VII. POTASSIUM

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Outline

7.1 INTRODUCTION

- Potassium is macro nutrient (essential and required in high amount)
- Potasssium in soil as limiting factor for high crop productivity, especialy in acid mineral soil and peat soil.
- K deficiency : in acid mineral soil and peat soil, Why …?
- How to manage K?

7.1 INTRODUCTION

- Scr umum, K dalam tanah sering ketersediaannya rendah dan tidak mencukupi kebutuhan K untuk produksi tanaman yang tinggi.
- Akibatnya tanaman sering menunjukkan gejala defisiensi K
- Oki, utk produksi yang tinggi perlu pemupukan K
- Bgm pemupukan K yang efektif dan efisien, faktor-faktor apa saja yang mempengaruhi efektivitas dan efisiensi pemupukan K perlu diketahui dg baik.

7.1 INTRODUCTION

Table 2.
Distribution of Soils With Reserves of K That Are Considered to Be Too Low for Crop Production

	Total Area	K-Deficient Area	% of Area Deficient in K
	(million ha)	(million ha)	
Africa			
Wetland tropics	238.7	2.4	1
Acid savannas	252.5	126.2	50
Steep-land tropics	265.2	23.9	9
Semiarid tropics	402.8	48.3	12
Subtotal	1,159.2	200.8	17
Asia			
Wetland tropics	123.9	13.6	11
Acid savannas	131.0	66.8	51
Steep-land tropics	415.5	128.8	31
Semiarid tropics	299.5	12.0	4
Subtotal	969.9	221.2	21
Latin America			
Wetland tropics	331.6	3.3	1
Acid savannas	142.5	94.1	66
Steep-land tropics	372.0	126.5	34
Semiarid tropics	303.4	106.2	33
Subtotal	1,149.5	330.1	29
TOTAL	3,278.8	752.2	23

Source: Conto, Sanchez, and Buol (1981).

7.2. FUNCTIONS & FORMS OF K IN PLANTS

Established date for essentiality/researchers:

- 1866 (Bimer and Lacanus)

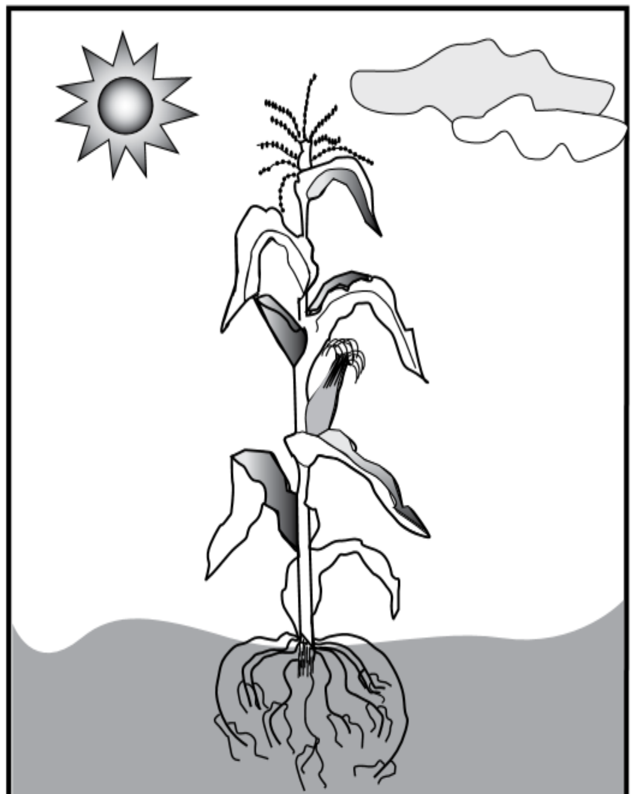
Functions in plants:

- Involved in maintaining the water status of the plant, the turgor pressure of its cells, and the opening and closing of its stomata.
- Required for the accumulation and translocation of newly formed carbohydrates.

7.2. FUNCTIONS & FORMS OF K IN PLANTS

How Potassium Functions in Plants

- *Helps retard crop diseases.*
- *Builds celluose needed for stalk and stem strength.*
- *Aids in photosynthesis and food function.*
- *Increases root growth and improves drought resistance.*



- *Produces grain rich in starch.*
- *Necessary for plant protein formation.*
- *Reduces water loss and wilting.*
- *Assists many enzyme actions.*

7.2. FUNCTIONS & FORMS OF K IN PLANTS

Stomata (plant leaf pores)
natural size 0.055 mm

Potassium ensures the turgor, or rigidity of plant cells. While the guard cells surrounding the stomata are rigid the stomata remain open, allowing carbon dioxide to pass into the leaf where the carbon is converted to sugars.

Sugar beet well supplied with potassium has a large leaf area to produce sugars. Lack of potassium leads to severe wilting (as below).

7.2. FUNCTIONS & FORMS OF K IN PLANTS

Table 8.
Effect of P and K Fertilizer on the Incidence of Cotton Blight

Treatment	kg P_2O_5/ha	kg K_2O/ha	Incidence of Cotton Blight
			(%)
Control (mineral N to all plots)	-	-	21.0
+P	90	-	20.0
+K	-	110	11.0
+P + K	90	110	0.4
+P + 1.5K	90	165	1.5
+P + 2K	90	220	0.5

Source: Chang and Liang (1978).

Content and distribution in plants

- Consists of 1.00% to 5.00% of the dry weight of leaf tissue with sufficiency values from 1.50% to 3.00% in recently mature leaf tissue for many crop plants.
- Considered deficient or in excess when K critical values are less than 1.50% or greater than 5.00%, respectively.
- See pages 136–137 for a listing of critical values and sufficiency ranges for a number of crop plants.
- When in excess, K levels may exceed the sufficiency level by two- to three-fold.
- Sufficient K can be as high as 6.00% to 8.00% in the stem tissue of some vegetable crops.
- Highest concentrations are found in new leaves, their petioles, and plant stems, content in leaves decreasing with age.
- High-yielding crops contain from 50 to 500 lbs K/A (56 to 560 kg/ha), with crops, such as banana containing 1,500 lbs/A (1,680 kg/ha).

Content and distribution in plant

- Most plants will absorb more K than they need; this excess is frequently referred to as *luxury consumption*.
- Harvest of most fruits removes sizable quantities of K from the soil.
- Because K does not exist in combined form in the plant, it can be extracted easily from fresh or dried tissue, the extracted concentration essentially equals that of the total, with some vegetable crops considered K deficient when extracted sap from fresh stems and petioles contain less than 2,000 ppm K, and adequate when the K content is greater than 3,000 ppm.

Interaction with other elements:

- Relationship between K and Mg is well known, as is the relationship between K and Ca; high K plant contents first result in a Mg deficiency, and when K is in greater imbalance, will cause a Ca deficiency.
- The K-to-Mg and K-to-Ca ratios are used as DRIS norms for interpreting a plant analysis result (see Beverly, 1998).
- The ammonium (NH_4^+) cation plays a role in the balance that exists among the three cations, K^+, Ca^{2+}, and Mg^{2+}.

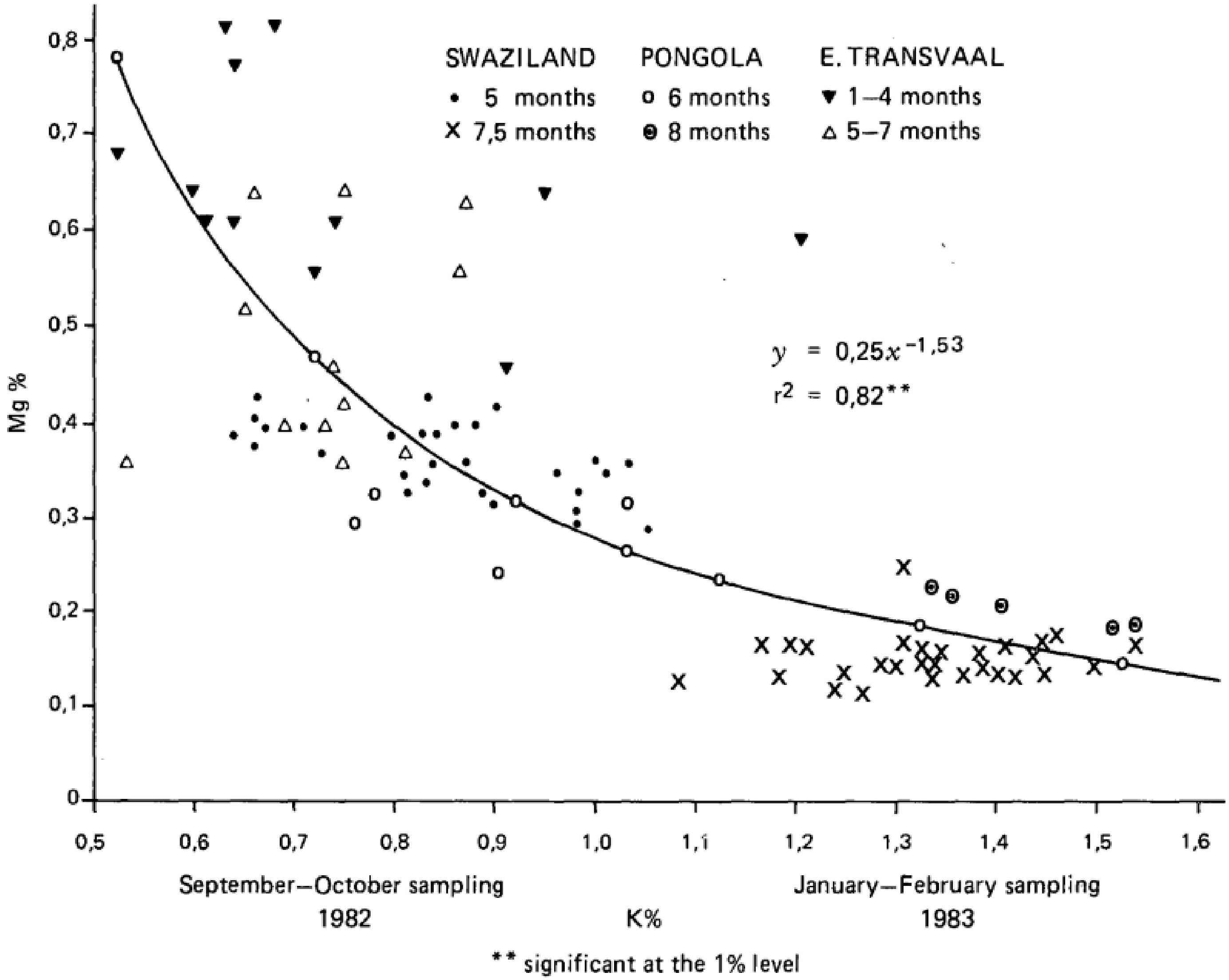
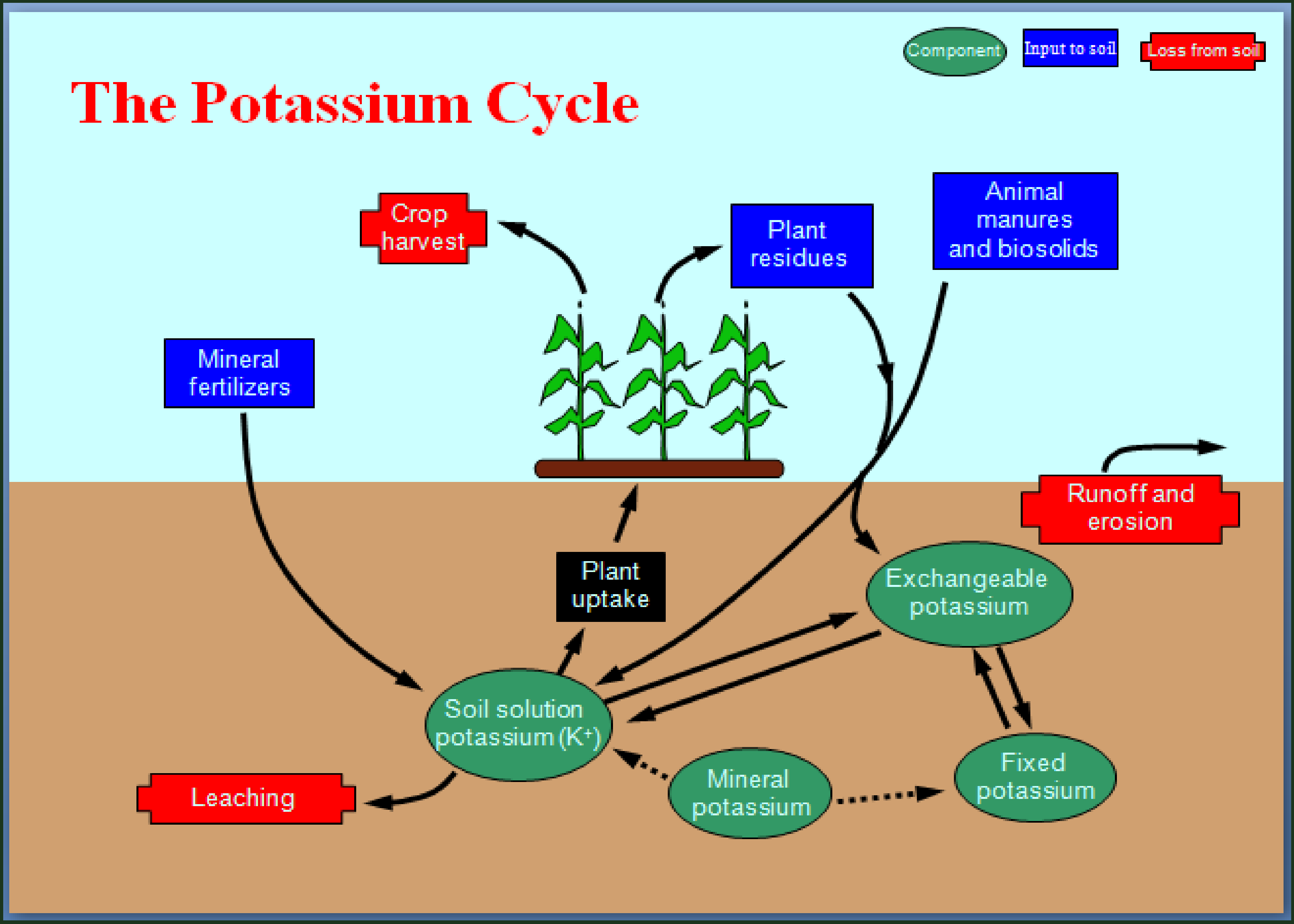


FIGURE 6 Changes in the relationship between third leaf K and Mg values after a winter harvest on estates in Swaziland, Pongola and the Eastern Transvaal.

K Cycles

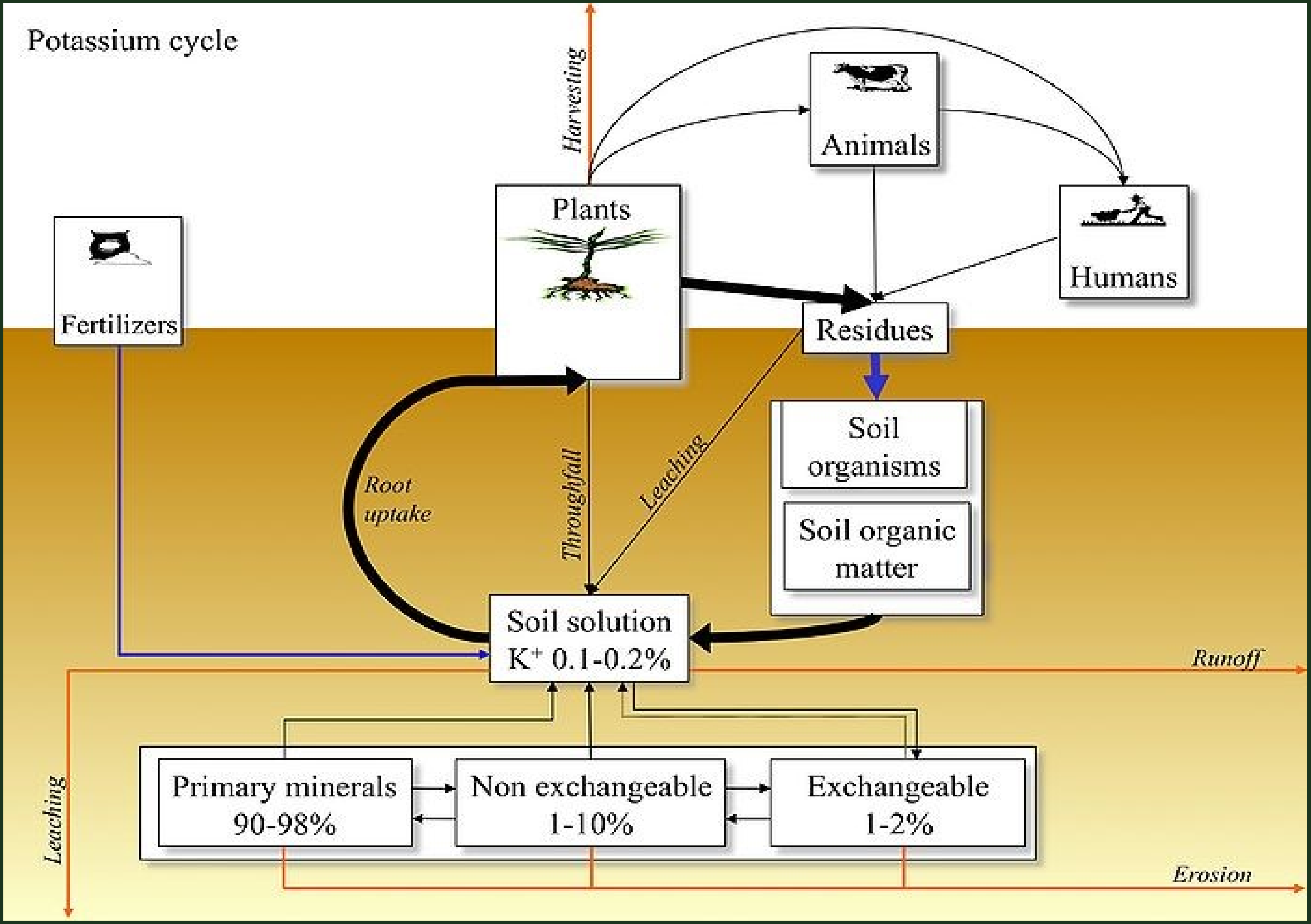
- Input: soil K sources
- Output: Soil K loss
- Process: K behaviour in soil

7.3 K cycles



Component
Input to soil
Loss from soil
The Potassium Cycle
Crop harvest
Plant residues
Animal manures and biosolids
Mineral fertilizers
Runoff and erosion
Plant uptake
Exchangeable potassium
Soil solution potassium (K+)
Leaching
Mineral potassium
Fixed potassium

7.3 K cycles


Potassium cycle
Harvesting
Animals
Plants
Humans
Fertilizers
Residues
Soil organisms
Soil organic matter
Root uptake
Throughfall
Leaching
Soil solution
K⁺ 0.1-0.2%
Runoff
Leaching
Primary minerals
90-98%
Non exchangeable
1-10%
Exchangeable
1-2%
Erosion

