5.8.2 PECAN NUTS

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Introduction

Pecan is one of the oldest nut crops that occur 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). As for other tree species, the fertilization of pecan is complex. At this stage in South Africa, the quality of the nut is a crucial sales-factor for producers who would like to utilize international markets. The quality of a nut is defined by it's size, as well as the degree to which the shell is filled by the kernel, i.e., kernel percentage. Thus, in broad it could be seen that the bigger the nut with good kernel-fill, the better. Smaller nuts will yield a lower price and therefore is in lower demand. These nuts, as well as those with low kernel-fill will rather be utilised by the cracking segment to be sold as nut pieces, viz. a *niche*-market. The producer who would like to stay in the forefront of international marketing, need to strive for size and high kernel-fill. Nut size is not the exclusive function of nutrition alone, but to a great extent those of water (Worley, 1994) in terms of quantity, but also at the appropriate time. Nut-filling, quality and number of nuts are stronger linked to nutrition. The number of nuts that a tree starts the season with, is amongst other, a major result of stored energy reserves.

Important keys in pecan nutrition

<u>Phenological growth stages</u>: It is necessary for pecan growers to understand the phenological growth and development in order to understand why and when certain actions need to be taken. General phenological growth for South African conditions is illustrated in Figure 1 (Schmidt, 2021a). Growth stages is approximate, since areas differ in climate. In the different areas growth could be earlier, or later, and therefore the illustration is approximate. New growth start during September/October from energy reserves. Also, during final nut-fill, energy from reserves is used for this purpose. Between the two mentioned events, plant nutritional needs need to be supplemented by fresh fertilizer applications. Literature shows that supplementary nutrition is needed three weeks after bud-break. Therefore, on bearing trees, fertilizer applications could be spaced between 5 and 10 times from bud-break, until winter fertilization, after harvest. The healthier the trees, the less spacings could be applied (with a minimum of 5), and *vice versa*. Factors like soil texture and type of irrigation will also impact on the spacings of fertilizer applications; in other words, with limitation of leaching losses in mind (Schmidt, 2021; from ARC-Tropical and Subtropical Crops, 2021). For non-bearing trees, fertilization could be split into six applications.

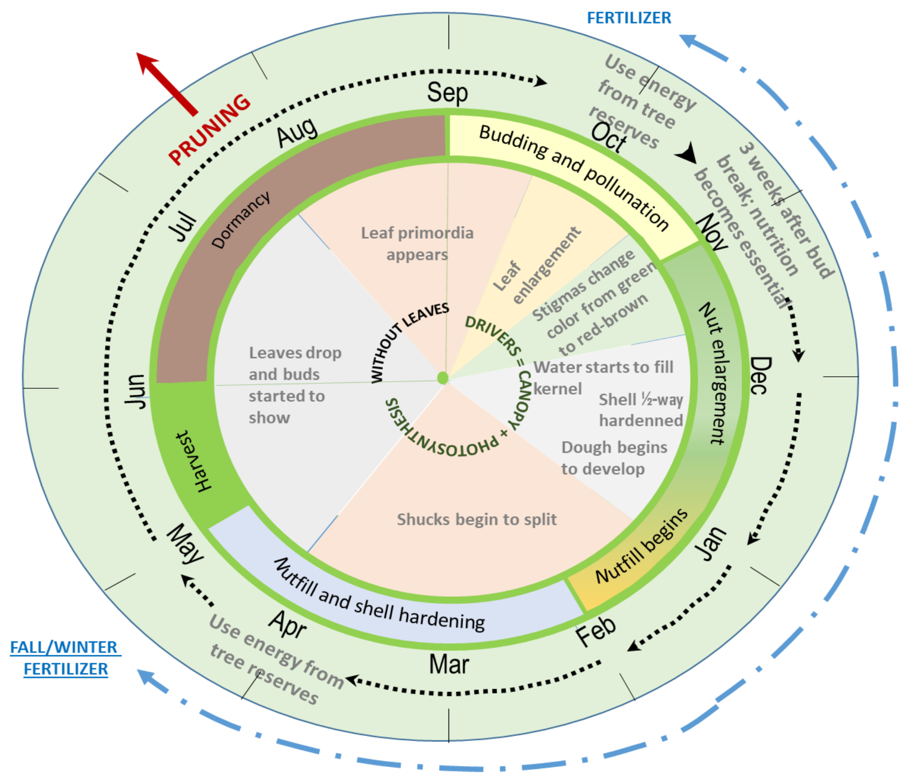

Figure 1: The Pecan growth wheel, applicable to bearing trees – a generalization of growth and phenological development for South African conditions (Schmidt, 2021)

<u>Energy, historic growth and future growth</u>: From literature (Wells, 2017), additional to the information from the Pecan growth wheel in Figure 1, male flowers during a specific season will develop approx. during October- and November. The number of male flowers will be determined by shoot length grown during the previous two years. Shoot growth as such is also partly a result of stored energy. The number of female flowers to open during a specific season are determined approx. eight months earlier according to the amount of stored energy reserves. For these reasons, an annual varying and changing fertilizer strategy by a producer should be avoided, since it could attribute to increasing amplitudes between on and off years (alternating bearing).

