

A Fresh look at Soil Acidity

How the residual
acidity can be
calculated

By **PIETER RAATH**

PhD Agric. (Prof. Nat. Sci. 400201/05)

With thanks and acknowledgment to

DAWID SAAYMAN

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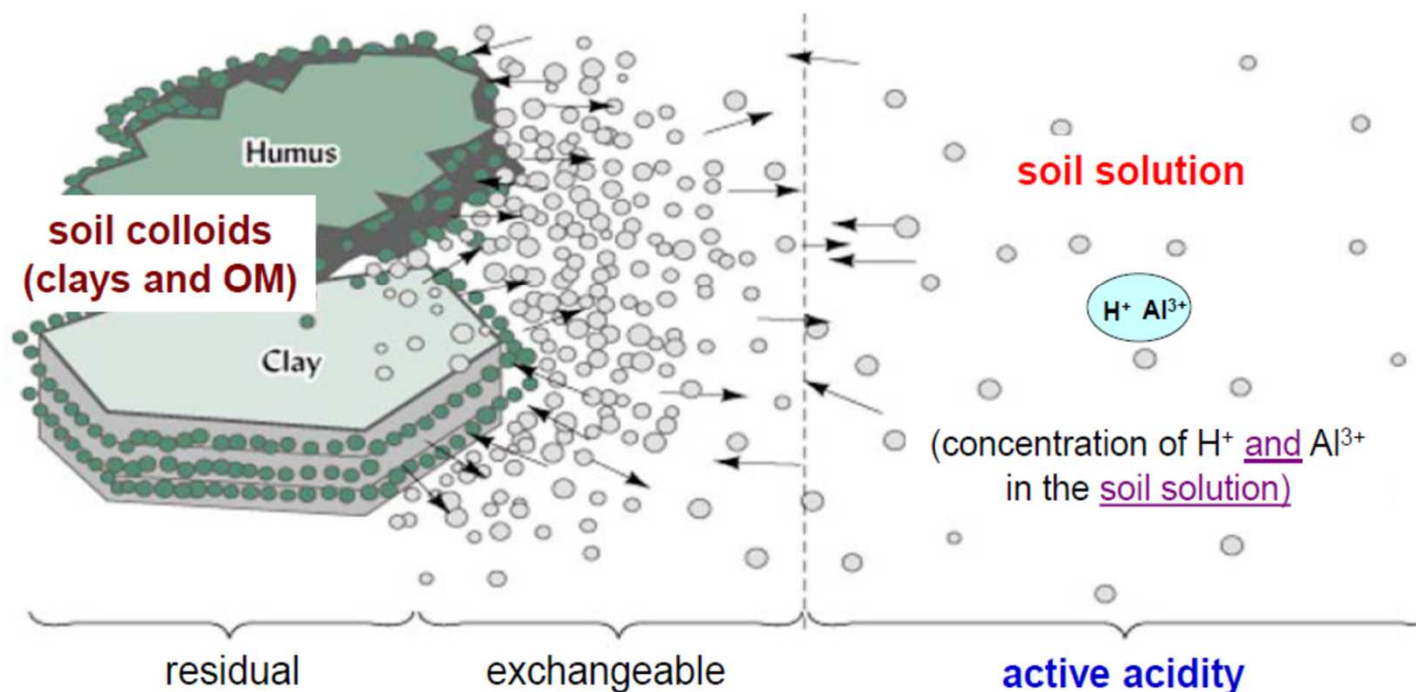
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Let's take
a closer
look...



$$\text{total acidity} = (\text{residual} + \text{exchangeable}) + \text{active}$$



