5.8.2 PECAN NUTS

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The Pecan nut is one of the oldest nut crops that occurs naturally in northern USA. The name "pecan" originates from the Algonquin Indian word "*pacaan*", which include the walnut and hickory, and is used to describe "nuts that need to be cracked by a rock" (Venkatachalam, 2004).

The fertilization of pecans is complex; nut quality is a crucial requirement for producers who intend to supply the international market. Nut quality is determined by size, as well as kernel percentage. Nut quality is not exclusively determined by nutrition alone, but also to a significant extent by the quantity of water available at the appropriate time.

The nutrient requirements of pecan trees are closely correlated with their phenology. The phenological cycle is more or less as follows:

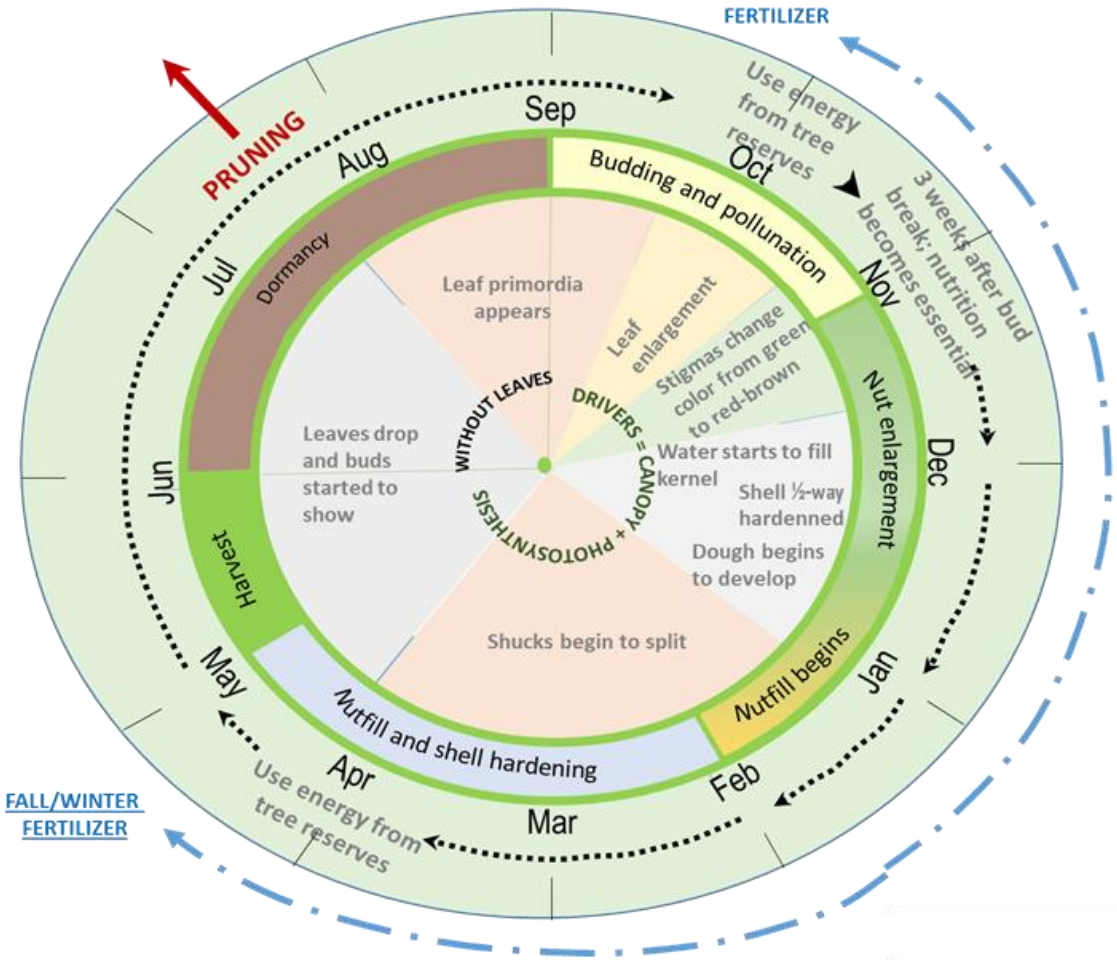

Figure 1: The Pecan growth wheel, applicable to bearing trees – a generalization of growth and phenological development for South African conditions (Schmidt, 2021)

