

# GUIDELINES FOR AMELIORATING SOIL ACIDITY

PE Haumann

FERTASA SYMPOSIUM 27 JULY 2016



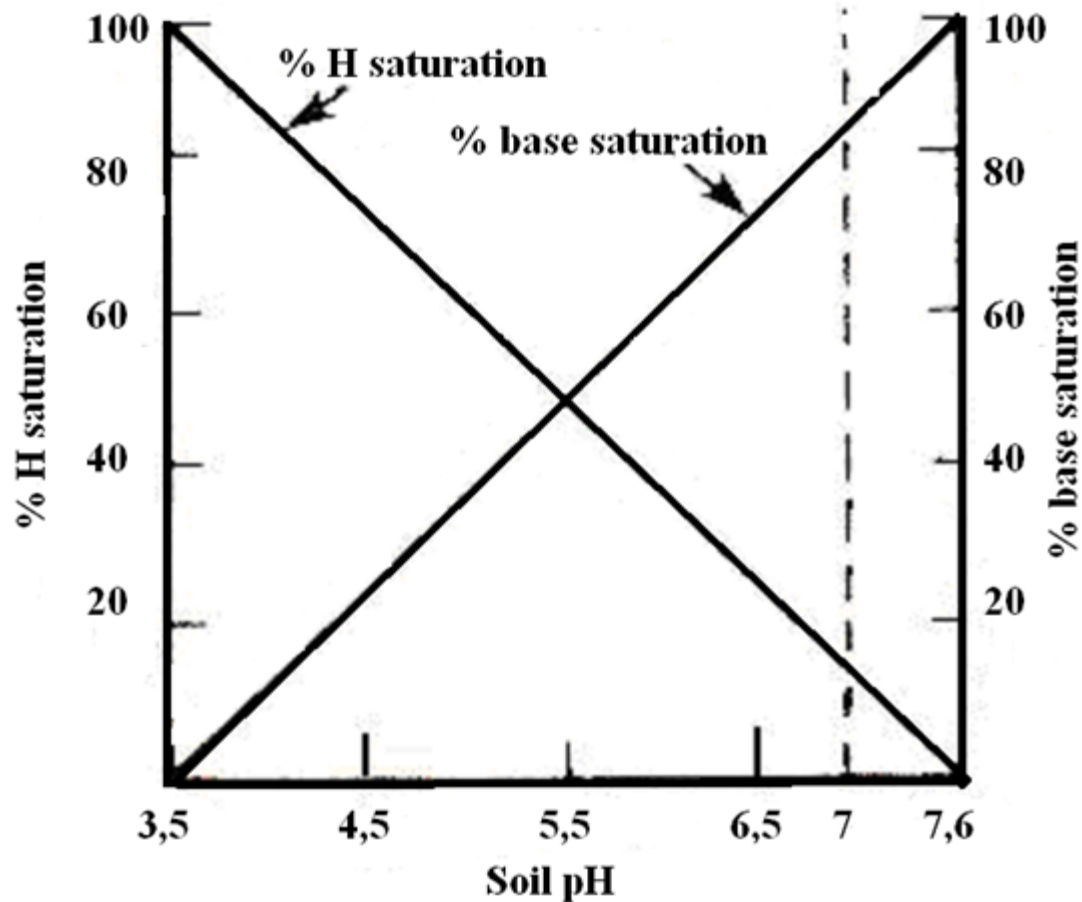
PO Box 75510  
Lynnwood Ridge 0040  
Republic of South Africa  
Website: [www.fertasa.co.za](http://www.fertasa.co.za)  
Tel: +27 (0)12 349 1450 • Fax: +27 (0)12 349 1463

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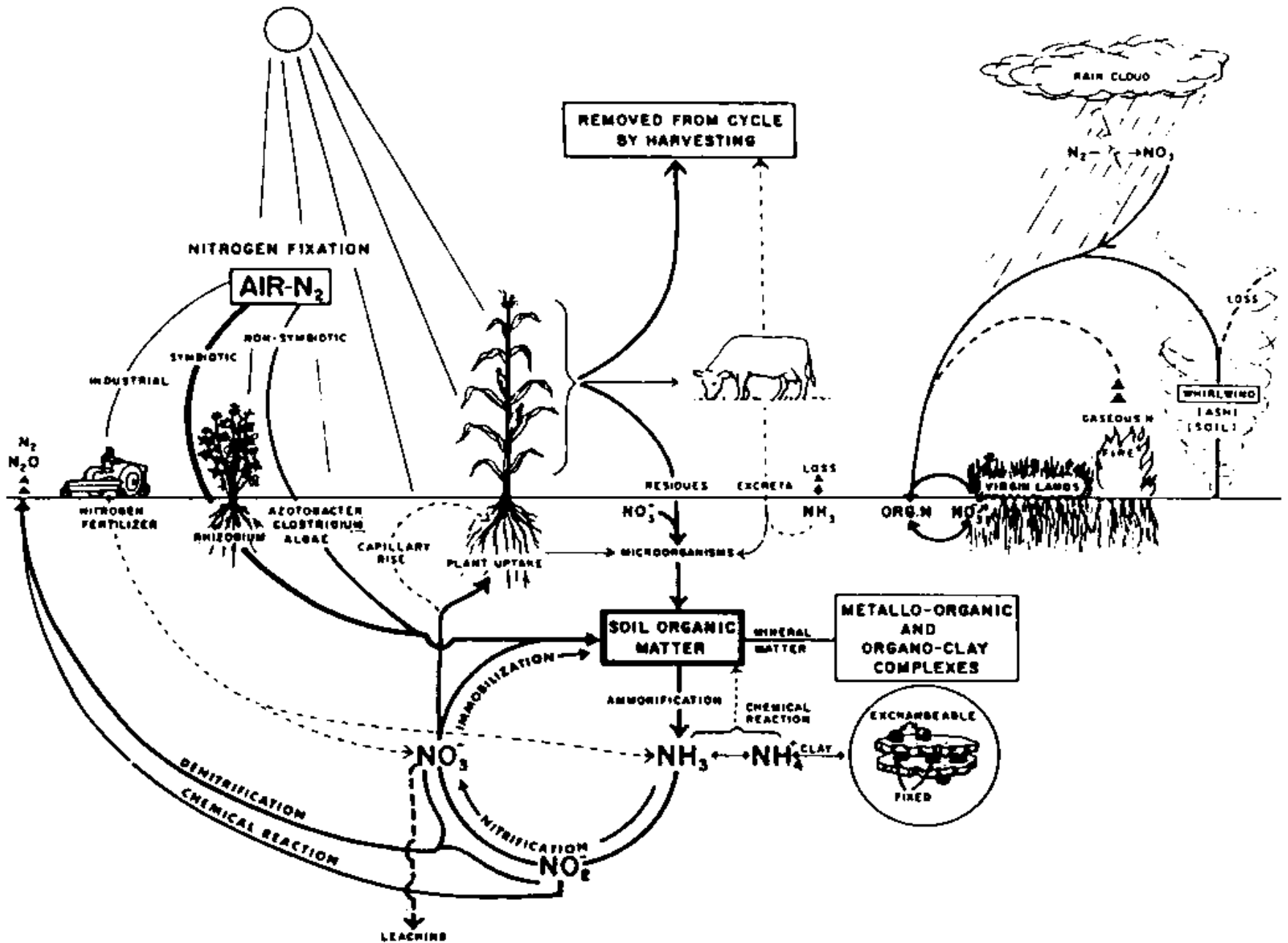
## CHAPTER 1.8 Soil acidity

- Causes and mechanisms of soil acidity (revision)
- The extent of soil acidity
- Categorization/measurement of soil acidity
- Amelioration of soil acidity
- Lime requirement of soils (revision)
- Lime requirement determination
- Subsoil acidity
- Surface crusting and soil hardness
- Practical considerations and recommendations
- Practical examples for soil acidity and liming

# Simplified explanation of soil acidity/alkalinity



# Causes of soil acidity (Revision)



## Fertilizers with High Ammonium Content Acidify Soils

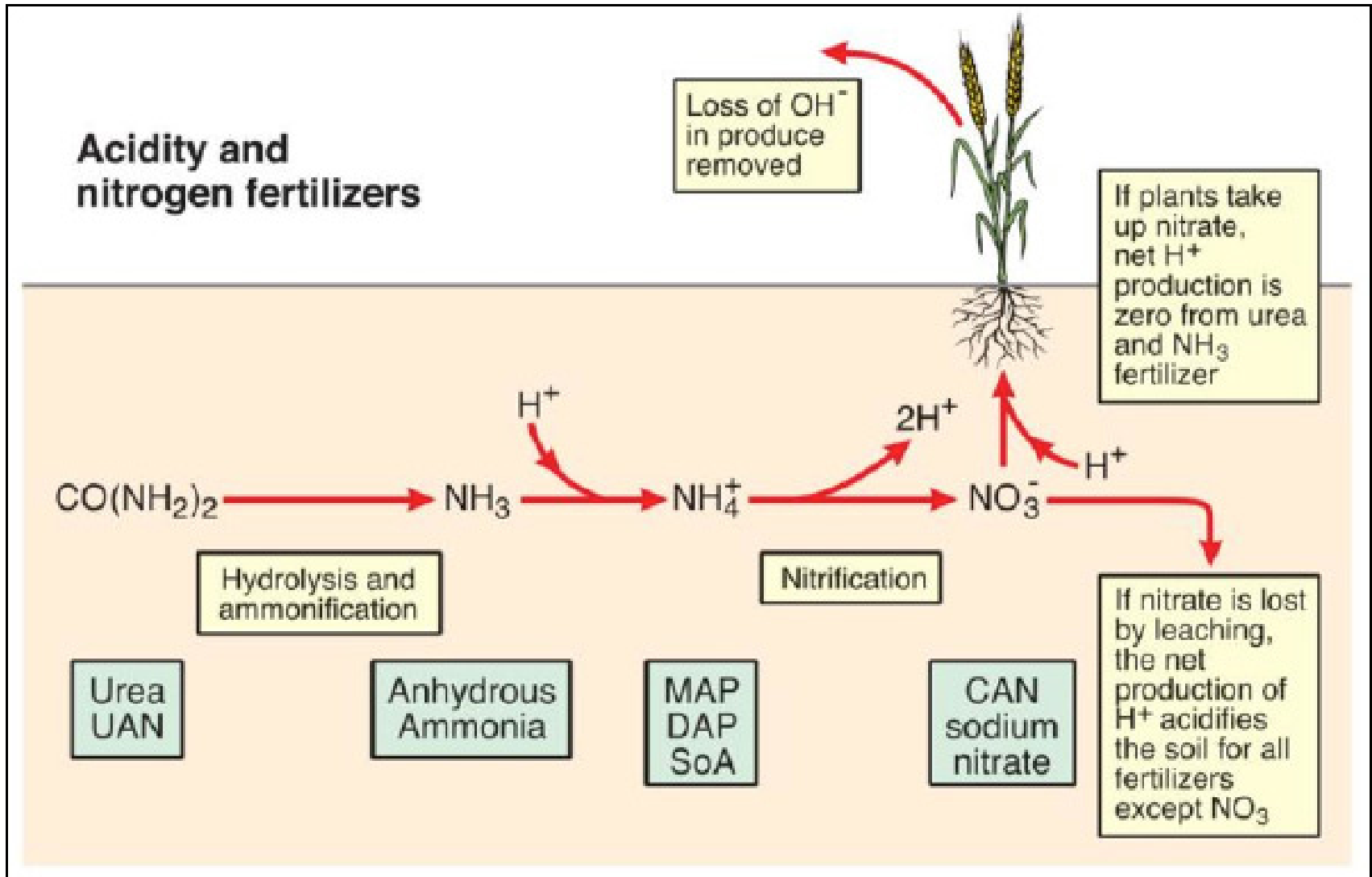
- Soil bacteria oxidize ammonium ( $\text{NH}_4^+$ ) to nitrate ( $\text{NO}_3^-$ ) - *Nitrification*
- The process produces two hydrogen ions ( $\text{H}^+$ )



