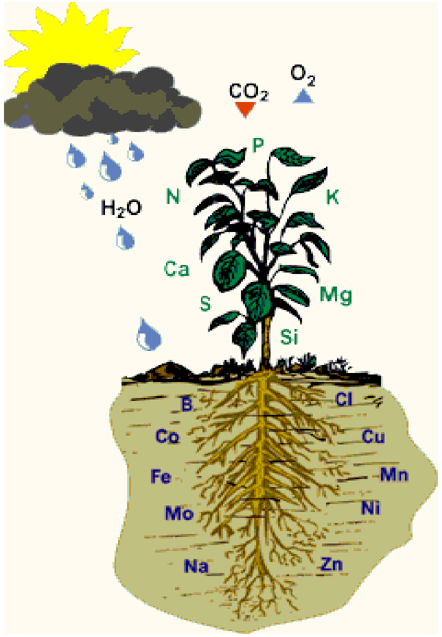
MINERAL NUTRITION TO IMPROVE YIELD AND QUALITY OF FRUIT BEARING VEGETABLES



Abdullah Ulaş

Erciyes University, Agriculture Faculty
Soil Science and Plant Nutrition Dept.
Kayseri, Turkey

World Population and Food Demand

World population (**7.2 bil.**) increasing at a rate of **80 million per year** and expected to be around **8.0 bil.** for the **year 2025** and **9.6 billion** for **2050** (FAO, 2015).

⇓

Increase in world **population** increases **food demand**

⇓

For this food demand, **production** have to **increase over 50%** from **current level**

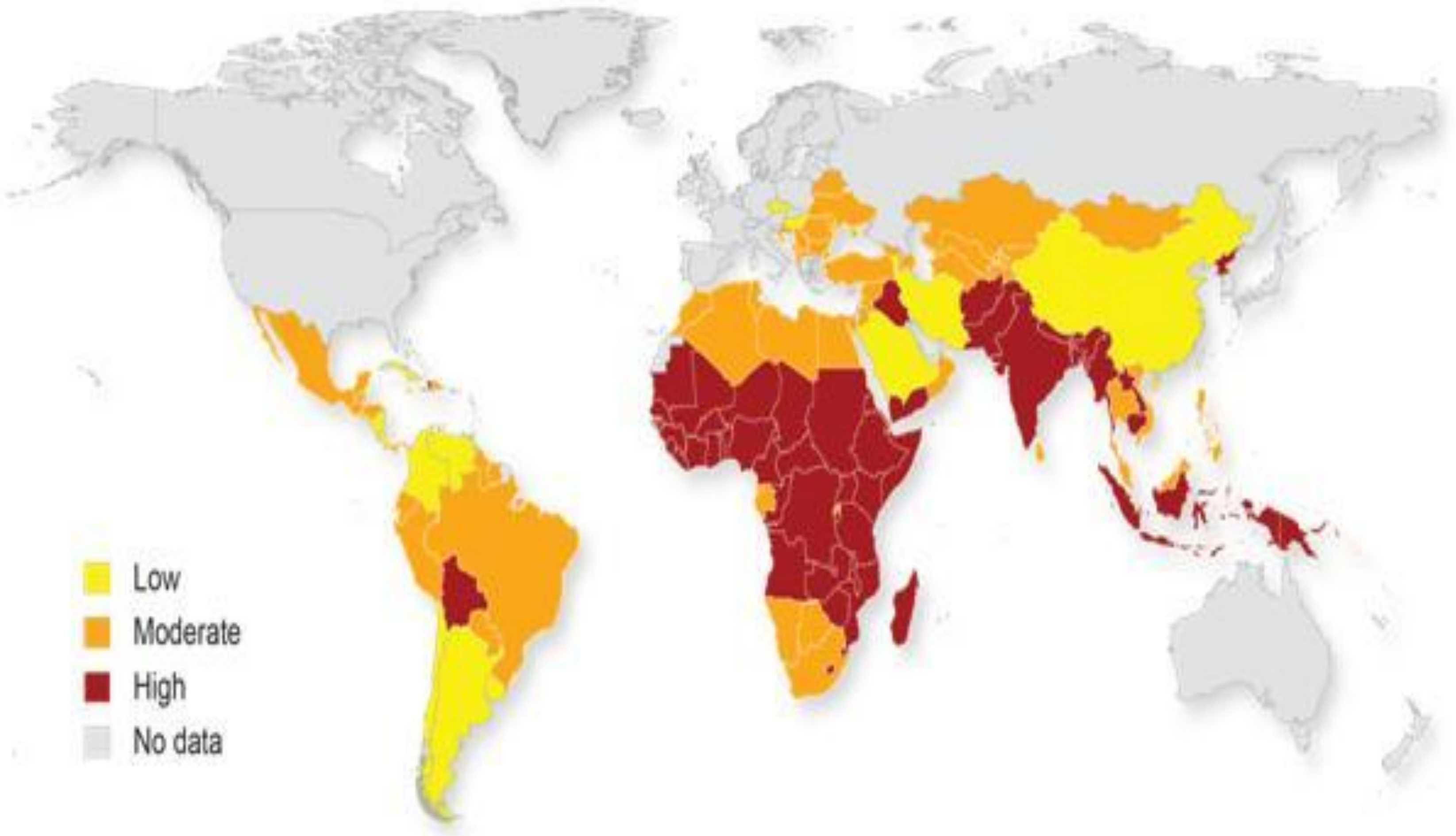
⇓

Increase **requires** more **application of fertilizer**

World Population and Food Demand

About 805 million people –
One in nine of the world`s population
were chronically undernourished!!!

Worldwide Severity of Most Common Micronutrient Deficiencies Vitamin A, Anemia, and Zinc