7.3 K cycles

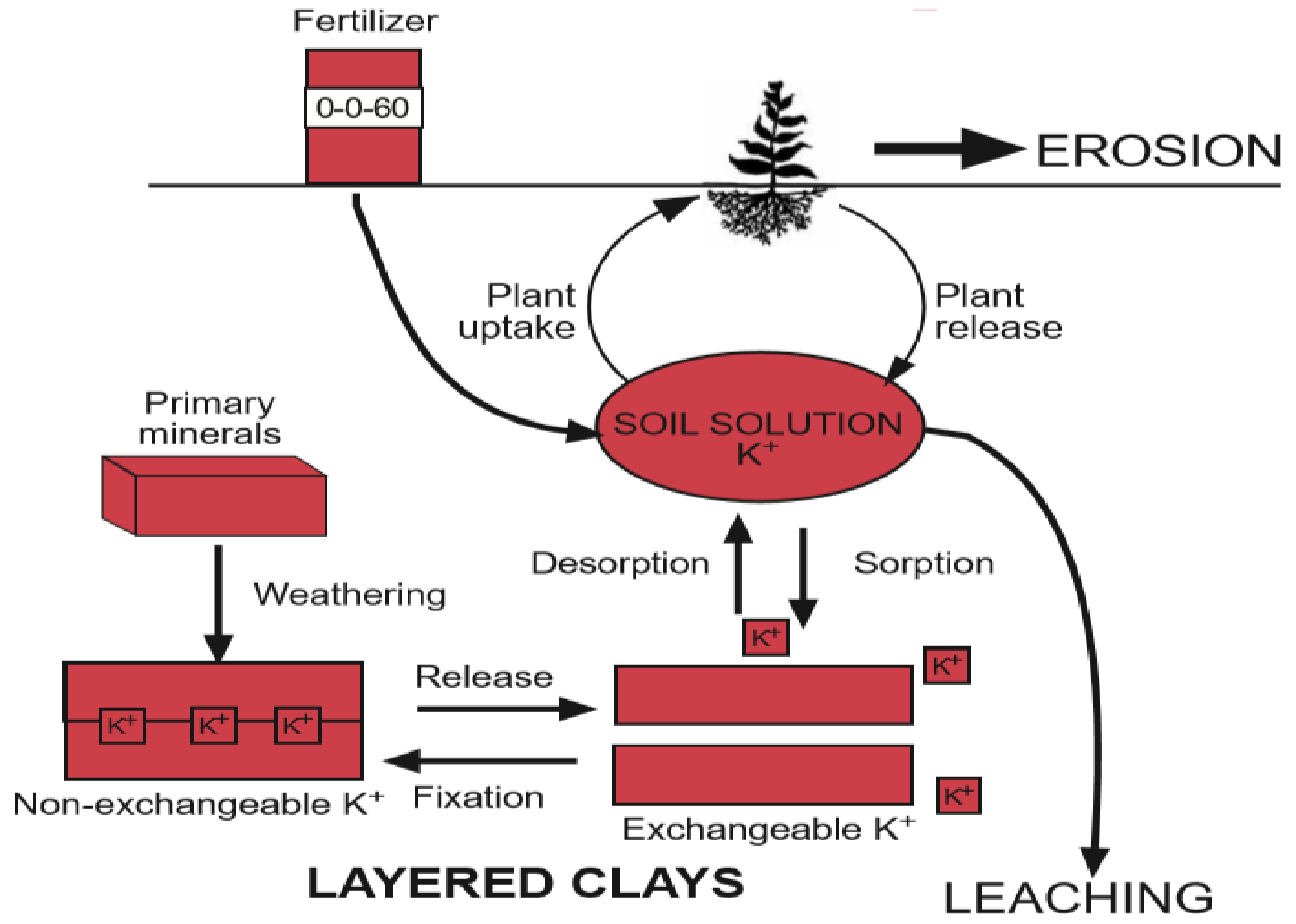
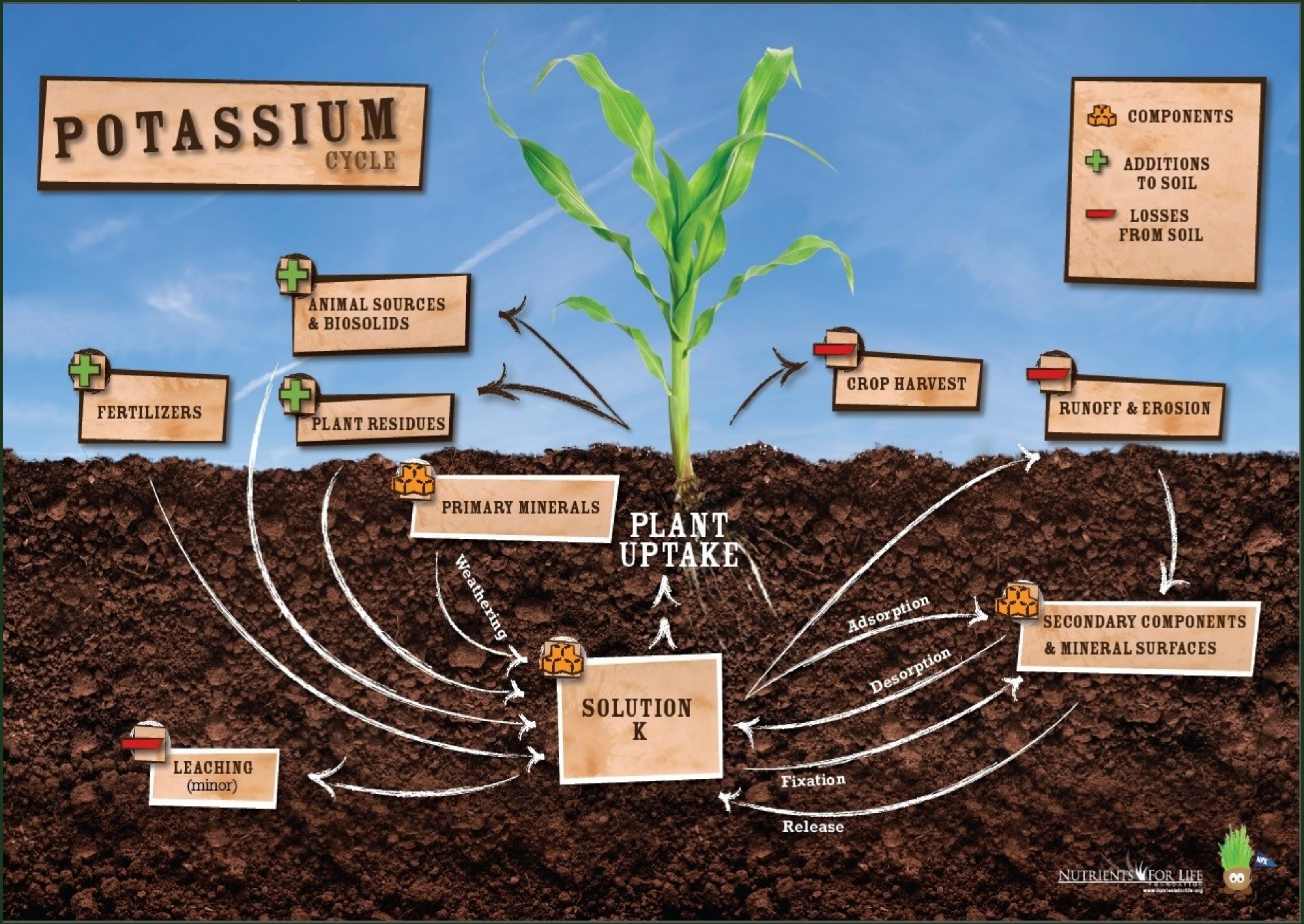


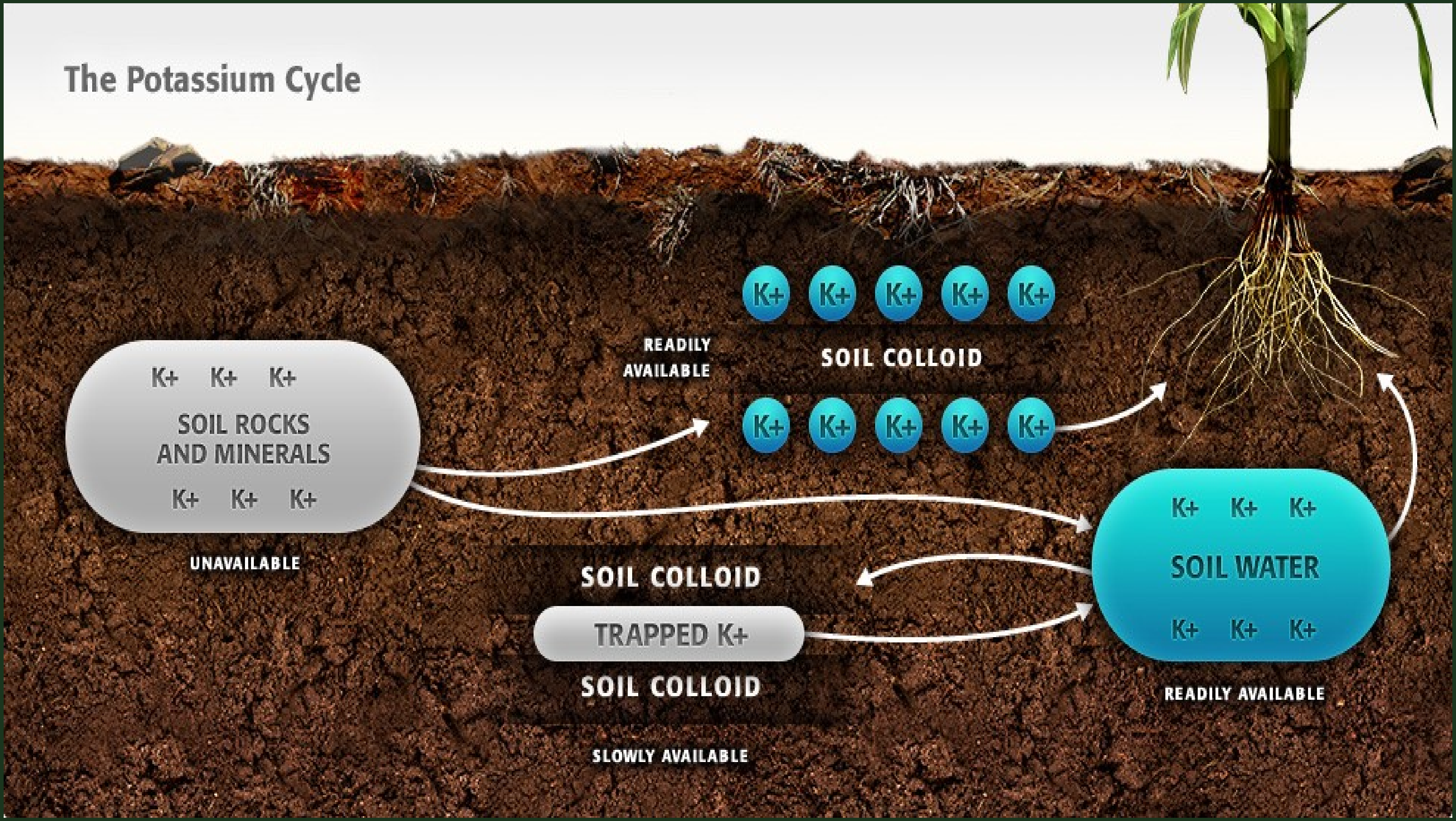
Figure 2. The potassium cycle.

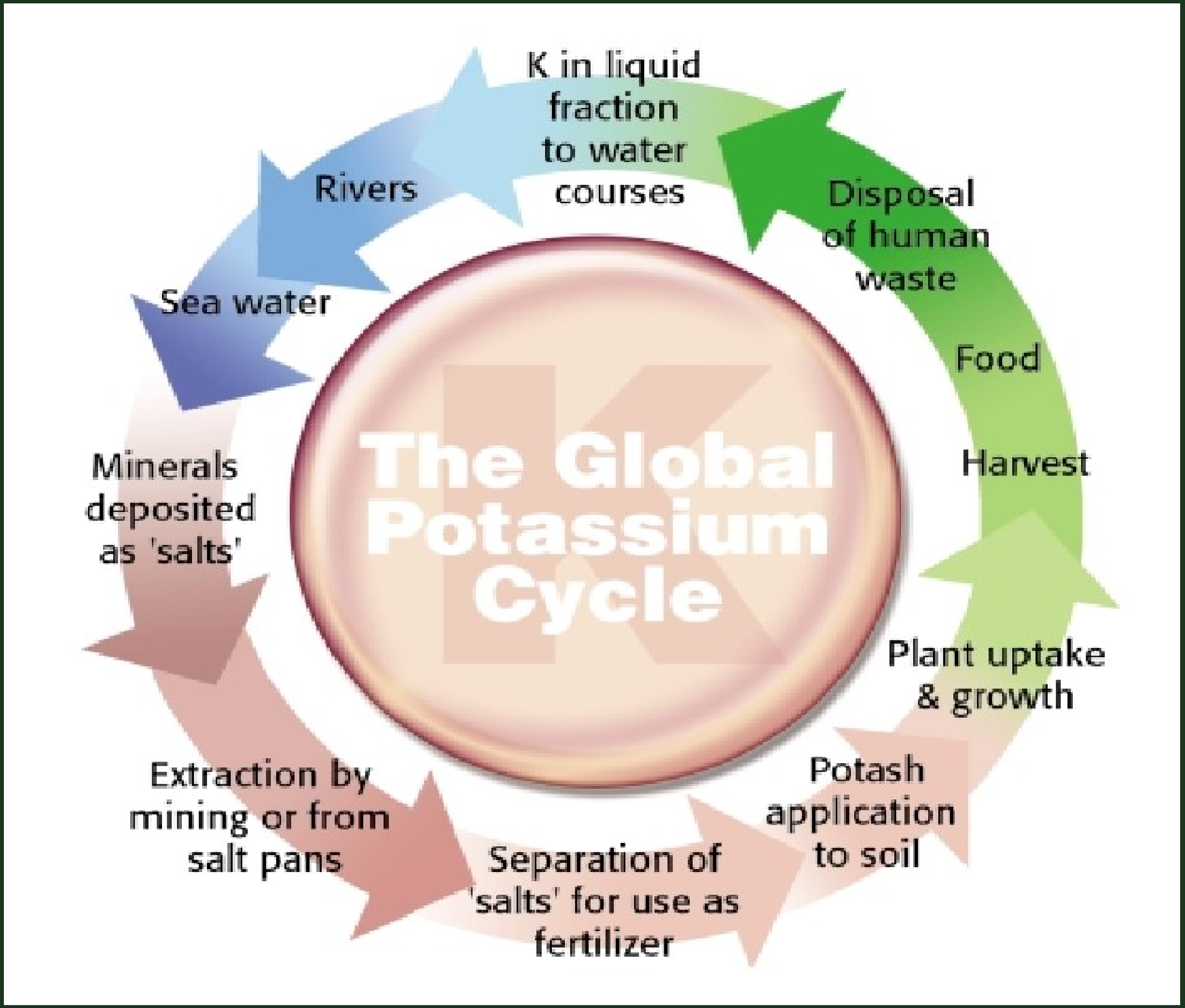
7.3 K cycles



POTASSIUM
CYCLE
COMPONENTS
ADDITIONS TO SOIL
LOSSES FROM SOIL
ANIMAL SOURCES & BIOSOLIDS
FERTILIZERS
PLANT RESIDUES
CROP HARVEST
RUNOFF & EROSION
PRIMARY MINERALS
PLANT UPTAKE
Weathering
SOLUTION K
Adsorption
Desorption
SECONDARY COMPONENTS & MINERAL SURFACES
Fixation
Release
LEACHING (minor)
NUTRIENTS FOR LIFE

7.3 K cycles


The Potassium Cycle
K+ K+ K+
SOIL ROCKS
AND MINERALS
K+ K+ K+
UNAVAILABLE
READILY
AVAILABLE
K+ K+ K+ K+ K+
SOIL COLLOID
K+ K+ K+ K+ K+
SOIL COLLOID
TRAPPED K+
SOIL COLLOID
SLOWLY AVAILABLE
K+ K+ K+
SOIL WATER
K+ K+ K+
READILY AVAILABLE


K in liquid fraction to water courses
Disposal of human waste
Food
Harvest
Plant uptake & growth
Potash application to soil
Separation of 'salts' for use as fertilizer
Extraction by mining or from salt pans
Minerals deposited as 'salts'
Sea water
Rivers
The Global Potassium Cycle

7.3 K cycles

Dalam studi kesuburan tanah, siklus K ditinjau dari 3 aspek yaitu: input ke-, output dari- dan proses dalam tanah.

INPUT

1. Residu tanaman
2. Pupuk K
3. Kotoran hewan/binatang
4. Deposisi udara
5. Pelapukan batuan ber K

7.3 K cycles

INPUT

1. Residu tanaman
2. Pupuk K
3. Kotoran hewan/binatang
4. Deposisi udara
5. Pelapukan batuan ber K

7.3.1 INPUT, 5. Pelapukan batuan ber K

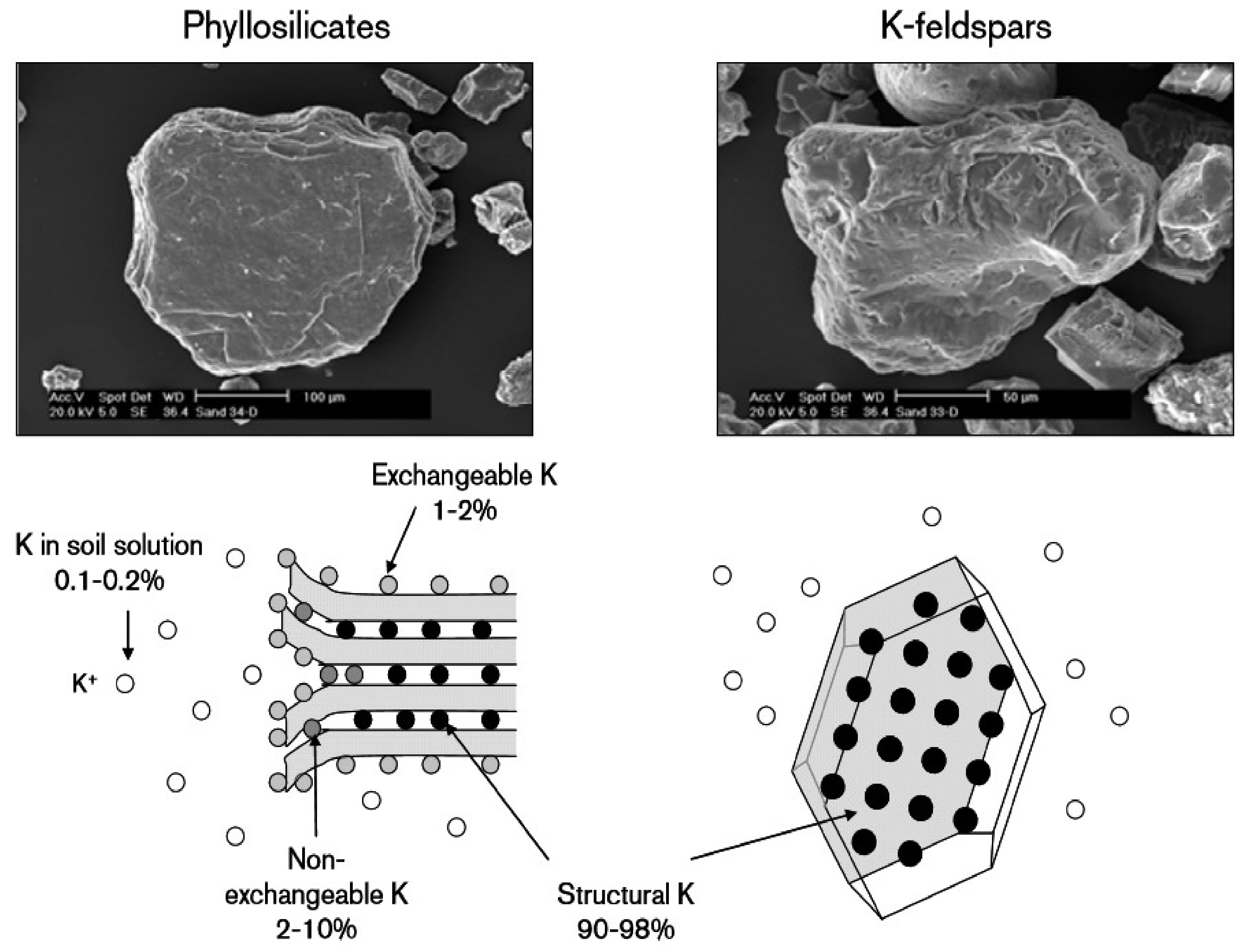
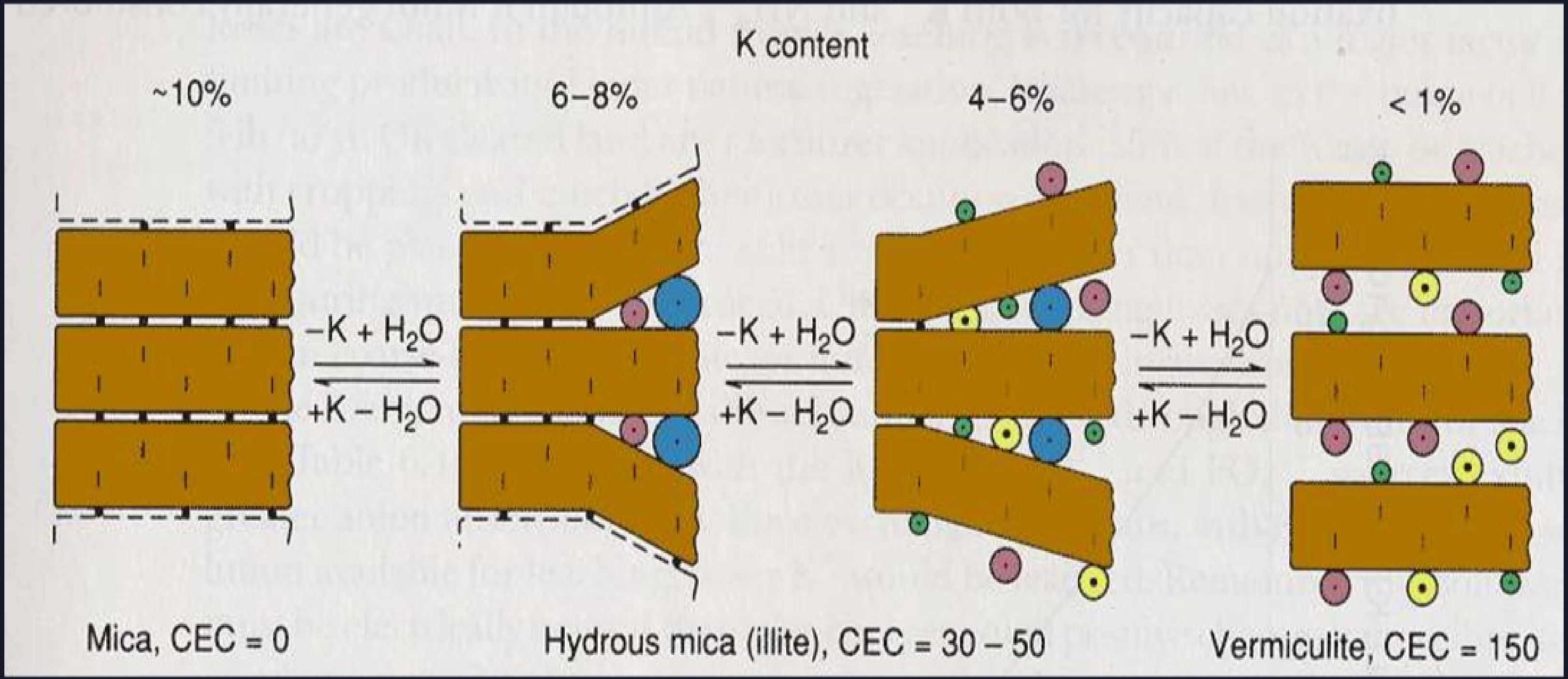