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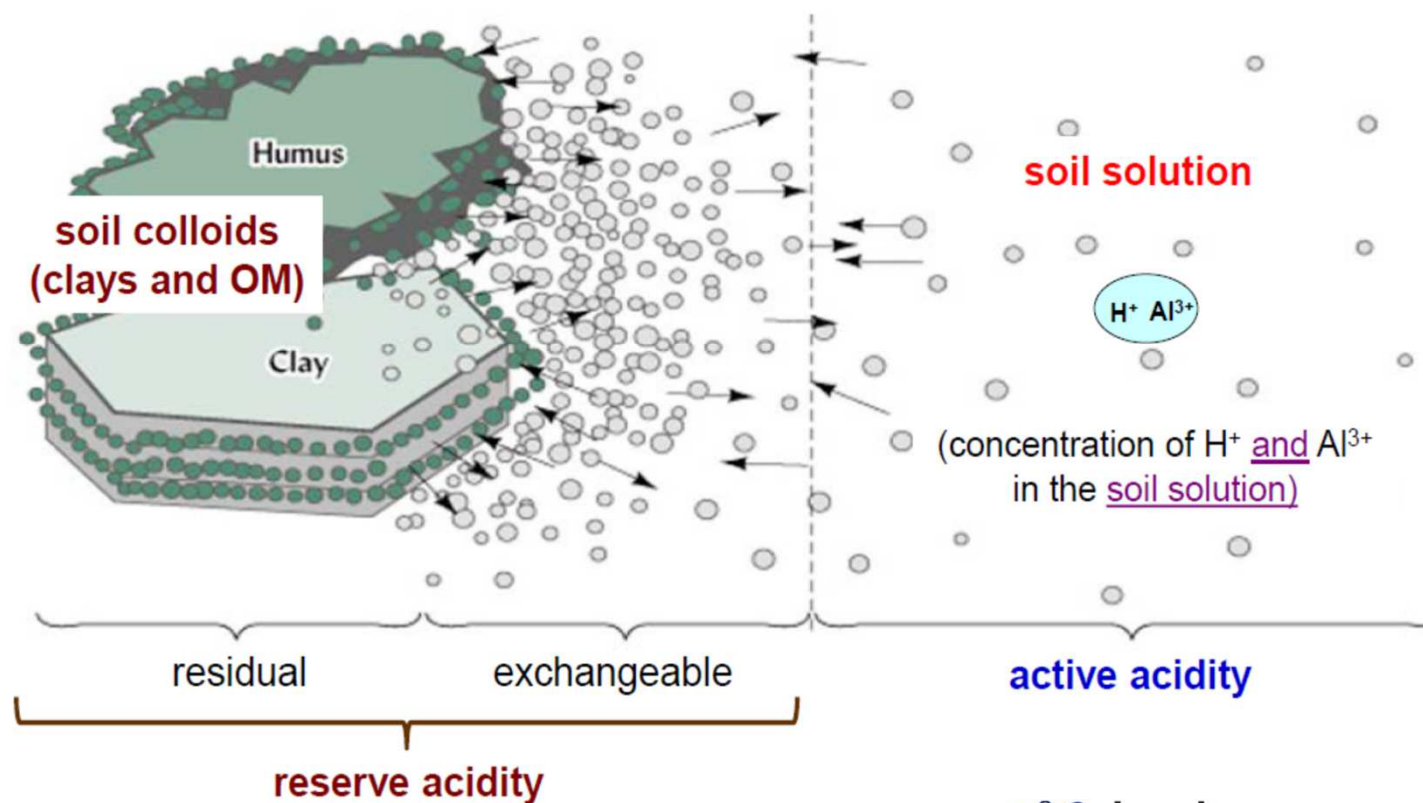
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Reserve acidity

$$\text{total acidity} = (\text{residual} + \text{exchangeable}) + \text{active}$$



Includes acidity from:

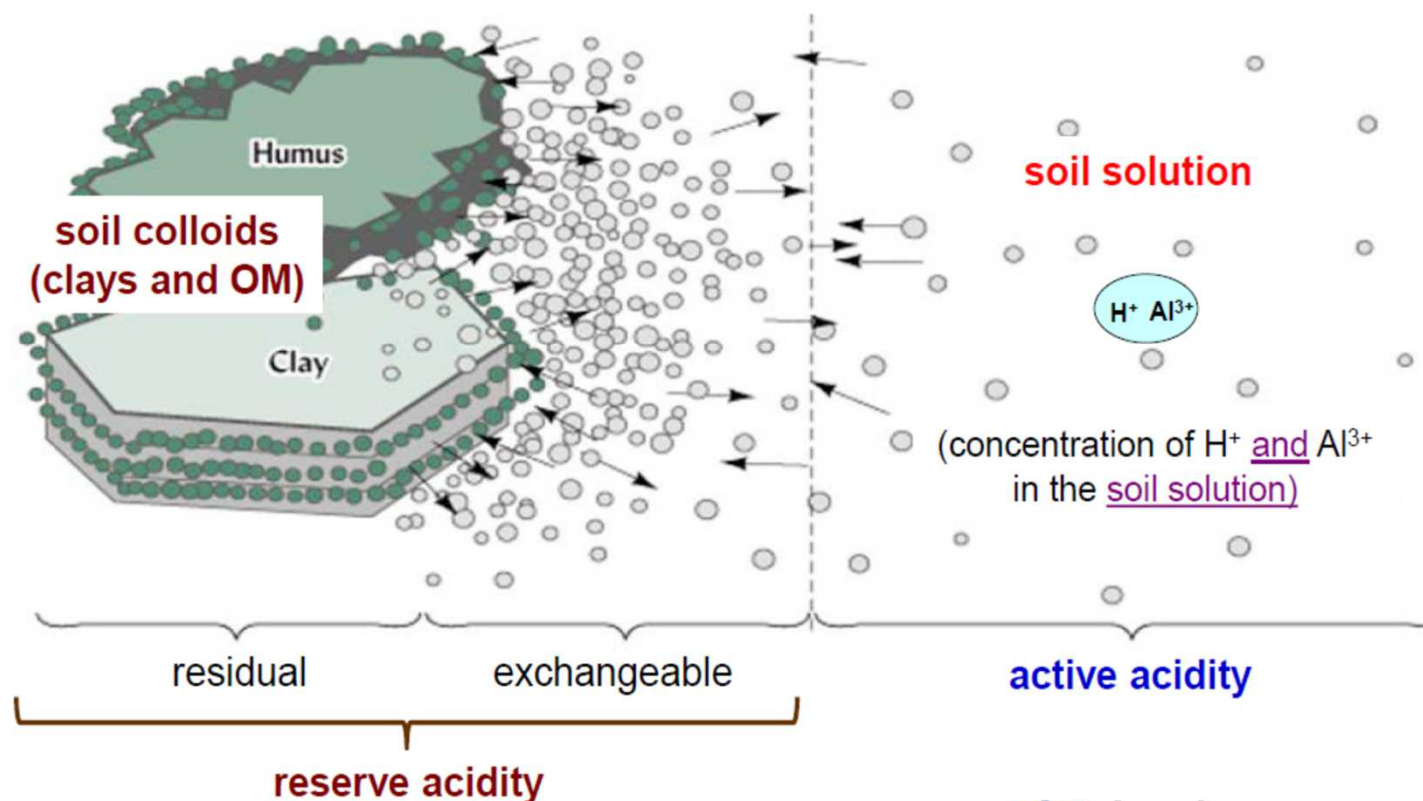
- (i) organic acid dissociation,
- (ii) hydrolyses of Al³⁺-organic complexes,
- (iii) exchangeable H⁺ & Al³⁺ through cation exchange, and
- (iv) non-exchangeable forms on mineral surfaces.

Reserve acidity



Soil Buffering
Capacity
(pH)

$$\text{total acidity} = (\text{residual} + \text{exchangeable}) + \text{active}$$



Includes acidity from:

- (i) organic acid dissociation,
- (ii) hydrolyses of Al^{3+} -organic complexes,
- (iii) exchangeable H^+ & Al^{3+} through cation exchange, and
- (iv) non-exchangeable forms on mineral surfaces.

Eksteen Method

Lime requirement (ton/ha) =

$$(\text{R} \times \text{H}) - (\text{Ca} + \text{Mg}) \times 4 / (\text{R} + 1) \times \text{depth} / 15 \text{ cm}$$

Titratable acidity = Reserve acidity
cmol/kg



To obtain $\text{pH}_{\text{KCl}} = 5.6$,
an R-value of 10 is used.



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Problem... ?