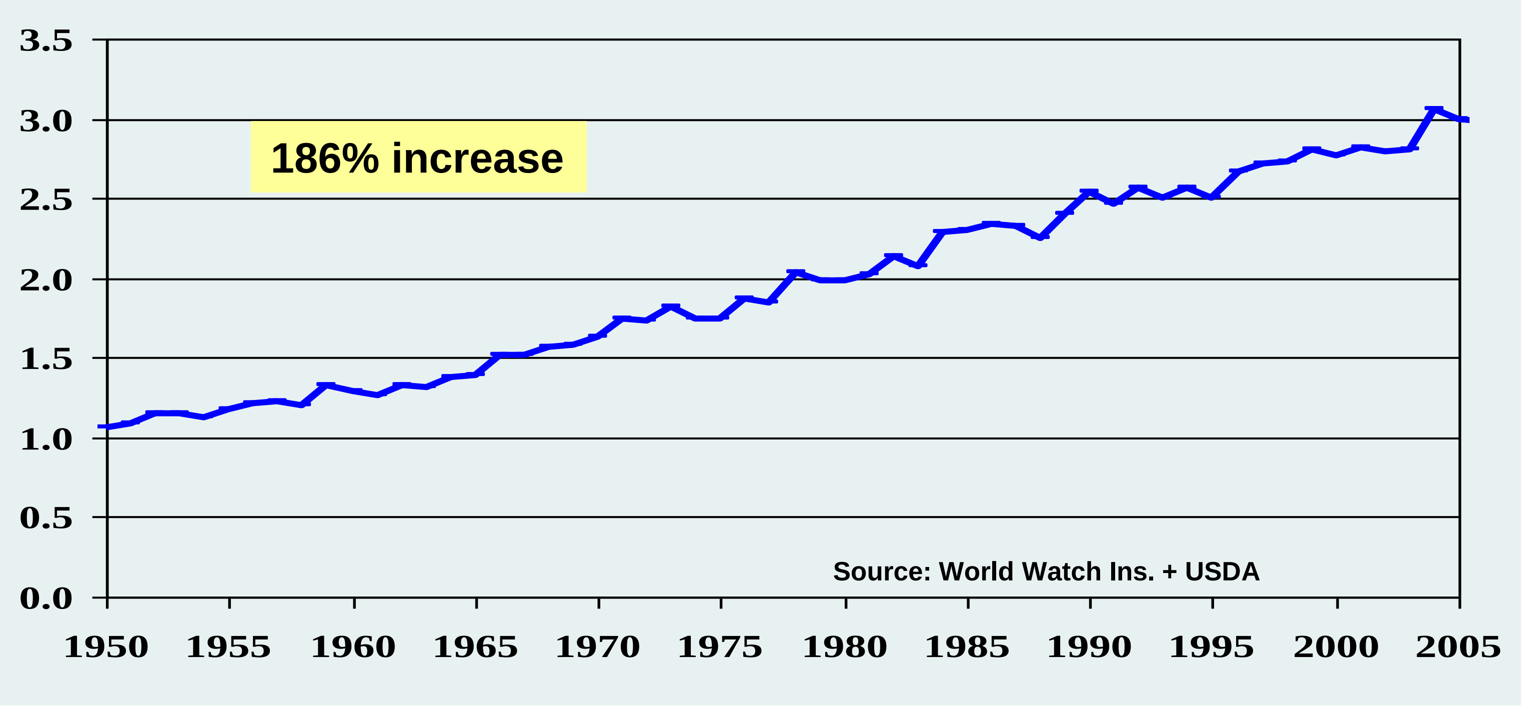


Source: FAO 2014

Increase in World Grain Yield

In the past world food demand was resolved by greatly increasing the inputs in agriculture (Green Revolution 1950-1970)

World grain yield (ton) per hectare 1950-2005



Green Revolution (1940s-1960s)

Breeding of new high-yielding, disease resistant, semi-dwarf cereal varieties

Irrigation infrastructure

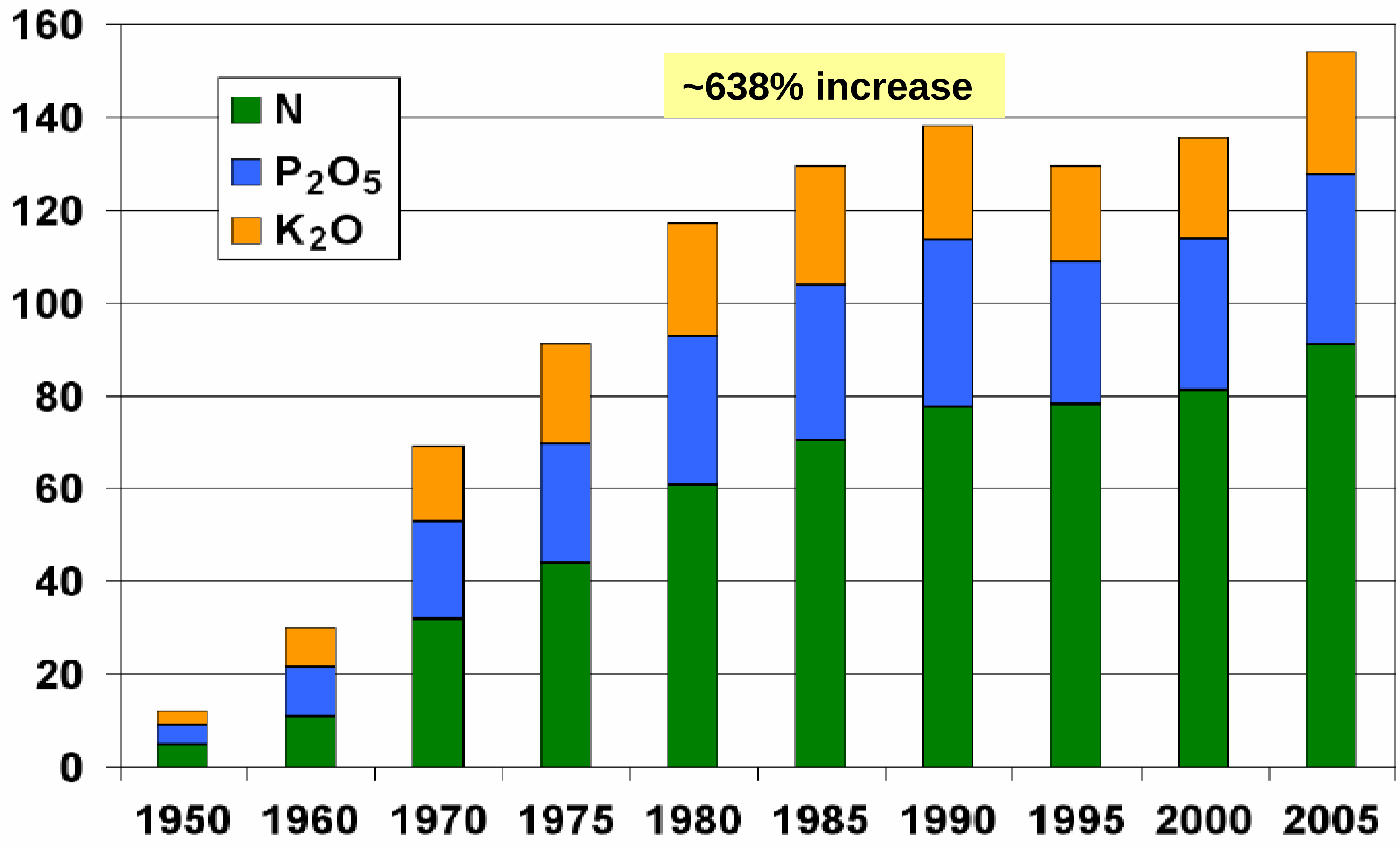
new mechanized technologies

synthetic fertilizers

❖ ***Dr. Norman E. Borlaug the "Father of the Green Revolution" receives the Congressional Gold Medal in 2007. Borlaug, a 1970 Nobel Laureate, was honored for his work in the 'Green Revolution,' saving over a billion people from starvation in India, Mexico, and the Middle East.***

Increase in World Fertilizer Use

World fertilizer use (million tonnes) 1950-2005



Source: FAO + IFA P. Csathó, 2007

Essential Plant Nutrients

➢A chemical element is considered an **essential element** if it **is required** for a plant **to complete** its **life cycle**

Chronology of discoveries of essentiality			
No	Element	Discoverer of Essentiality	Year
1	Carbon (C)	DeSaussure	1804
2	Hydrogen (H)	DeSaussure	1804
3	Oxygen (O)	DeSaussure	1804
4	Nitrogen (N)	DeSaussure	1804
5	Phosphorus (P)	Ville	1860
6	Potassium (K)	von Sachs, Knop	1860
7	Sulphur (S)	von Sachs, Knop	1865
8	Calcium (Ca)	von Sachs, Knop	1860
9	Magnesium (Mg)	von Sachs, Knop	1860

(Glass, 1989; Marschner, 1997)

Essential Plant Nutrients

Chronology of discoveries of essentiality			
No	Element	Discoverer of Essentiality	Year
10	Iron (Fe)	von Sachs, Knop	1860
11	Manganese (Mn)	McHargue	1922
12	Copper (Cu)	Lipman and	1931
13	Zinc (Zn)	MacKinney	1926
14	Molybdenum (Mo)	Sommer and Lipman	1938
15	Boron (B)	Arnon and Stout	1923
16	Chlorine (Cl)	Warington	1954
17	Nickel (Ni)	Broyer et al.	1987