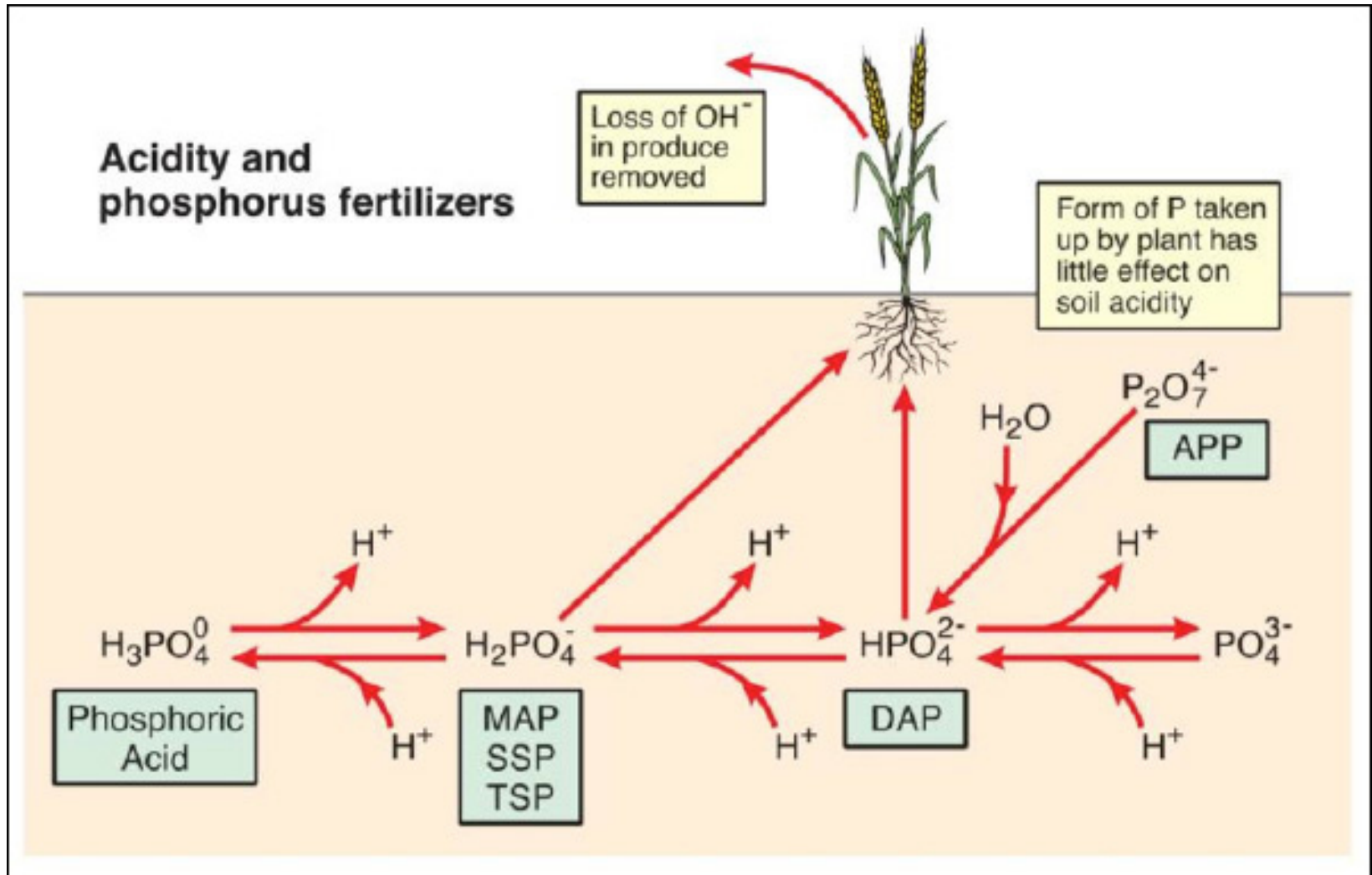
Soil Solution



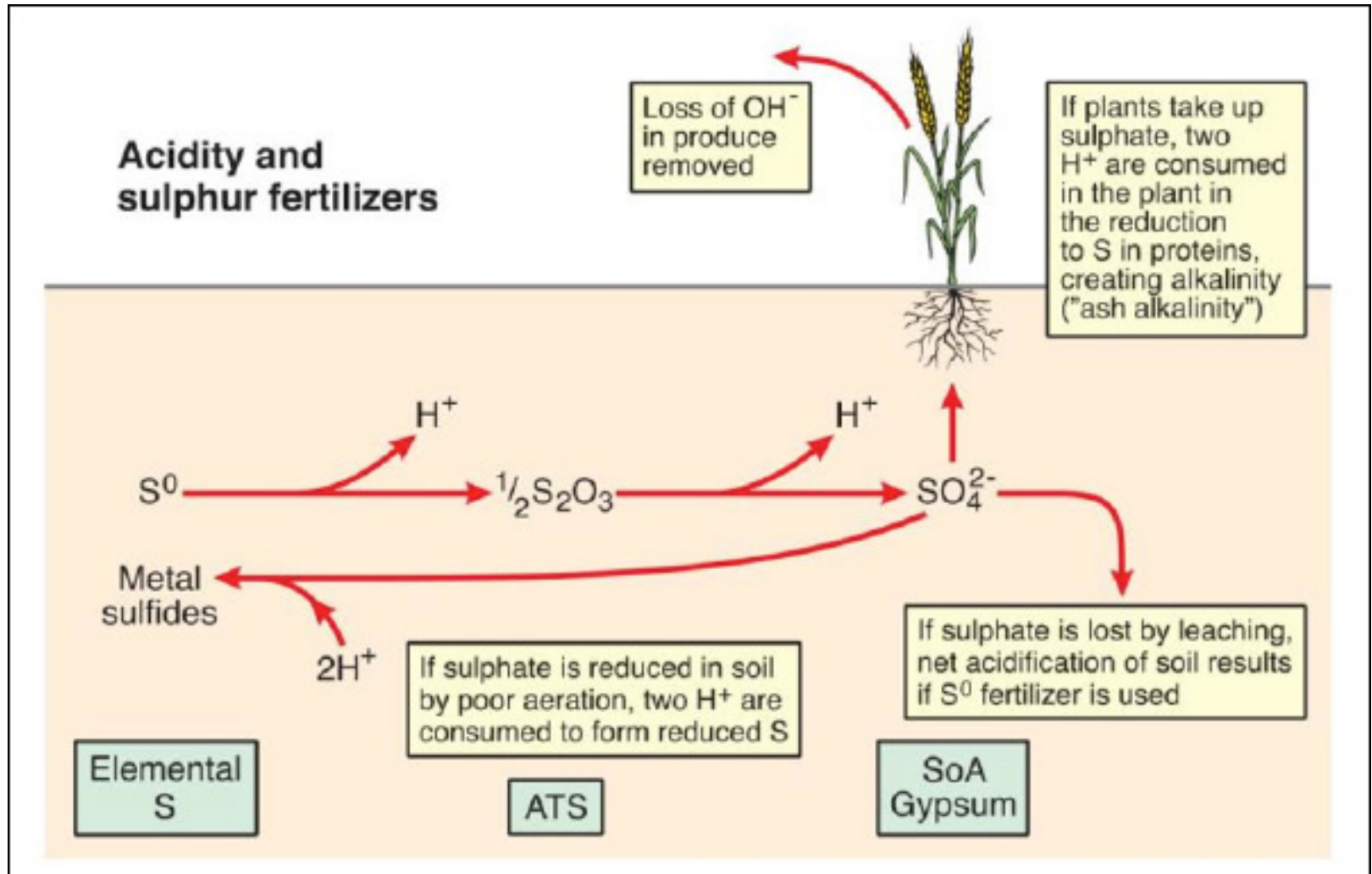
# Soil acidification due to N fertilizers



# Soil acidification due to P fertilizers



# Soil acidification due to sulphur fertilizers

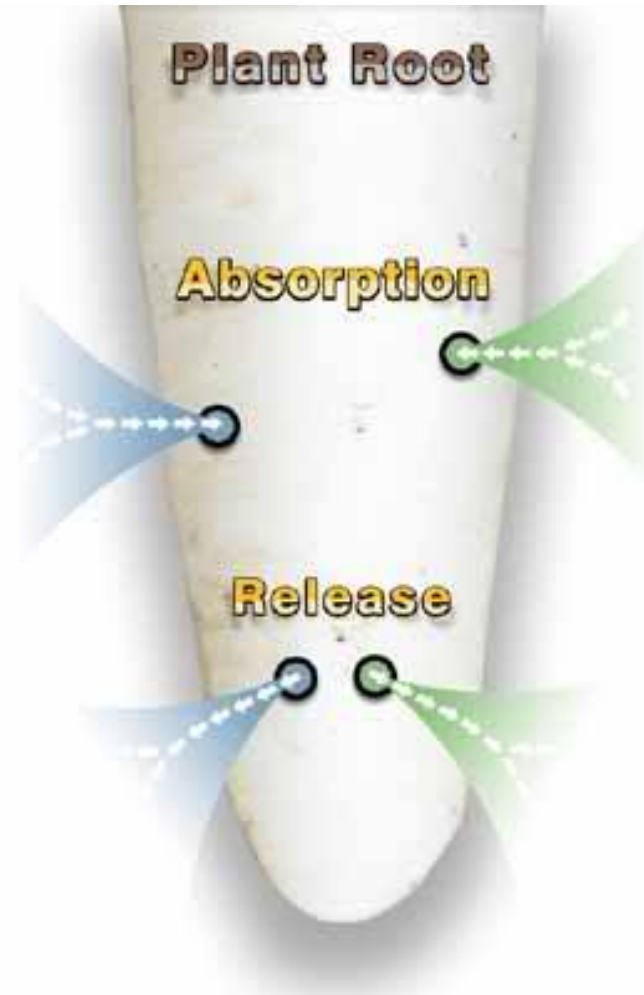


# Root-soil cation/anion interactions

## Cations are:

urea (nitrogen)  $\text{NH}_2$   
ammonium (nitrogen)  $\text{NH}_4$   
potassium K  
calcium Ca  
magnesium Mg  
iron Fe  
zinc Zn  
copper Cu  
manganese Mn  
cobalt Co

$\text{H}^+$   
Hydrogen Ion  
(Decreases pH)



## Anions are:

$\text{NO}_3$  nitrates (nitrogen)  
 $\text{H}_2\text{PO}_4$  phosphates (phosphorus)  
 $\text{SO}_4^{2-}$  sulfates  
 $\text{CO}_3$  carbonates  
 $\text{HCO}_3$  bicarbonates

$\text{OH}^-$   
Hydroxide Ion  
(Increases pH)

**Table 1. Acidification potential for various N, P and S fertilizers expressed as kg lime equivalent per kg of N, P or S applied or on a product weight basis (MicroEssentials versus MAP).**

Fertilizer	Acidification potential	
<b><i>Nitrogen fertilizers</i></b>		
	<b>kg lime equivalent to neutralize acidity per kg N</b>	
	<b>If all nitrate leached</b>	<b>If all nitrate taken up</b>
NO <sub>3</sub>	0	-3.6
NH <sub>4</sub> NO <sub>3</sub>	3.6	0
Urea	3.6	0
Liquid NH <sub>3</sub>	3.6	0
SoA	7.1	3.6
MAP (pH > 7.7)	10.7	7.1
MAP (pH < 6.7)	7.1	3.6
DAP (soil pH > 7.7)	7.1	3.6
DAP (soil pH < 6.7)	5.4	1.8
<b><i>Phosphorus fertilizers</i></b>		
	<b>kg lime equivalent to neutralize acidity per kg P</b>	
	<b>Soil pH &lt;6.7</b>	<b>Soil pH &gt;7.7</b>
SSP	0	1.6
TSP	0	1.6
MAP	1.6	3.2
DAP	1.6	3.2
PA	1.6	3.2
<b><i>Sulfur fertilizers</i></b>		
	<b>kg lime equivalent to neutralize acidity per kg S</b>	
SoA	0	
Elemental S	3.2	
ATS, (NH <sub>4</sub> ) <sub>2</sub> S <sub>2</sub> O <sub>3</sub>	4.8/3.2 (nitrate taken up)	
Gypsum	0	
<b>kg lime equivalent to neutralize acidity per kg product</b>		
<b><i>MAP vs. MicroEssentials (MES)</i></b>		
<b>Soil pH &lt; 6.7</b>	<b>If all nitrate leached</b>	<b>If all nitrate taken up</b>
MAP (11-52-0-0)	0.79	0.39
MES10 (12-40-0-10)	1.01	0.58
MES15 (13-33-0-15)	1.16	0.70
MES9 (10-46-0-9)	0.93	0.58

# Amelioration of soil acidity

Lime requirement  
(Revision)

# Generalised effect of soil pH on nutrient availability and plant growth

**Effect of pH on Nutrient Availability**

Nutrient	pH									
	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5
Nitrogen	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light
Phosphorus	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light
Potassium	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light
Sulfur	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light
Calcium	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light
Magnesium	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light
Iron	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark
Manganese	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark
Boron	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark
Copper/Zinc	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark	Dark
Molybdenum	Light	Light	Light	Light	Light	Light	Light	Light	Light	Light