ROUTINE SOIL ANALYSIS				
Farm Name	██████	██████	██████	██████
Sample Number	P1	P2	P3	P4
Lab Number	3556573	3556573	3556573	3556573
Crop	Grapes (Table)	Grapes (Table)	Grapes (Table)	Grapes (Table)
Hectares	1.0	1.0	1.0	1.0
Sample depth	Top-Soil	Top-Soil	Top-Soil	Top-Soil
Colour	Gr	Gr	Gr	Gr
Bulk Density (kg·m ⁻³)	1236.5	1107.5	1176	1122.5
pH (KCl)	3.9	4.6	4.1	4.7
Ex Acid	0.45	-	0.28	-
Acid Saturation (%)	10.3	-	4.9	-
S (mg·kg ⁻¹)	36	27	21	16
P (Bray I) (mg·kg ⁻¹)	134	90	120	128
P (Olsen) (mg·kg ⁻¹)	-	-	-	-
K (mg·kg ⁻¹)	249	366	390	429
K(% of ECEC)	15	13	17	15
Ca (mg·kg ⁻¹)	529	1020	671	1060
Ca(% of ECEC)	60	69	59	71
Mg (mg·kg ⁻¹)	77	157	128	132
Mg(% of ECEC)	14	18	18	14
Na (mg·kg ⁻¹)	5	6	6	6
Na(% of ECEC)	0	0	0	0
ECEC (cmolc·kg ⁻¹)	4.4	7.3	5.7	7.5
Ca / Mg	4.2	4.0	3.2	4.9
Mg/K	1.0	1.4	1.1	1.0
(Ca + Mg) / K	5	7	4	6

Problem... ?

Eksteen Method

Lime requirement (ton/ha) =

$$\{(R \times H) - (Ca + Mg)\} \times 4 / (R+1) \times \text{depth} / 15 \text{ cm}$$

Not titratable acidity...



ROUTINE SOIL ANALYSIS				
Farm Name	■■■■■	■■■■■	■■■■■	■■■■■
Sample Number	P1	P2	P3	P4
Lab Number	■■■■■	■■■■■	■■■■■	■■■■■
Crop	Grapes (Table)	Grapes (Table)	Grapes (Table)	Grapes (Table)
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Problem... ?

Eksteen Method

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Not titratable acidity...

$$\{(10 \times 0.45) - (2.65 + 0.64)\} \times 0.727 = \dots$$



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Lab Number				
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Ca / Mg	4.2	4.0	3.2	4.9
Mg/K	1.0	1.4	1.1	1.0
(Ca + Mg) / K	5	7	4	6

2.65 cmol/kg

0.64 cmol/kg

Problem... ?

Eksteen Method

Lime requirement (ton/ha) =

$$\{(R \times H) - (Ca + Mg)\} \times 4 / (R+1) \times \text{depth} / 15 \text{ cm}$$

Not titratable acidity...

$$\{(10 \times 0.45) - (2.65 + 0.64)\} \times 0.727 =$$

0.9 ton/ha/30 cm



ROUTINE SOIL ANALYSIS				
Farm Name	■■■■■	■■■■■	■■■■■	■■■■■
Sample Number	P1	P2	P3	P4
Lab Number	355573	355574	355575	355576
Crop	Grapes (Table)	Grapes (Table)	Grapes (Table)	Grapes (Table)
Hectares	1.0	1.0	1.0	1.0
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Ca / Mg	4.2	4.0	3.2	4.9
Mg/K	1.0	1.4	1.1	1.0
(Ca + Mg) / K	5	7	4	6

2.65 cmol/kg

0.64 cmol/kg

Now what ... ?



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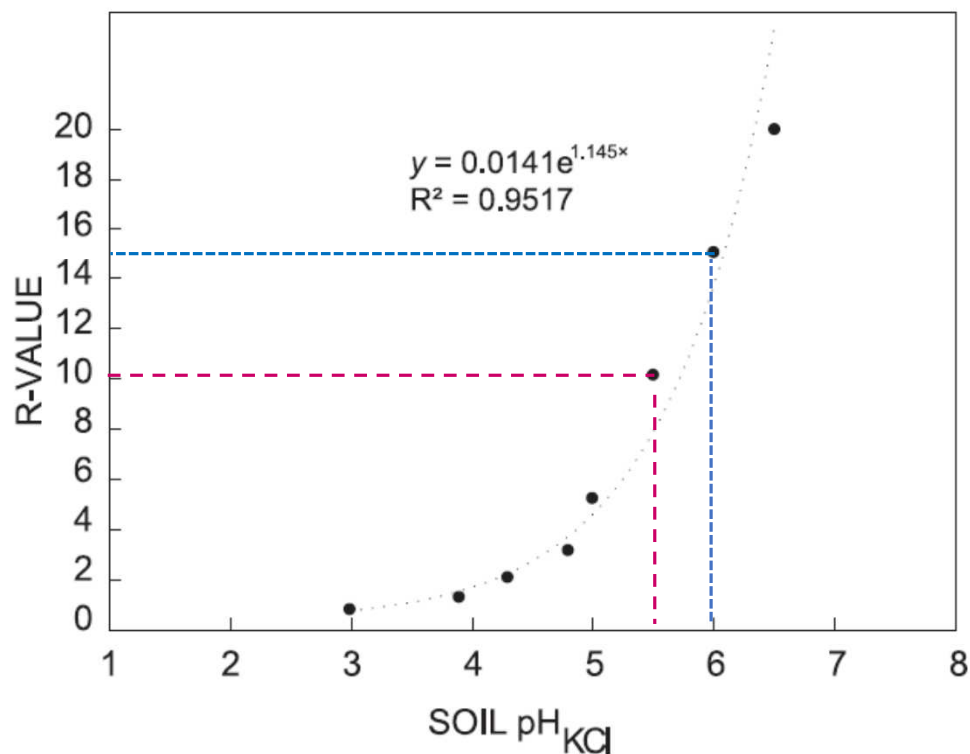