(Glass, 1989; Marschner, 1997)

❖Researchers use hydroponic culture to determine which chemical elements are essential

Essential Plant Nutrients

Essential plant nutrients (17)

Frame work elements (Taken from air and water: 3)

- Carbon
- Hydrogen
- Oxygen

Mineral elements (Taken mainly from soil in ionic forms: 14)

Macronutrients (6)

Primary nutrients (3)

- Nitrogen
- Phosphorus
- Potassium

Secondary nutrients (3)

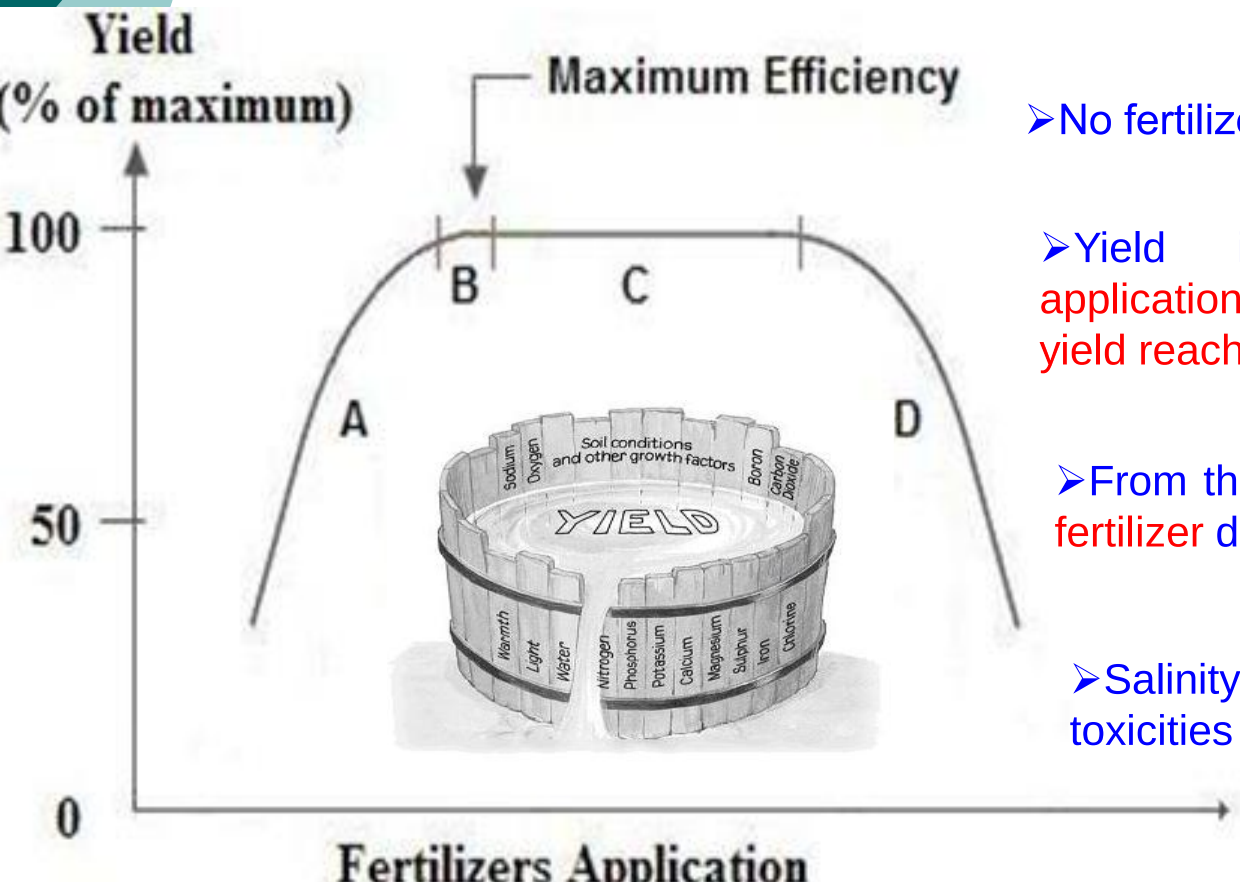
- Calcium
- Magnesium
- Sulphur

Micronutrients (8)

- Zinc
- Copper
- Manganese
- Iron
- Boron
- Molybdenum
- Chlorine
- Nickel

Crop Yield Response to Fertillizers Application

➢Crop yield is dependent on many factors, such as soil properties, irrigation, genetics, climate, cultural practices, pests and disease control and <u>fertilizer application</u>.



➢No fertilizer → yield is minimum

➢Yield increases as fertilizer application rate increases (A), then yield reaches to a maximum point (B).

➢From this point on, any addition of extra fertilizer does not increase the yield (C).

➢Salinity damages and specific nutrient toxicities occur, and yield declines (D).

Definition of Quality

- The word "quality" comes from the Latin qualitas that means attribute, property or basic nature of an object.

- Nowadays it can be defined as the "degree of excellence or superiority" (Kader, et al., 1985).

- We can say that a product is of better quality when it is superior in one or several attributes that are objectively or subjectively valued.

- Quality is a complex perception of many attributes that are simultaneously evaluated by the consumer either objective or subjectively