**Note:** Darker shading indicates greater availability.

**From:** <http://www.sws.uiuc.edu/data/altcrops/gisoils.asp>

Msinga: limed on left and right,  
not limed in centre



# Msinga: 16 tons of lime/ha versus no lime



# Mg deficiency



# Effect of lime and phosphate on maize roots



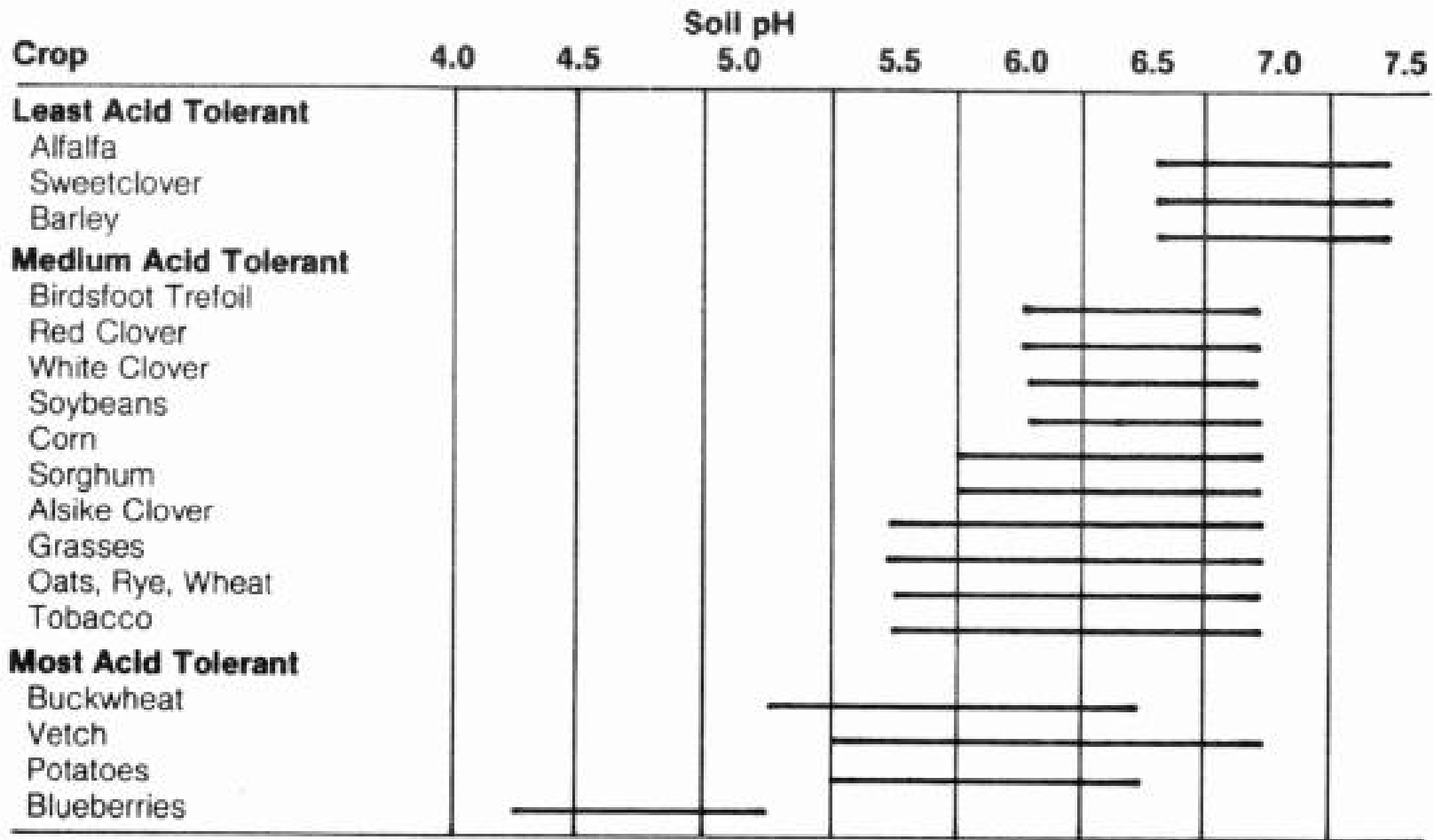
# Ca deficiency



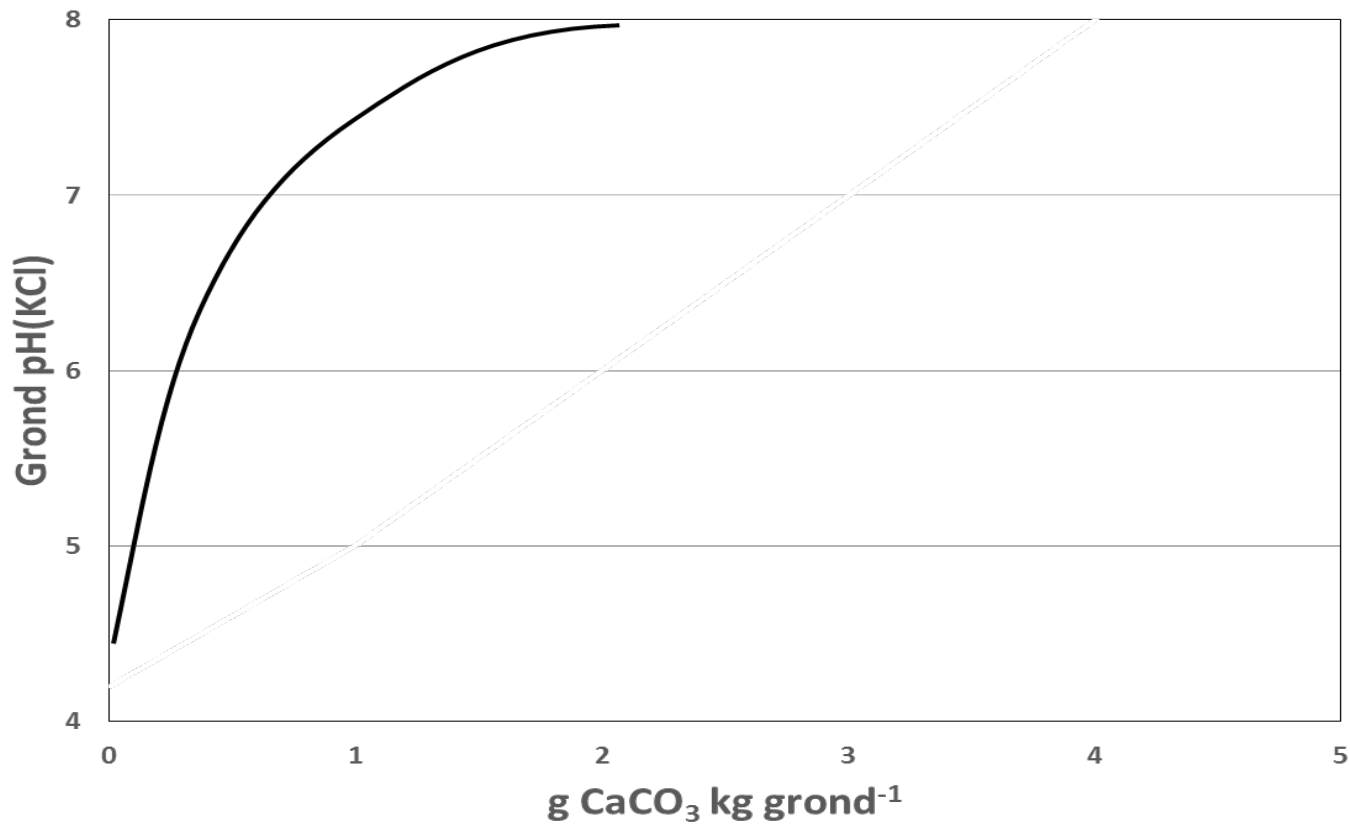
# Ca deficiency



# Optimal soil pH(H<sub>2</sub>O) range for selected crops



### Grond Titrasiekromme (inkubasie)

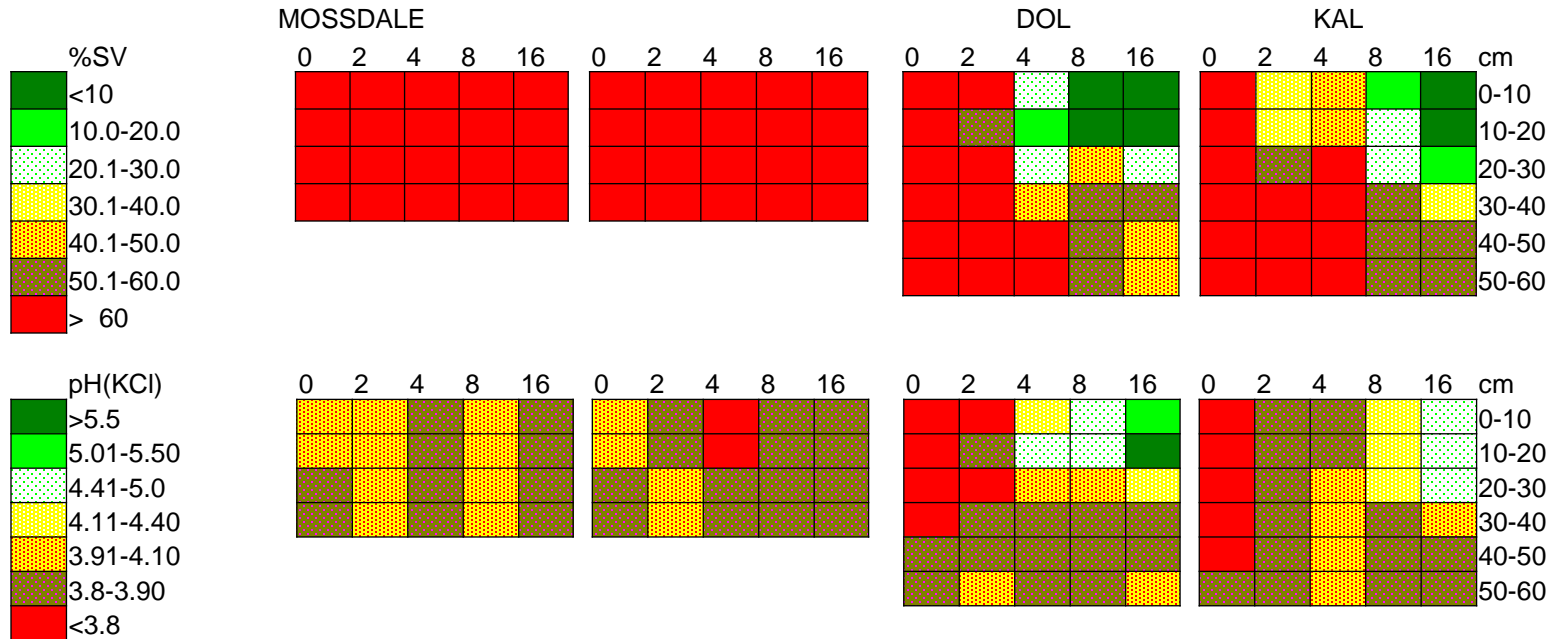


# Subsoil acidity and influence of soil acidity on maize production

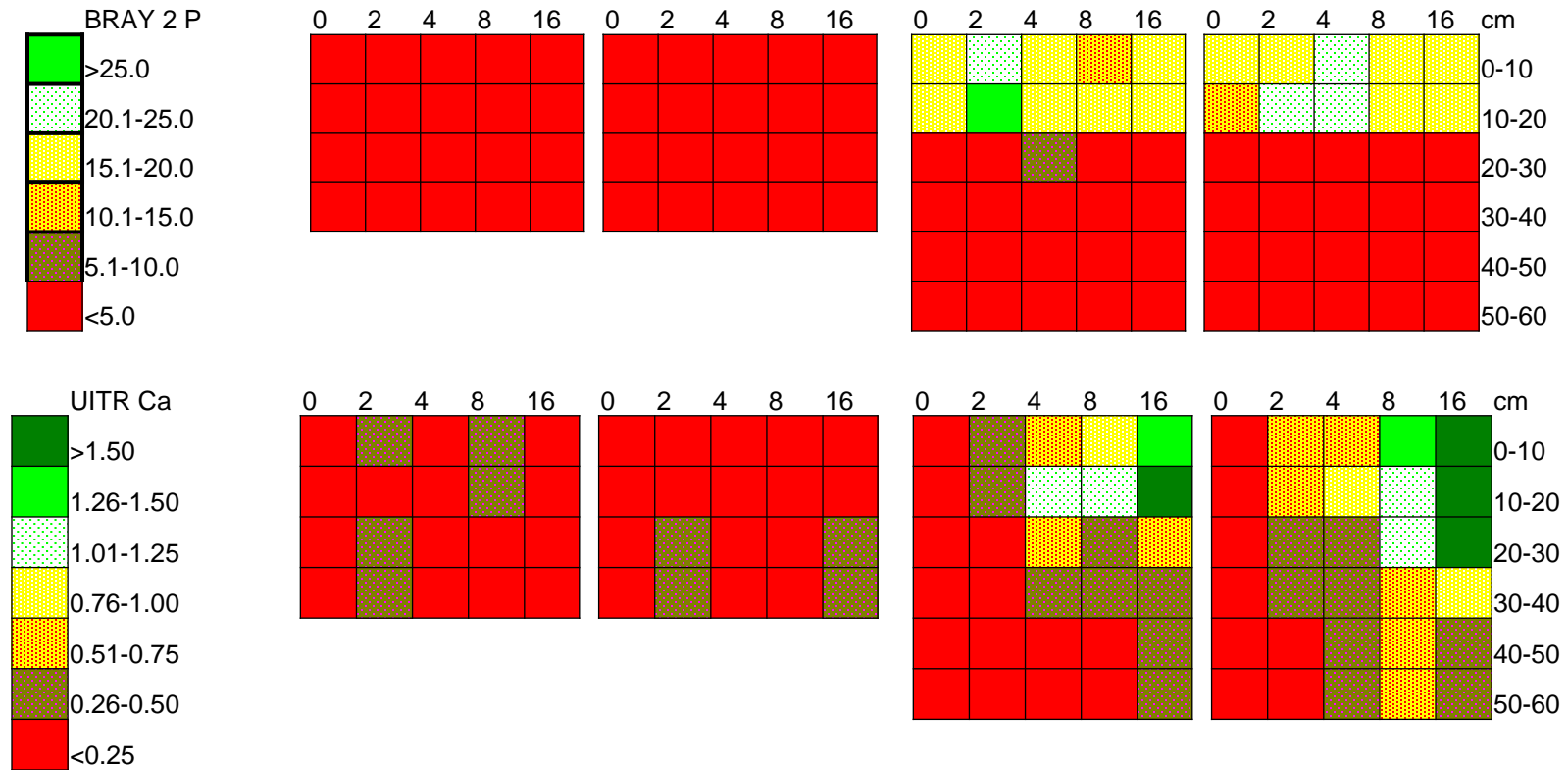
# Clovelly Mossdale physical and chemical properties (Heidelberg)

	Topsoil	Subsoil
CEC ( $\text{cmol kg}^{-1}$ )	3.58	2.86
% Clay	11.80	14.40
% Silt	1.95	5.10