Figure 2. The four forms of K and their location in phyllosilicates and K feldspars with corresponding SEM images. (SEM images: A. Tharande)

7.3.1 INPUT, 5. Pelapukan batuan ber K

K release during mineral weathering



7.3.1 INPUT, 5. Pelapukan batuan ber K

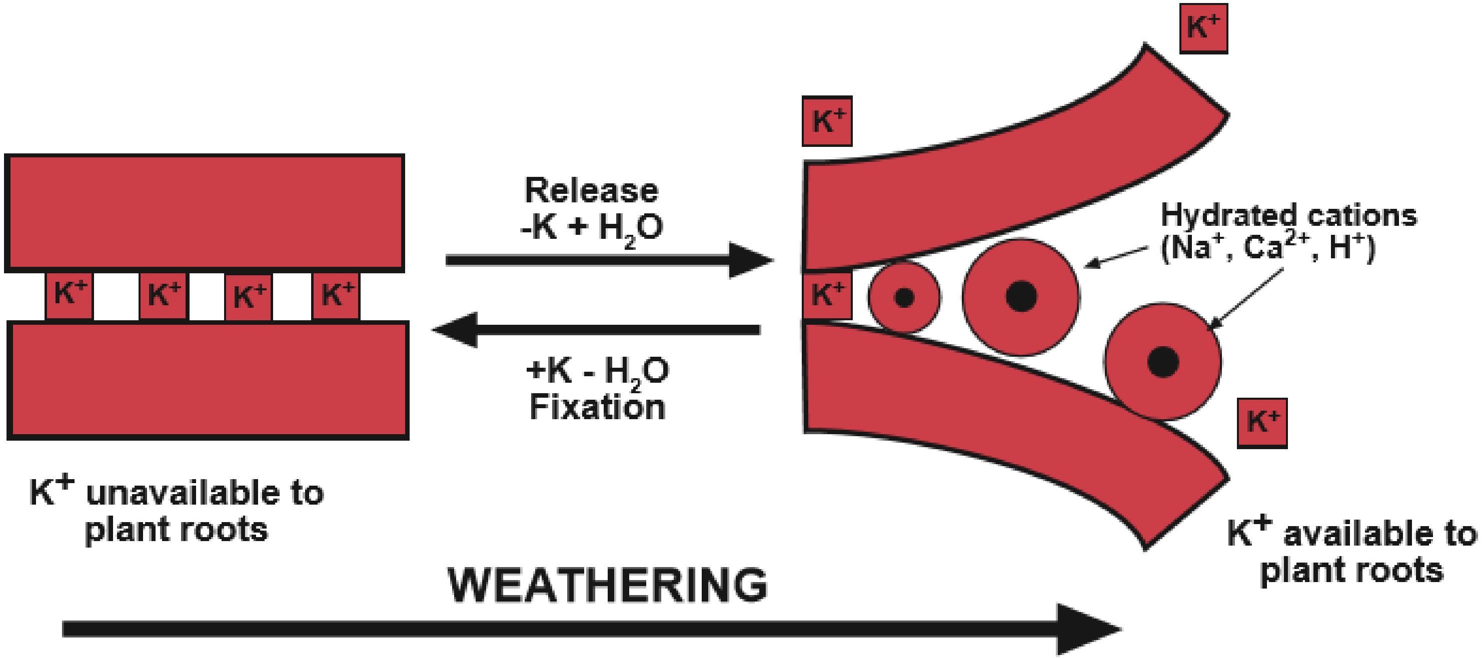


Figure 3. The weathering and "unzipping" of mica and layered clay minerals release K into soil solution. Fixation immobilizes K in a form unavailable to plants (Modified from McLean, 1978).

7.3 K cycles

- Output:

1. Terangkut panen
2. Run off dan erosi
3. Pencucian

7.3.1 Terangkut panen

Table 1. Average K removal in the harvested portion of some common agronomic and horticultural crops (International Plant Nutrition Institute, 2007; Natural Resources Conservation Service, 2007).

Crop	Scientific name	K removal, lb K/ton
Alfalfa	*Medicago sativa*	45
Almond	*Prunus dulcis*	100
Corn grain	*Zea mays*	8
Corn silage	*Zea mays*	7
Potatoes	*Solanum tuberosum*	10
Spinach	*Spinacia oleracea*	11
Squash	*Cucurbita pepo*	10
Rice	*Oryza sativa*	8
Tomatoes	*Lycopersicon esculentum*	6
Wheat	*Triticum aestivum*	10

Moisture is based on marketing conventions.

7.3.1 Terangkut panen

Tabel 1. Total hara yang terkandung dalam sisa panen (kecuali akar)

Tanaman	Total hara dalam sisa tanaman kecuali akar					
	N	P	K	Ca	Mg	S
	kg ha^{-1}					
Kacang-kacangan						
K. tunggak	25	2	21	17	8	6
K. tanah	70	5	59	60	17	16
K. hijau	35	3	54	18	9	7
Kedelai	15	2	13	1	2	6
K. panjang	65	6	33	23	16	8
Biji-bijian						
Jagung Hibrida	45	7	58	7	12	6
Jagung lokal	25	4	32	4	7	4
Padi unggul	30	2	93	10	6	1
Padi lokal	15	2	49	5	3	1
Umbi-umbian						
Singkong	61	5	41	42	11	6
Kentang	39	8	46	9	4	5
Ubi jalar	30	5	29	4	2	3

Diolah dari: Agus dan Widianto (2004)

7.3.3 Pencucian

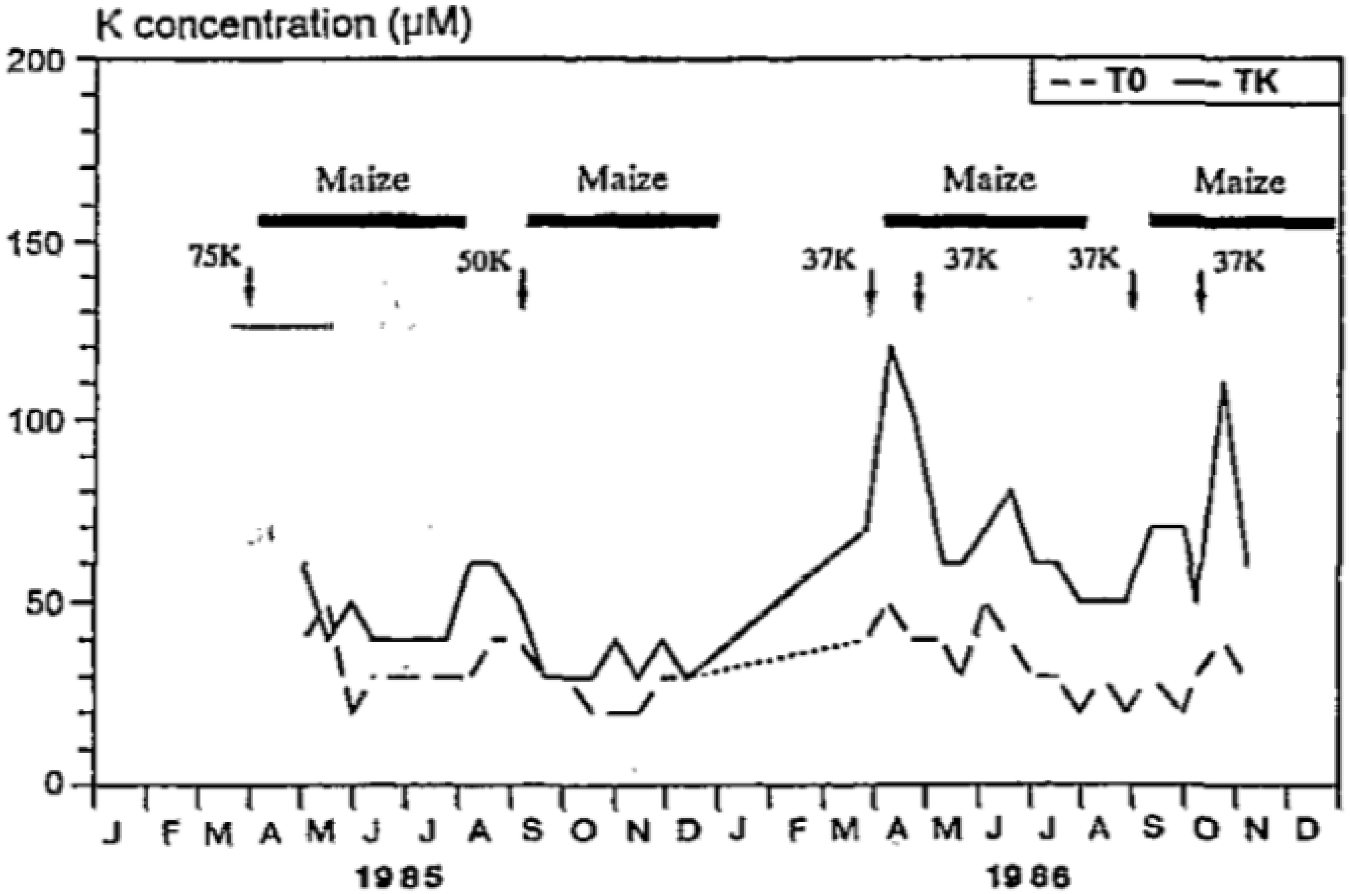


Figure 2. Potassium concentration in the soil solution at 180 cm

7.3.3 Pencucian

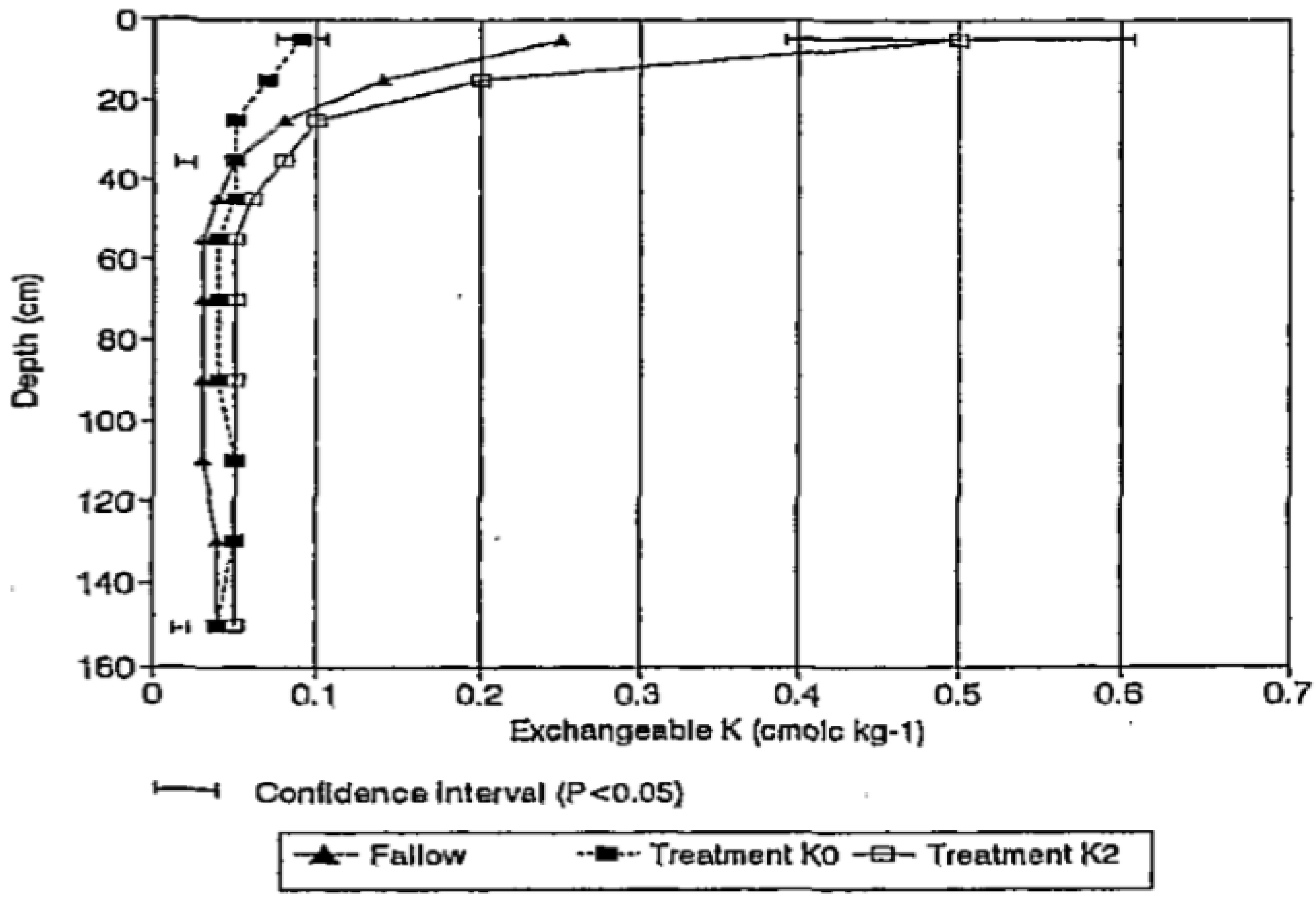


Figure 3. Profiles of NH4 OAc-exchangeable K

7.3 K cycles

- Process:

1. K organik mengalami dekomposisi
2. K anorganik:

   a. Diambil tanaman dan biota tanah

   b.

Available forms for root absorption:

- As the K^+ cation in the soil solution.
- As exchangeable K^+ adsorbed to soil colloids.
- As fixed K in the lattice of 2:1 clays.
- As a component in K-bearing minerals.
- An equilibrium exists between K in the soil solution, exchangeable K, and fixed K.
- When K fertilizer is applied to the soil, the equilibrium shifts toward exchangeable and fixed K, a shift that is reversed as K is removed from the soil solution by root absorption.
- Plant availability is influenced by soil water pH (see Figures 9.2 and 9.3).

Movement in soil and root absorption:

- Moves to the root-absorbing surface by diffusion in the soil solution, the rate of diffusion highly temperature dependent.
- The extent of root contact (root density) with the soil also has a significant effect on uptake.
- Soil oxygen (O_2) has a greater effect on K uptake than for most of the other ions in the soil solution.

7.4. SOIL K RESOURCES

1. Pant Residue
2. K fertilizer
3. Animal manure/residue
4. Atmosferic Depostion
5. Rock K weathering

7.4.1 Plant Residue

Kadar K beberapa tanaman

Tanaman	Kadar K (%)	Tanaman	Kadar K (%)
Kc. Tunggak		Singkong	
Kc. Tanah	2,03	Ubi jalar	4,01
Kc. Hijau			
Kc. Kedelai	2,41	TKKS (%)	
Kc. Panjang		Jerami padi (%)	
Jagung Hibrida	2,39	Batang jagung	1,42
Jagung lokal			
Padi unggul			
Padi loka			

7.4.2 K fertilizer

Box 11

The components of some potash fertilizers.

Potassium chloride (muriate of potash) KCl	60% K_2O	
Potassium sulphate (sulphate of potash) K_2SO_4	50% K_2O	45% SO_3
Potassium nitrate (nitrate of potash) KNO_3	46% K_2O	13% N
Sylvinite (crude potassium salts)	21% K_2O	26% Na_2O
Kainit (crude potassium salts)	11% K_2O	27% Na_2O

7.4.3 Animal manures/residue

Pupuk kandang	Kadar K (%)	Pupuk kandang	Kadar K (%)
Sapi	0,82	Kambing	1,35
Ayam	2,18		
Domba	1,61		
Kuda			

7.4.4 Atmosferic deposition

7.4.5 Rock K weathering

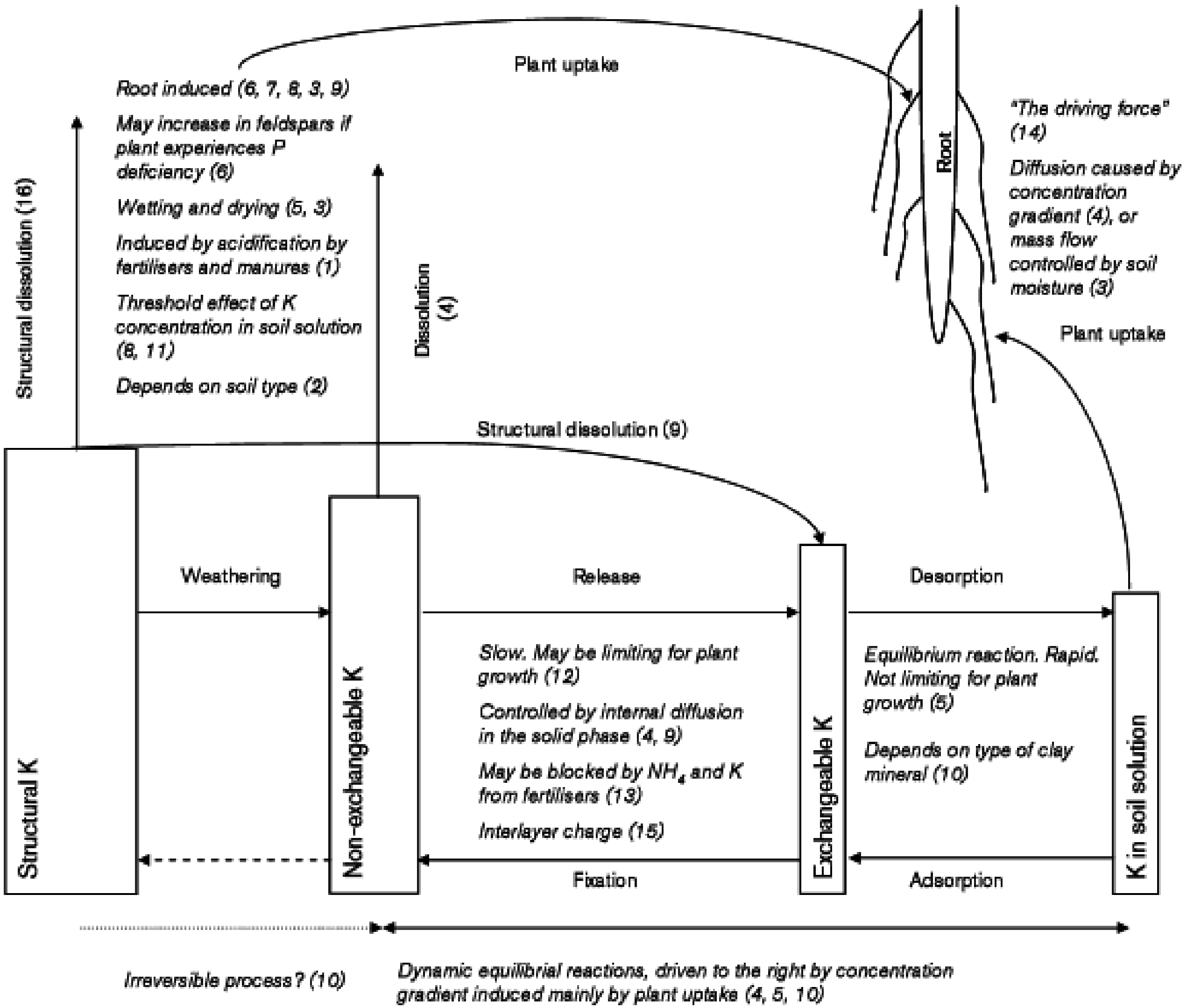


Figure 3. The different forms of K pools, reactions between them, and factors controlling these reactions. Numbers refer to references listed in Table 1.

