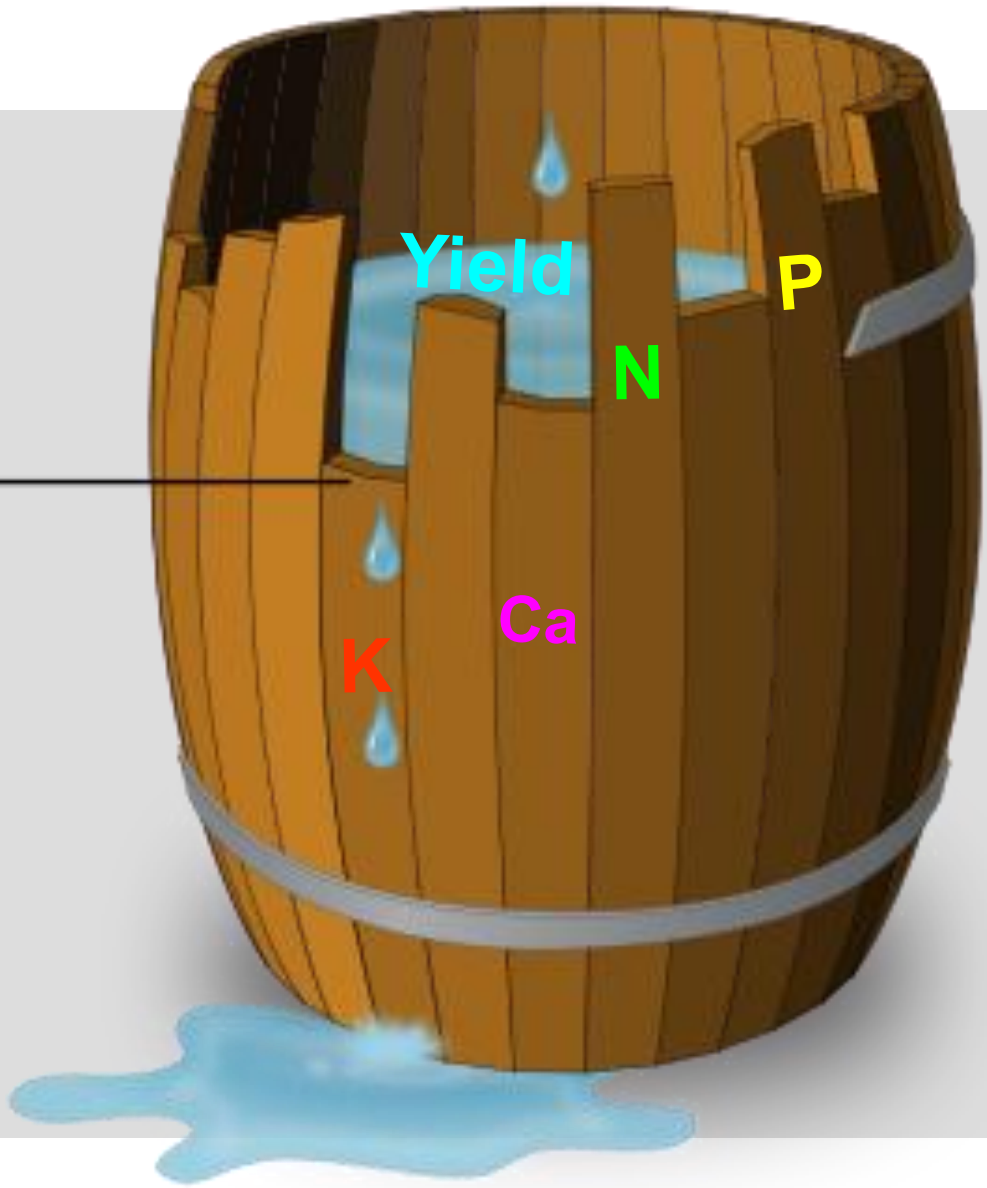
Balanced Fertilization

- Integration of SST into Nutrient Balanced Fertilization Technology (NBFT)

Law of the Minimum

If the crop growth is controlled by the scarcest nutrient, e.g. K,

then application excessive amounts of N, P can not improve the yield, unless the most limiting nutrient (K) is increased.