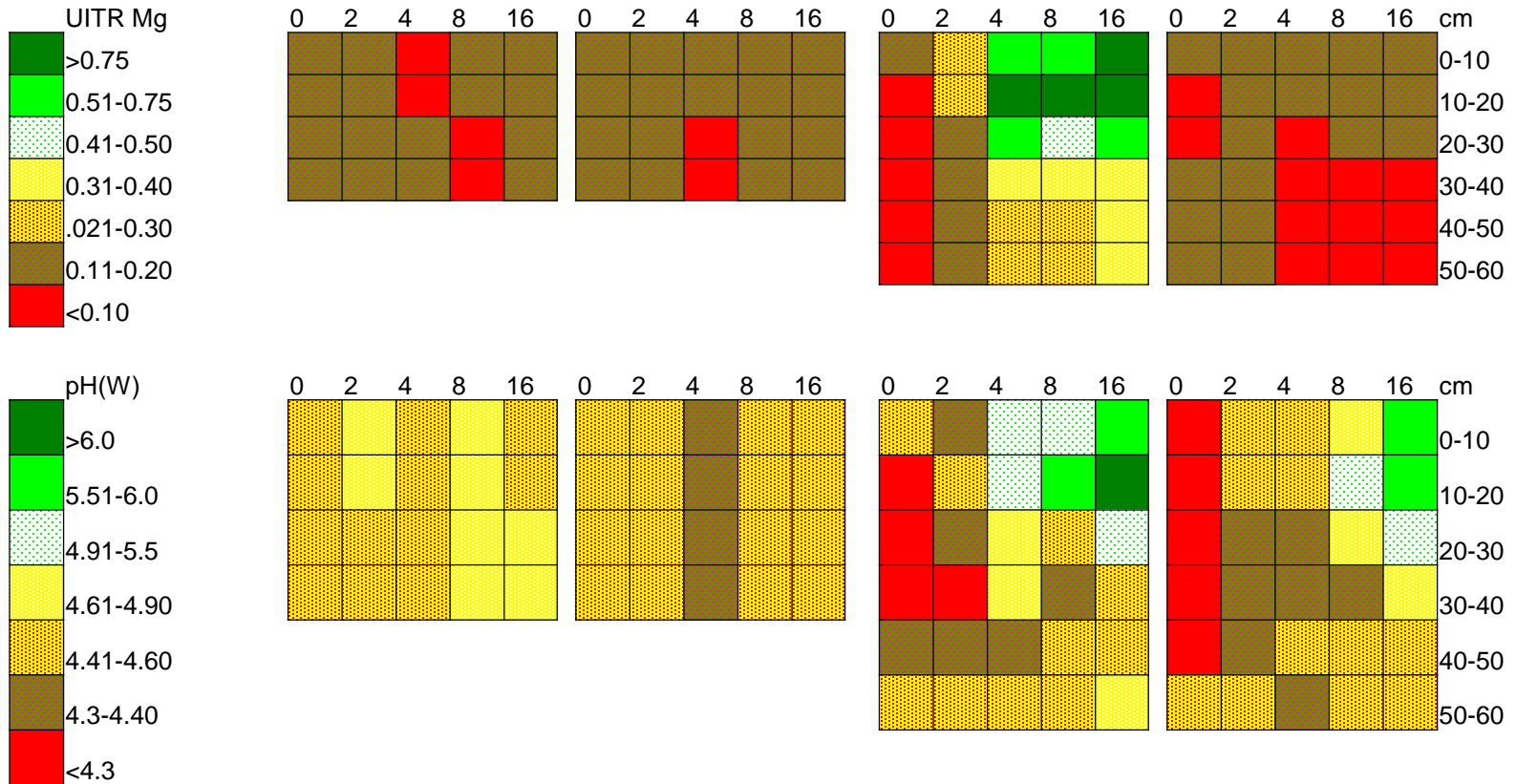
# Clovelly Mosssdale 3 years (1983) after liming and P application



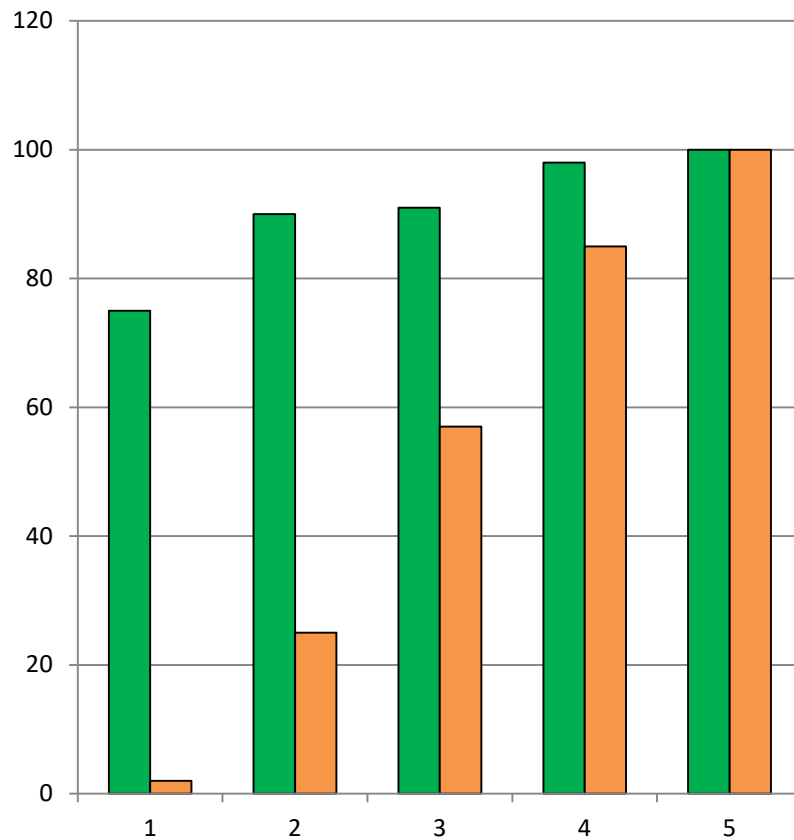
# Clovelly Mossdale 3 years after liming and P application



# Clovelly Mossdale 3years after liming and P application



# Mossdale: maize % yield in dry and wet seasons



MIELIEOPBRENGS (t/ha)

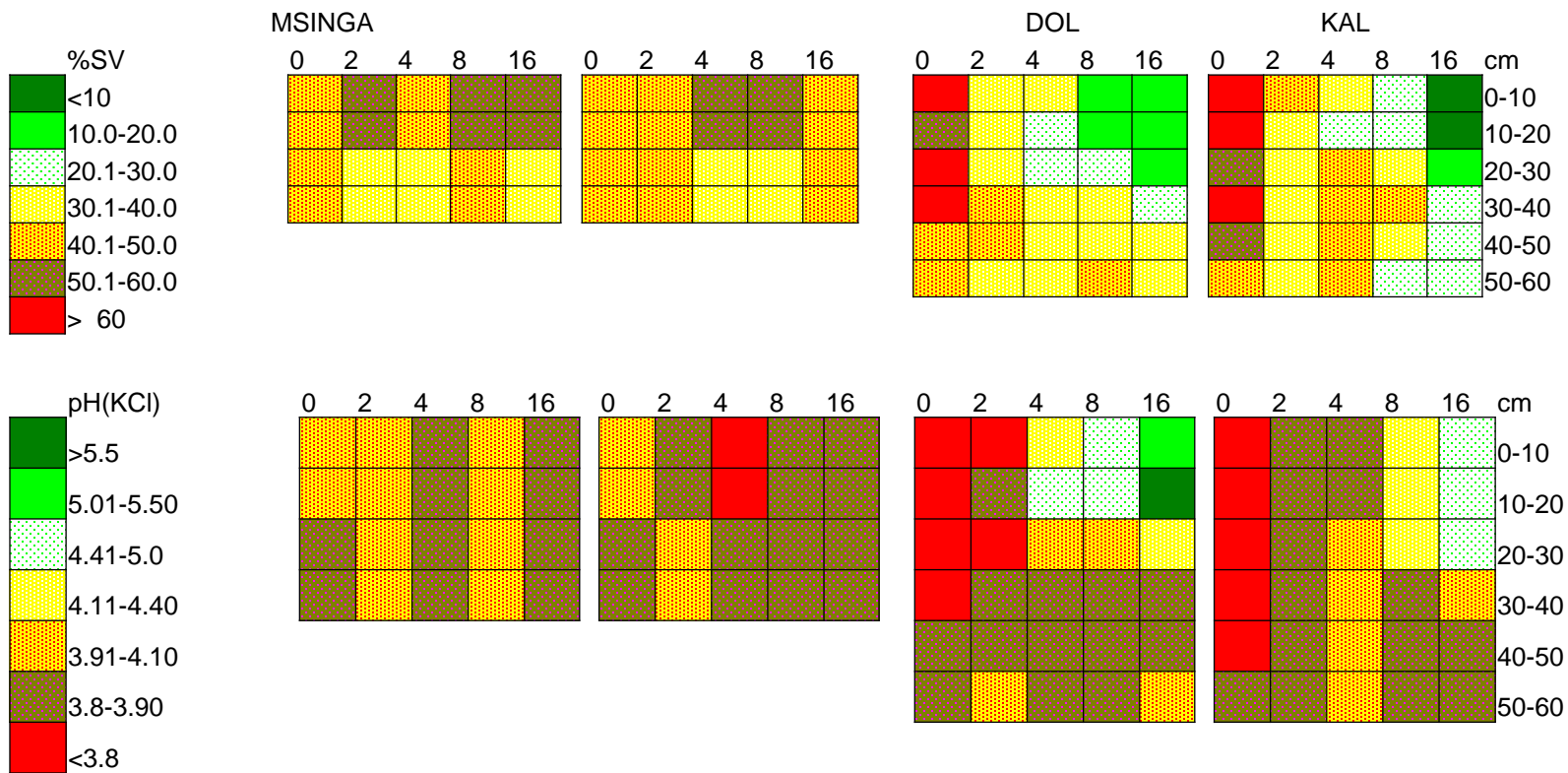
	3.92	4.72	4.79	5.12	5.24
	0.03	0.3	0.7	1.04	1.22

	75	90	91	98	100
	2	25	57	85	100
0-60					
SV	74	60	48	39	28
pH(K)	3.77	3.84	4.02	4.07	4.47
Ca	32	64	98	134	216
Mg	12	19	35	35	49
0-20					
SV	76	49	31	16	4
pH(K)	3.76	3.85	4.18	4.41	5.26
Ca	30	103	161	228	370
Mg	12	24	53	54	84

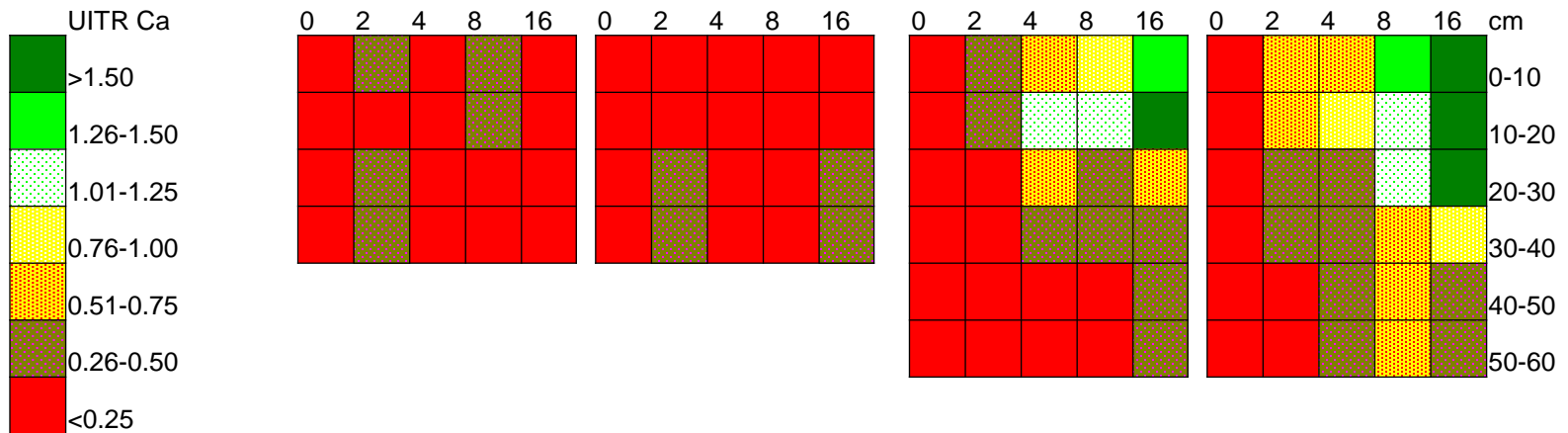
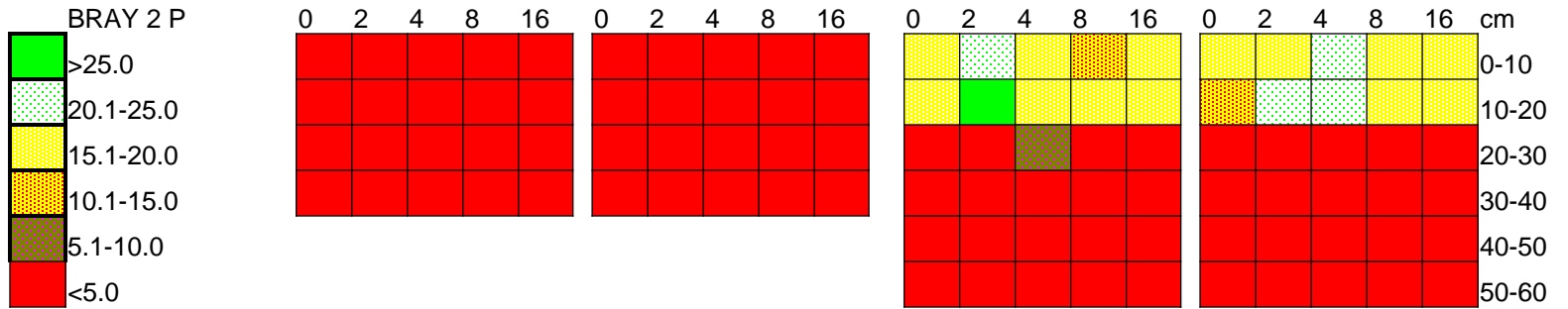
# Hutton Msinga physical and chemical properties (Randfontein)

	Topsoil	Subsoil
CEC (cmol kg <sup>-1</sup> )	3.48	2.97
% Clay	15.30	23.50
% Silt	3.40	6.80