SOIL K LOSS

1. Run off and erosion
2. Leaching
3. Removal by crop harvest

1. Run off and erosion

Tabel 1. Pengaruh vegetasi dan lereng terhadap erosi dan kehilangan hara.

Perlakuan	Lereng (%)	Erosi (ton/ha)	Aliran Permukaan (mm)	Unsur hara yang hilang (kg/ha)				
				N	P	K	Ca	Mg
Tanah bera, dibajak setiap bulan	22	225.4	1730	25	0.98	24	238	152
Rumput ternak	22	7.1	513	7	0.15	6	25	26
Tanaman kopi muda	45	1.8	190	8	0.04	2	6	7
Kopi muda dengan teras	45	0.2	410	4	0.14	4	8	9
Tanaman kopi tua tanpa konservasi	55	0.6	59	1	0.08	1	2	2

Sumber : Castro dan Rodriguez (1958) dalam Sanchez, 1976.

1. Run off and erosion

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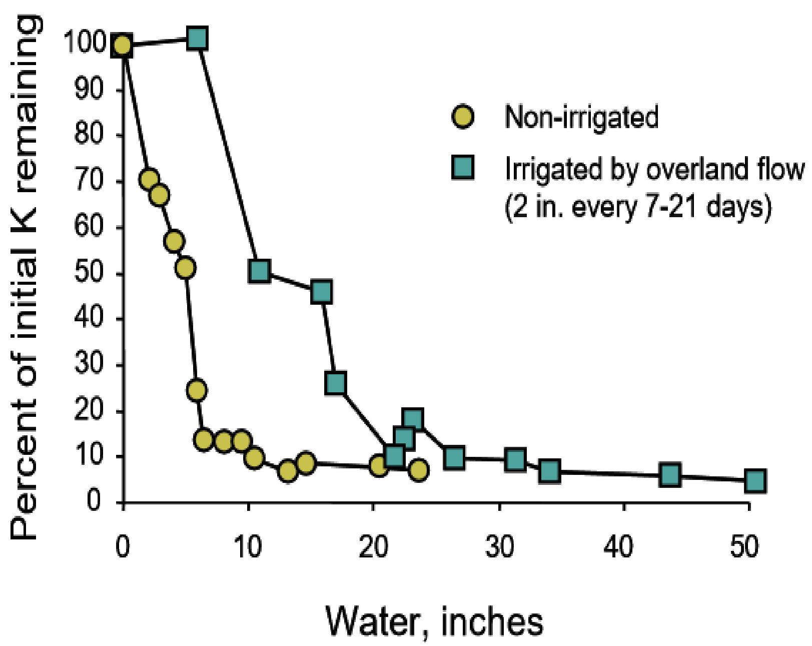
SOIL K LOSS

2. Leaching

Figure 4. Leaching of K from corn residue left at the soil surface under different moisture regimes imposed after harvest (53).



3. Removal by Crop Harvest

Table 4.
Nutrients in Harvests of Some Common Tropical Crops

Crop	Yield Per Hectare	N	P	K
		----- (kg/ha) -----		
	Food Crops Grown on Small Farms			
Maize	1,100 kg of grain	17	3	3
Rice	2,200 kg of paddy	26	8	8
Groundnuts	600 kg of kernels	28	2	3
	200 kg of shells	2	0.2	2
Cassava	11 mt of tubers			
	(30% dry matter)	25	3	65
Yams	11 mt of tubers			
	(30% dry matter)	38	3	39
Cacao	600 kg of beans	13	3	11
	600 kg of husks	11	1	25
	Cash Crops Grown on Large Farms			
Oil palm	2.5 mt of oil	162	30	217
Sugarcane	88 mt of cane	45	25	121
Coconuts	1.4 mt of dry copra	62	17	56
Bananas	45 mt of fruit	78	22	224
Rubber	1.1 mt of dry rubber	7	1	4
Soybeans	3.4 mt of grain	210	22	60
Coffee	1 mt of coffee beans	38	8	50
Tea	1,300 kg of dried leaves	60	5	30

Source: Cooke (1982).

3. Removal by Crop Harvest

The average potassium content of some crop products:

	Product	Grams K per kg fresh weight*
Fruits	Banana	3.7
	Plum	3.0
	Apricot	2.8
	Orange	2.0
	Grape/strawberry	1.6
	Apple	1.1
Vegetables	Spinach	4.7
	Potato	4.1
	Carrot/celery	3.4
	Tomato	2.4
	Lettuce/cucumber	1.6
Beverages**	Milk/fruit juices	1.6
	Coffee	0.9
	White wine	0.8
	Light beer	0.4

* *These are only average values and there can be a wide range.*

** *per litre for beverages*

3. Removal by Crop Harvest

Period	Yield, grain t/ha	Potassium offtake in grain plus straw, kg K_2O/ha
1852-1871	2.70	55
1966-1967	3.07	53
1970-1975	5.48	106
1991-1992	8.69	117
1998-1999	9.35	108

3. Removal by Crop Harvest

Table 1. K removal amounts in harvested portions of selected agricultural crops.

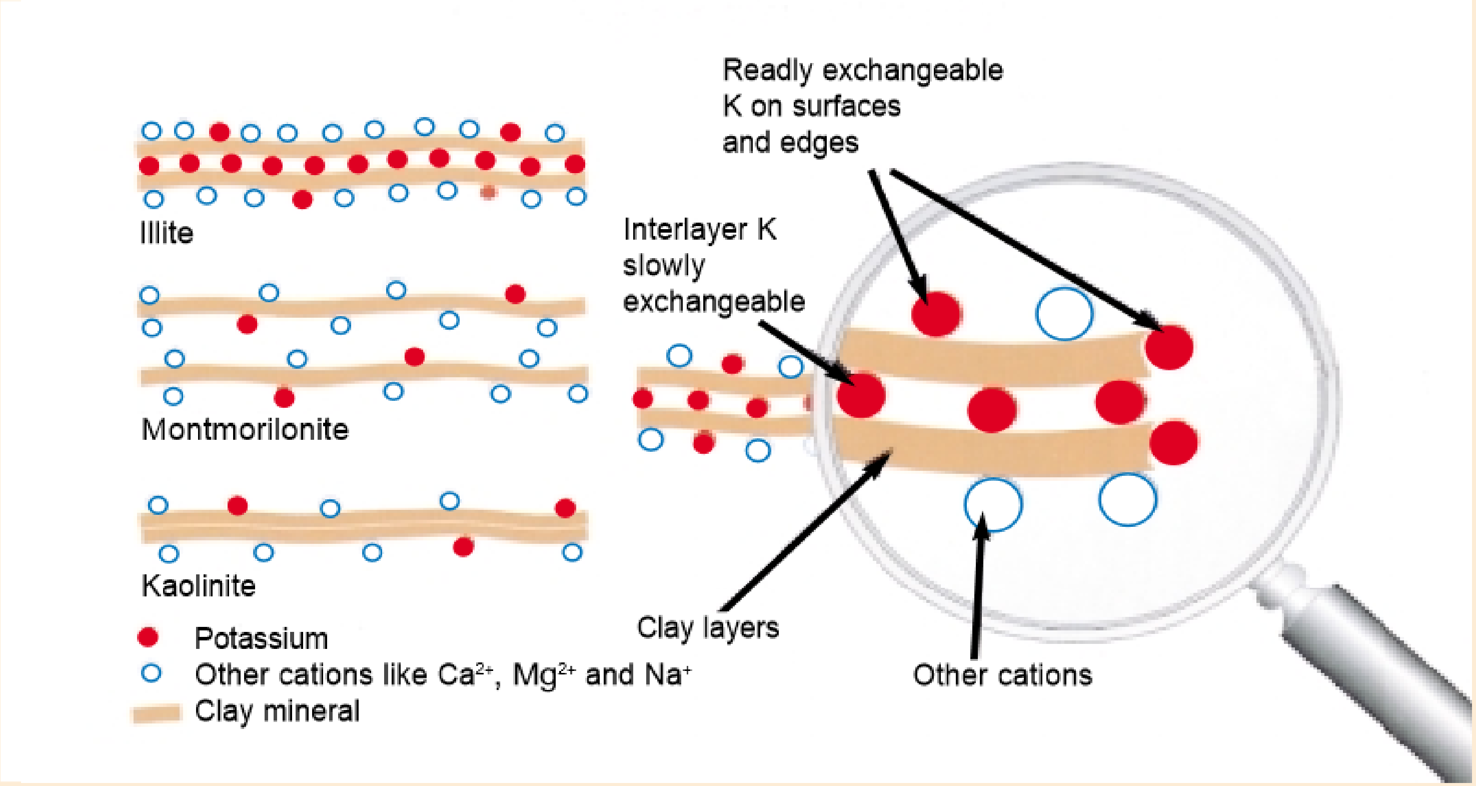
Crop	Assumed yield per acre	K_2O removal (lb/ac)
Alfalfa	2.5 t	150
Barley	50 bu	80
Brome	1.5 t	95
Corn silage	20 t	167
Orchard grass	1.5 t	75
Potatoes	300 cwt	330
Sugar beets	25 t	460
Timothy	1.5 t	94
Wheat	40 bu	80

From CFA (1995). Wheat and barley removal include head and straw.

7.5. SOIL K

Box 15

Potassium and clay minerals



Clay minerals consist of lattices and layers and cations are held in various positions in and around the layers.

7.5. SOIL K

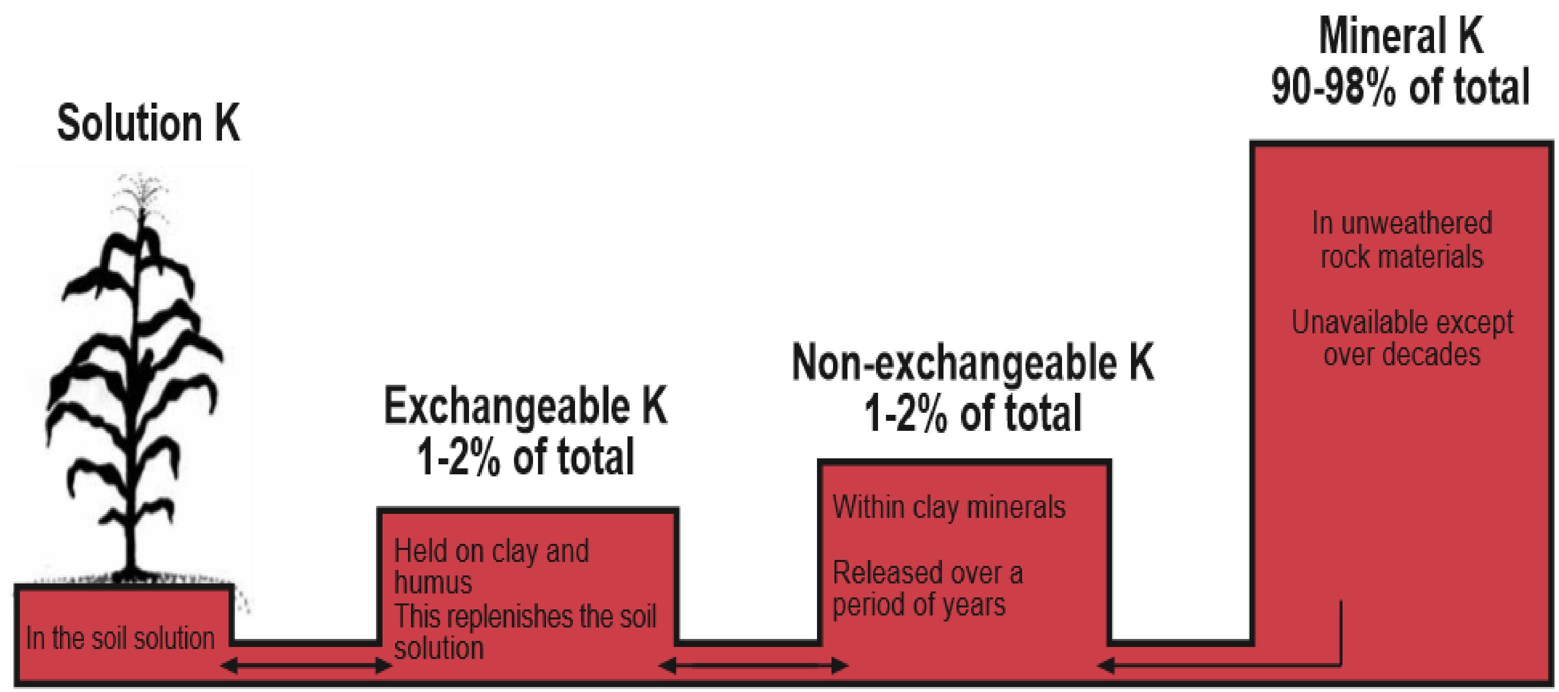


Figure 1. Forms of K found in the soil (Hoeft et al., 2000).

7.5. SOIL K

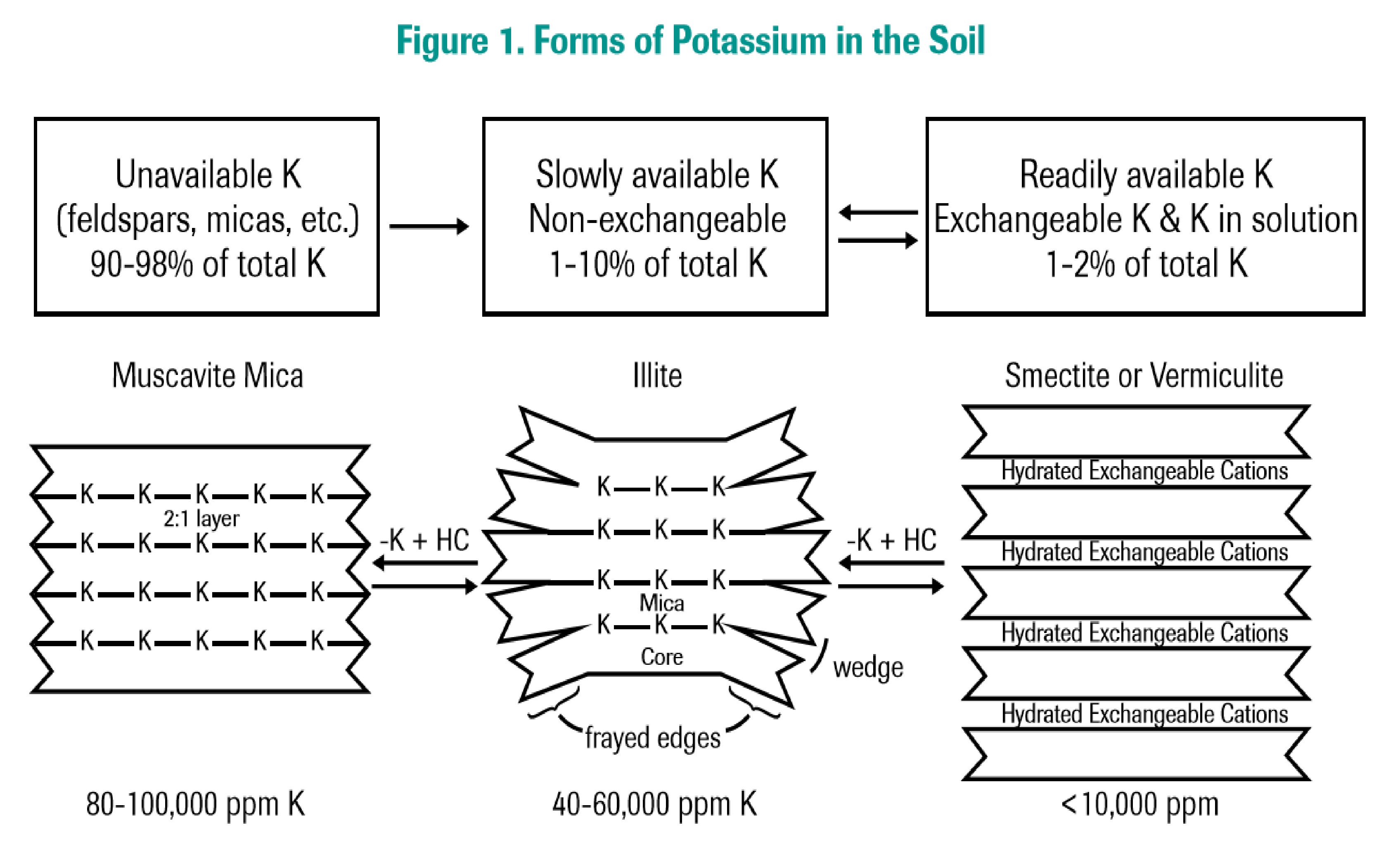
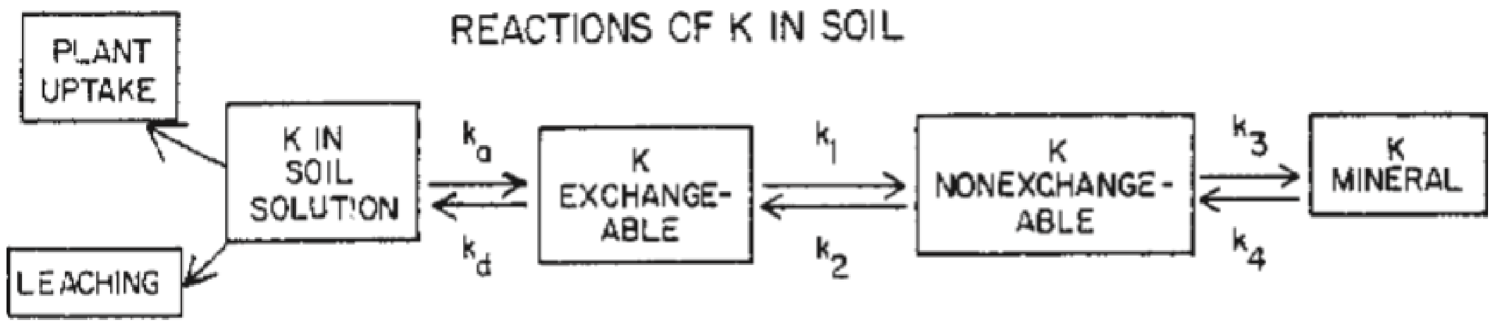


Figure 1. Forms of Potassium in the Soil
Unavailable K
(feldspars, micas, etc.)
90-98% of total K
Slowly available K
Non-exchangeable
1-10% of total K
Readily available K
Exchangeable K & K in solution
1-2% of total K
Muscavite Mica
Illite
Smectite or Vermiculite
2:1 layer
-K + HC
-K + HC
Mica
Core
wedge
frayed edges
Hydrated Exchangeable Cations
Hydrated Exchangeable Cations
Hydrated Exchangeable Cations
Hydrated Exchangeable Cations
80-100,000 ppm K
40-60,000 ppm K
<10,000 ppm

7.5. SOIL K



where

k_a = adsorption rate coefficient in h^{-1},

k_d = desorption rate coefficient in h^{-1},

Figure 2. Kinetic reactions between soil K phases. (From Selim *et al.*, 1976).

up by plants, converted into unavailable forms, or released into available forms (**Figure 2**).