- June – September: Dormancy
- September – November: Budding and pollination
- November – December: Nut enlargement
- January – February: Nut fill
- February – May: Nut fill and shell hardening
- May: Harvest

New growth supported from energy reserves starts during September/October. During the final nut-fill stage again energy from reserves is used for the filling of nuts. In-between these periods, plant nutritional requirements need to be supplemented with fertilizer applications. Supplementary nutrition is required three weeks after bud-break. Therefore, on bearing trees, fertilizer applications could take place between 5 and 10 times from bud-break, until winter fertilization and after harvest. The healthier the trees, the less applications can be applied (with a minimum of 5),. Factors such as soil texture and irrigation method should be taken into consideration on the timing of fertilizer applications; in order to limit leaching losses Since applied fertilizer took time to move vertically in the soil, additional nutrition should not start sharply on three weeks after bud-break, but earlier.

The number of male flowers set is determined by shoot length grown over the previous two years and also partially as a result of stored energy. The number of female flowers that open during a specific season are determined approximately eight months earlier and is dependent on the amount of stored energy reserves

Woodroof & Woodroof (1934) described the pecans' root development and character and defined the roots as mycorrhizal. This could indicate a poor correlation between soil nutrient levels and pecan yield. According to Cooke (1982), it is difficult to interpret soil nutrient levels in soils under trees, since the depth of root penetration, the root volume, distribution and eventual utilization, is unknown and variable A productive pecan tree requires a healthy and vigorous root system in order to support sustainable yield. Roots provide anchorage, water uptake, nutrient uptake, hormone production, energy and starch storage.

One component of pecan production is the maintenance of the tree, which includes energy reserves, as well as fresh nutrient additions to support yield. The last mentioned includes not only quantity, but also quality. For this very reason it is better to apply nutrition over the whole spectrum of the active growing season / phenological stages) to stimulate and support growth according to the growth stages as suggested by the Pecan growth wheel (Figure 1)

Soil analysis norms:

Element	Method of extraction	Ideal level**
pH(H_2O)	1:2.5 soil:water ratio	± 6.0
pH(KCl)	10 mL or gram soil : 25 mL 1M KCl	± 5.0 – 5.5
Sulphate sulphur	Calcium-u81`Phosphate	10-15 mg kg^{-1}
Phosphorous	Bray 1	Sandy neutral to slightly soil ± 30-40 mg kg^{-1}
	Ambic	Sandy alkaline soil ± 30-40 mg kg^{-1}
Potassium	Exchangeable (Ammonium Acetate)	± >100-110 mg kg^{-1}
Calcium		± >250 mg kg^{-1}
Magnesium		± >80 mg kg^{-1}
Sodium		< ideally <2% of exchangeable cations on $cmol_c$ kg^{-1} basis
Acid saturation	Calculation from extractable acidity and T-value	0-1%

** Remember that South Africans are well acquainted with soil elemental levels applicable to grain crops and vegetables, which are all annual crops and not permanent. Therefore, the possibility is real that a permanent crop, like Pecan, could have different soil nutrient level preferences, than grain crops. The above indicated norms are a general approach and do not cover normal and extreme deviations in soil characteristics.

The pecan in it natural habitat is associated with deep well drained sandy soils. This, however, does not indicate that a producer cannot plant pecan on soils that deviate from its natural habitat, but it is important that producers should consider that the more the soil deviates from the natural habitat, the more difficult it could be to manage, with a possible negative impacts on growth and yield. For this reason, it is important to communicate with knowledgeable consultants before establishing an orchard.

Sodium and salt sensitivity: The pecan is salt sensitive with an upper electrical conductivity (EC) limit of 190 mS/m. A soil with an EC of 250 mS/m in the top 0 to 30.5 cm, could limit yield by approximately. 10%, 350 mS/m by approximately. 25% and 490 mS/m by approximately. 50%. Die-back of branches could occur at EC levels of 500 mS/m. Trees could die at EC-levels of 600 mS/m. A typical scorching symptom due to excessive levels of salts (including sodium), is shown in Figure 2 (Schmidt, 2016).

Figure 2: Typical salt scorch symptoms on pecan leaves; it will show on the oldest leaves first (Schmidt, 2016).