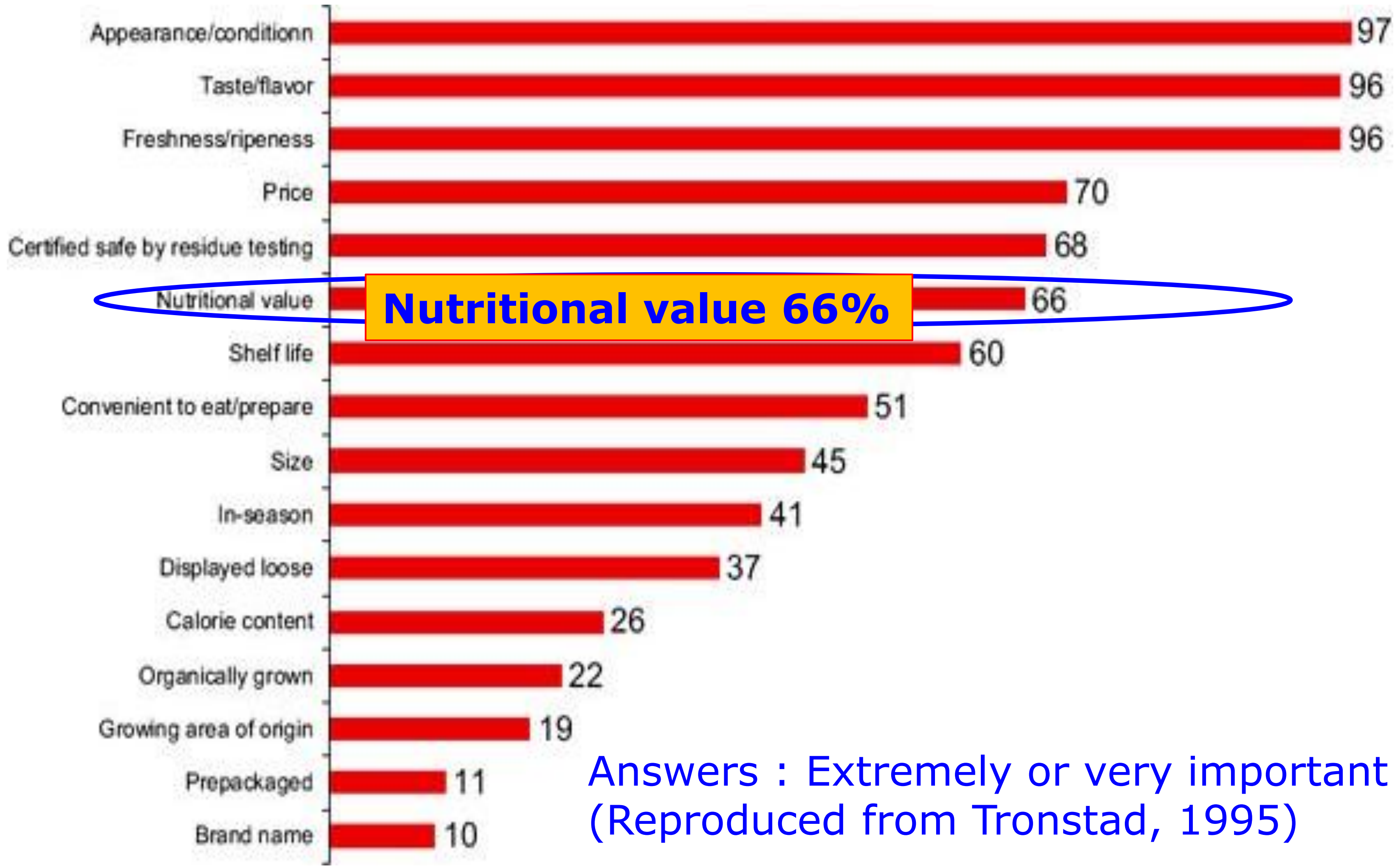
Definition of Quality

Which Parameters determine Quality?

Appearance	**Contents**
Shape	Minerals
Size	Carbohydrates
Weigth	Organic-N-compounds
Color	Oils and fatty acids
Freshness	Organic acids
Ripeness	Vitamines
Texture	Flavours
Sign of disease	Bioactive substances
Market value	**Nutritional value**

Judging the Quality of Tomato

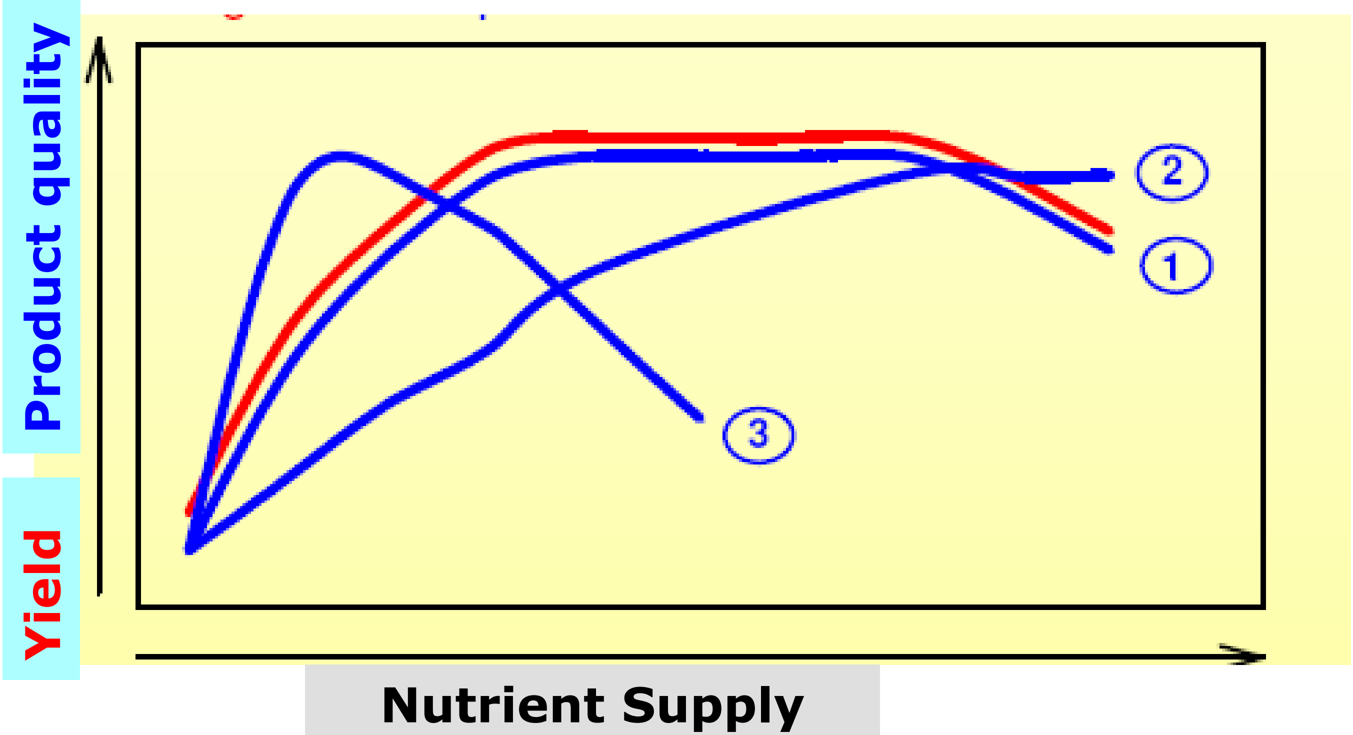
% answer by the different consumers



Answers : Extremely or very important
(Reproduced from Tronstad, 1995)

Relationship Between Nutrient supply - Yield and Quality

➢Yield and quality are often not increased synchronously by the amount of nutrient supply.



1: Yield and product quality curves overlap

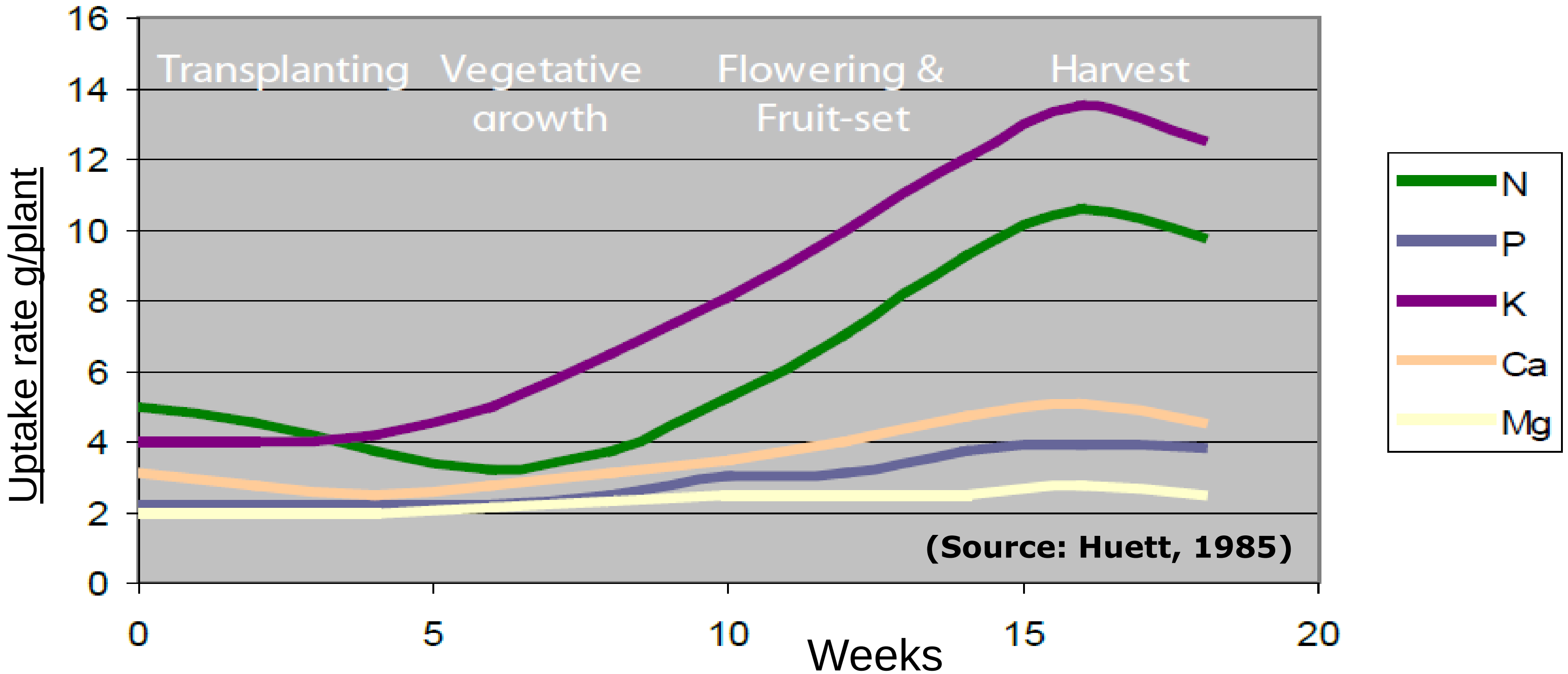
2: To reach maximum product quality, more nutrients are needed than to reach maximum yield