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Correlation between pH_{KCl} and the R-value (Eksteen, 1969)



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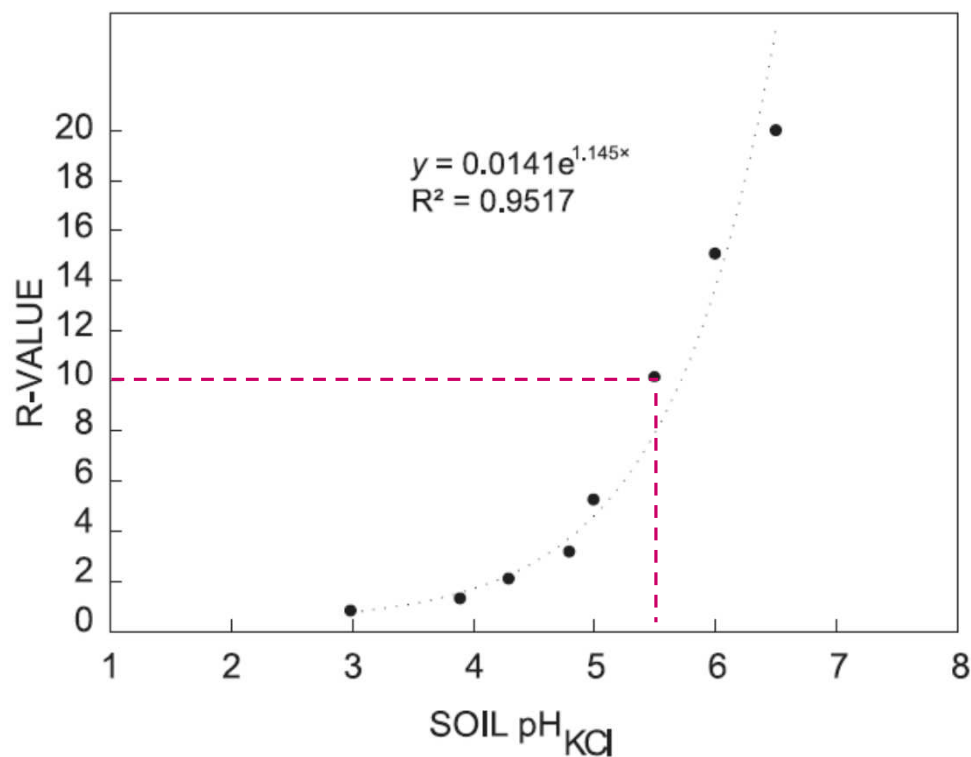


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$$R = \text{Ca} + \text{Mg} / \text{H}$$



Eksteen L. 1969. The determination of the lime requirements of soils for various crops in the winter rainfall region. Fertilizer Society of South Africa Journal 2: 13–14.