Source: http://en.wikipedia.org/wiki/Liebig's_law_of_the_minimum

Nutrient Balanced Fertilization Concept - NBF

4 Nutrient Balances

- Amounts: balances between nutrient uptake/total nutrient removal (outputs) and total fertilizers applied (inputs)
- N:P:K Ratio: balances between ratios of major nutrients N, P, and K
- Methods: balances between liquid, solid forms of fertilizer application
- Sources: balances between organic and inorganic fertilizer sources

NBF Concept 1 – Quantity Balance

Constraints

Over or low fertilizer inputs

Input: total fertilizer rates (mineral + organic)

Balance between

Output: total nutrient removal by crop harvests

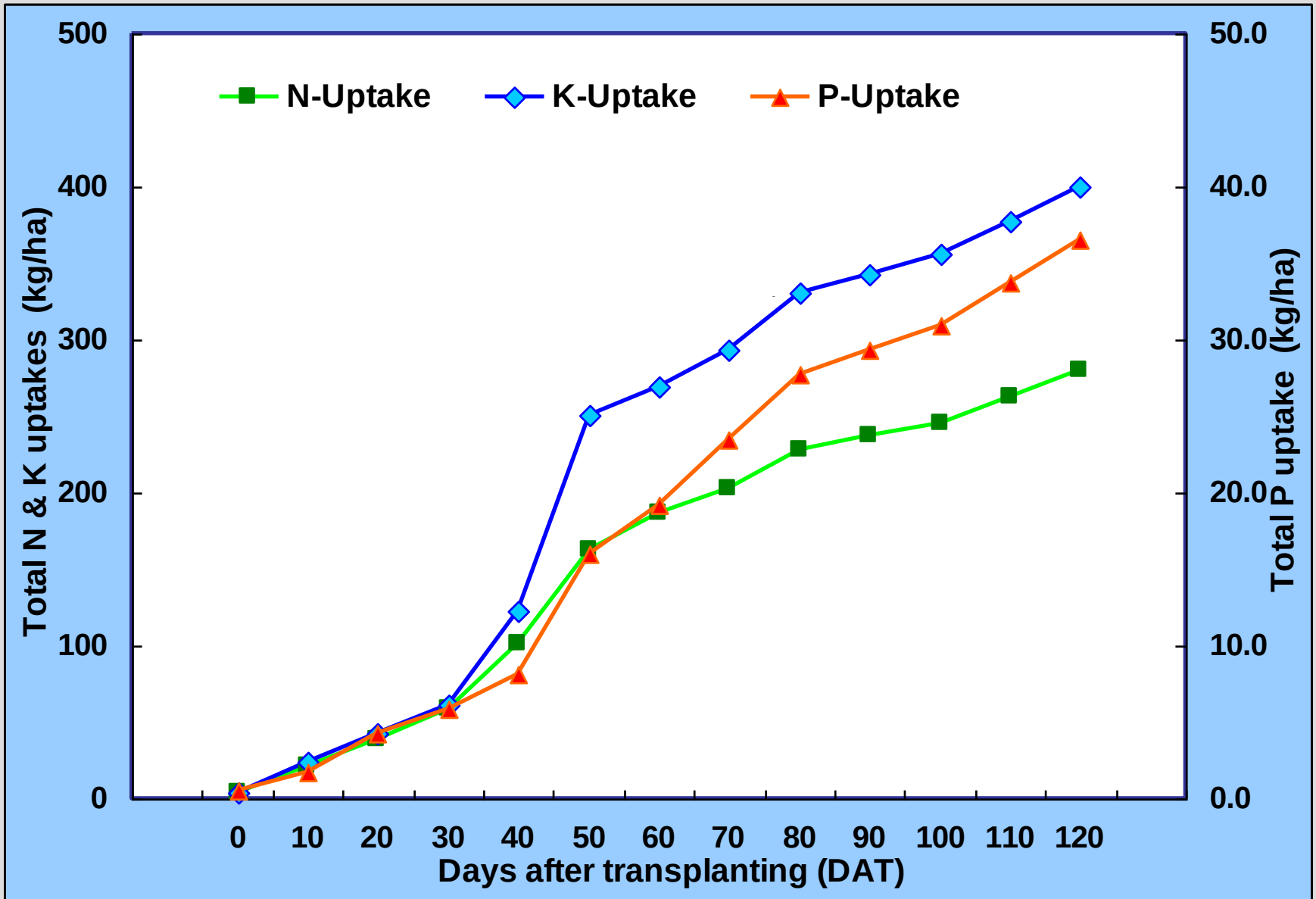
Application practice

Synchronize with plant's nutrient uptake pattern & amounts

Nutrient requirement pattern of tomato plant

Total N-P-K uptakes = 280 - 36 - 400 kg/ha (yield 80 t/ha)

N : P : K = 1 : 0.13 : 1.43



Adding fertilizers synchronized with the growth patterns of tomato plants

- Every crop has a unique dry matter accumulation pattern and nutrient uptake patterns
- Timing of fertilizer applications and amounts applied must match the growth pattern of crops for optimum efficiency
- Important growth stages for nutrient uptake occurred during early fruit initiation and fruit setting stages when maximum rate of nutrient accumulation takes place