3: Product quality decreases with increasing mineral supply, before reaching maximum yield

Main Functions of Plant Nutrients

Nutrient	Functions
Nitrogen (N)	Synthesis of proteins (growth and yield).
Phosphorus (P)	Cellular division and formation of energetic structures.
Potassium (K)	Transport of sugars, stomata control, cofactor of many enzymes, reduces susceptibility to plant diseases and a-biotic stresses, counteracts salinity
Calcium (Ca)	A major building block in cell walls, and reduces susceptibility to diseases.
Sulphur (S)	Synthesis of essential amino acids cystin and methionine.
Magnesium (Mg)	Central part of chlorophyll molecule.
Iron (Fe)	Chlorophyll synthesis.
Manganese (Mn)	Necessary in the photosynthesis process.
Boron (B)	Formation of cell wall. Germination and elongation of pollen tube. Participates in the metabolism and transport of sugars.
Zinc (Zn)	Auxins synthesis.
Copper (Cu)	Influences in the metabolism of nitrogen and carbohydrates.
Molybdenum (Mo)	Component of nitrate-reductase and nitrogenase enzymes.

Uptake Dynamics of the Macro- and the Secondary Nutrients by a Tomato Plant

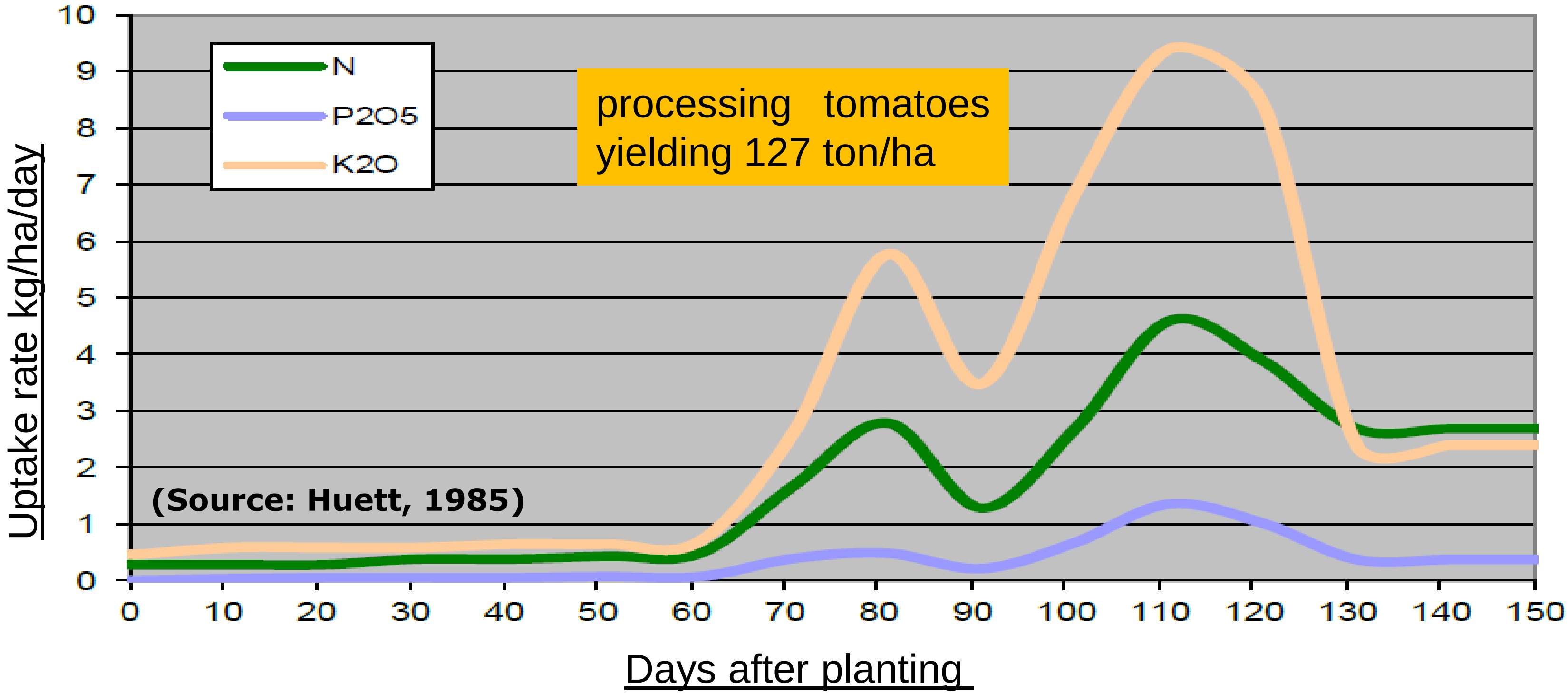


➢N and K uptake is initially slow but rapidly increases during the flowering stages.

➢K is peaking during fruit development, and nitrogen uptake occurs mainly after the formation of the first fruit.

➢P and secondary nutrients, Ca and Mg, are required at a relatively constant rate, throughout the life cycle of the tomato plant.

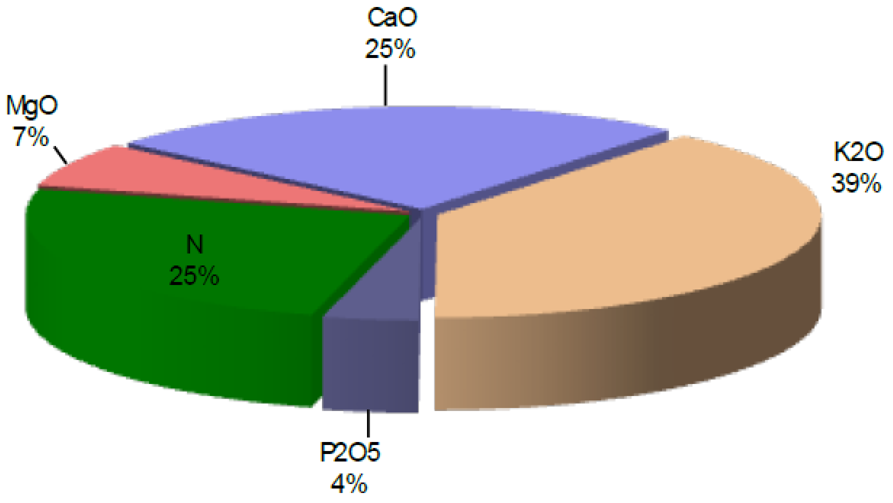
Uptake Dynamics of the Macro- and the Secondary Nutrients by a Tomato Plant



➢High absorption of nutrients occurs in the first 8 to 14 weeks of growth, and another peak takes place after the first fruit removal.