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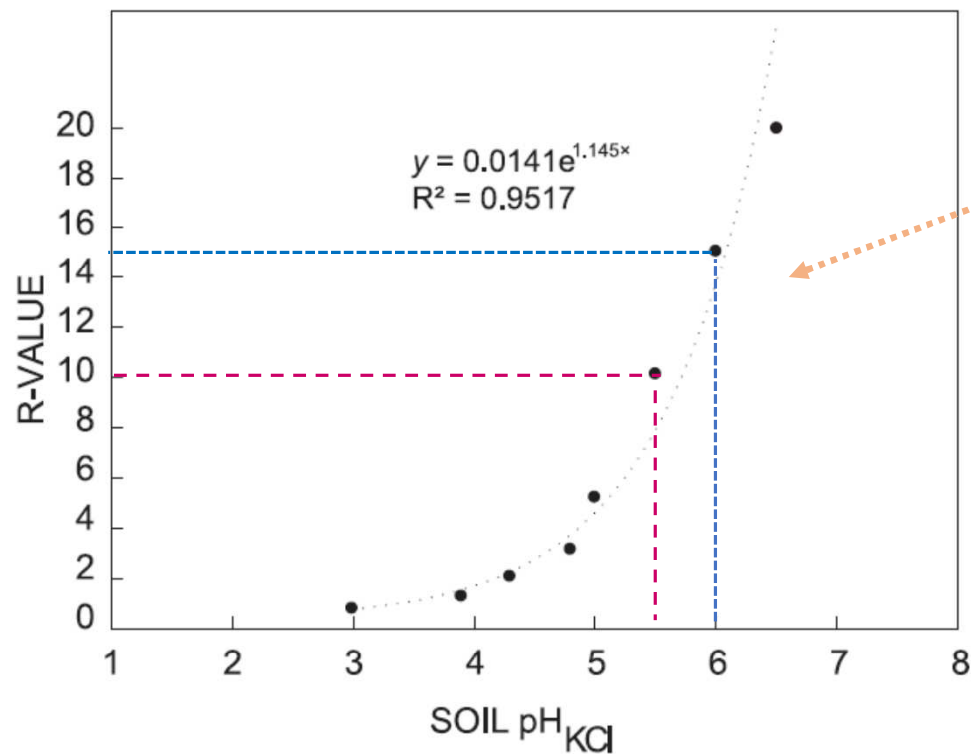
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$$R = Ca + Mg / H$$

$$H = Ca + Mg / R$$

Eksteen L. 1969. The determination of the lime requirements of soils for various crops in the winter rainfall region. Fertilizer Society of South Africa Journal 2: 13–14.



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$$\text{H} = \text{Ca} + \text{Mg} / \text{R}$$



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LabserveMycro Stellenbosch database

5 915 soil samples of which the titratable H^+ (TA) was determined

Various models were trialled

Goal was to determine the theoretic TA vs the true TA

$$H = Ca + Mg / R$$



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LabserveMycro Stellenbosch database

5 915 soil samples of which the titratable H^+ (TA) was determined



Various models were trialled

Goal was to determine the theoretic TA vs the true TA



Stellenbosch
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Outcome – Significant correlation between true TA and:

- Theoretically calculated TA
- Soil pH,
- Org. C,
- Ca & Mg



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The following equation can be used to calculate the **TA** with $\approx 80\%$ accuracy:

$$\text{TA}_{\text{calculated}} = 5.75 - 1.65^{\text{pH}} + 1.01^{\text{Ca}} + 1.009^{\text{Mg}} + 1.55^{\text{OC}} + 1.023^{\text{Rwaarde}} + 1.01^{\text{TAEksteen}} + 1.25^{\text{DeltapHC}}$$


 $\underline{\text{H}} = \text{Ca} + \text{Mg} / \text{R}$



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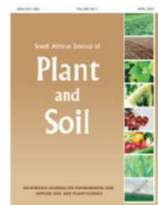
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South African Journal of Plant and Soil

ISSN: (Print) (Online) Journal homepage: <https://www.tandfonline.com/loi/tips20>

Calculating soil titratable acidity from routine soil analyses of cultivated South African soils using various model structures

VG White, PJ Raath, AG Hardie, V van der Berg & GF Sutton


$$\underline{\text{H}} = \text{Ca} + \text{Mg} / \text{R}$$



Link to this article: <https://doi.org/10.1080/02571862.2023.2212191>

A Simpler Approach...



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A Simpler Approach...