NBF Concept 2 – N:P:K Ratio Balance

Constraints

Imbalanced N:P:K fertilizer application

N:P:K in total inputs

Balance between

N:P:K in plant total uptakes

Application practice

Apply fertilizers according to plant uptake's N:P:K ratio

NBF Concept 3 – Methods Balance

Constraints

Low fertilizer efficiency

Conc. liquid solution as starter and side-dress

Balance between

Solid side-dress

Application practice

Apply ST+ liquid and solid side-dress, apply close to root zone

NBF Concept 4 – Sources Balance

Constraints

Depletion of soil organic matter (SOM) & fertility

Organic fertilizer + organic amendment

Balance between

Inorganic fertilizer

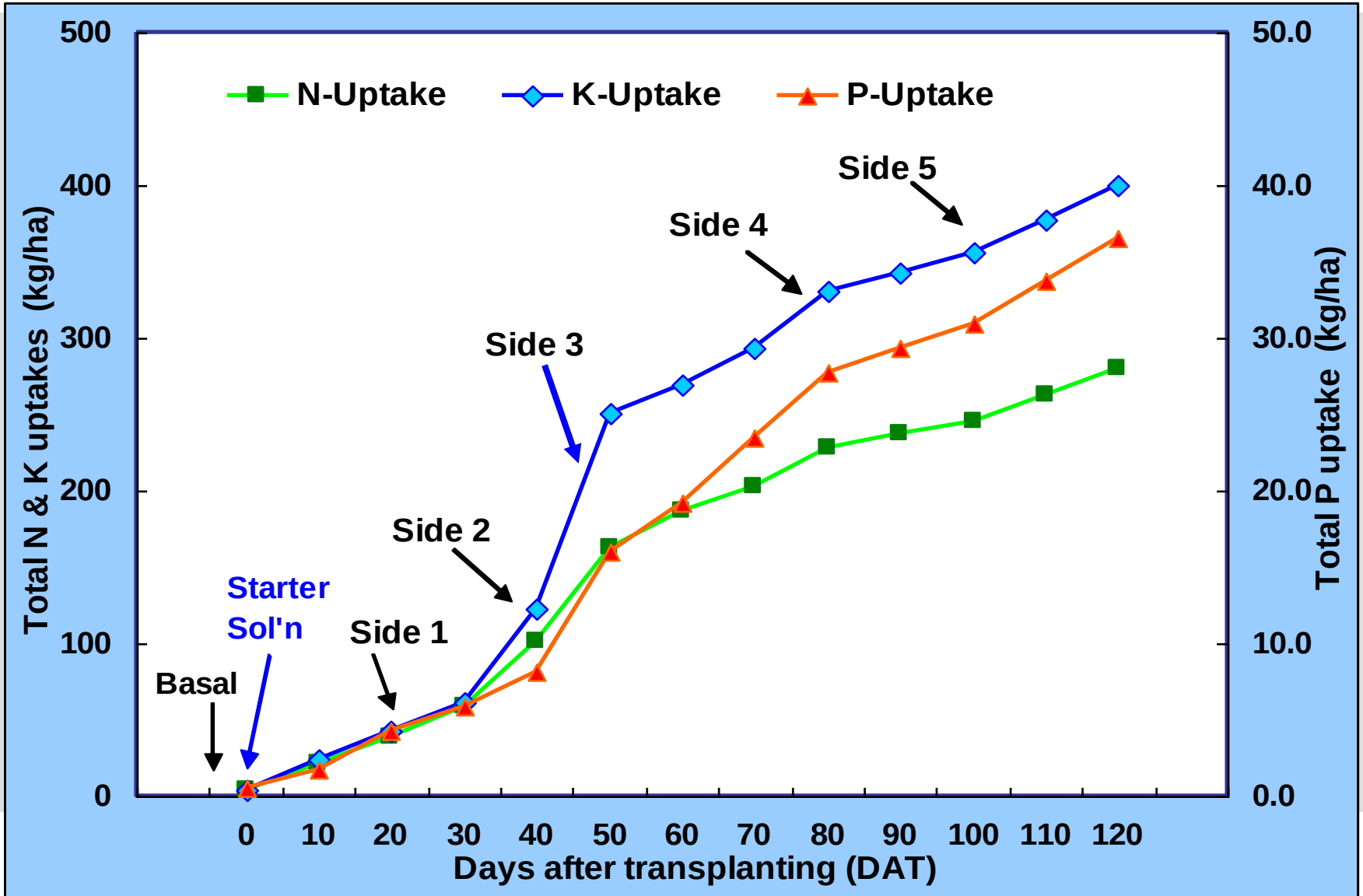
Application practice