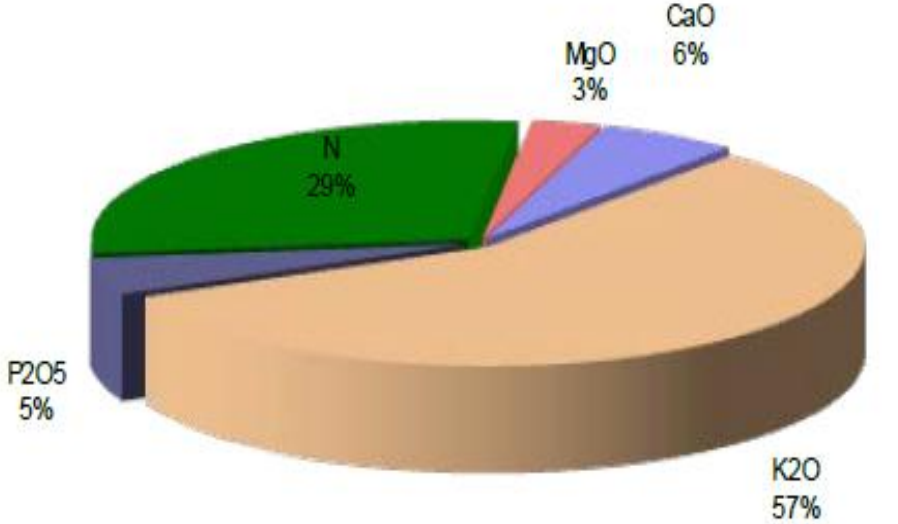
➢Plant requires high nitrogen application early in the growing season with supplemental applications after the fruit initiation stage.

Element composition of a tomato plant and fruit



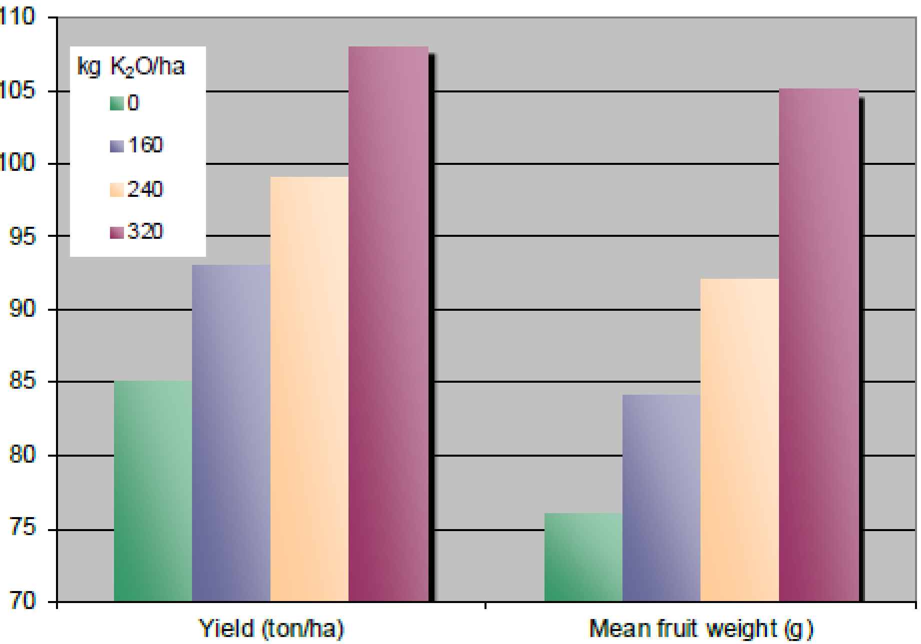
Element composition of a tomato plant
(Atherton and Rudich, 1986)

- The most prevalent nutrient found in the developed tomato plant and fruit is potassium (K), followed by nitrogen (N) and calcium (Ca).



Element composition of a tomato fruit
(Atherton and Rudich, 1986)

The effect of K rate on the yield and quality of processing tomatoes

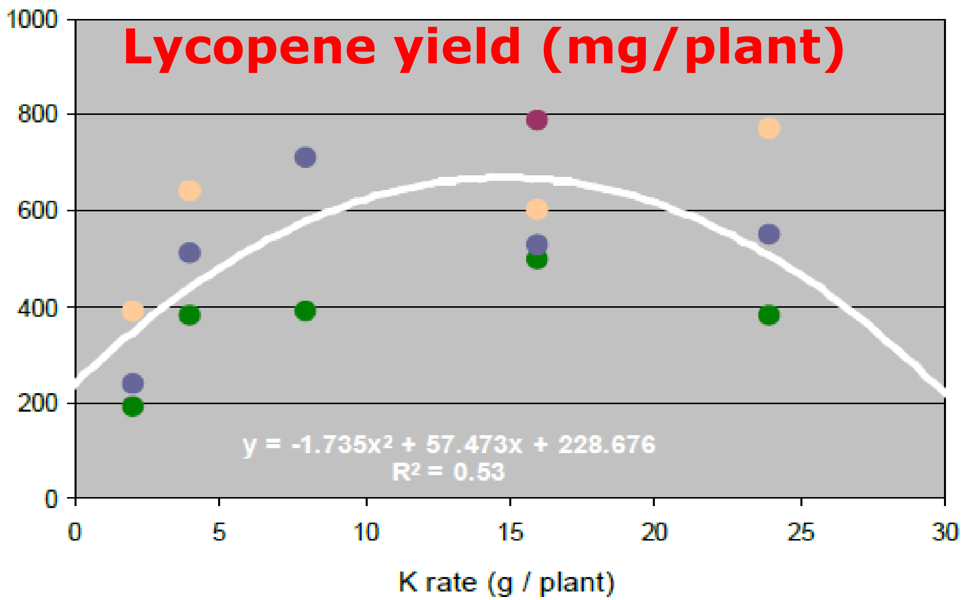


Key role of K in tomato plant:

➢Balancing of negative electrical charges of organic and mineral anions

➢Regulating metabolic processes in cells (activating enzymes - synthesis of protein, sugar, starch)

➢Regulation of osmotic pressure



➢Lycopene is an important constituent, as it enhances the resistance against cancer.

➢ K rates increases lycopene content.

➢The function is described by an optimum curve

Nutrients contents in tomato plant leaves and overall requirements of macro-nutrients under various growth conditions

Nutrient	Conc. in leaves (%)	
	Before fruiting	During fruiting
N	4.0-5.0	3.5-4.0
P	0.5-0.8	0.4-0.6
K	3.5-4.5	2.8-4.0
Ca	0.9-1.8	1.0-2.0
Mg	0.5-0.8	0.4-1.0
S	0.4-0.8	0.4-0.8

Nutrient	Conc. in leaves (ppm)	
	Before fruiting	During fruiting
Fe	50-200	50-200
Zn	25-60	25-60
Mn	50-125	50-125
Cu	8-20	8-20
B	35-60	35-60
Mo	1-5	1-5

1.0 ton tomato ► 2.5 – 3.0 kg N, 0.8-0.65 kg P_2O_5 , 5.2-4.5 kg K_2O/ha

	Yield (ton/ha)	N	P_2O_5	K_2O	CaO	MgO
Outdoor	80	241	62	416	234	67
	150	417	108	724	374	110
Processing	60	196	50	336	203	56
	100	303	78	522	295	84
Tunnels	100	294	76	508	279	80
	200	536	139	934	463	138
Greenhouse	120	328	85	570	289	86
	240	608	158	1065	491	152