7.5. SOIL K

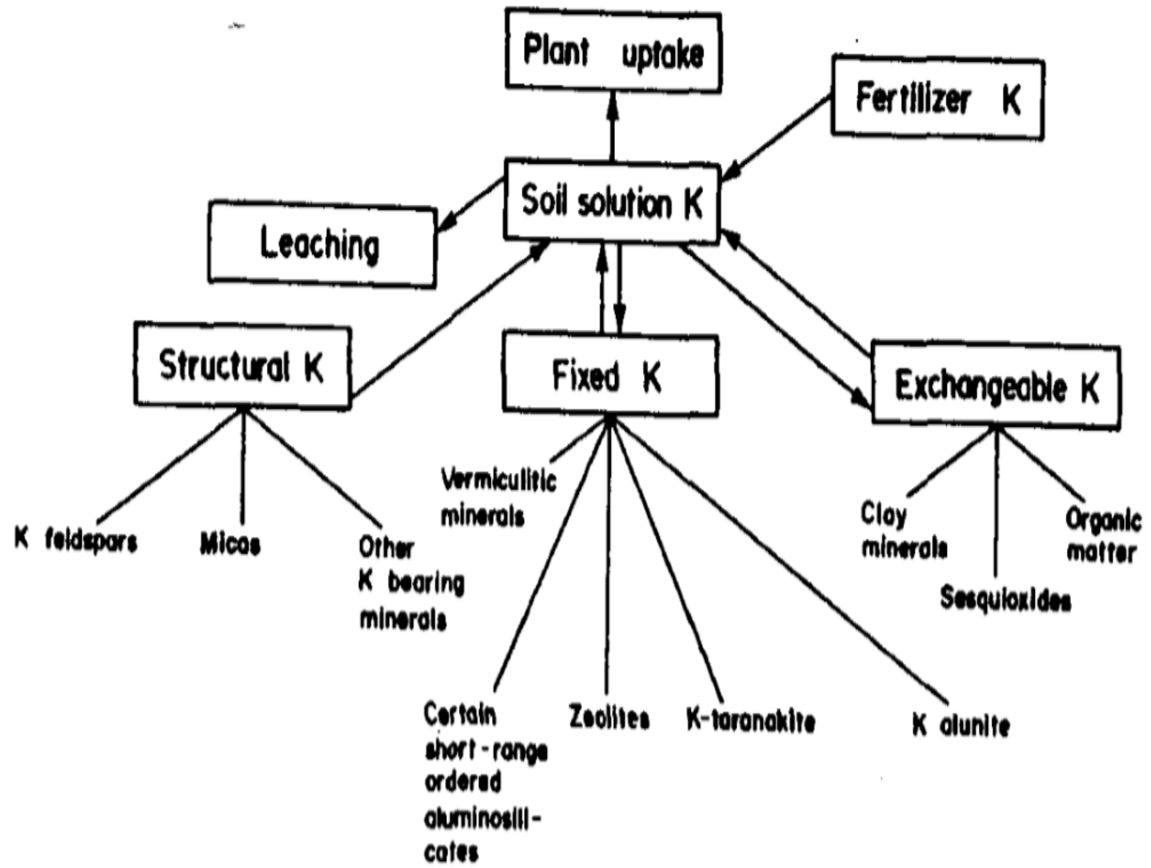


Fig. 1.13 Interrelationships of various forms of soil K [Reprinted from Sparks and Huang, 1985. Munson. (ed.) Potassium in agriculture with permission of the Soil Science Society of America]

7.5. SOIL K

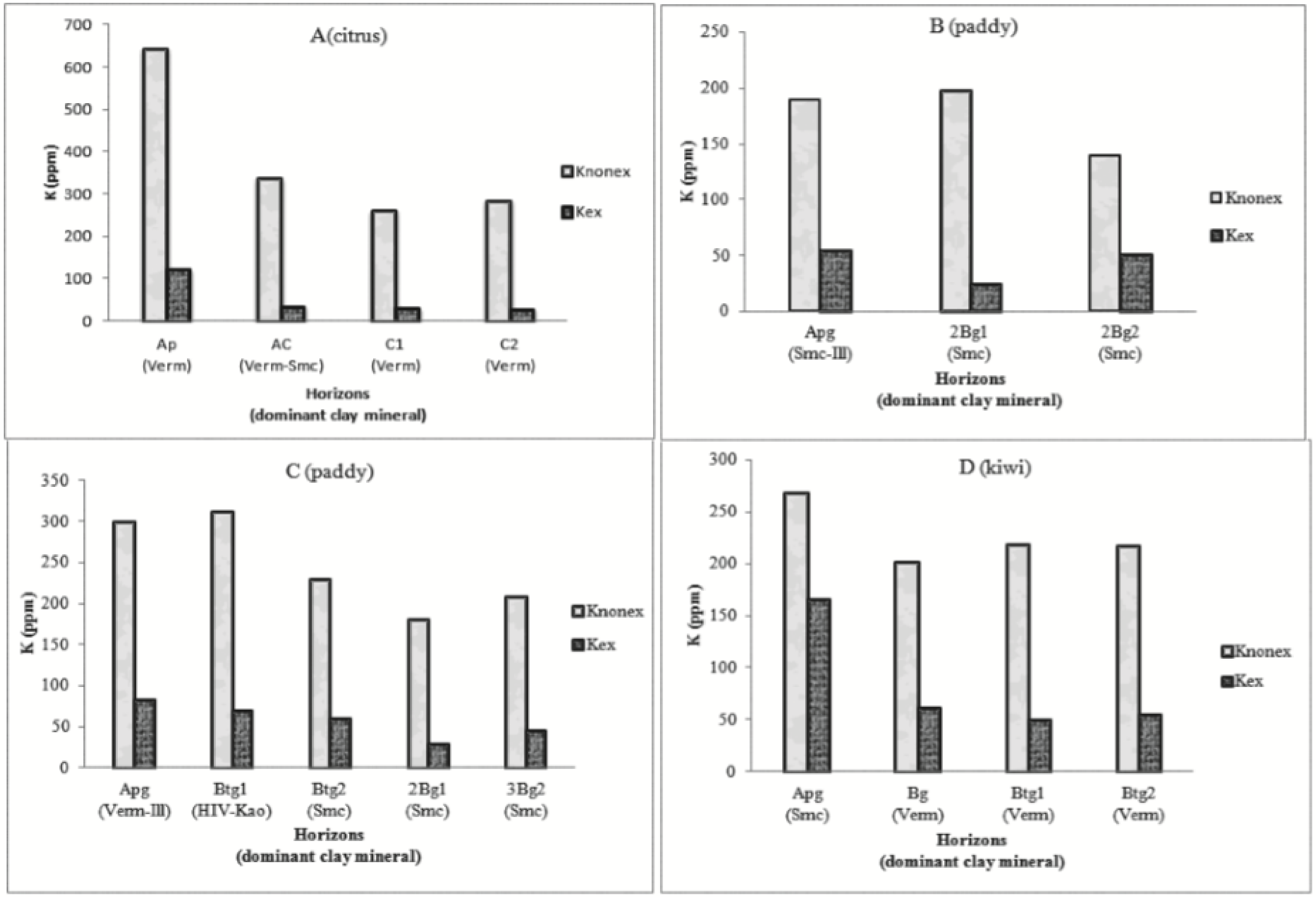


Figure 3. Relationship between dominant clay minerals with exchangeable and non-exchangeable potassium in different horizons, A: pedon 1(citrus), B: pedon 4 (paddy), C: pedon 5 (paddy), D: pedon 8 (kiwi).

7.5. SOIL K

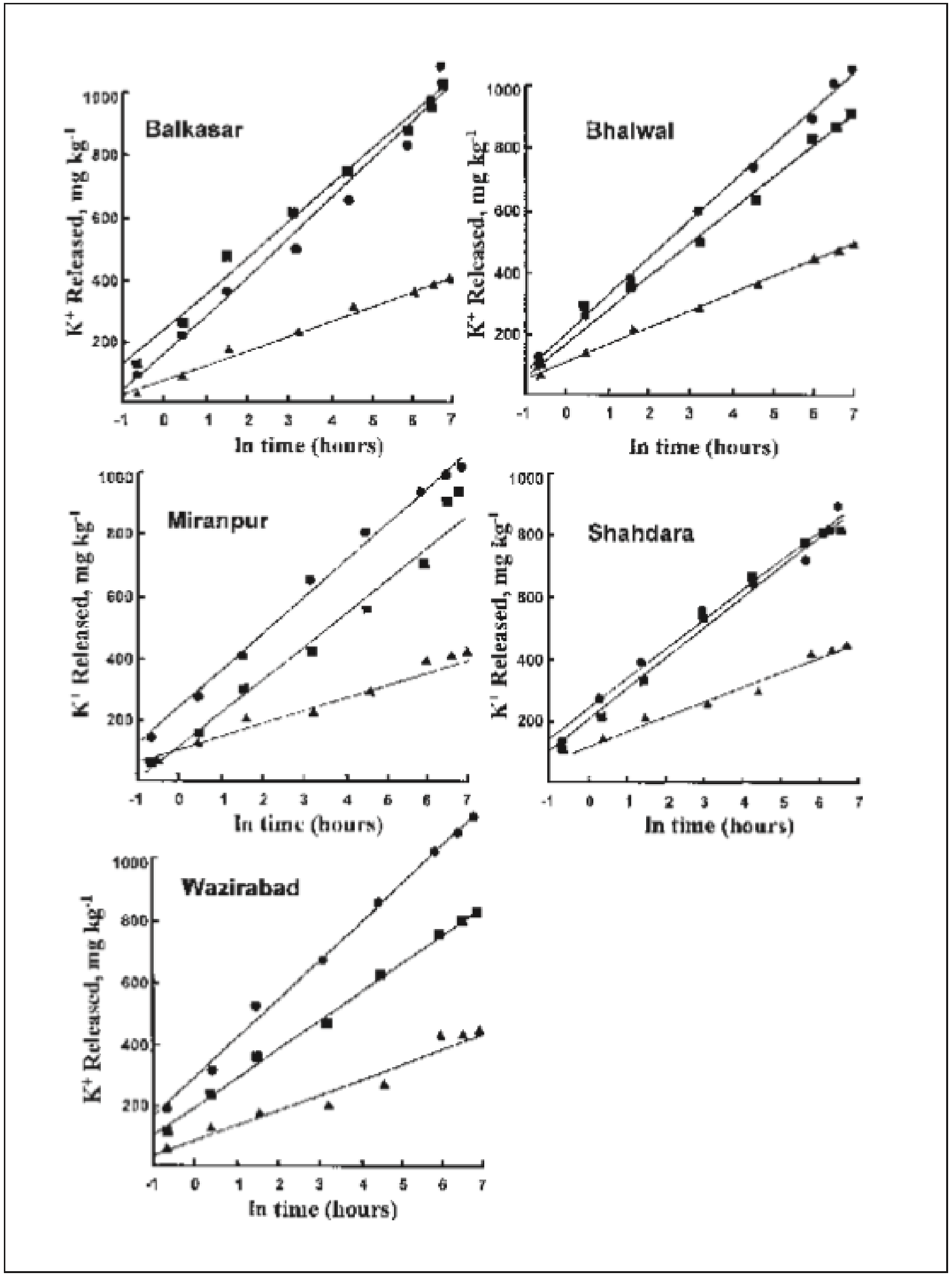


Figure 4. Release of nonexchangeable K^+ form sand (▲), silt (■) and clay (●) fractions. From Rahmatullah and Mengel (2000)

7.5. SOIL K

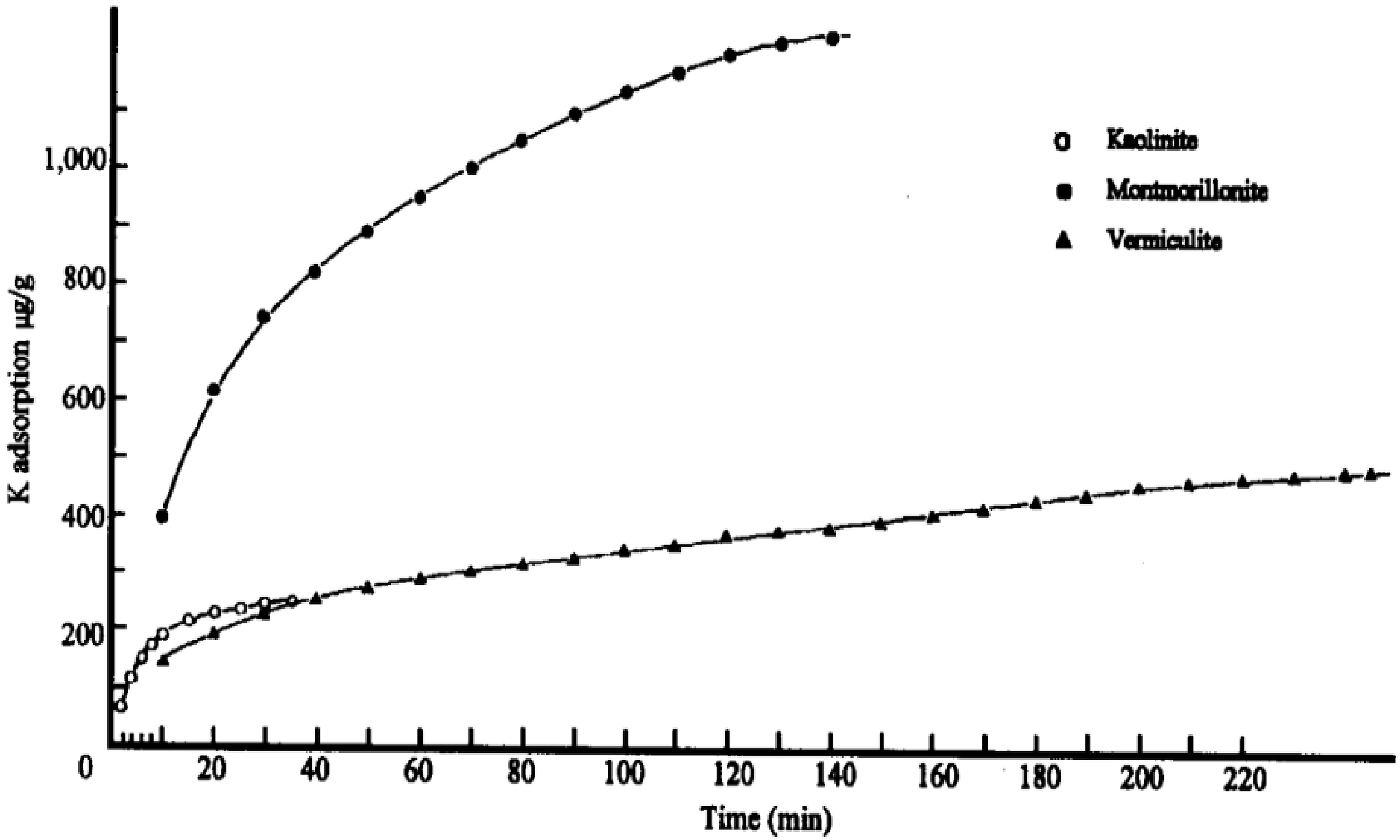
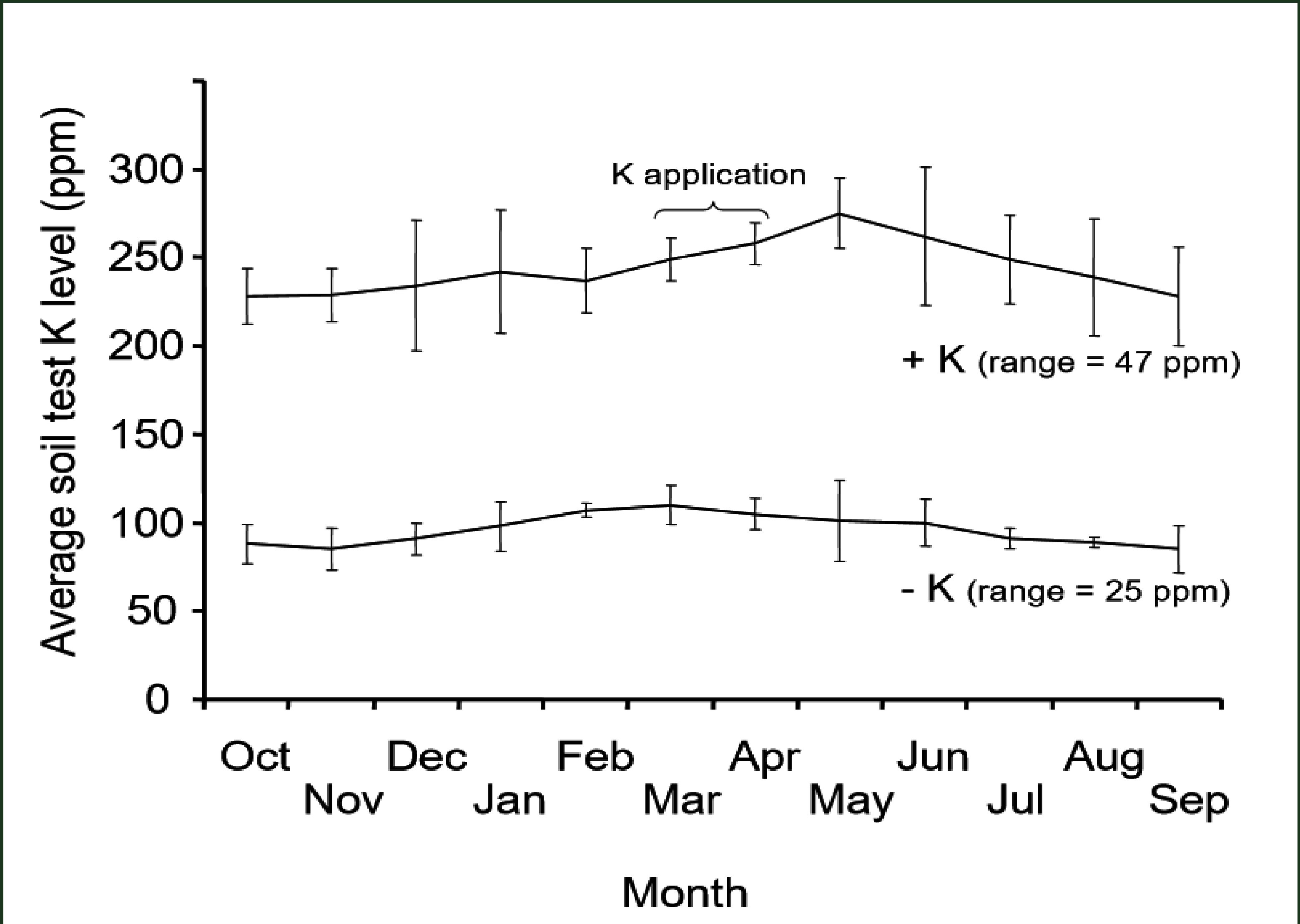


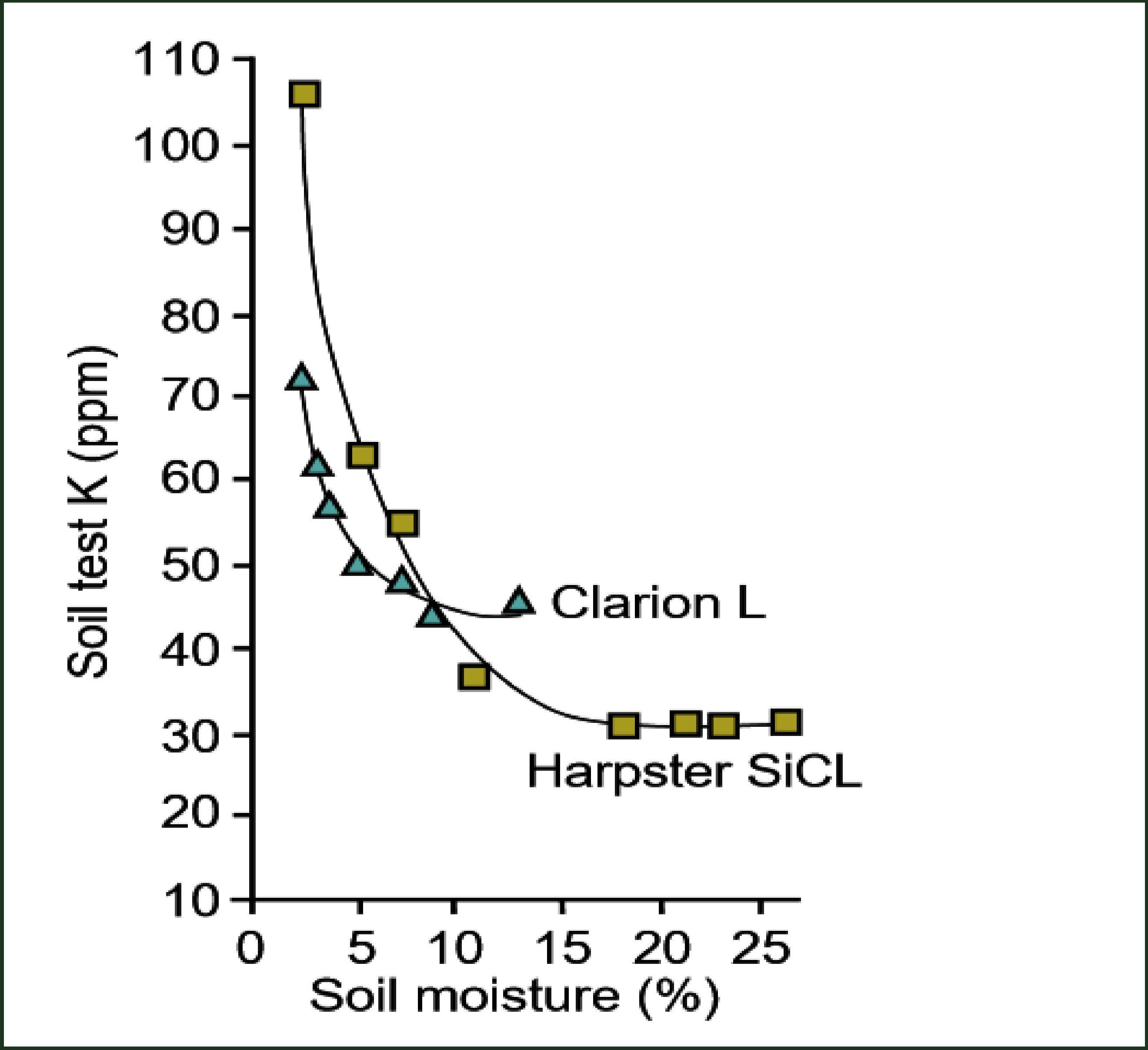
Fig. 1.14 Potassium adsorption versus time in pure systems [Reprinted from Sparks and Jardine, 1984. Comparison of kinetic equations to describe K-Ca exchange in pure and mixed systems. Soil Sci. 138:115-122 with permission of Williams and Wilkins, Baltimore, MD]