Apply basal fertilizers in 2/3 organic & 1/3 inorganic forms

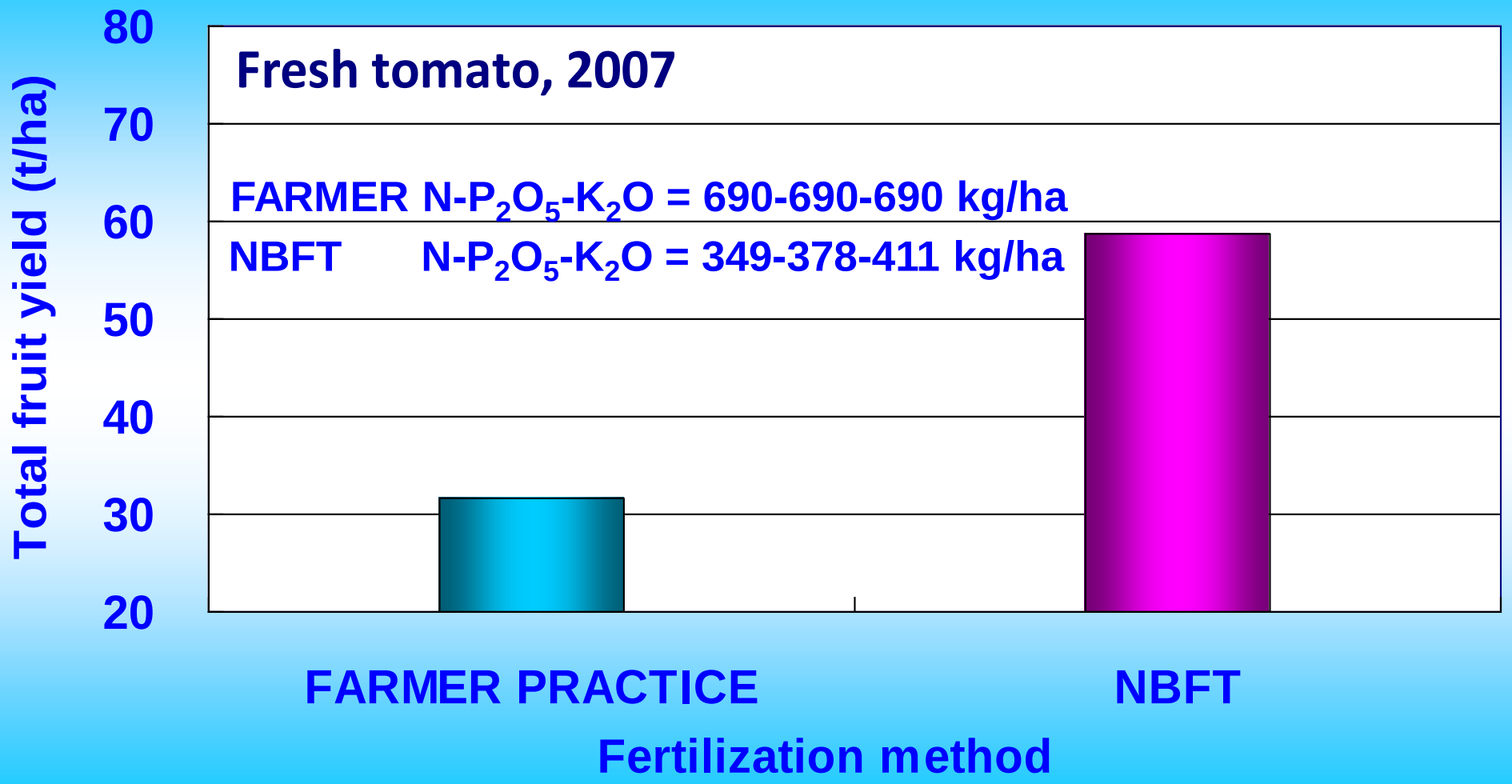
The Principles of Nutrient Balanced Fertilization

1. Decide total N-P_2O_5-K_2O fertilizer rate based on the yield target, nutrient uptake pattern of target vegetables and adjusted with soil fertility level
2. Apply 1/3~1/2 of total N-P_2O_5-K_2O rate as basal in band application, in which 2/3 of fertilizers are applied as organic fertilizer and 1/3 as inorganic fertilizer
3. Apply ST three times during the crop period, first immediately after transplanting, and second at 7~20 days after transplanting, and the third time at flowering or fruit setting stage
4. Apply 2~4 times solid inorganic fertilizers as side-dress depending on growth duration of the crops