Leaf nutritional status

The nutrient levels in leaves change with age. For instance, levels for N, P and K tend to decrease with age, while those for Ca and B, will increase (Walworth & Kilby, 2002). A leaf norm is defined as those nutrient levels at a particular age and position on the plant that correlates the best with yield (Storey, 2012). In this regard, the following two aspects are critically important:

a). Leaf samples – timing and position on the tree: For South African conditions, leaves are collected between 120 to 150 days after flowering (Peyper, 2021). Mostly, this would be during mid-January. The position of leaves to sample is indicated in the presentation (Figure 3), below.

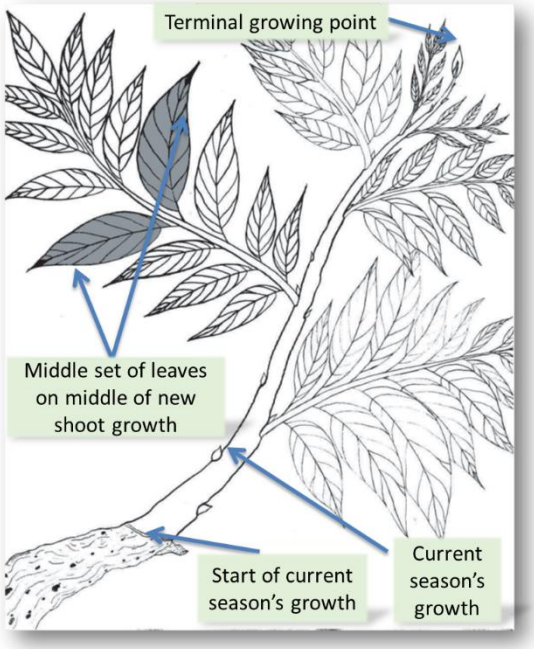

Figure 3: An illustration of leaf sampling method for pecan; from Heerema (2013) and Wells (2015).

b). Norms: It is important to apply the correct norm for your area when evaluating leaf analysis values. South Africa does not have its own scientific and published norms and for that reason we make use of published USA-norms. Norms for the southern part of the USA are summarized for the different states from east to west (Table 2) to illustrate differences.

Table 2: Leaf norms for the southern part of USA as it differs between the eastern and western states (Walworth, ?)

Element	Western ←						→ Eastern
	Arizona	New Mexico	Texas	Oklahoma	Alabama	Georgia	Florida
N (%)	2.1-3.0	2.6-3.0	2.5-4	2.4-3.0	2.7-2.9	2.5-3.0	2.7-3.5
P (%)	0.1-0.16	0.12-0.19	0.12-0.30	0.14-0.30	0.14-0.30	0.12-0.30	0.14-0.30
K (%)	1.0-1.59	0.9-1.2	0.75-1.25	1.0-2.5	-	1.25-2.50	-
Fe (ppm)	40-80	50-250	50-300	50-300	-	50-300	-
Cu (ppm)	6-10	8-30	10-30	6-30	-	6-30	-
B (ppm)	75-150	50-200	20-45	15-30	-	50-100	-

From the above (Table 2), the fact that US norms differ in the different states is probably due to climate and geographical reasons. It is recommended to producers and agriculturalists to investigate the average annual or long-term climate for a specific orchard in an area and to compare that with the three options in the Southern parts of the US, namely Georgia, Arizona and New Mexico (Table 3).

Table 3: Summary of leaf norms for pecan in three states in Southern US

Element		New Mexico[1]	Arizona[2]	Georgia[3]
N	%	2.5-3.0	2.05-2.96	2.5-3.0
P		0.14-0.19	0.1-0.16	0.14-0.3
K		1.2-2.5	1.0-1.59	1.3-2.5
Ca		0.9-1.8	1.57-2.43	1.3-1.75
Mg		0.3-0.6	0.39-0.59	0.35-0.6
S		0.15-0.35	0.14-0.2	0.25-0.5
Zn	mg/kg	50-100	85-257	50-100
Fe		50-250	43-81	50-300
Ni		>2.5	8.5-14.3	
Mn		100-300	104-674	100-800
Cu		8-30	6-10	6-30
B		50-150	74-147	50-100

[1] - Hereema (2013)
[2] - Walworth (?); Walworth & Kilby (2002); Walworth (2006).
[3] - Wells (2015)

From studies on high-yielding trees (6 years and older), in Georgia-USA, it is proposed that the **N:K ratio** in leaves should be **2:1** (Wells & Wood, 2007). The ratio could be managed by N and K fertilizer inputs.