<u>Roots</u>: Already during 1934, Woodroof & Woodroof described the pecans' root development and character. The study defined pecan roots as mycorrhizal roots. This could implicate 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 depth of root penetration, the root volume, distribution and eventually utilization, is not known and varies. In addition, Woodroof & Woodroof (1934) and Wells (2015 & 2017) stated that a productive pecan tree should have a healthy and vigorous root system in order to support sustainable yield. Roots provide anchorage, water uptake, nutrient uptake, hormone production, and energy and starch storage.

<u>Nutrients</u>: One component of pecan production is the maintenance of the tree, which includes energy reserves, as well as fresh nutrient addition to support yield. The last mentioned includes not only quantity, but also quality. For this very reason it is better to apply nutrition to support the mentioned components, rather than provide nutrients only according to yield removal.

The role and function of most nutritional elements are known, but when literature is finely looked through, interesting facts are summarized in Table 1 below, describing the roles and interactions of different nutrients in plants and in pecan. The contents are thus presented as representative for pecan.

Table 1: Summary of nutritional roles and interactions for pecan (Schmidt, 2021a).

Funksie in gewas (pekan)	Elemente*														
	N	P	K	Ca	Mg	S	Na	Zn	Fe	Mn	Cu	B	Mo	Ni	Si
Koolhidraatproduksie, -vervoer, -metabolisme; energieberging en -oordrag in plant biochemiese prosesse; suiker en stysel metabolisme; beweging van suikers en fotosintese-produkte in die plant	√	√	√	√	√			√	√		√	√			
Ca-opname en gebruik deur plante; reguleer die Ca:P en K:Ca verhouding												√			
Selwand en membraan integriteit; deurlaatbaarheid, sterkte, vorming, verdeling en groei; respirasie	√	√√		√		√		√	√		√	√			√
Chrorofil sintese en vorming; respirasie	√				√	√		√	√	√	√				
Verbind met verskeie polihidroksie-verbindings												√			
Komponent van aminosure, nukleïnsure (DNA), sitoplasma, organellas, mitokondria; chloroplast-beskerming	√	√			√	√			√			√			
Omskakeling van Mg									√						
Detoksifiseringsagent				√											
Vernietigend tot gesondheid wanneer in ligte oormaat							X								
Vroeë rypwording		√													
Behou elektriese balans					√										
Ensiem aktiveerder en katalis		√	√	√	√	√			√	√	√	√	√	√	√
Blom, vrugset, -vorming, -ontwikkeling, -grootte, -rypwording, -kwaliteit en opbrengs		√	√	√	√	√		√	√			√			√
Genetiese integriteit, chromosoomstrukture en oordrag tussen selle, regulering en identifisering van gene, reproduksie, hormoonaktiwiteite, -konsentrasies, -metabolisme en-produksie		√		√				√		√	√	√			
Glikolaat siklus									√						
Hidrolise van verskeie verbindings					√										
Blaarvergroting en -effektiwiteit								√							
Ligverbruik gedurende koel en bewolkte weerstoestande			√												
Lignien sintese, asook ander reaksies									√	√	√	√			
Verbind molekules in inter-molekulêre kompleksering		√		√											
Membraanfunksie (integriteit), -deurlaatbaarheid, -pH-beheer, -struktuur en -stabiliteit		√	√	√								√			
Mn-transport binne weefsel word verbeter															√
Mo-opname															√
N-assimilasie, -metabolisme en aktief in CO_2-assimilasie en vervoer in plante; N-gebruikseffektiwiteit						√		√	√	√	√	√	√		
N_2-binding											√		√	√	
Olie vorming		√	√			√									
P-opname en vervoer					√										√
Fotosintese en respirasie	√	√	√		√			√	√	√	√				√
Plantgroei, oorlewing en produksie	√	√	√	√	√	√		√	√	√	√	√	√	√	√
Stuifmeelvorming								√							
Stuifmeelbuis se groei				√								√			
Proteïnproduksie, -sintese, -stabilisering en -metabolisme	√		√	√	√	√		√	√		√	√			
Vrylating van stuifmeel											√				
Weerstand teen koue-stres en skok		√	√	√									√		√
Weerstand teen droogte-stres			√	√							√		√		√
Weerstand teen oormaat swaarmetale															√
Weerstand teen meganiese stres				√											
Weerstand teen peste en siektes	√	√	√	√		√				√	√	√		√	√
Weerstand teen soutstres			√	√									√		√
Weerstand teen ultravioletbeskadiging				√				√					√		
Wortelverlenging, -ontwikkeling en ontwikkeling en groei van wortelhare		√		√	√			√				√			√
Saadontkieming														√	
Loot en strukturêle groei					√	√		√							
Strukturêle bestanddeel van fosfolipiede, nukluïensuur, nukleotides, ko-ensieme, fosfo-proteïne; en strukturêle stabiliseerder van verskeie nukleotides		√			√										
Swael metabolisme									√				√		
Vervoerfunksie binne plante			√	√											
Opname van ander voedingselemente								√							
Ureade-vervoer in hidrofiele plante, asook essensiële bestanddeel van die plantensiem, urease														√	
Vitamienproduksie en komponent van vitamines	√					√					√				
Wateropname, handhaaf waterverhoudings binne die plant, asook watergebruikseffektiwiteit en stomata-beheer	√		√					√			√	√			√