NBFT Application for Tomato



Effect of NBFT to Fresh Tomato

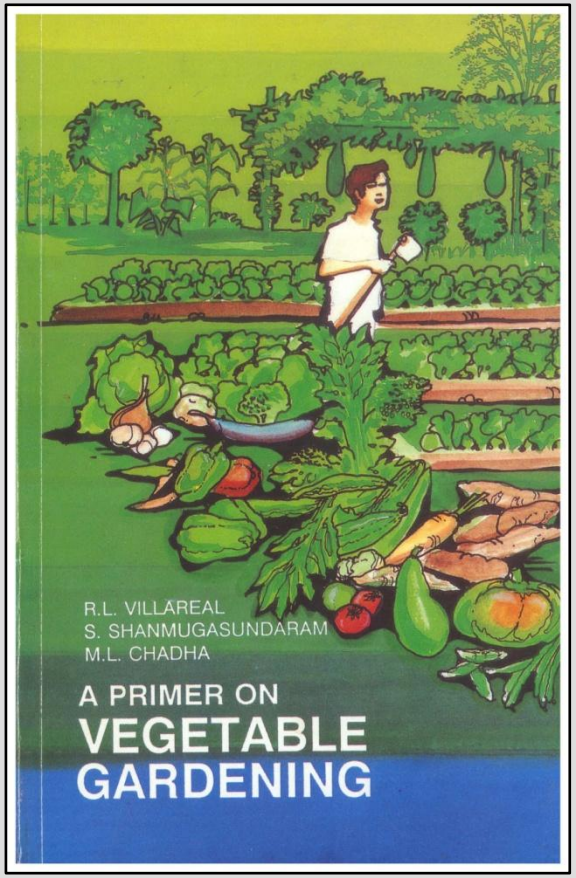


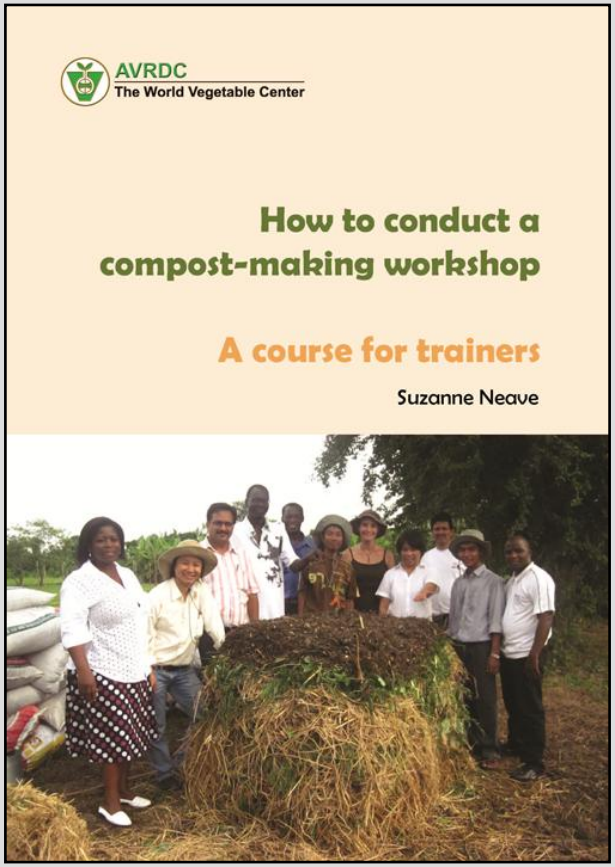
Benefits of NBFT

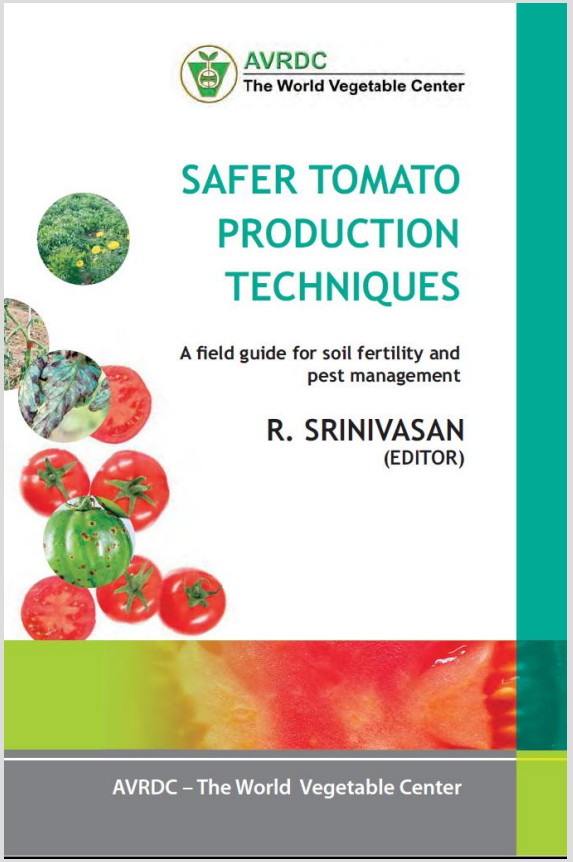
Promotion of balanced and efficient use of plant nutrients can:

- increase productivity/fertilizer efficiency
- improve farmer's profits
- minimize environmental risk due to over-fertilization
- reduce nutrient accumulation/ soil degradation
- replenish OM in soil
- maintain soil sustainability

Publications available online







Happy gardening

Thank You