7.5. SOIL K



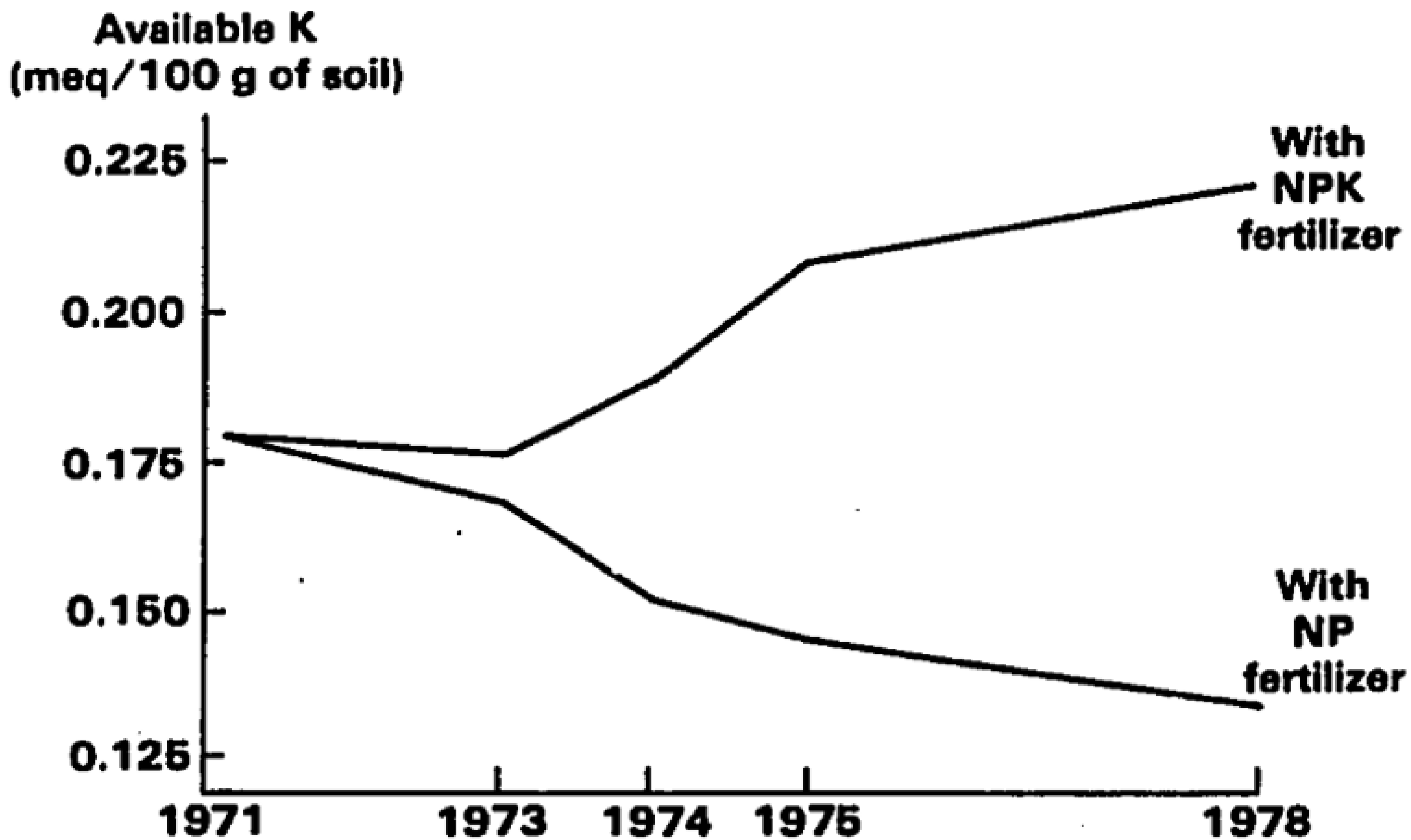
Average soil test K level (ppm)
300
250
200
150
100
50
0
K application
+ K (range = 47 ppm)
- K (range = 25 ppm)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month

7.5. SOIL K



Soil test K (ppm)
110
100
90
80
70
60
50
40
30
20
10
0
5
10
15
20
25
Soil moisture (%)
Clarion L
Harpster SiCL

7.5. SOIL K

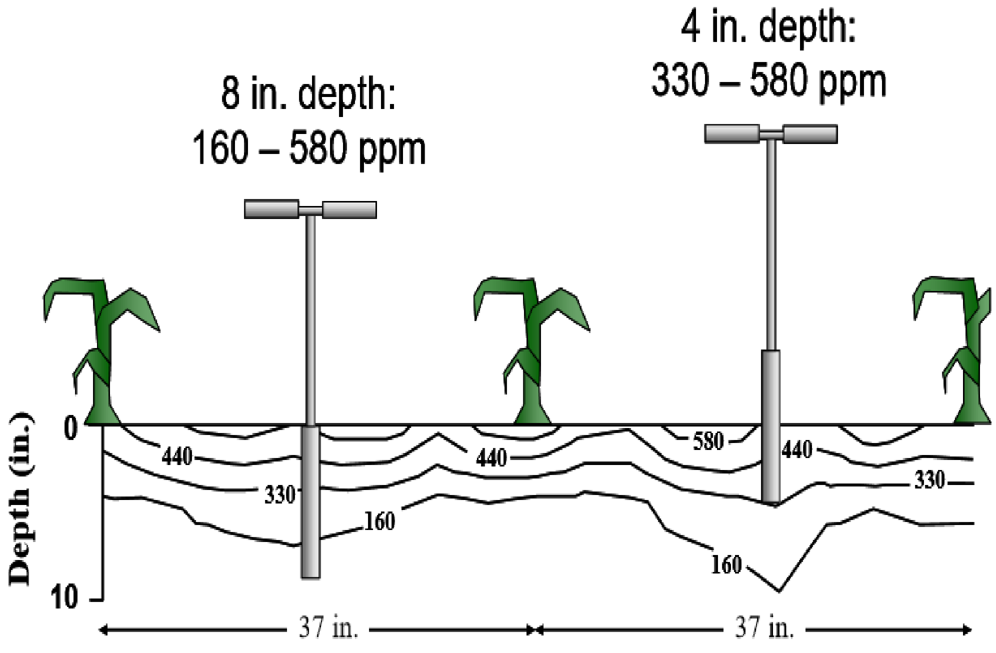


Source: ICAR, 1980.

Figure 4. Changes in Available Potassium in Soils of a Long-Term Fertilizer Experiment in India From 1971 to 1978.

7.5. SOIL K

Figure 8. Stratification of soil test K after 10 years of no-till production (adapted from 51).



7.5. SOIL K

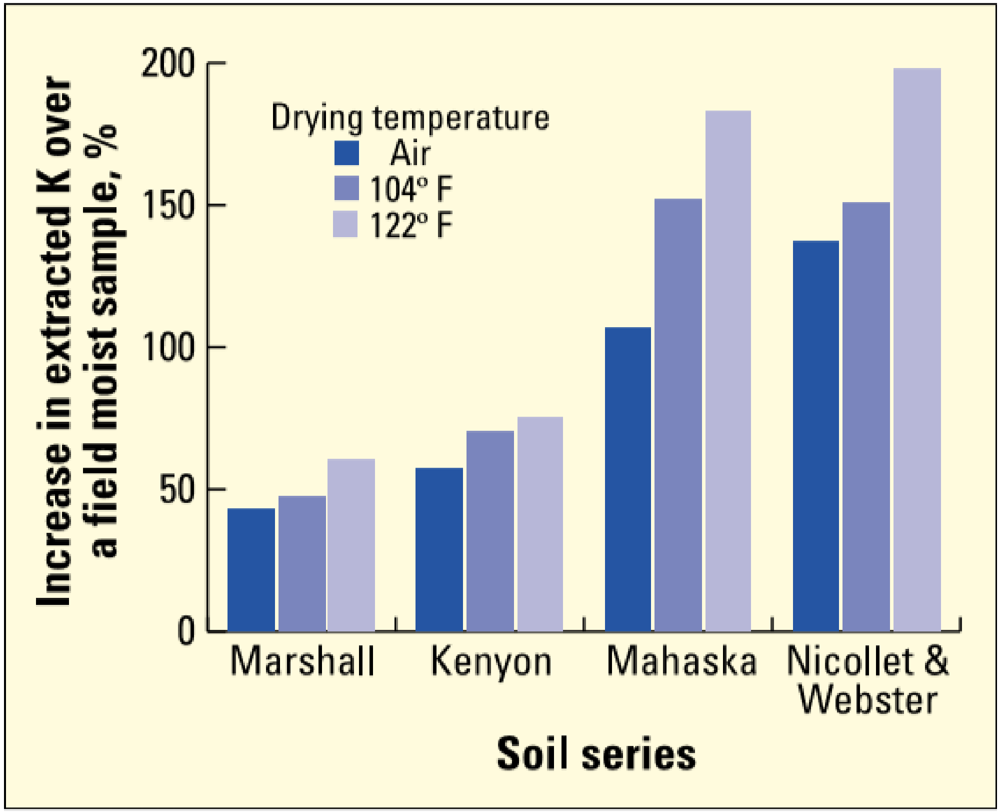


Figure 2. Example of the effect of sample drying temperature on K extracted from dried samples using the ammonium acetate procedure. All results are compared to those attained from the same procedure conducted on field-moist samples.

7.6. SOIL K AVAILABILITY

7.6.2 Factors affecting Soil K availability

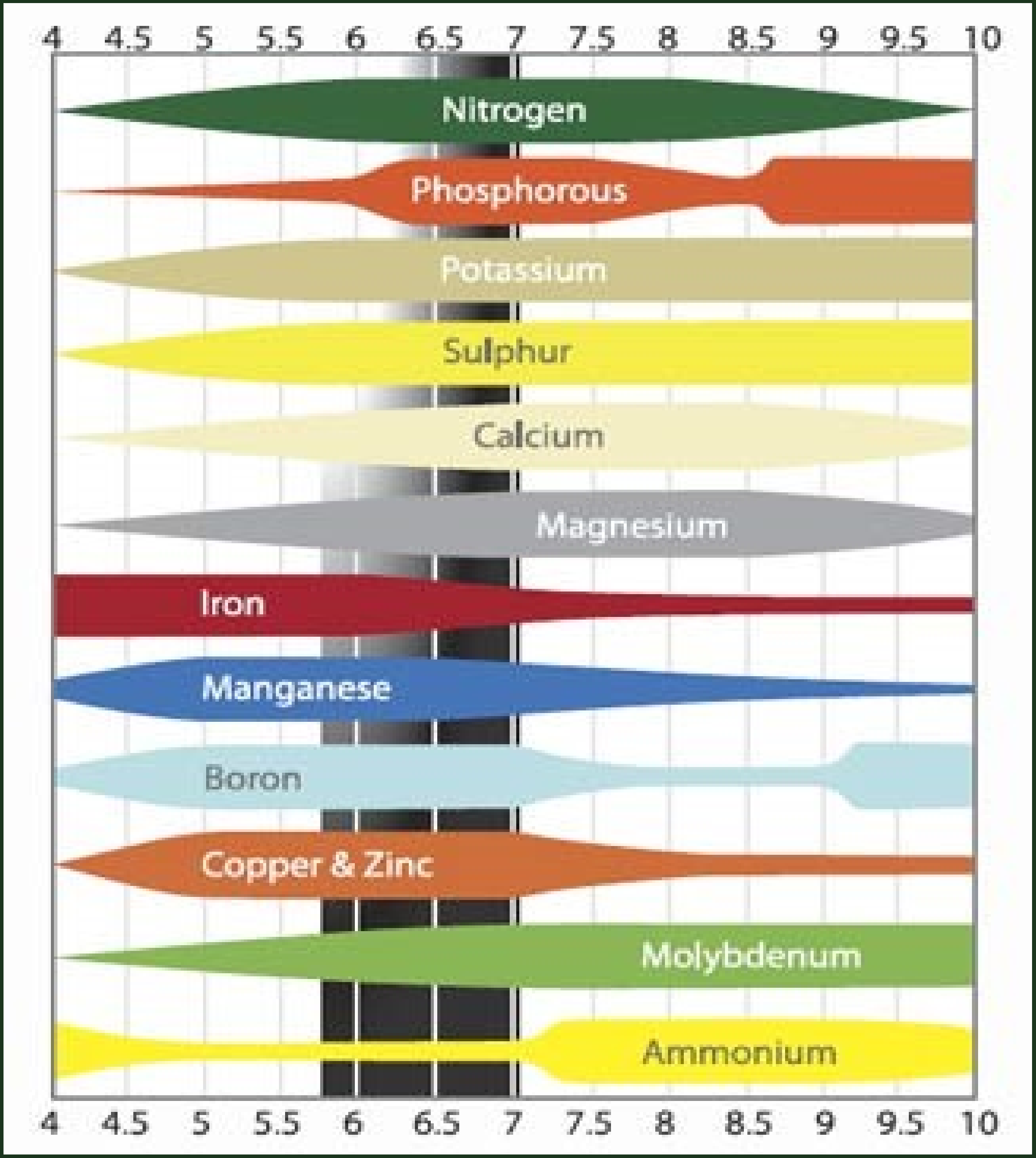
- Soil pH
- Water availability
- Organic matter decomposition & mineralisation

  a. OM quality

  b. Decomposer

  c. Environment

Soil pH


4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
Nitrogen
Phosphorous
Potassium
Sulphur
Calcium
Magnesium
Iron
Manganese
Boron
Copper & Zinc
Molybdenum
Ammonium

Soil pH

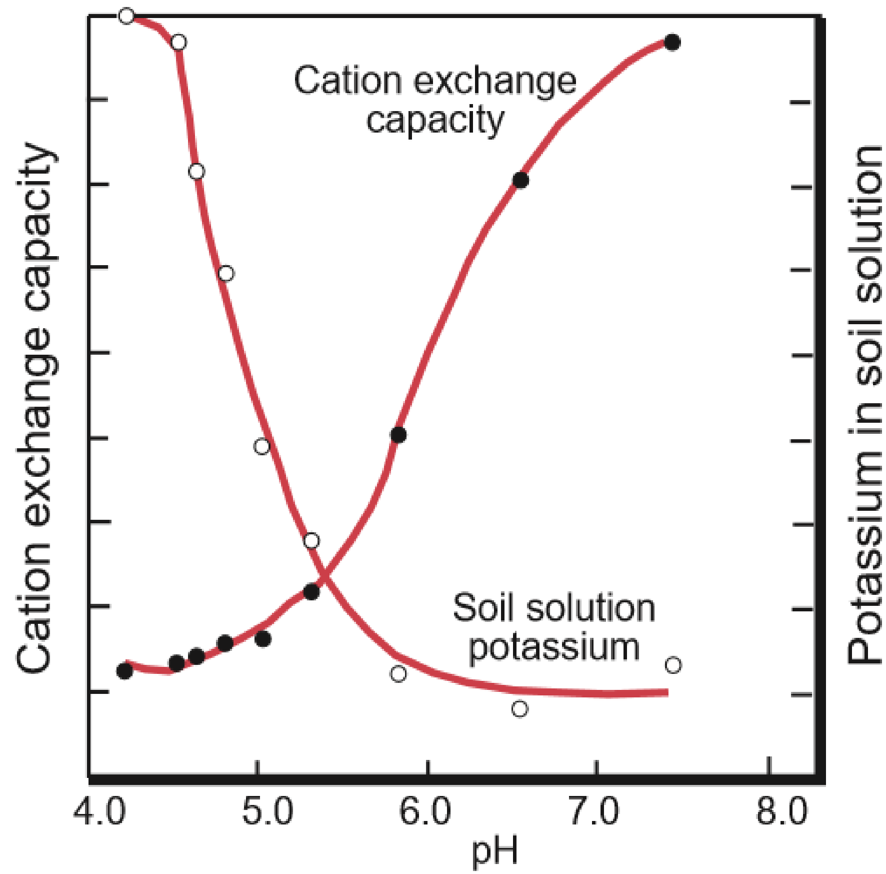


Figure 4. Relationship between pH-dependent cation exchange capacity and K concentration in soil solution (Modified from Brady and Weil, 1999).

Water availability

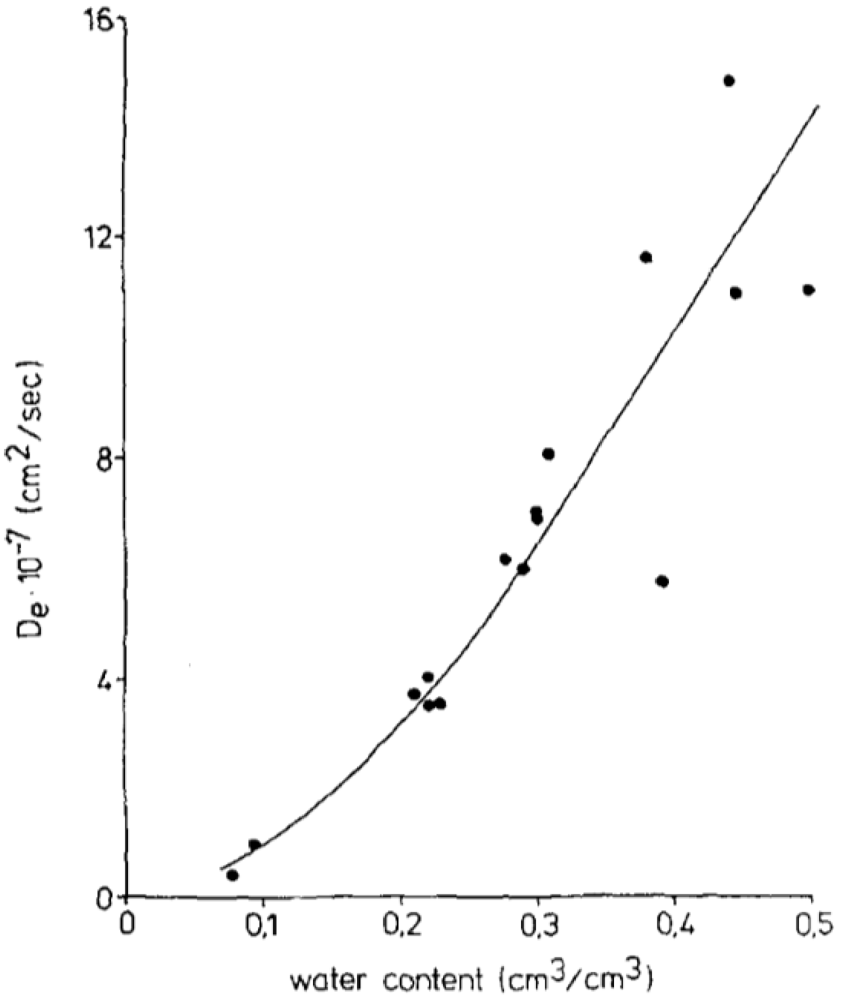


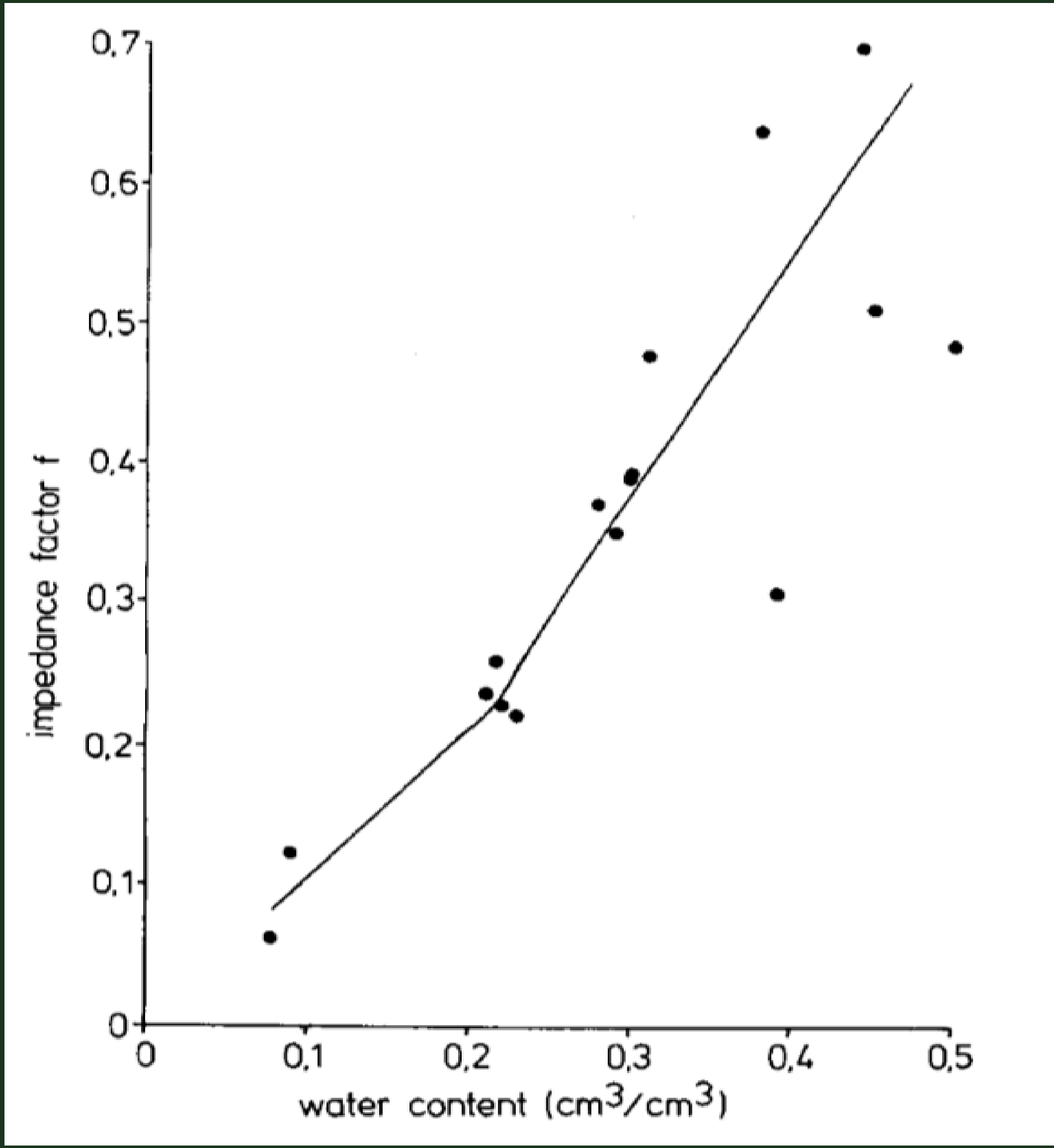
Fig. 2. Effective potasssium diffusion coefficient in relation to the water content of the soil.
Abb. 2. Effektiver K-Diffusionskoeffizient in Abhängigkeit vom Wassergehalt des Bodens.