Literature references for nutritional contribution	
N	- (FAO, 1984; IPNI, 2014)
P	- (FAO, 1984; Smith, 1990; FAO, 2006; IPNI, 2006; Sanchez, 2007)
K	- (FAO, 1986; FAO, 2006; IPNI, 2006; Mengel, 2007)
Ca	- (FAO, 1986; FAO, 1990; FAO, 2006; IPNI, 2006; Pilbeam & Morley, 2007; Midwest Laboratories, ?)
Mg	- (FAO, 1986; FAO, 2006; Merhaut, 2007)
S	- (FAO, 1986; FAO, 2006; Haneklaus et al., 2007a; Haneklaus et al., 2007b; Till, 2010; IPNI, 2014)
Na	- (Epstein & Bloom, 2005; Gorham, 2007)
Zn	- (Römheld & Marschner, 1991; Worley, 1994; Hererra, 2000; Alloway, 2008; Bell & Dell, 2008; Wells, 2015c)
Fe	- (FAO, 2006; Expert, 2007; Römheld & Nikolic, 2007; Bell & Dell, 2008; Kabata-Pendias, 2011)
Mn	- (FAO, 2006; Humphries et al., 2007; Bell & Dell, 2008)
Cu	- (FAO, 1986; FAO, 2006; Bell & Dell, 2008; Kabata-Pendias, 2011; IPNI, 2014)
B	- (FAO, 1986; FAO, 2006; Gupta, 2007; Midwest Laboratories, ?)
Mo	- (FAO, 2006; Graham & Stangoulis, 2007; Hamlin, 2007; Bell & Dell, 2008; Kabata-Pendias, 2011)
Ni	- (Schubert & Boland, 1990; Worley, 1994; Wood, Reilly & Nyzepir, 2004; IPNI, 2006; Brown, 2007; Wood & Reilly, 2007; Kabata-Pendias, 2011)
Si	- (Datnoff et al., 2007; Snyder et al., 2007; Kabata-Pendias, 2011)

From Table 1 it is clear that elements interact in a matrix (in other words supplements should be made over the whole spectrum of the active growing season / phenological stages) to stimulate and support growth. Because of this, it is advisable to fertilize according to the growth stages as suggested by the Pecan growth wheel (Figure 1), and also to take notice of the periods that the pecan need energy directly from reserves to support growth and yield.