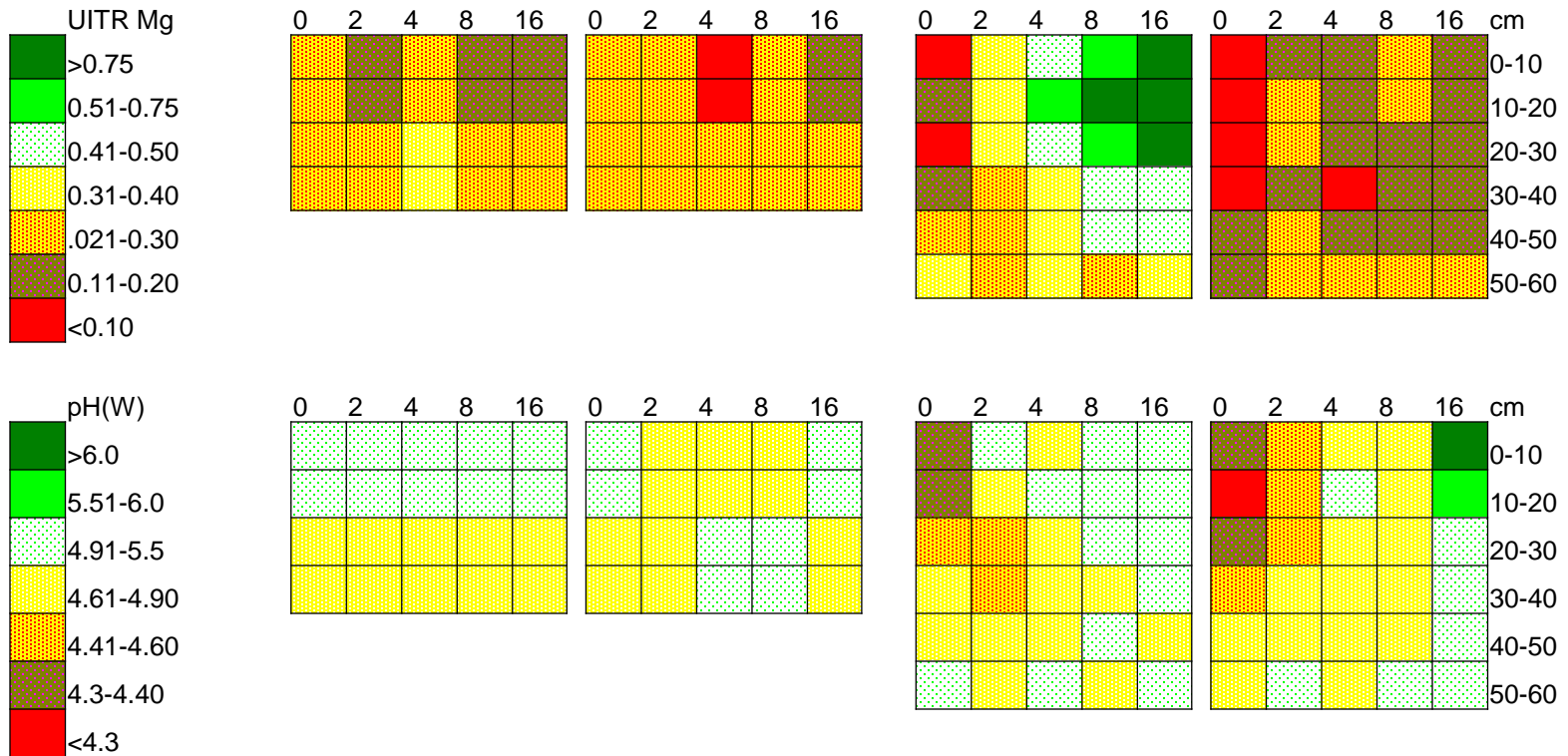
# Hutton Msinga 3 years (1983) after liming and P application



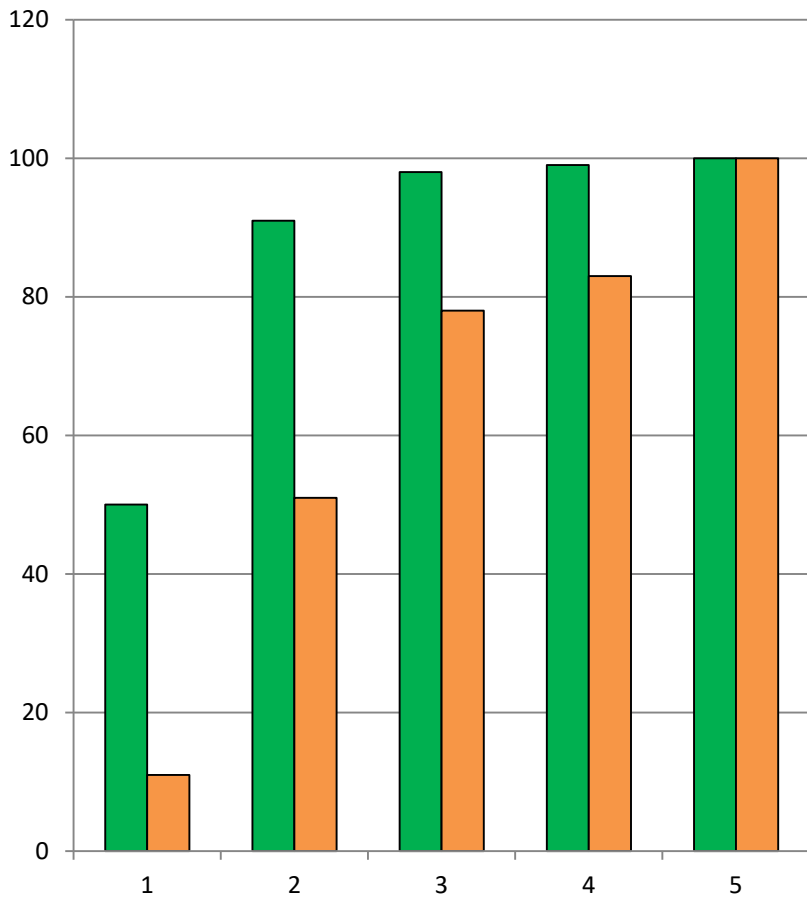
# Hutton Msinga 3 years after liming and P application



# Hutton Msinga 3 years after liming and P application



# Msinga: maize % yield in dry and wet seasons



MIELIEOPBRENGS (t/ha)

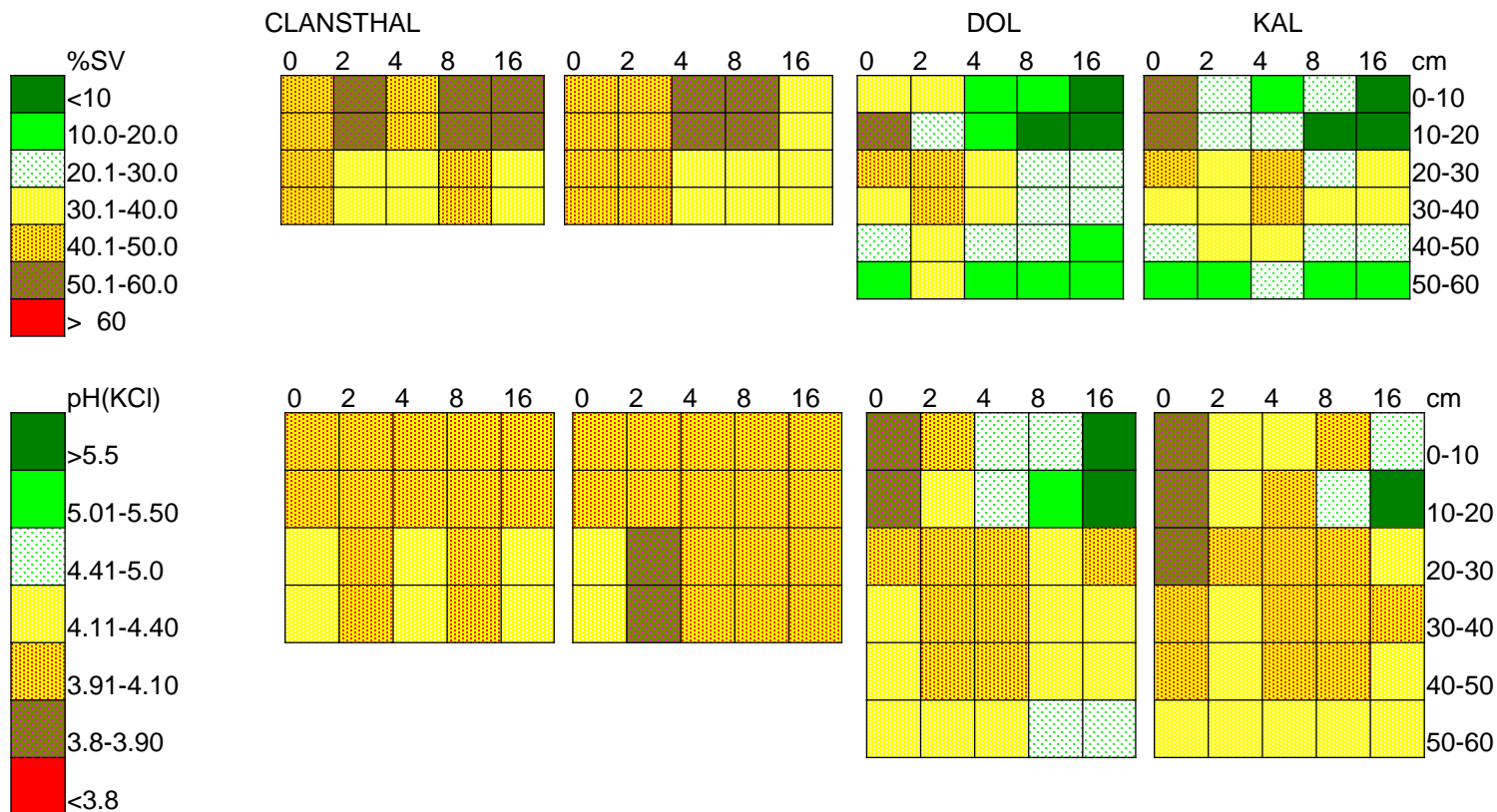
	1.69	3.08	3.34	3.36	3.40
	0.26	1.09	1.67	1.76	2.13

	50	91	98	99	100
	11	51	78	83	100
0-60					
SV	57	38	35	30	19
pH(K)	4.05	4.10	4.18	4.27	4.64
Ca	61	116	120	138	229
Mg	16	30	33	41	48
0-20					
SV	64	37	28	20	7
pH(K)	3.98	4.07	4.15	4.40	5.41
Ca	52	131	154	191	363
Mg	10	32	37	53	61

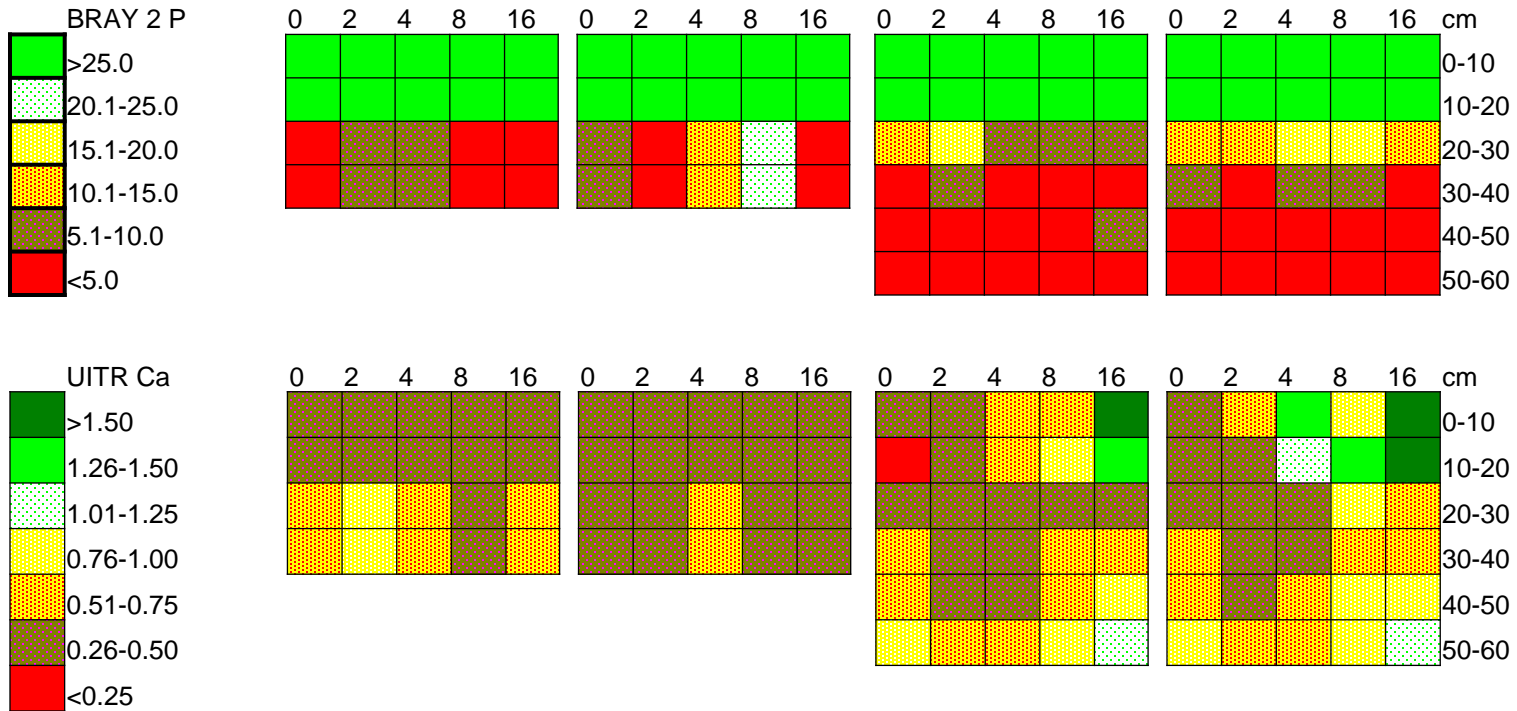
# Hutton Clansthal physical and chemical properties (Klerksdorp)

	Topsoil	Subsoil
CEC (cmol kg <sup>-1</sup> )	2.32	2.29
% Clay	8.60	11.25
% Silt	3.05	3.50