Nutritional management

Leaf samples collected and analysed timeously, together with current and historical soil samples and fertilizer applications, are used collectively to compile a fertilizer strategy, as well as to make certain changes. In doing this, it is important to avoid sudden big changes (thus applying significantly different fertilizer strategies). Significant differences in fertilization levels between seasons could increase alternating yield amplitudes, by impacting negatively on the building of energy reserves and the transfer thereof between seasons. This could have a huge impact on the formation of male and female flowers. Good record-keeping regarding fertilizer levels and strategy (application dates and quantities), leaf analyses, yield (quality, quantity and size distribution), growth disorders (vivipary, sticktights, shuck split and pops), for example, should be recorded on a continual basis.

Fertilizer guidelines

As explained in the ARC-Tropical and Sub-tropical guide, there is a lack of published fertilizer guidelines (Schmidt, 2021c). Therefore, in the market, there may be numerous guidelines being followed by different companies. Below, in Table 4, one guideline is shown. The guideline distinguishes between in-season and winter, fertilization (Schmidt, 2021c).

Table 4: Proposed fertilization guideline for pecan according to age and a distinction between in-season (Schmidt, 2021c) and winter fertilization.

Proposed application rates for N, P and K (Schmidt, 2021c)						
Tree age (years)	**N**	**P**	**K**	**N**	**P**	**K**
	kg/ha/in-season (excluded winter fertilization)			**Factor to multiply in-season N, P and K rates, with, to determine winter fertilization of each element to apply after harvest (kg/ha)**		
Young non-bearing trees (0-3 year)	50-75	25-35	35-45	0		
Young bearing trees (4-7 year)	80-110	35-45	60-100	0.43	0.53	0.23
Adult bearing trees (>7 years plus)	120-140+	45-55+	130-160+			

* Soil P- and K-levels will influence P and K-application strategy

To calculate the quantity of N, P and K needed for winter fertilization, which needs to be applied during or after harvesting, the N, P and K quantities applied in-season (according to Table 4), are multiplied with factors 0.1, 0.25 of and 0.5, respectively; thus, in-season N x 0.25, P x 0.1 and K x 0.3-0.5, respectively. Soil P- and K-levels will influence P and K fertilizer strategy.

Fertilization approaches between orchards with flood irrigation (who will mainly use granular fertilizer, or banding with dry or liquid fertilizers), and fertigation, differs and should be applied differently. It is important to know the effective wetting area per tree, the amount of water per emitter (or tree; rate

and volume), as well as tree spacings, which will determine how a specific fertilizer strategy needs to be approached and applied. For instance, if a producer fertigates adult trees with only one drip-line, because of risk to the tree and roots due to the high salt-index and concentrations of the actual needed fertilizer, it would be impossible to apply to that tree (orchard) the required amount of fertilizer (Schmidt, 2021c). The risk balance between wetting type, wetting area per tree, and fertilizer requirement (application) must always be considered. For this purpose, a producer needs to consult with a qualified professional.

Fertilization of young trees during orchard establishment

A common practise by leading pecan producers is the commitment to making soil "corrections"/remediation, before orchard establishment. Once the remediation is complete and the trees established very little fertilization will take place until trees start to bear fruit. Many South African producers avoid soil remediations, as well as fertilization during the first couple of years after planting. Soil ought to be remediated before establishing an orchard. Physical restrictions, such as restrictive layers, as well as chemical imbalances need to be addressed beforehand. If physical restrictions (layers) are not removed, water movement patterns could be restricted for the rest of the tree's life, afterwards, with no opportunity to be removed. If soil remediation was done, then minimal fertilization needs to be done until the fourth year. If remediations were not done, then focus should be placed on the addition of low-salt-index products during planting, in the planting pits. This excludes the need to alleviate soil acidity. If soils are acid, then they should be limed beforehand. The size of planting pits will determine the quantity of fertilizer that could be mixed in with the pit's soil. During this process the use of nitrogen could be avoided and focus could be placed upon P, K and Zn, as well as products to stimulate root development (which could include Mg and Ca). Also, avoid too small wetting areas per tree. Try and provide a large enough wetting area so that trees can develop a strong, large and vigorous root volume from establishment.