High zinc (Zn)-demand: Apart from normal macro, secondary and micro-element requirements, the pecan shows a constant need for Zn (Wood, 2021). It is also known that Zn is worldwide an element closely related to deficiencies (Knudsen & Frank, 1977; Daroub & Snyder, 2007; Rice, 2007). Furthermore, it is known that Zn is a non-mobile element within the tree. Pecan trees with a serious Zn-deficiency will appear "rusty" from a distance. The deficiency will show as leaf margin curliness, associated with chlorosis between veins, as well as necrosis. Leaves usually tend to be dwarfed with rosette. Shoot and branch die-back could occur with serious Zn-deficiencies (Arnold & Crocker, 1998; Hererra, 2000; Wells, 2015a&c), including die-back of the leaf canopy (Begnaud, 2012). Soil amendments of zinc on slightly acid and acid soils are easy and effective, and could be done by zinc sulphate applications. Together with foliar sprays, zinc management in orchards on these soils is fairly easy and effective. In contrast to this, zinc management on alkali soils and soils with free carbonates is not that simple and require better management. For this reason, literature from the USA should be interpreted with caution. Soils in the eastern parts of northern America is naturally acidic (Smith, 1990; Worley, 1994), while those form the western parts, as well as northern Mexico, are more alkali (Hererra, 2000). According to Hererra (2003), in New Mexico one could expect soils with a pH higher than 7. Historically pecan producers and even academics thought that foliar zinc applications to be the only effective way of zinc management. According to literature the availability of zinc cations declines with increasing soil-pH. In these soils, Zn^{2+} ions will be complexed on $CaCO_3$ surfaces. This implicates that the presence of free carbonates in a soil, will restrict the availability of Ca^{2+} ions for plant uptake (Havlin, Beaton, Tisdale & Nelson, 1999). In these conditions the usage of Zn-edta (ethylenediamine tetra-acetic acid chelated Zn) for Zn-amendments to the soil, is advised. In Florida-USA (south eastern; acidic soil) Zn sulphate is suitable for soil Zn-amendments (Arnold & Crocker, 1998; Andersen, 2006). In Arizona-VSA (south westerly; alkali soils) Zn-edta shown significantly positive results during studies (Nu´n˜ez-Moreno, Walworth, Pond & Kilby, 2009; Hereema, Van Leeuwen, Thompson, Sherman, Comeau & Walworth, 2017; Walworth, White, Comeau, & Hereema, 2017). In Texas the results of various studies by Worley (1994) and Walworth, White, Comeau & Hereema (2017) were discussed. Mixed information is discussed, but Zn-edta obtained better results than Zn sulphate for amendments. It is mentioned that Zn-applications in 3 cm deep bands alongside driplines, is a superior method of application than a powder broadcasted on top of the soil surface. Zn broadcasted on the soil surface tend to show a delayed (comet tail type) reaction, especially on more clayish soil types. According to Liu, Hanlon & Li (2018), the use of a Zn-edta, in general, is not needed on soils with a pH less than 5.3, but it may be needed on soils with pH values between 5.3 and 6.5. However, on soils with a pH higher than 6.5, a chelate is recommended. At higher soil pH values, for instance 8, more stable chelates, like for instance an EDDHA [(ethylenediamine-N,N′-bis(2-hydroxyphenylacetic acid)], could be considered. The use of chelates for higher soil-pH conditions, is proven (Walworth, 2013).

<u>Hydrophilic specie</u>: Pecan has a high need for Nickel (Ni) and cannot survive without it. Ni is needed in catalyst reactions of at least eight principal enzymes (including urease – nitrogen conversion) and it is estimated to be involved in complexing with at least 500 protein and peptides. It also refers to the fact that the pecan is a water-loving specie (Wood, 2021).

<u>Soil preference</u>: From literature it is evident that pecan in their natural habitat is associated with deep soil that is well drained (Wells, 2017). It also seems that there is a tendency of preference towards more sandy soils. This, however, does not implicate that a producer cannot plant pecan on soils that deviate from the natural preference, but it is important that producers should notice that the more soil deviate from the natural preference, the more difficult it could be to manage, with a possible negative impact on growth and yield. For this reason, it is important to communicate with knowledgeable individuals before establishing an orchard.

<u>Sodium and salt sensitivity</u>: Although it is generally assumed that a soil with an electrical conductivity (EC; due to salt accumulation) of 0 to 200 mS/m (milli-Siemens per meter; measured in a saturated paste) will have no negative impact on crop growth (MVSA, 2002). However, the pecan is salt sensitive with an upper 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 with approx. 10%, 350 mS/m with approx. 25% and 490 mS/m with approx. 50%. Die-back of branches could occur at EC levels of 500 mS/m. Trees could die at EC-levels of 600 mS/m. These figures are applicable only to the 0-30 cm topsoil. If the sub-soil shows signs of excessive EC, it is unknown how to add the negative impact in addition to those of the top-soil. In this regard there is a total lack of scientific information (Kotuby-Amacher, Koenig & Kitchen, 2000; Koenig, 2016 - Personal communication; Schmidt, 2016). 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 purpose and development of leaf norms are more complicated than most individuals realize. Viewpoints on the accuracy and the application of leaf analysis and the incorporation thereof in nutritional strategies and programmes, differ. For example, Cooke (1982) said that the composition of leaves cannot be accurately correlated with levels of plant available nutrients in the top and subsoil. Depth of root penetration, as well as the utilization of the soil volume by the roots, is not always known. Furthermore, trees store large quantities of energy-reserves in trunks, branches and roots and therefore nutrient levels found in leaves will not always be a result of soil provided nutrients, and thus soil levels. Also, trees (permanent crop) grow for a long time on the same spot, but utilizes to a great extend only a small portion of the soil. The uptake of soil nutrients will be influenced by various factors, and therefore nutrient levels of the tree could not be accurately forecasted, even if soil levels are known. The viewpoint expressed by, for instances, Mengel & Kirky (1987), among others, differs from the previous by Cooke (1982). It is also important to realize that the nutrient levels in leaves changes 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). Also important, 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 regards to this, the following two aspects are critical important, namely:

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.