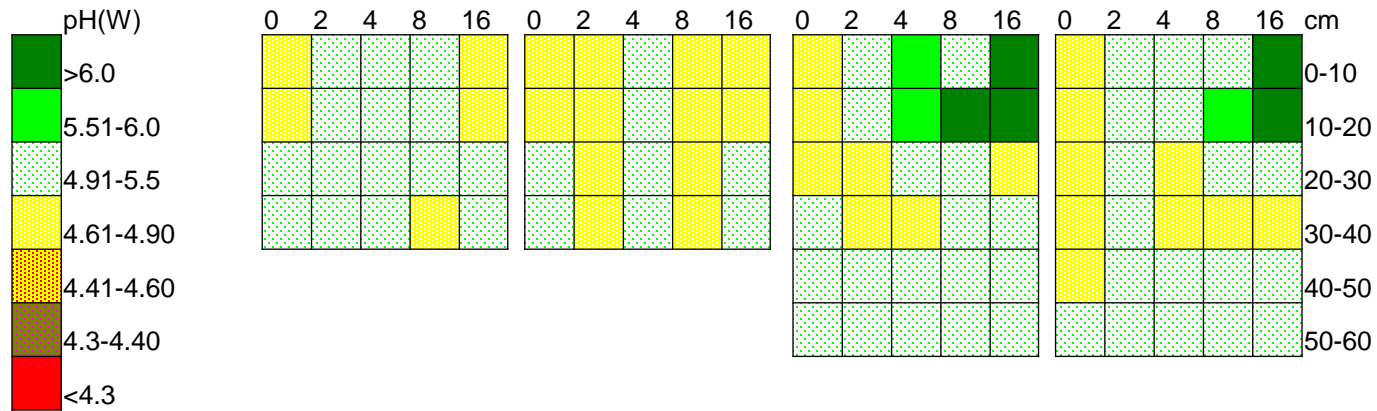
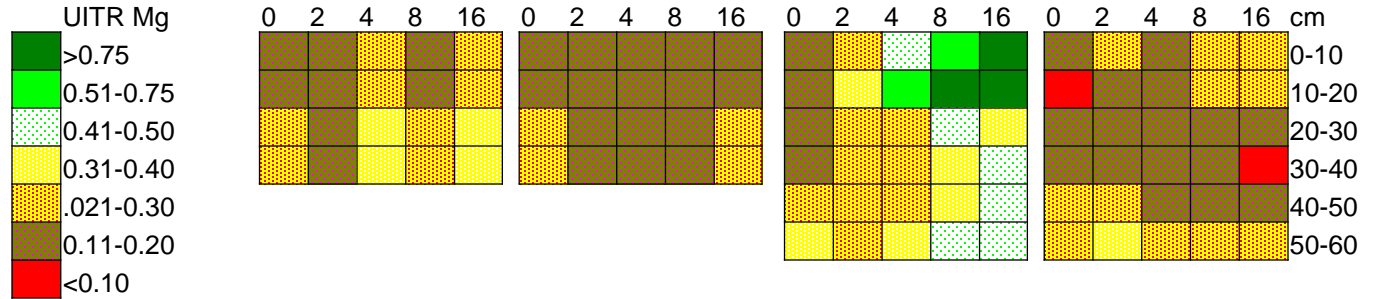
# Hutton Clansthal 3 years (1983) after liming and P application



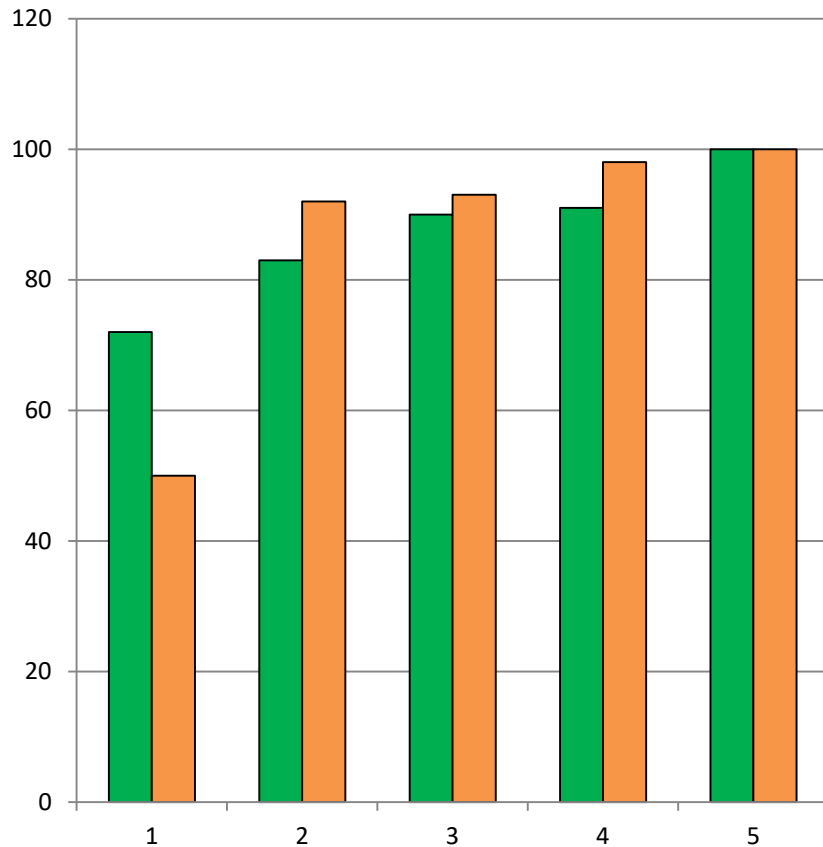
# Hutton Clansthal 3 years after liming and P application



# Hutton Clansthal 3 years after liming and P application



# Clansthal: maize % yield in dry and wet seasons



MIELIEOPBRENGS (t/ha)

	3.11	3.57	3.90	3.94	4.31
	0.85	1.56	1.58	1.68	1.70

	72	83	90	91	100
	50	92	93	98	100
0-60					
SV	37	32	25	19	14
pH(K)	4.02	4.15	4.19	4.31	4.72
Ca	102	92	137	157	255
Mg	23	30	32	40	55
0-20					
SV	51	28	13	11	1.5
pH(K)	3.95	4.25	4.40	4.98	6.10
Ca	56	92	195	192	455
Mg	17	31	43	56	95

# Neil Miles & MPW Farina, 2013

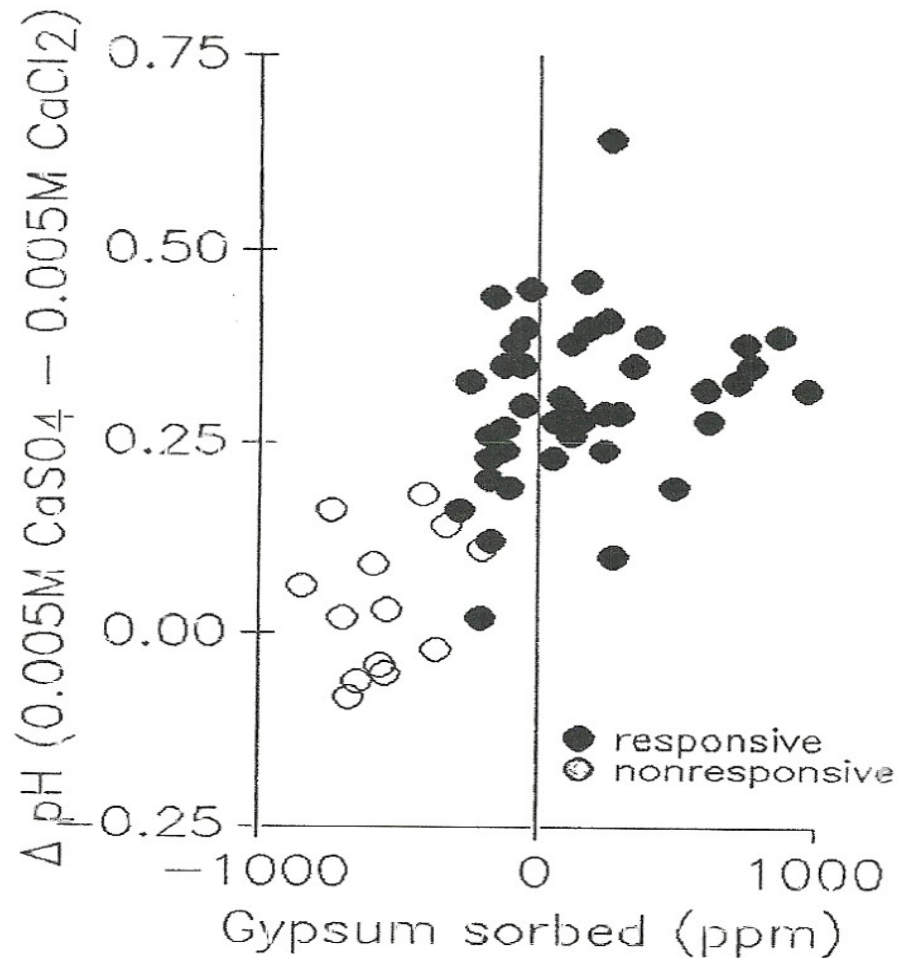


Photo 1: Soil acidity corrected by liming (right) and uncorrected (left). Note severe moisture stress in maize on unlimed soil due to aluminium damage to root systems.



Photo 2: Markedly improved growth (right) as a result of subsoil amelioration with gypsum.

# ME Sumner et al, 1990 test whether gypsum will produce “self liming” effect or not



# Chapter 4.8.1

# Agricultural lime

- Requirements of Act 36 of 1947
- Types of agricultural lime
- Reactivity of agricultural lime
- Factors that influence the reactivity of lime
- Evaluation of agricultural lime
- Lime choice

# Act 36 limitations on heavy metals for agricultural lime

- **Heavy metals: In table 12 of the regulations.**
- **As: <20 ,**
- **Cd: <20,**
- **Cr: <1750,**
- **Cu: <750,**
- **Hg: <10,**
- **Ni: <200,**
- **Pb: <400,**
- **Se: <15 en**
- **Zn <2750.**

# Meaning of fineness

Tabel 4.8.1.2. Oppervlakte en aantal deeltjies  $\text{cm}^{-3}$  per fynheidsfraksie van deeltjies

Deeltjiegrootte mm	Oppervlak as sfeer $\text{mm}^2/\text{cm}^3$	Oppervlak as sfeer $\text{cm}^2/\text{cm}^3$	Oppervlak as kubus $\text{mm}^2/\text{cm}^3$	Oppervlak as kubus $\text{cm}^2/\text{cm}^3$	Aantal deeltjies
1.700	1 848.00	18.48	3 529.41	35.29	204
1.000	3 141.59	31.42	6 000.00	60.00	1 000
0.500	6 283.19	62.83	12 000.00	120.00	8 000
0.250	12 566.37	125.66	24 000.00	240.00	64 000
0.106	29 637.67	296.38	56 603.77	566.04	839 619
0.052	60 415.25	604.15	115 384.62	1 153.85	7 111 971
0.040	78 539.83	785.4	150 000.00	1 500.00	15 625 000
0.026	120 830.50	1 208.31	230 769.23	2 307.69	56 895 767
0.013	241 661.00	2 416.61	461 538.46	4 615.38	455 166 136
0.0065	483 322.00	4 833.22	923 076.92	9 230.77	3 641 329 085
0.00325	966 644.00	9 666.44	1 846 153.85	18 461.54	29 130 632 681
0.001625	1 933 288.00	19 332.88	3 692 307.69	36 923.08	233 045 061 447
0.001 (1 $\mu$ )	3 141 593.00	31 415.93	6 000 000.00	60 000.00	1 000 000 000 000

# Chapter 4.8.2

# Gypsum

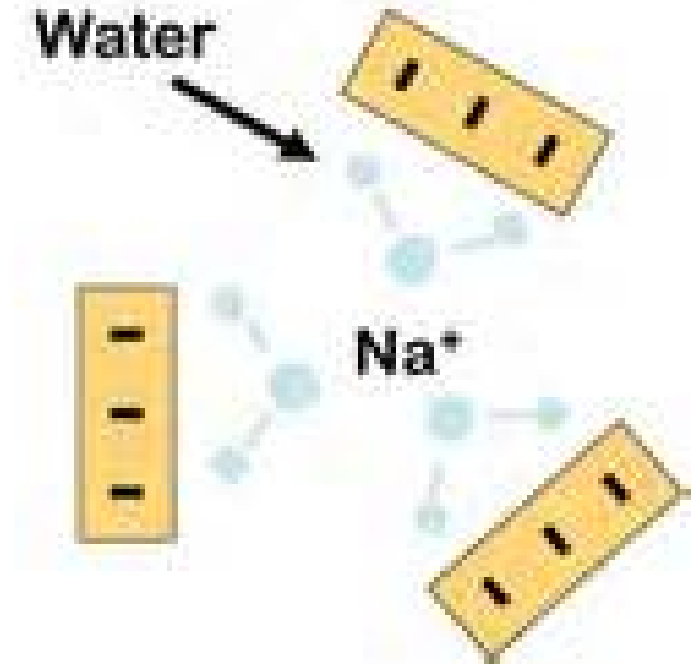
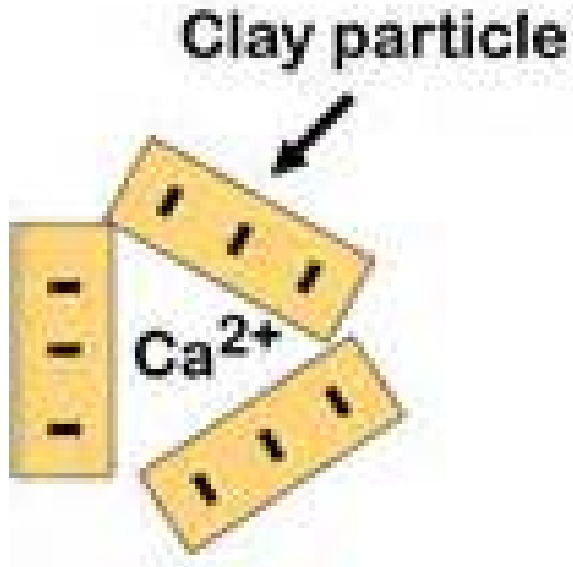
- Requirements of Act 36 of 1947
- Chemical and physical properties of gypsum
- The effect of gypsum on the soil/plant system
- Proved effects
- Misconceptions of gypsum
- Effect of gypsum on soil pH
- Application rates for gypsum

- **VEREISTES VAN WET 36 VAN 1947:**
- Gips mag slegs as 'n misstof (Groep2) geregistreer en verkoop word in Suid-Afrika as dit aan die minimumvereistes van bogenoemde Wet voldoen. Die belangrikste vereistes is soos volg:
  - **Ca-inhoud:** Minimum van  $180\text{gkg}^{-1}$  (18%).
  - **S-inhoud :** Minimum van  $120\text{gkg}^{-1}$  (12%).
  - **Fynheid:** Ten minste 90% deur 'n 2000 mikrometer (2mm)sif.
  - Ten minste 50% deur 'n 250 mikrometer (0.25mm) sif.
  - Gegrond op S-inhoud, word dit toegelaat dat gips wat ongeveer 63% suiwer is as gips geregistreer word.
- **Swaarmetale:** In table 12 van die regulasies word die volgende maksimum waardes in  $\text{mgkg}^{-1}$  vir swaarmetale gegee: As: <20 , Cd: <20, Cr: <1750, Cu: <750, Hg: <10, Ni: <200, Pb: <400, Se: <15 en Zn <2750.