Water availability

Table 2. Influence of the volumetric water content (θ) of the soil on the K concentration of the soil solution (C_{li}) buffer power (b) and effective diffusion coefficient (D_e) of K

θ ($cm^3\ cm^{-3}$)	C_{li} ($\mu mol\ cm^{-3}$)	ΔC ($\mu mol\ cm^{-3}$)	b	D_e ($cm^2\ sec^{-1}$)
0.19	1.36	3.64	2.68	$2.55 \cdot 10^{-7}$
0.26	1.18	3.64	3.09	$4.91 \cdot 10^{-7}$
0.34	1.06	3.64	4.42	$6.40 \cdot 10^{-7}$

Water availability



Water availability

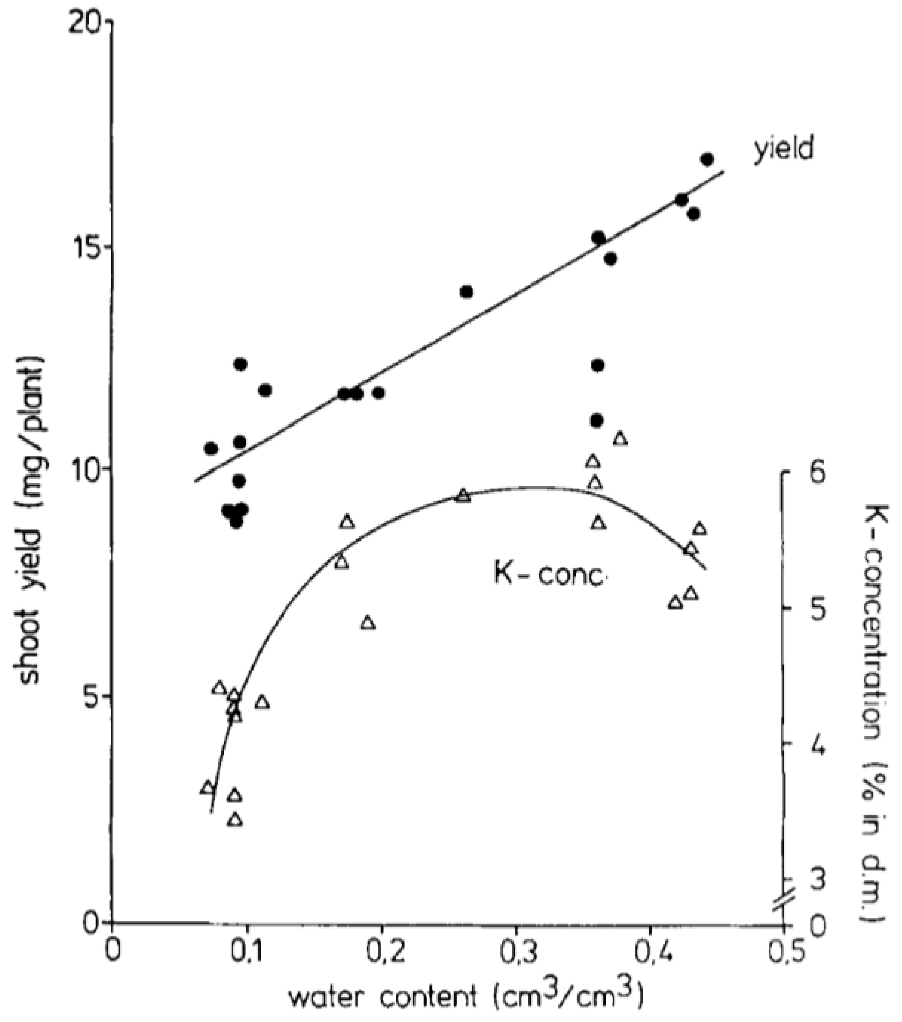


Fig. 4. Influence of soil moisture of Söderhof silt loam on growth and K content of onion plants.

Water availability

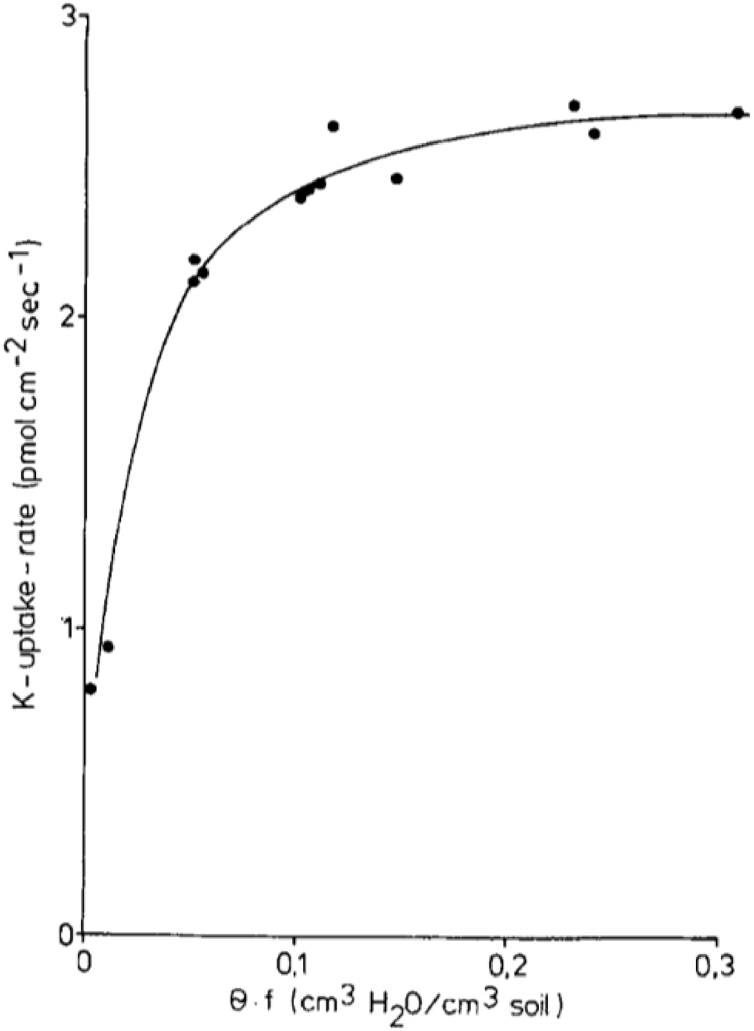


Fig. 6. Rate of potassium uptake per unit surface in relation to the product of volumetric water content (θ) and impedance factor (f).

Abb. 6. K-Aufnahmerate in Abhängigkeit vom Produkt $\theta \cdot f$ bei Zwiebelpflanzen.

OM DECOMPOSITION & MINERALISATION

- Organic matter decomposition & mineralisation determine by:

  a. OM quality

  b. Decomposer

  c. Environment

7.5. AGRONOMIC ROLE OF K

Table 1.9 Critical K concentrations in agronomic crops [From Westerman, 1990. Soil testing and plant analysis. Soil Science Society of America with permission]

Crop	Time of Sampling	Plant Part	Critical Concentration‡ $g\ kg^{-1}$
Sugarbeet		Blade	10
Cotton		Leaves	< 9-15
Wheat	Jointing (GS6)	Total tops	20-25
	Early Boot (GS9)	Total tops	15-20
Rice	Flag Leaf to Mid-Tillering		10-14
Corn	At tassel	Ear leaf	19
	At tassel	Leaves	17-27
	At silk	Sixth leaf from base	13
	At silk	Leaf opposite and just below ear shoot	20
Grain sorghum	Full heading	Second blade below apex	18
Alfalfa		Whole top	8-22
Red Clover		Tops	15-22.5
Bermudagrass		Tops	13-15
Orchardgrass		Tops	23-25
Tall Fescue		Tops	24-38
Kentucky Bluegrass		Tops	16-20

‡ Critical concentration is that nutrient concentration at which plant growth begins to decrease in comparison with plants above the critical concentration.

7.5. AGRONOMIC ROLE OF K

Box 2

Effect of potassium on yield and quality of oranges

K_2O applied	Fruit weight	Yield	Juice	TSS [1]	Acidity	Vitamin C
g/tree	g	kg/tree	%	%	%	mg/100ml
0	165.2	31.9	46.3	9.77	0.549	52.8
200	173.1	36.2	47.2	9.89	0.542	54.1
400	178.0	37.5	47.2	10.06	0.533	55.9

[1] *TSS – total soluble solids*
(personal communication from Desai et al., 1986)

7.5. AGRONOMIC ROLE OF K

Table 5. Effect of K applications on corn grain yields at four sites over three growing seasons. Yield was not significantly ($p = 0.05$) affected by treatment for any year-site combination[a].

Annual K Application[b] *kg K ha^{-1}*	*Rumford*	*Kenansville*	*Matapeake*	*Sassafras*
	Soil — yield, Mg ha^{-1}			
		1982		
0	13.1	12.4	12.1	13.1
94	13.4	12.3	11.3	12.9
94S	14.0	12.3	11.7	13.0
282	13.5	11.4	11.1	13.1
282S	13.8	11.4	11.2	12.2
SEM[c]	0.3	0.5	0.4	0.4
		1983		
0	8.9	–	12.7	9.2
94	9.4	–	12.5	9.1
94S	8.5	–	12.1	7.6
282	11.5	–	11.8	6.9
282S	11.5	–	12.2	6.9
SEM	0.9	–	0.4	1.2
		1984		
0	9.8	–	8.7	–
94	10.1	–	9.2	–
94S	10.3	–	9.8	–
282	10.0	–	9.4	–
282S	10.5	–	9.3	–
SEM	0.2	–	0.4	–

[a]*From Parker et al. (1989b).*
[b]*S indicates K was applied in three equal portions to give the total rate indicated.*
[c]*Standard error of the mean.*

7.5. AGRONOMIC ROLE OF K
7.5.1 Effect of K on growth and production

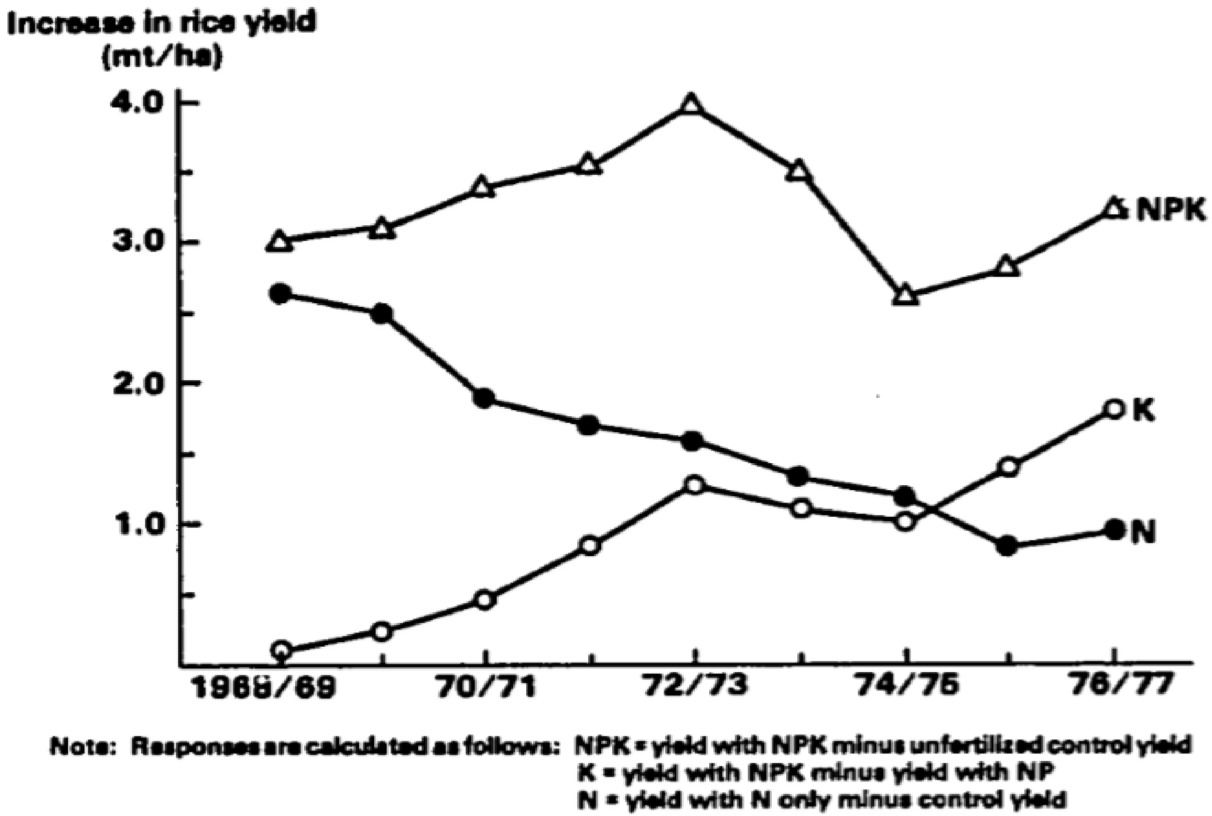


Figure 1. Response of Rice (in the dry season) to N, P, and K Fertilizers in the Long-Term Fertility Experiment at Maligaya, Philippines (moving two-year averages).

7.5.1 Effect of K on growth and production

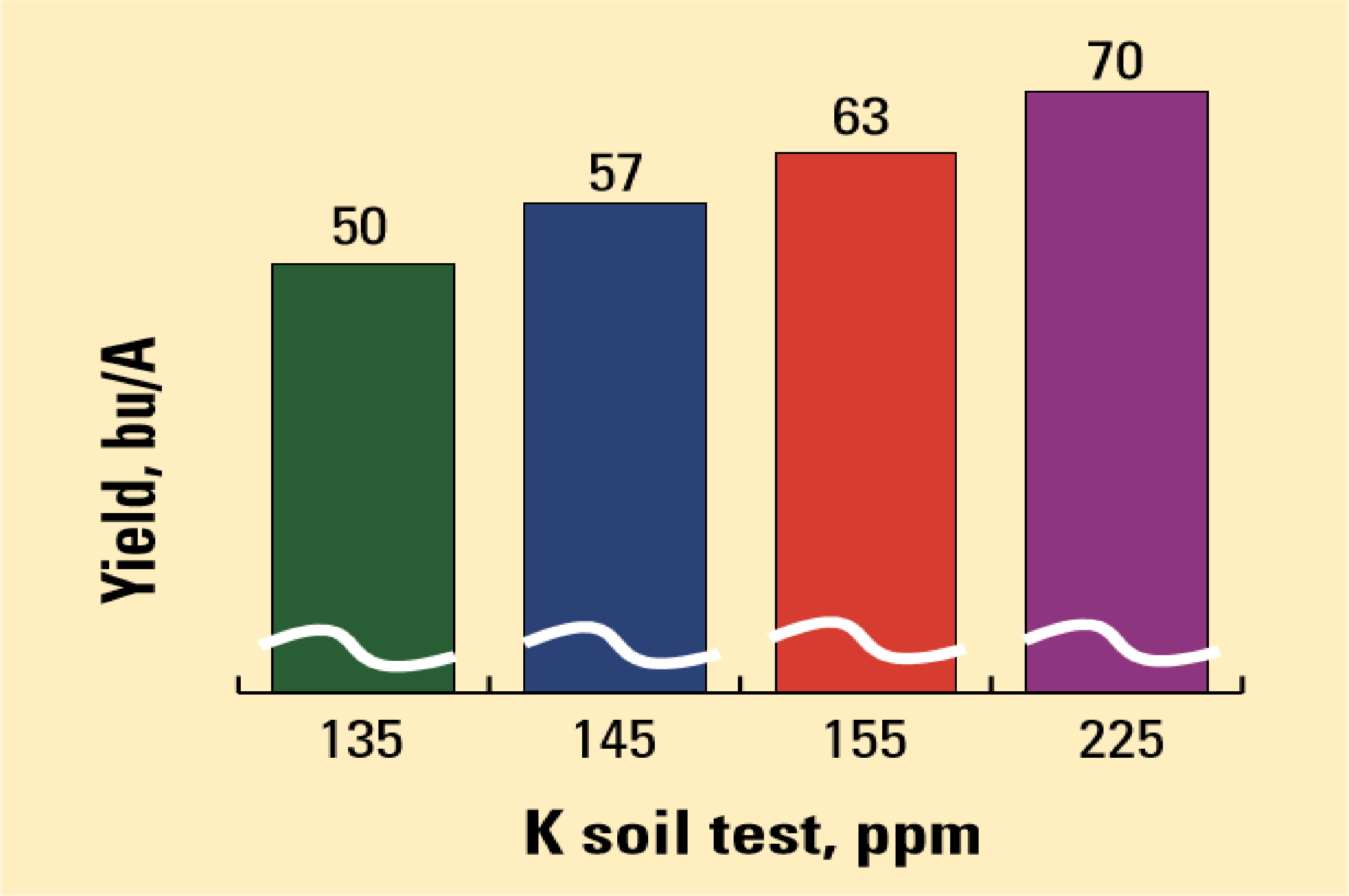
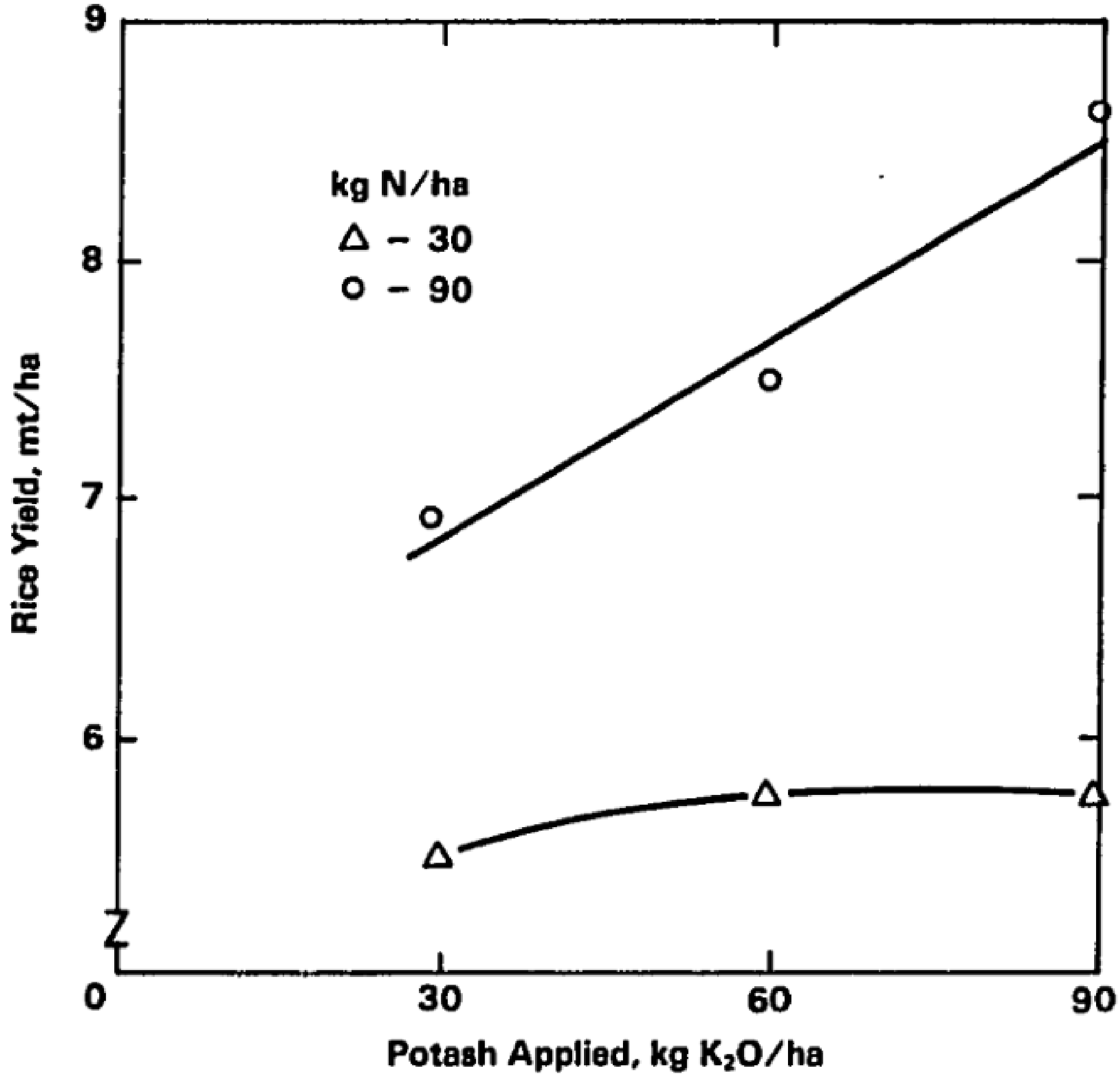


Figure 1. Higher K soil tests can increase soybean yields.