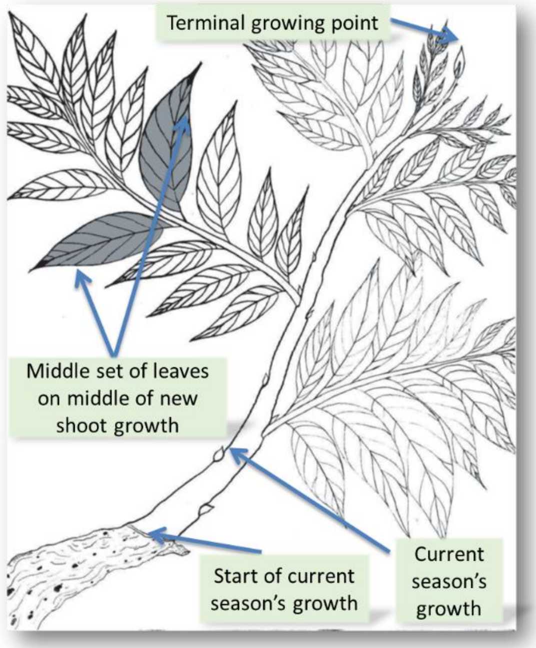

Figure 3: An illustration of leaf sampling method for pecan; from Heerema (2013) and Wells (2015).

b). Norms: It is important to apply the correct norm for your area when evaluating leaf analysis values. South Africa do not have own scientific and published norms and for that reason we are making 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 in Table 2 regarding the fact that US norms differ in the different states, probably due to climate and geographical reasons, it is pointed out 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 bearing 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 timely, together with soil samples and fertilizer applications over years, 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 significant 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 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 will be one or more 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)						
	N	P	K	N	P	K
Tree age (years)	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	0.25	0.10*	0.3-0.50*
Adult bearing trees (>7 years plus)	120-140+	45-55+	130-160+			

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

For calculating 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 of 0.25, 0.1 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 that effective wetting area per tree, the amount of water per emitter (or tree; rate and volume), as well as tree spacings, will determine how a specific fertilizer strategy need 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 by the high salt-index and concentrations of the actual needed fertilizer, it would be impossible to apply to that tree (orchard) the needed amount of fertilizer (Schmidt, 2021c). The risk balance between wetting type, wetting area per tree, and fertilizer requirement (application) always need to be considered. For this purpose, a producer needs to consult with a professional.

Fertilization of young trees during orchard establishment

A general practise by leader pecan producers in the USA, is the amount of effort done on soil "corrections"/remediation, before orchard establishment. After the remediation, and then the planting of young trees, none to <u>little</u> 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, like restricted 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 remove. 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 it 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 big enough wetting area so that trees could develop a strong, large and vigorous root volume from early.

Foliar application suggestions

Foliar sprays are an important way to support sustainable and productive management of crops. Complex interactions occur between the environment, plant species, phenological growth and development, timeliness of applications, as well as the basic components of the spraying operation. The basic components of foliar sprays are made up by the concentration of the spraying solution, water quality used, time of the day, humidity, temperatures and wind conditions, size of droplets, and the use of adjuvants. A spray solution with a high concentration, or a low concentration, could result in very different outcomes (Schmidt,2021c). The use of adjuvants, like wetting agents, stickers, humectants and uptake enhancers are highly recommended.

Mostly, arial surfaces of leaves are covered by a hydrophobic cuticle, making absorption of water more difficult. Also, the outer surface of the cuticle is covered by waxes that are also hydrophobic, contributing to reduced absorption of foliar sprays. Too many spray applications during a season could be difficult to maintain due to several factors such as cost implications, as well as climatic deviations (like winds, for instance). A summary of information applying 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 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 right-through 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 need 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 type**. Leaf absorption of both Zn-sulphate, Zn-chelate, Zn-nitrate and organic complexed Zn are all acceptable. **Spray on the right time**. Zn is needed on shoot tips and therefore Zn-applications should start early in a 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 on 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 are 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 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. Also, 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 mentioned. 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.

Compiled by Dr Chris Schmidt, Kynoch-fertilizer.

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