Create Soil pH that Ensures Long-term Citrus Orchard Performance

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Soil Acidity: Challenge Number One

Soil acidity is world-wide regarded as a major production constraint in citrus. In South Africa between 37% (Northern Provinces), 60% (Winter Rainfall Region), and 85% (KwaZulu Natal) of soil is acidified. Low soil pH conditions lead to elevated concentrations of aluminium and heavy metals. Aluminium is toxic to plant roots, reducing its growth, activity and health, leading to poor water and nutrient uptake. As soil pH_{KCl} progressively decreases from 5.0 and lower, the availability of some nutrients (e.g. P and Mo) are also significantly reduced. Furthermore, many acidic soils are highly leached, and is therefore often depleted of the base cations, e.g. Na, K, Ca, Mg.

Ironically, the world's top citrus production is mostly obtained from acidic soils. This is possible by means of accurate liming practices, that raise the soil's pH_{KCl} to a level between 5.5 and 6.5 (pH_{Water} = 6.0-7.5). Liming during soil preparation is therefore a required practice in regions with acidic soils. Over-liming (raising the soil's pH_{KCl} to levels >6.5), however, is also not desirable since the availability of nutrients like P, Zn, Fe, Mn is then also reduced - to the level where it is unavailable for uptake by the tree.

Accurate calculation of the lime requirement during soil preparation is essential for three reasons:

1) Healthy root development occurs only in soil with an optimal, homogenous pH level throughout the profile;

2) The pH of the subsoil (>30 cm depth) of established orchards cannot be corrected by liming;

3) Optimal nutrient availability is limited to a narrow pH-range.

Producers must therefore ensure that optimal soil pH conditions (a pH_{KCl} that is in the narrow range of 5.5 to 6.5) are created that will remain so for most, or preferably the whole, of the new orchard's lifespan. Accurate calculation of the amount of lime required during soil preparation can only be done if proper soil analyses procedures are followed and the correct lime requirement calculation method is used.

Best method for Lime Requirement Calculation

In a recent study, conducted in collaboration with Stellenbosch University, seven well-known methods for calculation of lime requirement was evaluated using 40 diverse acidic soils from four provinces in South Africa. The modified Eksteen-method was found to be the most versatile, practical and accurate method for South African soils. Some of the other methods, also commonly used in South Africa, tend to underestimate the lime requirement for perennial crops like citrus. Consequently, when the lime requirement for a new orchard needs to be determined, producers are advised to insist that the soil analyses and consequent calculation of lime requirement, is done according to the well-known Eksteen method. This is described below so that producers can provide the method to their laboratory if necessary. It must be done for all soils with a $pH_{KCl} < 6.0$, and since it is a commonly known method, should not entail additional costs apart from the normal soil analyses conducted by the laboratory.

Calculation of the Eksteen method for lime requirement entails two steps. *Firstly,* a laboratory analysis of the soil is done. This includes determination of the base cations using 1M NH_4AOc extraction, as well as the titratable acidity using 0.5M K_2SO_4 (buffered at pH 7) as extracting solution; note that KCl should not be used. Last mentioned filtrate is titrated with 0.1 M NaOH until a pink colour is achieved in the presence of phenolphthalein.

Secondly, the lime requirement is calculated from the analyses results, using the following formula:

Lime requirement (ton.ha^{-1}/30 cm soil) = [(H x 10) – (Ca + Mg)] x 0.727

where H, Ca and Mg is expressed in cmol.kg^{-1}

It is also very important that producers insist that the laboratory determines the stone volume. Since stones (all particles > 2 mm in diameter) are inert, and do not contribute to the acidity, over-liming becomes a huge risk on soils with an appreciable to high amount of stones. It is therefore critical that the calculated lime requirement is decreased in accordance with the volume of stones in the soil, e.g. if the stone volume is 10%, then only 90% of the calculated lime requirement is applied.

Since South Africa's soils are so diverse, the Eksteen method also provides the flexibility to make adjustments for specific circumstances, to ensure accurate liming rates, namely:

- **For soil with a high magnesium (Mg) content,** the calculated lime requirement tends to be too low. Consequently, where the Ca/Mg-ratio is <6, the (Ca + Mg) component in abovementioned formula should be replaced by (Ca x 1.25).
- **In soils with high organic matter,** acidity due to the presence of Al^{3+} is dramatically reduced. Consequently, the calculated lime requirements can be excessive. The following adjustments, based on the soil's organic C content, should therefore be made:

CARBON CONTENT OF SOIL (%)	ADJUSTMENT OF LIME REQUIREMENT
<1	None
1-2	80% of calculated value
2-3	60% of calculated value
3-4	40% of calculated value

- **For bleached sandy soils,** Al^{3+}-concentrations (which contributes to the formation of acidity) tend to be low. For these soils, the lime requirement should be calculated as follows:

Lime requirement (ton.ha^{-1}/30 cm soil) = H x 3.2

However, if these sandy soils have Ca + Mg >1.5 cmol.kg^{-1}, the measured titratable acidity (H^+) used in the abovementioned formula should be corrected as follows: Corrected H = H – [(Ca + Mg) – 1.5] with H, Ca and Mg in cmol.kg^{-1}

Select the Correct Type of Lime

To address the variation of Ca and Mg concentrations that occur between soils, the correct choice of liming material is very important. As a guideline the Ca/Mg ratio of the soil is used to establish the type of lime that must be applied. Calcitic lime ($CaCO_3$) is used where the ratio is <6, while dolomitic lime ($CaMgCO_3$) is used for a ratio that is >6. In sandy soils, with a low exchange capacity, cations are rapidly leached, including highly hydrated and mobile Mg. It is therefore wise to always use dolomitic lime on coarse sandy soils.

In closing, soil acidity has an extremely negative effect on tree performance. It needs to be corrected during soil preparation since it is impossible to amend subsoil acidity in existing orchards. Over-liming, on the other hand is also detrimental to tree nutrition. Producers must therefore pay close attention to ensure correct calculation of lime requirements for soil preparation. This is not a simple procedure and various factors need to be borne in mind, but the modified Eksteen method was proven to be the most versatile and suitable method for most South African soils. Producers ought to insist that this well-known method, as described above, is used when their soil's lime requirement is calculated. Finally, successful liming depends on correct soil preparation methodology as well as homogenous mixing of lime into the subsoil. This is a topic that will be addressed in a future edition.

Fig.1. Root distribution can be adversily affected by sharp transitions in the soil's pH.

Fig. 2. Variability of soil acidity, because of differences in parent material, requires accurate sampling and separate lime requirement calculation.

Fig. 3. To avoid over-liming, stone volume must be either estimated or determined in the laboratory.

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