# Benefits of gypsum on soil properties

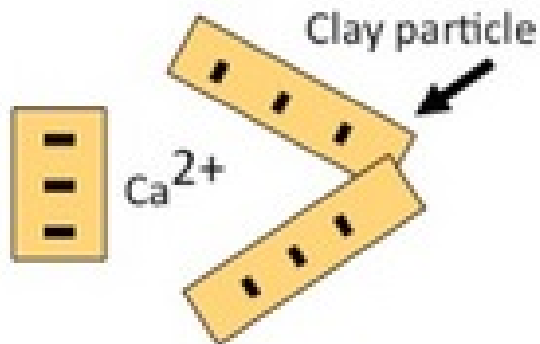
- Op grond het gips die volgende bewese voordele:
- Regstelling van die nadelige uitwerking van té hoë natrium ( $\text{Na}^+$ ) in brakgronde.
- 'n Bron van geredelik plantbeskikbare  $\text{Ca}^{2+}$ .
- 'n Bron van geredelik plantbeskikbare  $\text{SO}_4^{2-}$  - Swael.
- Verhoog die pH van uifers suur ondergronde (met genoegsame seskwioksiedes) (Sumner, et al.1990)
- Verminder  $\text{Al}^{3+}$  toksisiteit van uifers suur ondergronde.(Sumner, et al .1990)
- Moontlike voordele deur die oppervlak korsvorming op gronde te verminder.(Dontsova & Norton.1999)
- Gips kan die vervlugtiging van ammoniak vanaf ureum en UAN kunsmis verminder.(Fenn&Miyamoto. 1981; Gascho.1986)

# Soil dispersion caused by $\text{Na}^+$

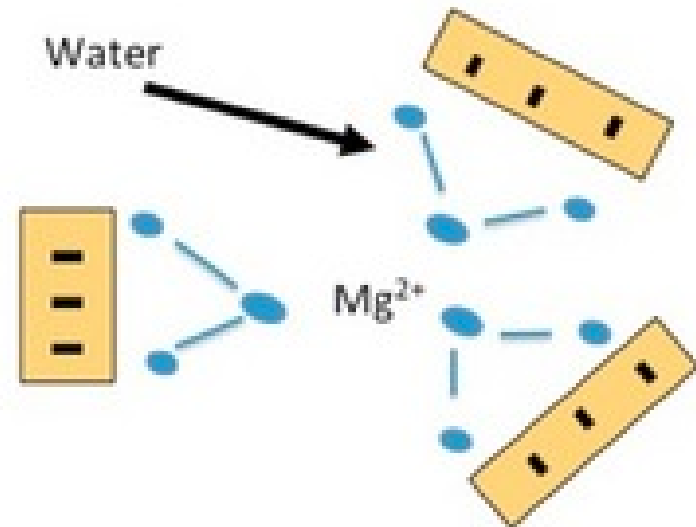


# Soil Structure

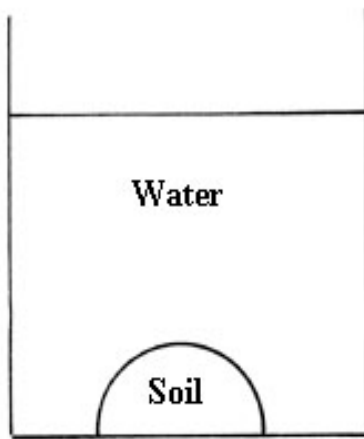
Flocculated



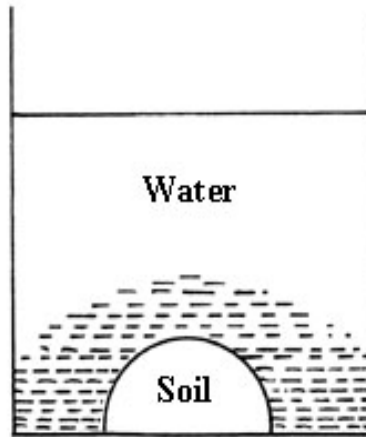
Dispersed



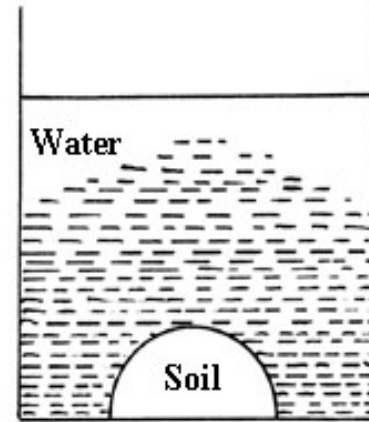
# Test to establish whether gypsum will improve soil structure



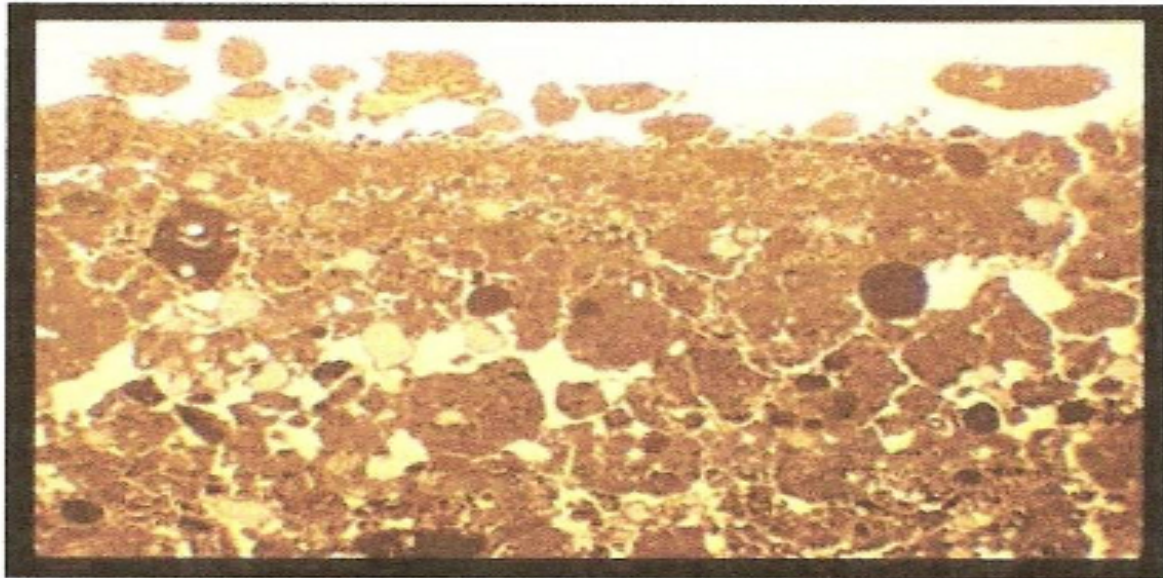
No dispersion of soil particles. Gypsum will not improve this soil.



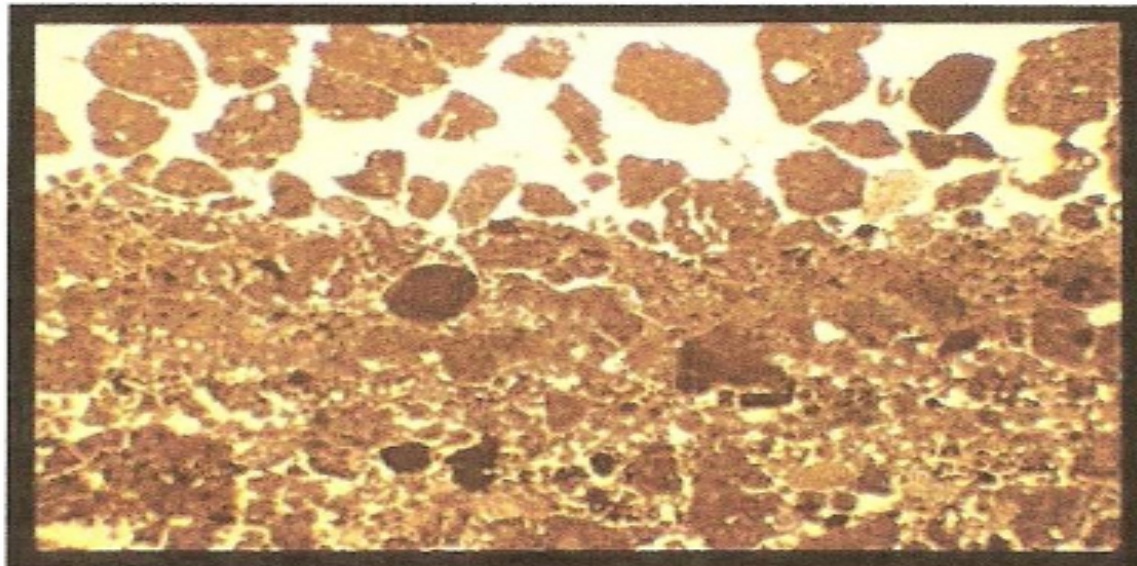
Slight dispersion of soil particles. Gypsum will improve this soil slightly.



Very noticeable dispersion of soil particles. Gypsum will improve this soil greatly.



**Soil treated with magnesium (above)  
and calcium (below).**



# Misconceptions regarding Gypsum effects on soil

- Daar bestaan heelwat wanopvattinge oor die voordele van gips vir gronde en plante. Die volgende punte ontstaan uit algemene wanopvattinge.
- Gips sal nie die mees algemene (meganiese) grond kompaksie regstel nie.
- Gips sal nie die pH van gronde verander wat nie genoegsame seskwioksiedes bevat nie.
- Gips sal nie “toksiese stowwe” uit gronde dryf nie.

# Application rate of gypsum

- Indien kwantitiewe uitruiling van toegediende oplosbare kalsium vir geadsorbeerde natrium aanvaar word, sal die verplasing van elke  $\text{cmol}_c \text{ kg}^{-1}$  geadsorbeerde natrium 'n halwe  $\text{cmol}_c \text{ kg}^{-1}$  suiwer oplosbare kalsium benodig. Die hoeveelheid suiwer gips benodig om 'n halwe  $\text{cmol}_c \text{ kg}^{-1}$  te verskaf per 20 cm diepte grond word soos volg bereken: (neem aan dat die brutodigtheid van grond  $1200 \text{ kg m}^{-3}$  is)
- $$\frac{\text{molekulêre massa van gips}}{200} = \frac{172}{200} = 0,86 \text{ g kg}^{-1} \text{ grond}$$
- $= 86 \times 10^{-5} \text{ kg gips kg grond}^{-1}$
- $= 86 \times 10^{-5} \times 2.40 \times 10^6 \text{ kg ha}^{-1}$
- $= 2064 \text{ kg}$  of  $2,064 \text{ ton ha}^{-1}$
- Indien die gips 70% suiwer is beteken dit dat die hoeveelheid gips wat toegedien moet word
- $2,064 \times 1.43 = 2.9 \text{ ton ha}^{-1}$  is.

# Application method of gypsum

- Breedwerpige toediening is die mees algemene praktyk. Navorsing het bewys dat gips ingewerk moet word vir doeltreffende werking. Die optimum diepte vir inwerking blyk in die orde van 15 tot 20 cm te wees. Dieper inwerking veroorsaak verdunning van die gips en gevolglik minder verlaging van uitruilbare natrium persentasie deur die diepte profiel van die grond.

# Fineness of gypsum

Dit blyk vir optimum werking dat die fynheid van gips tussen 2mm en 0.25 mm moet wees. Die fyner deeltjies reageer relatief vinnig maar die growwer deeltjies het 'n langer nawerking op permeabiliteit tot gevolg. Indien gips baie fyn gemaak word is bevind dat hidrouliese konduktiwiteit aanvanklik baie hoog is, maar dat dit skerp afneem met tyd. Die rede daarvoor blyk te wees dat die hoër oplosbaarheid van die fyn deeltjies reaksie met vrye natrium karbonaat veroorsaak wat oplosbare kalsium vasgelê in die vorm van onoplosbare kalsium karbonaat.

- **ENKELE OPMERKINGS**

- Gips is ongetwyfeld 'n baie belangrike produk in die die landbou en speel 'n belangrike rol in beide plante en die grond. Dit is egter ook waar dat Ca meesal in genoegsame hoeveelhede in die grond voorkom. Swael vlakke in gronde moet ook getoets word. Dit kan ook met die kunsmis toegedien word. Voordat gips of kalk toedienings gedoen word moet die produsent en landboukundige vasstel wat die behoeftes van die gewas is voordat onnodige uitgawes aangegaan word. Dit behels die gebruik van grondontledings , plantontledings en die spandering van tyd om navorsings resultate of proewe op die plaas te evalueer. Die ekonomiese waarde moet, soos met alle insette , deeglik ge-evalueer word voordat toedienings gedoen word.