7.5.1 Effect of K on growth and production



Source: Malavolta, 1978.

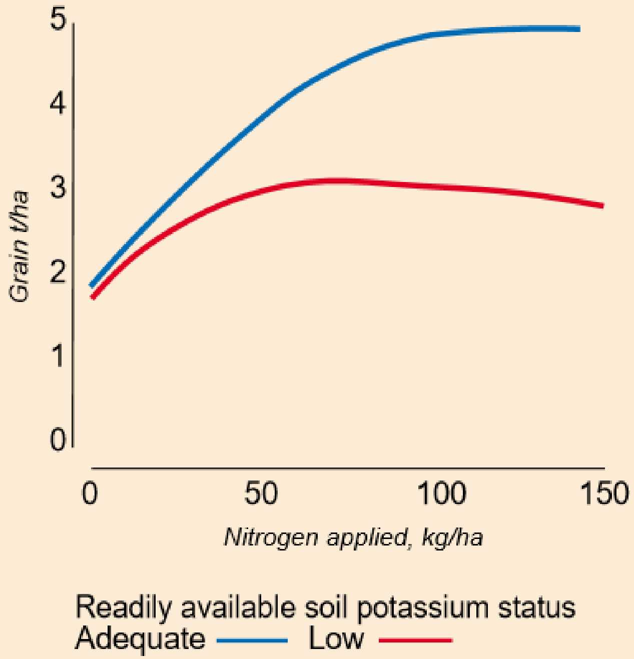
Figure 3. Response of Rice to Potash Under Two Levels of Nitrogen.

7.5.1 Effect of K on growth and production

Box 3

Plant available potassium and the uptake of nitrogen

Adequate amounts of potassium must be readily available in the soil for plant uptake to maintain cell turgor and efficient photosynthesis. If there is not sufficient potassium, nitrogen will be used inefficiently, as shown by the yields of spring barley.



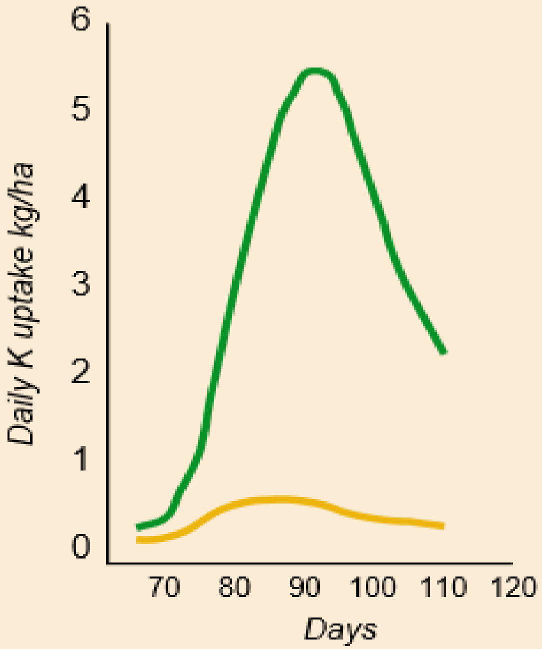
With too little readily plant available potassium in the soil, it was only justified to apply 50 kg nitrogen per hectare (kg N/ha) but with adequate potassium, 100 kg N/ha gave the optimum yield.

When nitrogen does not increase yield because of lack of potassium, the excess nitrogen remains in the soil after harvest as nitrate, at risk to loss.

7.5.1 Effect of K on growth and production

Box 4

Pattern of potassium uptake by spring barley and its effect on grain yield



Daily uptake rate of potassium by spring barley in a field experiment on soil well (green line) and poorly (orange line) supplied with plant available potassium.

7.5.1 Effect of K on growth and production

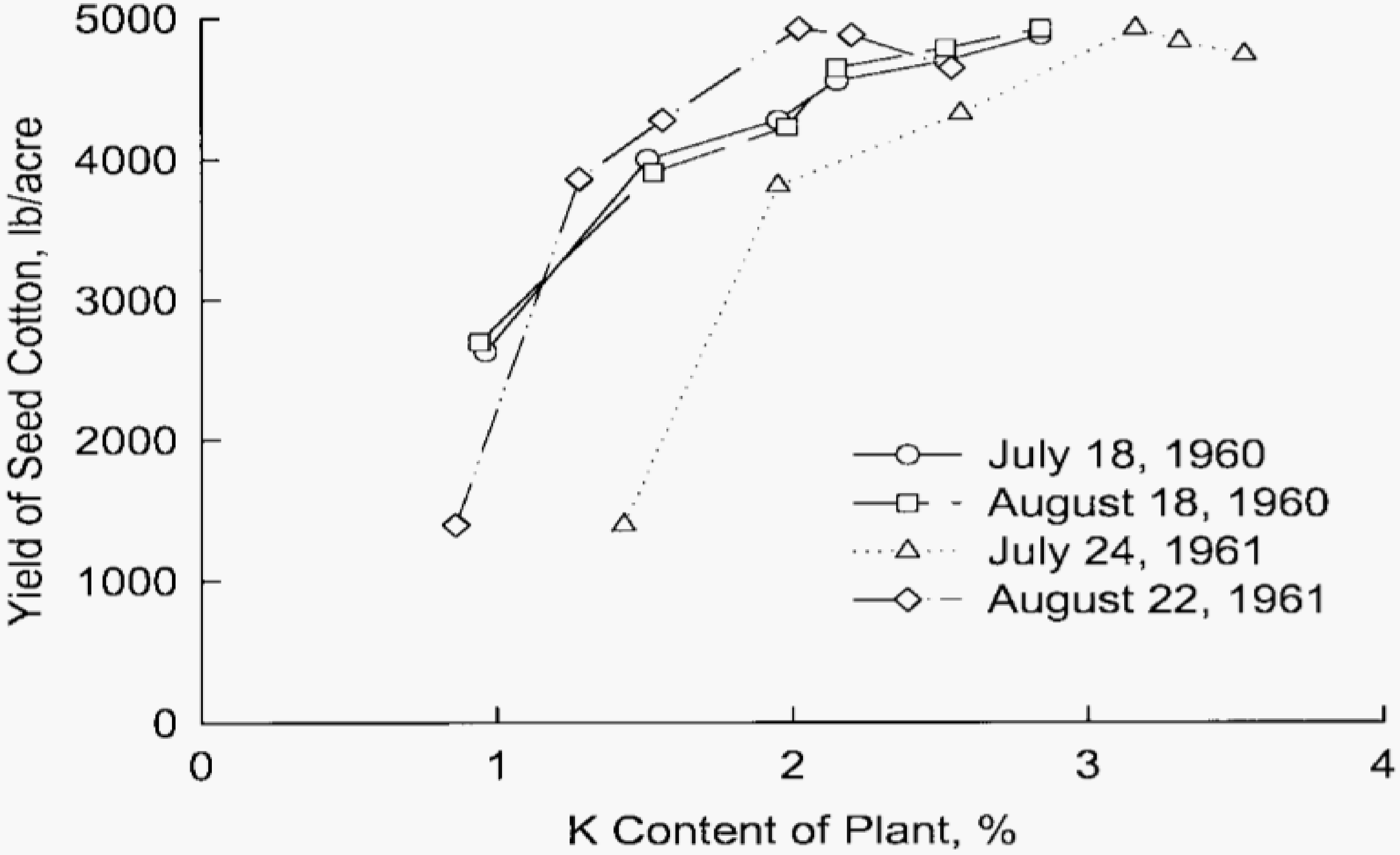


Figure 5. Relation between yield and potassium content of above-ground cotton plants (redrawn from Bennett et al. 1965).

7.5.1 Effect of K on growth and production

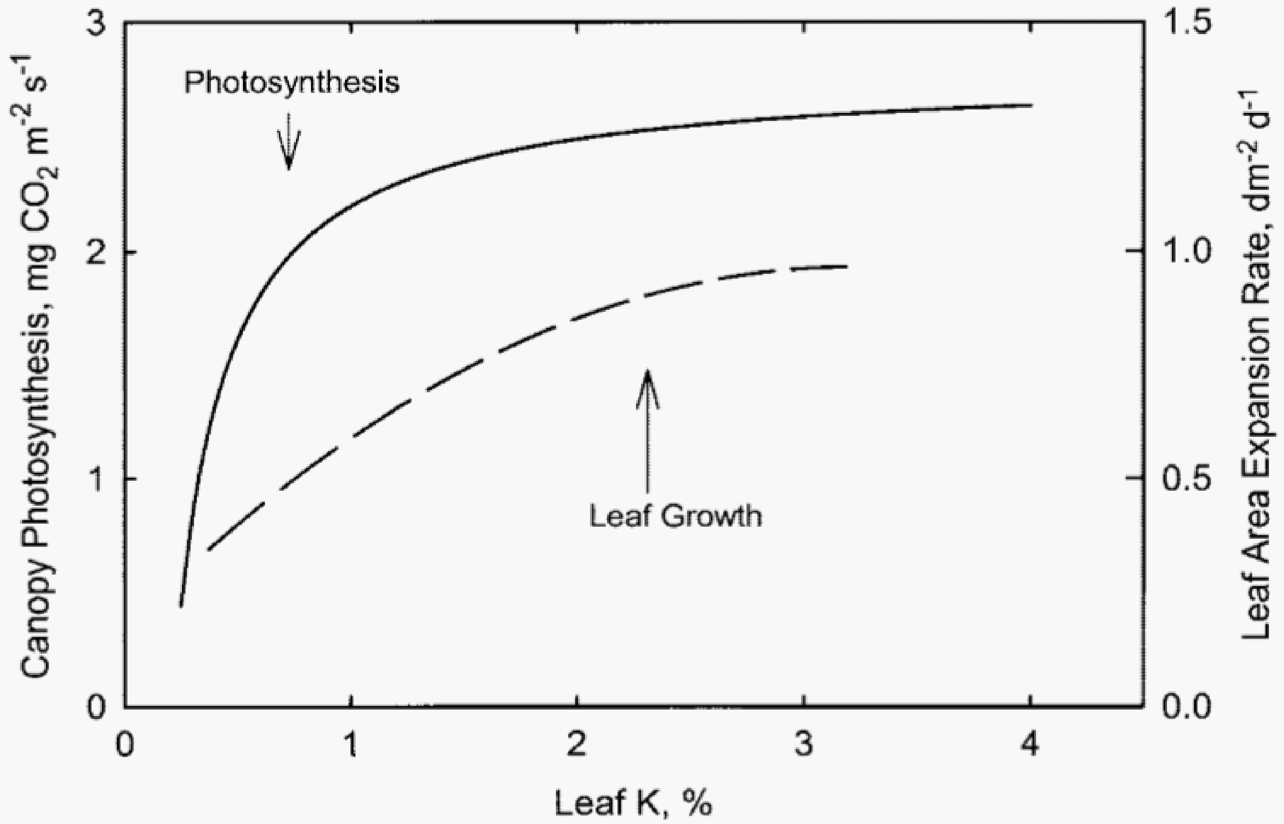


Figure 3. Cotton canopy net photosynthesis and leaf area expansion as a function of leaf K concentration. Plants were grown in optimum day/night (86/72°F) temperatures in a range of K-deficient conditions but with sufficient water and other macro and micro nutrients. Potassium was determined in the uppermost fully expanded leaves.

7.5.1 Effect of K on growth and production

Table 7.
The Effect of Applying Potassium Fertilizer on the Increases in Yield Given by Nitrogen Fertilizer

	Increase in Yield (kg) Produced by 1 kg/ha of N	
	Without K Fertilizer	With K Fertilizer[a]
Rice		
India	17	23 (60)
Madagascar	3	14 (45)
Wheat		
Frence	7	9 (80)
Maize		
Nigeria	1	15 (90)
France	10	16 (75)
Cassava		
India	26	41 (100)
Potatoes		
France	18	40 (100)
Oil palm		
Ivory Coast	-23	8 (144)

a. The amount of K_2O applied, in kg/ha, is stated in parentheses.

7.5.1 Effect of P on growth and production

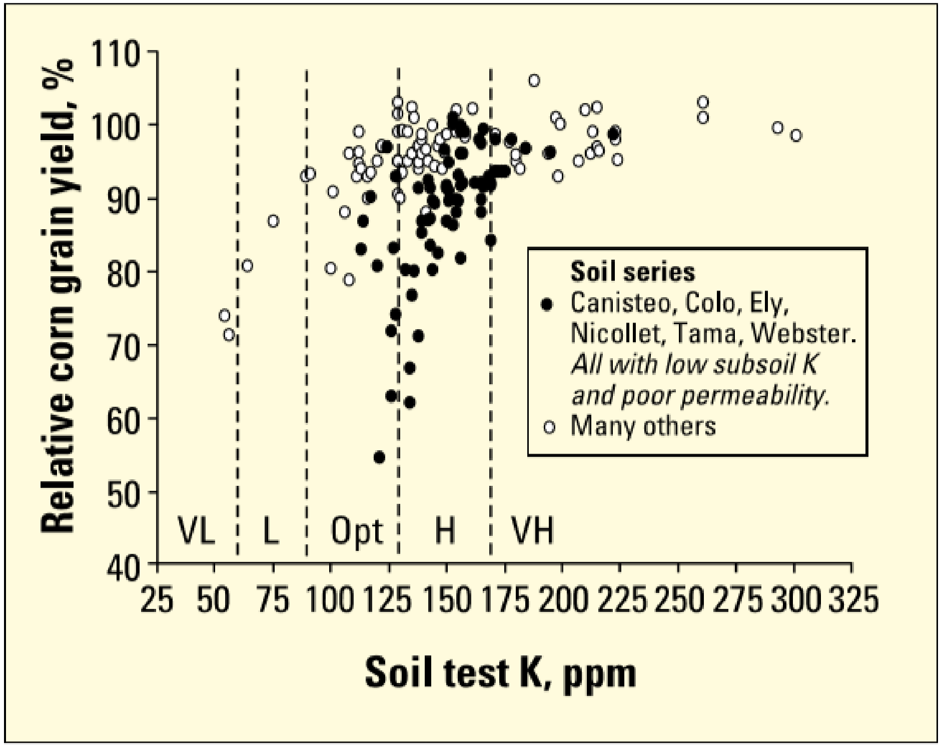


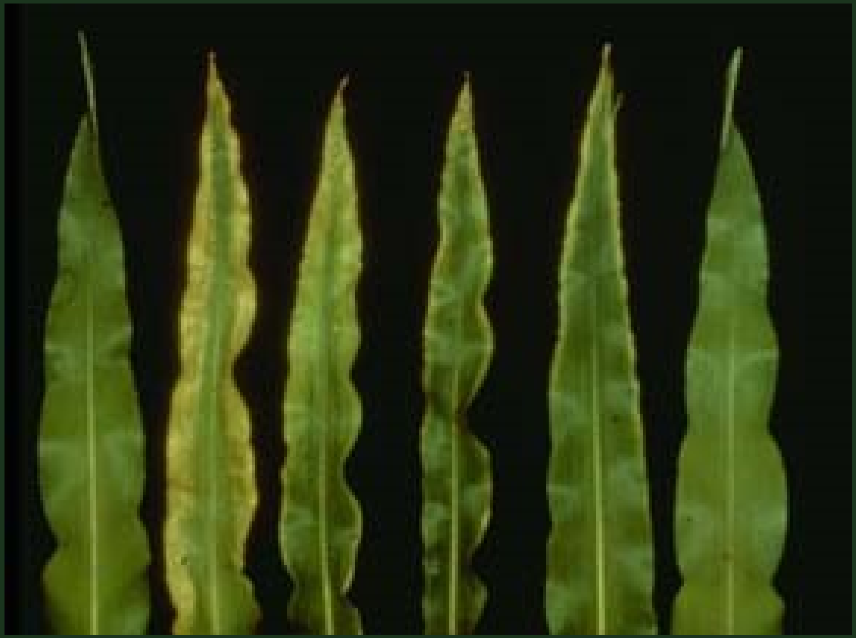
Figure 1. Relationship between relative corn yield and ammonium acetate soil test K values for various Iowa soils. VL, L, Opt, H, VH are abbreviations for the Very Low, Low, Optimum, High, and Very High soil test interpretation classes. Interpretation classes were used until October 2002.

K deficiency symptom

Deficiency symptoms:

- Plants will lodge easily.
- Are sensitive to disease infestation.
- Fruit yield and quality will be reduced.
- Older leaves will look as if they had been burned along the edges, a deficiency symptom known as *scorch*, as K is mobile in the plant.
- Deficiency symptoms first appear in older plant tissue, as K is mobile in the plant.
- K-deficient plants may also become sensitive to the presence of NH_4, leading to a possible NH_4 toxicity syndrome.

K Deficiency Symptom



Corn

Soybean

7.5. AGRONOMIC ROLE OF K

7.5.2 K deficiency simptoms

Alfalfa

Banana

K deficiency symptom

Kelapa sawit

Kelapa sawit

K deficiency symptom

Leaf K content	Leaf development	Leaf growth	Stem growth	Photosynthesis
1.15%	88%	66%	100%	85%

Leaf K content	Leaf development	Leaf growth	Stem growth	Photosynthesis
0.94%	85%	59%	98%	80%

Leaf K content	Leaf development	Leaf growth	Stem growth	Photosynthesis
0.39%	83%	37%	42%	45%

Leaf K content	Leaf development	Leaf growth	Stem growth	Photosynthesis
0.30%	82%	32%	5%	25%

K toxicity (excess) symptom

Excess (toxicity) symptoms:

- Will become deficient in Mg and possibly Ca, due to the imbalance.
- Mg deficiency is most likely to occur first.

8. K RECOMENDATION

Table 1.9 Critical K concentrations in agronomic crops [From Westerman, 1990. Soil testing and plant analysis. Soil Science Society of America with permission]

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	At silk	Leaf opposite and just below ear shoot	20
Grain sorghum	Full heading	Second blade below apex	18
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Bermudagrass		Tops	13-15
Orchardgrass		Tops	23-25
Tall Fescue		Tops	24-38
Kentucky Bluegrass		Tops	16-20

‡ Critical concentration is that nutrient concentration at which plant growth begins to decrease in comparison with plants above the critical concentration.

8. POTASSIUM MANAGEMENT

8.1 Decreasing K Losses

8.2 Increasing K uptake

8.3 Organic matter management

8.4. Management of K fertilization