ROUTINE SOIL ANALYSIS		
Farm Name		████████
Sample Number		P1
Lab Number		3000019
Crop		Grapes (Table)
Hectares		1.0
Sample depth		Top-Soil
Colour		Gr
Bulk Density	(kg·m ⁻³)	1236.5
pH	(KCl)	3.9
Ex Acid		0.45
Acid Saturation	(%)	10.3
S	(mg·kg ⁻¹)	36
P (Bray I)	(mg·kg ⁻¹)	134
P (Olsen)	(mg·kg ⁻¹)	-
K	(mg·kg ⁻¹)	249
K(% of ECEC)		15
Ca	(mg·kg ⁻¹)	529
Ca(% of ECEC)		60
Mg	(mg·kg ⁻¹)	77
Mg(% of ECEC)		14
Na	(mg·kg ⁻¹)	5
Na(% of ECEC)		0
ECEC	(cmolc·kg ⁻¹)	4.4
Ca / Mg		4.2
Mg/K		1.0
(Ca + Mg) / K		5

A Simpler Approach...

Lime requirement (ton/ha) =

$$\{(R \times H) - (Ca + Mg)\} \times 4 / (R+1) \times \text{depth} / 15 \text{ cm}$$

$\underline{H} = Ca + Mg / R$

R-value at soil pH_{KCl} = 3.9



ROUTINE SOIL ANALYSIS		
Farm Name		██████████
Sample Number		P1
Lab Number		3000019
Crop		Grapes (Table)
Hectares		1.0
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A Simpler Approach...

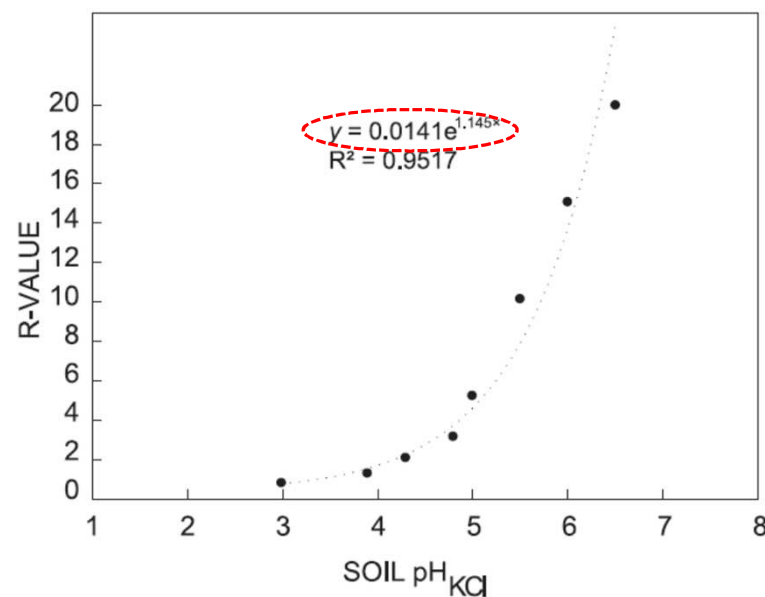
Lime requirement (ton/ha) =

$$\{(R \times H) - (Ca + Mg)\} \times 4 / (R+1) \times \text{depth} / 15 \text{ cm}$$

$$R = 0.0141e^{1.145pH}$$

$$= 0.0141 \times 2.718^{(1.145 \times 3.9)}$$

$$= \underline{1.27}$$



ROUTINE SOIL ANALYSIS		
Farm Name		████████
Sample Number		P1
Lab Number		3000519
Crop		Grapes (Table)
Hectares		1.0
Sample depth		Top-Soil
Colour		Gr
Bulk Density	(kg·m ⁻³)	1236.5
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A Simpler Approach...

Lime requirement (ton/ha) =

$$\{(R \times H) - (Ca + Mg)\} \times 4 / (R+1) \times \text{depth} / 15 \text{ cm}$$

$$\begin{aligned} H &= Ca + Mg / R \\ &= (2.65 + 0.64) / 1.27 \\ &= \underline{2.02 \text{ cmol/kg}} \end{aligned}$$



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To obtain pH_{KCl} of 5.6, the R-value used = 10

$$\{(10 \times 2.02) - (2.65 + 0.64)\} \times 0.727 =$$

12 ton/ha/30 cm

versus 0.9 ton/ha/30 cm

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Conclusion(s)

- Don't use $H^+(KCl)$ for lime requirement calculations
- You can make a much better lime recommendation by using a theoretically calculated H^+ , using the R-value
- **LABSERVE MYCRO** will soon provide a **FREE** calculator on our Website for use by our clients



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