# Practical calculations related to soil acidity and liming

Ontleding		Waarde	Optimum*
Brutodigtheid (kg m <sup>-3</sup> )		1 680	-
pH (KCl)		4,0	5,55**
Uitruilbare suur (cmol <sub>c</sub> kg <sup>-1</sup> ) (US)		0,99	-
Suurversadiging (%)		53,1	0%
K	(mg kg <sup>-1</sup> )	102	80*
	(% van EKUK)	14	-
Ca	(Mg kg <sup>-1</sup> )	84	300*
	(% van EKUK)	23	-
Mg	(Mg kg <sup>-1</sup> )	22	80*
	(% van EKUK)	10	-
Na	(Mg kg <sup>-1</sup> )	3	-
	(% van EKUK)	1	-
EKUK of "T" (cmol <sub>c</sub> kg <sup>-1</sup> ) Bereken		1,9	-
Ca / Mg		2,3	1,5 - 4,5*
Mg / K		0,7	3 - 4*
(Ca + Mg) / K		2	10 - 20*

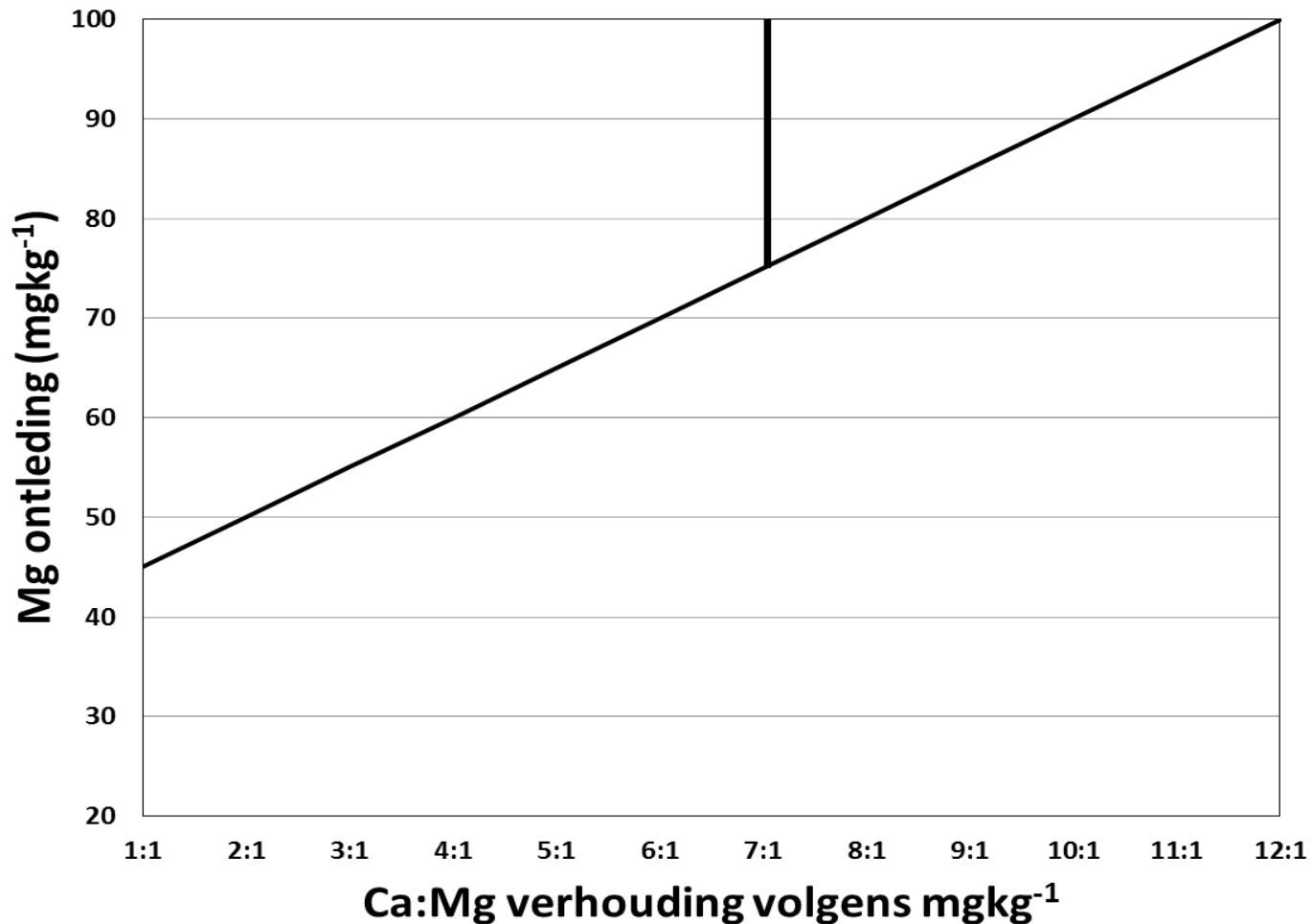
# Analyses of two limes for example

Kalktype	Dolomities	Kalsities
% Ca	25,0	32,0
% CaCO <sub>3</sub>	62,5	80,0
% Mg	5,0	0,1
% MgCO <sub>3</sub>	17,5	0,35
KKE (HCl) (%)	82	80
KKE (HARS) (%) RH	70	74
< 1,7mm (%)	99	100
< 1,0mm (%)	87	90
< 0,25mm (%)	60	75
< 0,106mm (%)	35	60

**STEP 1: EVALUATE SOIL ANALYSIS**

**STEP 2: DETERMINE TYPE OF LIME**

Dolomitic lime below the diagonal line, calcitic lime above the diagonal line and any type of lime in the triangle above the diagonal line



## **STEP 3: DETERMINE AMOUNT OF LIME REQUIRED**

(Table 2 vir RH-waarde) (Also Table 1.8.4 in  
Manual)

# LCF(Liming correction factor) calculation

Rh-waarde	BKF
	(1/Rh-waarde)
0.74	1.351
0.70	1.429
0.60	1.667

B. pH-Target:

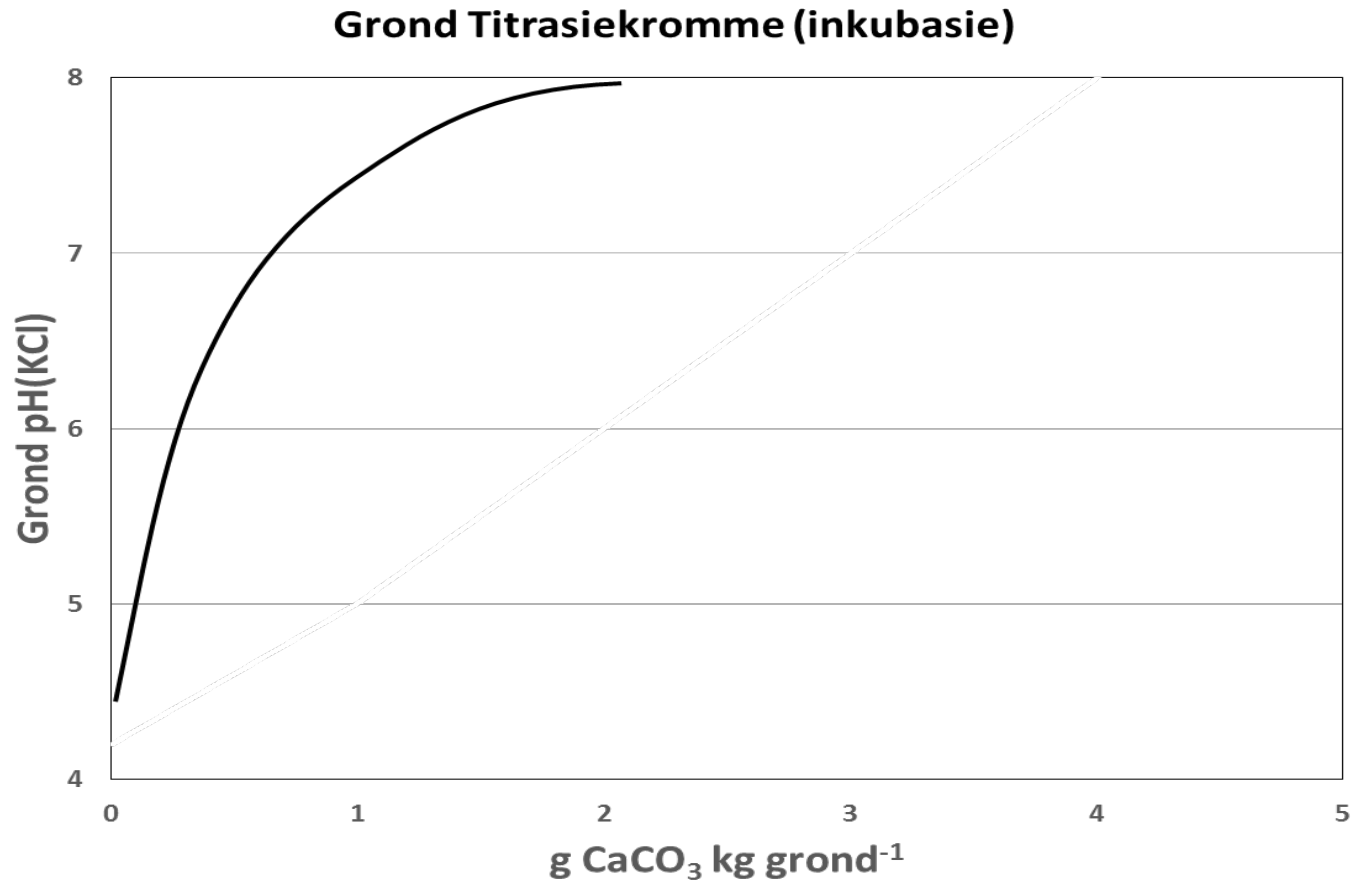
B.1 Incubation / titration determined lime requirement

Bulk density of the soil

Depth to be limed

The LCF (liming correction factor) for the lime.

# Soil titration curve



## B.2 pH-Texture table

Klei	Kalkbehoefte vir grond-pH(KCl)-waardes				
	3.7/3.8	3.9/4.0	4.1/4.2	4.3/4.4	4.5/4.6
%	t CaCO <sub>3</sub> ha <sup>-1</sup>				
0-6	3.0	2.0	1.5	1.0	0.5
7 -15	4.0	2.5	2.0	1.5	1.0
16 - 35	5.0	3.0	2.5	2.0	1.0
36 - 55	6.0	4.0	3.0	2.5	1.5
> 56	7.0	5.0	3.5	3.0	1.5

### C. PERSENTASIE SUURVERSADIGING

Die kalkbehoefte om 'n bepaalde persentasie suurversadiging (%SV) te bereik, word soos volg bereken:

Vir % SV van 0%

Kalkbehoefte (KB) = (Uitruilbare suur - 0,0T) x 3 000

=

#### D. R- W AARDE (EKSTEEN-METODE)

Volgens die metode word die volgende berekening gedoen om 'n R-waarde van 5 te verkry wat ook naastenby 'n pH(KCl) van 5 behoort te lewer.

$$\text{KB} = \frac{(\text{RxH}) - (\text{Ca} + \text{Mg})}{\text{R} + 1} \times 4$$

LW! Die formule maak klaarblyklik reeds voorsiening vir 'n kalk met 'n KKE van 70% of Harswaarde van 70%.

### B.3 Praktiese boerderyrekords of navorsingsresultate:

Die doel met gereelde grondontleding is om die reaksie van behandelings op die gewas te monitor en ook om behandelings te evalueer. Indien dit noukeurig gedoen word kan rekords aandui hoeveel kalk van 'n spesifieke bron nodig is om grondsuurheid doeltreffend te bestuur. Die metodiek van presisieboerdery maak dit vir die boer moontlik om sy eie navorsing te kan doen sodat wegbeweeg kan word van algemene riglyne af.

**STAP 4 KATIOONVERHOUDINGS OF VERSADIGING  
VAN DIE GROND SE UITRUILKOMPLEKS**

## Verwagte verandering in $\text{Ca}^{2+}$ en $\text{Mg}^{2+}$ met bekalking:

Om dit te kan bepaal is die volgende inligting nodig:

- . Ontleding van die kalk (Kyk Tabel 2) in terme van  $\text{CaCO}_3$  en  $\text{MgCO}_3$  en reaktiwiteit van die kalk, bv Harswaarde of RH-waarde (Tabel 2)
- . Hoeveelheid kalk wat toegedien word in ton  $\text{ha}^{-1}$
- . Die diepte van bekalking
- . Die brutodigtheid van die grond in  $\text{kg m}^{-3}$ .

Opsommend dus vir 1 ton ha<sup>-1</sup> bekalking 20cm diep op 'n grond met 'n brutodigtheid van 1200 kg m<sup>-3</sup> vir die twee kalke wat se ontleding gegee is in Tabel 2 , is die volgende te verwagte:

	Verandering (mg kg <sup>-1</sup> )	
	Ca	Mg
Dolomities	+72,92	+14,58
Kalsities	+98,67	+0,31

Indien die bekalking dieper is as 20cm sal die verwagte verandering in Ca en Mg kleiner wees en so ook sal die verwagte verandering in Ca en Mg kleiner wees indien die brutodigtheid hoer is as 1 200 kg ha<sup>-1</sup>.

**Daar moet ook gelet word daarop dat sekere laboratoriums per volume ontledings gee. In sulke gevalle word die brutodigtheid van die grond nie benodig nie. Die ontleding sal dan in terme van mg per liter of per  $\text{dm}^{-3}$  wees, maar kan op dieselfde wyse bereken word. In plaas van die brutodigtheid word 1 000 gebruik wat die volume in  $\text{dm}^{-3}$  gee of liter.**

# Gypsum

Dieselfde beginsels soos hierbo geld vir regstellings met gips , maar omdat gips wateroplosbaar is , sal loging ook in ag geneem moet word.

Om die persentasie versadiging van die uitruilkompleks met verskillende kaione te bereken moet gebruik gemaak word van ekwivalente hoeveelhede soos uiteengesit in die bemestingshandleiding in die hoofstuk wat oor interpretasie van grondontledings handel.

**BUY THE MANUAL AND GET THE  
FULL DETAIL**

# THANK YOU !!!!