Nutritional and Health Values of the Cucumber Fruit

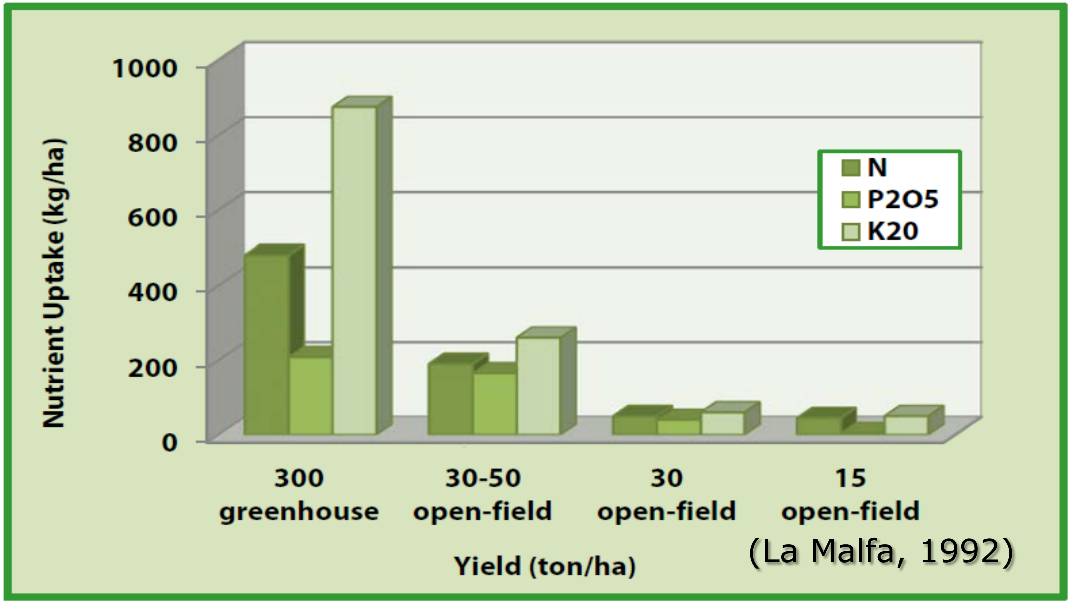
Energy	12 cal	Vitamin A	45 IU
Protein	0.6 g	Vitamin B1	0.03 g
Fat	0.1 g	Vitamin B2	0.02 g
Carbohydrate	2.2 – 3.6 g	Niacin (vitamin B3)	0.3 g
Dietary fiber	0.5 g	**Vitamin C**	**12 mg**
Calcium	**14 mg**		
Magnesium	**15 mg**	Iron	0.3 mg
Potassium	**124 mg**	Sodium	5 mg
Phosphorus	**24 mg**	zinc	0.2 mg

➢The high water content makes cucumbers a diuretic and it also has a cleansing action within the body by removing accumulated pockets of old waste material and chemical toxins.

➢Cucumbers help eliminate uric acid which is beneficial for those who have arthritis, and its fiber-rich skin and high levels of potassium and magnesium helps regulate blood pressure and help promote nutrient functions.

➢The magnesium content in cucumbers also relaxes nerves and muscles and keeps blood circulating smoothly.

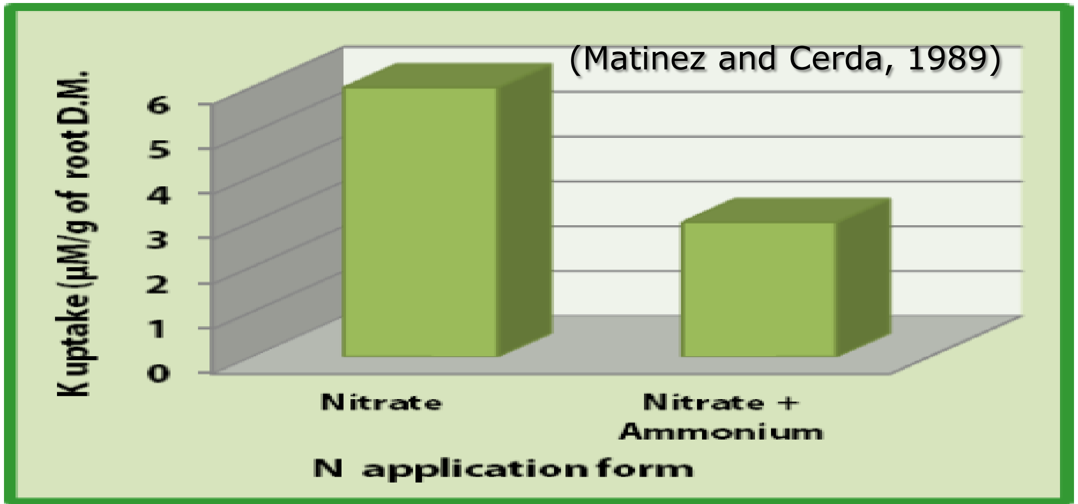
Effect of N-P-K Nutrients on Yields of Cucumber Plants Growing at Various Conditions



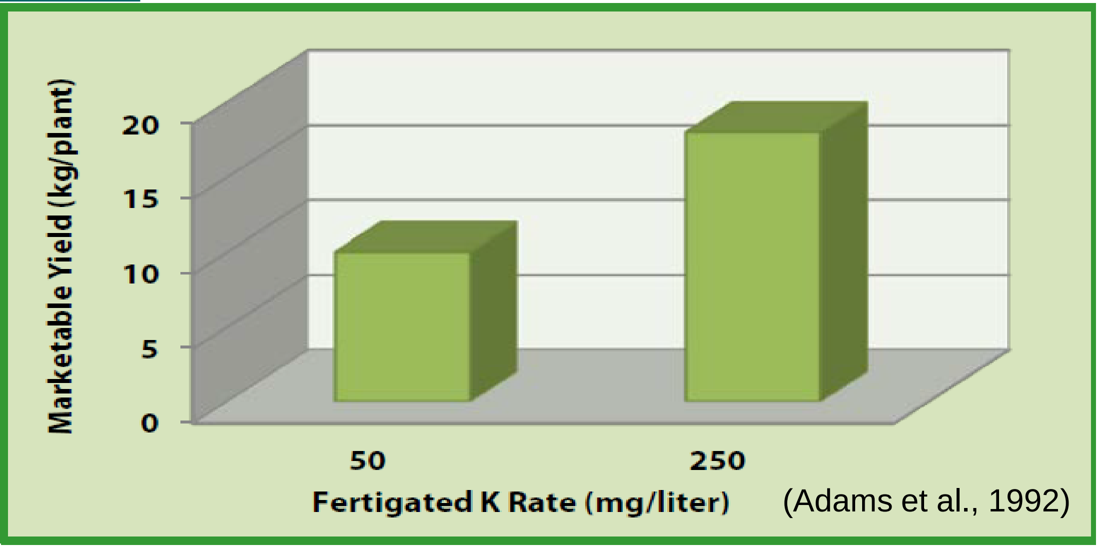
	Open Field	Greenhouse
Expected yield (Ton/ha)	15 - 30	120 - 300
Typical N:P:K ratio	1:0.5:1.5	1:0.5:2

- ➢Cucumbers are unique among most crops in their high potassium requirements
- ➢Cucumber plant is one of the only crops requiring more potassium than nitrogen