Foliar application suggestions

Foliar sprays are an important method of supporting sustainable and productive management of crops. Complex interactions occur between the environment, plant species, phenological growth and development, timeliness of applications, time of the day, humidity, temperatures and wind conditions, size of droplets, and the use of adjuvants are important. The use of adjuvants, such as wetting agents, stickers, humectants and uptake enhancers are highly recommended.

The surfaces of leaves are covered by a hydrophobic cuticle, making absorption of water more difficult in addition, the outer surface of the cuticle is covered by waxes that are also hydrophobic, contributing to reduced absorption of foliar sprays. A high number of spray applications during a season may be difficult to maintain due to several factors such as cost implications, as well as climatic deviations such as wind A summary of information particular to foliar spraying is presented in Table 5, below (from the ARC-Tropical and Subtropical Crops guideline; Schmidt, 2021c). Producers are advised to make use of a professional for guidance regarding spraying strategies and options.

Table 5: A summary of information on foliar applications for pecan, to consider (Schmidt, 2021c)

N, P, K	Could be sprayed almost throughout the season, but should be focused during nut-fill period until mature, especially for K.
Ca, Mg	Is difficult to incorporate into a practical and manageable foliar program and therefore it is not common as a foliar. However, if chlorophyll needs to be addressed, Mg is important. It is preferred that both nutrients should rather be soil applied. However, foliar application is not wrong.
S	Although S could play an important role in resistance to disease, from a nutritional viewpoint it would also rather be included in soil applications. However, as a foliar for health purposes, it is important to consider.
Zn	**It is important to make use of the correct source**. Leaf absorption of both Zn-sulphate, Zn-chelate, Zn-nitrate and organic complexed Zn are all acceptable. **Spray at the right time**. Zn is needed on shoot tips and therefore Zn-applications should start early in the season. On adult trees approximately four sprays should be needed as maintenance, early in the season. The 1st spray should be at 50% leave expansion, the 2nd 7 days later, the 3rd 14 days later, and the 4th 14-21 days later. New growth ("*flushes*") should be sprayed, additional to the first four application. On young trees the same procedure should be followed, except trees should be sprayed every two weeks until end of January (South Africa). **Apply at the right place**. Since the "**lower** side" (abaxial surface) of Pecan leaves absorb better than the "**upper** side" (adaxial surface), spray should be from the soil, upwards, into the tree. Arial sprays is less effective. Zn is absorbed and utilized by young fast-growing leaves. It is essential that the sprayer, or mist blower, used, should spray and cover, effectively. **Spray the correct dosage**. In terms of Zn-sulphate, a suggested rate is 0.9 to 1.4 kg (Zn-sulphate; 36% Zn) per 380 litre water, plus 1.65 litre 32 % UAN. The N helps with better absorption (Hererra, 2003 – New Mexico). In other instances, follow label information. Usually 1000 L water ha^{-1} will be sprayed.
	In Texas, the proposal is to start with the 1st spray at green Tip, the 2nd one week after Green Tip, the 3rd three weeks later Green Tip, the 4th spray approx. 5-6 weeks after Green Tip, and the 5th eight weeks after Green Tip. On young trees spraying should be done every two weeks from RSA-October until February (Begnaud, 2012). Read Green Tip = Bud break/Budding.
B	Is important for pollination and should be included in an early application with Zn. The need for further applications would be determined by leaf analysis data, geographical area, and history, as well as water quality.
Cu	The need for applications for nutritional purposes would be determined by leaf analysis data, geographical area, and history. Usually, Cu forms part of disease control and could be added in such a way.
Fe and Mn	Fe is important for pollination and should be included in an early application with Zn.
	When considering the need for applications, the important issue to consider will be the ratio between Fe and Mn. Otherwise, just like all other nutrients, leaf analysis should dictate.
Ni	The importance and need for Ni by Pecan during all its life-cycle, is clear. Ni-applications should be dictated by the leaf analysis value. It is important to follow instructions on product labels. Always keep in mind that Ni is a toxic heavy metal and strict safety precautions should always be taken and followed.
Si	The importance and need during certain conditions are well documented. If such conditions apply, as for instance high salt levels, or presence of acidity and heavy metals, Si should be considered once or twice as a foliar during the active growing season.
Mo	Geographical area and soil-pH will greatly influence the decision for spraying. There is a lack of clear guidelines on Mo.