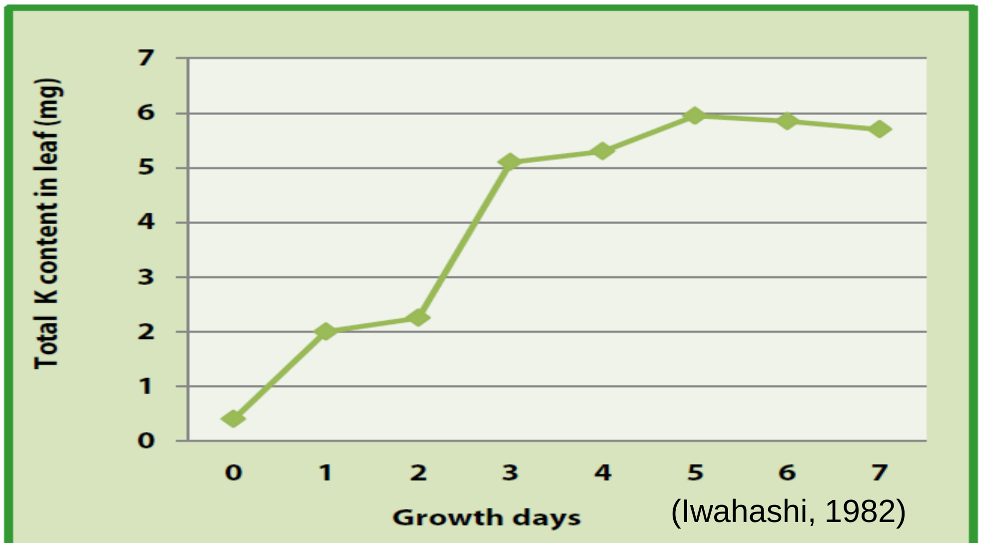
- ➢Uptake of K is greatly inhibited in cucumber seedlings fed by nutrient solution containing NH_4^+ + NO_3^- (2:1 ratio), compared to NO_3^- only

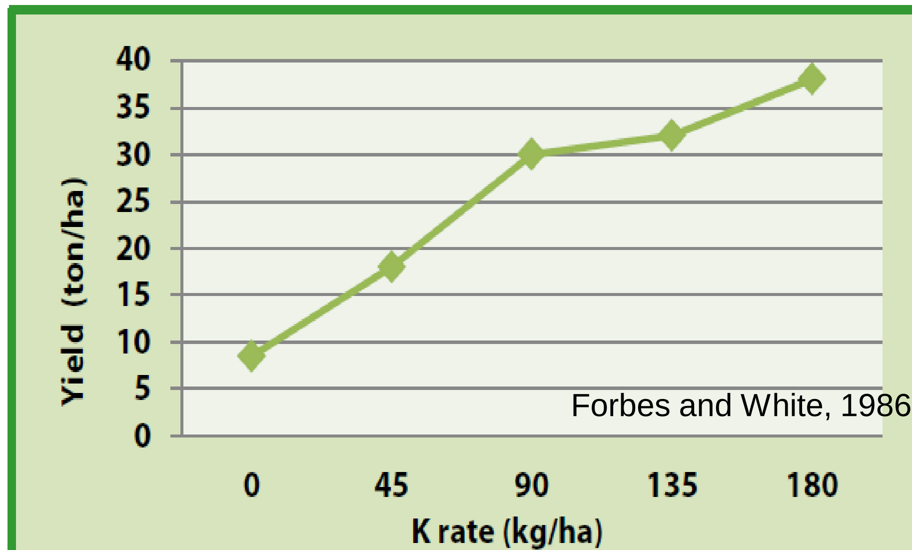


Role of Potassium Nutrient in Cucumber Yield



➢Yield was increased by 91% from 9.98 to 19.1 kg/plant when the potassium level was raised from 50 to 250 mg/l grown on peat bags





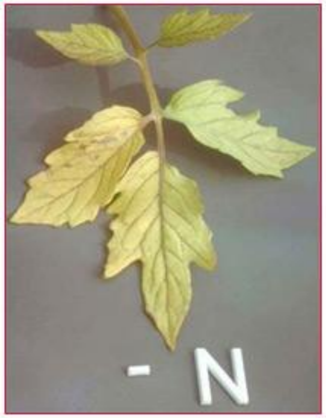
Nutrients contents in cucumber plant leaves and overall requirements of macro-nutrients under various growth conditions

Nutrient	Unit	Deficient	Low	Normal	High	Excessive
Nitrogen	%	<1.8	1.8–2.5	2.5–4.5	4.5–6	>6
Phosphorus	%	<0.20	0.20–0.3	0.3–0.7	0.7–1.0	>1.0
Potassium (K)	%	<2.0	2.0–3.0	3.0–4.0	4.0–5.0	>5.0

1.0 ton cucumber ► 1.7 – 3.1 kg N, 0.6 - 0.8 kg P_2O_5 , 2.7- 4.3 kg K_2O/ha

Growing method	Expected yield (t/ha)	N	P_2O_5	K_2O	MgO	CaO
		Kg / ha				
Under glass	300	450-500	200-250	800-1,000	130	300
Outdoor crop	High-yielding	170	130	270		
Outdoor crop	30-40	100	100	200		
Outdoor crop	30	50	40	80		
Outdoor crop	15	47	13	65		

Nitrogen (N) Deficiency Symptoms



A light red cast can also be seen on the veins and petioles. Under nitrogen deficiency, the older mature leaves gradually change from their normal characteristic green appearance to a much paler green. As the deficiency progresses these older leaves become uniformly yellow (chlorotic).

Capsicum—pale-green to yellow nitrogen-deficient leaf (right), healthy leaf (left)

2-Phosphorus (P) Deficiency Symptoms

As a rule, P deficiency symptoms are not very distinct and thus difficult to identify. A major visual symptom is that the plants are dwarfed or stunted.

Tomato—phosphorus-deficient seedling
(right) is dark reddish and stunted

3-Potassium (K) Deficiency Symptoms

Typical potassium (K) deficiency of fruit is characterized by color development disorders,including greenback, blotch ripening and boxy fruit

The leaves on the left-hand photo show more advanced deficiency status, with necrosis in the interveinal spaces between the main veins along with interveinal chlorosis. This group of symptoms is very characteristic of K deficiency symptoms.

4-Calcium (Ca) Deficiency Symptoms

These calcium-deficient leaves show necrosis around the base of the leaves. The very low mobility of calcium is a major factor determining the expression of calcium deficiency symptoms in plants.

Classic symptoms of calcium deficiency include blossomend rot (BER) burning of the end part of tomato fruits.

The blossom-end area darkens and flattens out, then appearing leathery and dark brown, and finally it collapses and secondary pathogens take over the fruit.

5-Mangnesium (Mg) Deficiency Symptoms

Tomato—veins remain green (C. Chen)

Magnesium-deficient tomato leaves show advanced interveinal chlorosis, with necrosis developing in the highly chlorotic tissue.

In the case of magnesium deficiency the symptoms generally start with mottled chlorotic areas developing in the interveinal tissue.

The interveinal laminae tissue tends to expand proportionately more than the other leaf tissues, producing a raised puckered surface, with the top of the puckers progressively going from chlorotic to necrotic

6-Boron (B) Deficiency Symptoms

This boron-deficient leaf shows a light general chlorosis.

Boron is an essential plant nutrient, however, when exceeding the required level, it may be toxic.
Less than 20 µg/g deficient, 30–70 µg/g optimal and over 100 µg/g toxic.

Boron is poorly transported in the phloem. Boron deficiency symptoms generally appear in younger plants at the propagation stage.

Slight interveinal chlorosis in older leaves followed by yellow to orange tinting in middle and older leaves.

Leaves and stems are brittle and corky, split and swollen miss-shaped fruit

Thank you…

… for attention !