TESSENDERLO Kerley

NUTS

Nut is a general term for the dry seed or fruit of some plants. Nuts are an important source of nutrition, containing unsaturated fatty acids, vitamins and mineral elements such as potassium, phosphorus and magnesium. Consequently, they are currently recommended as a healthy food group in many dietary guidelines. This could lead to a substantial increase in future global nut production. Global nut production today is more than 4.5 million tons per year, of which 1.36 million tons is almond production. The most common nuts includes almond, walnut, pistachio and hazelnut that are being produced worldwide under either irrigated or rainfed (often water stressed) areas. Therefore, a large variation in yield can be observed, which is also affected by different cropping practices, in particular, fertilization. The common denominator across the various nut crops is the need to achieve balanced fertilization. A balanced fertilization program is a prerequisite to ensure healthy root growth, maintain tree vigour and productivity in order to achieve the target yield to meet growing market demand.

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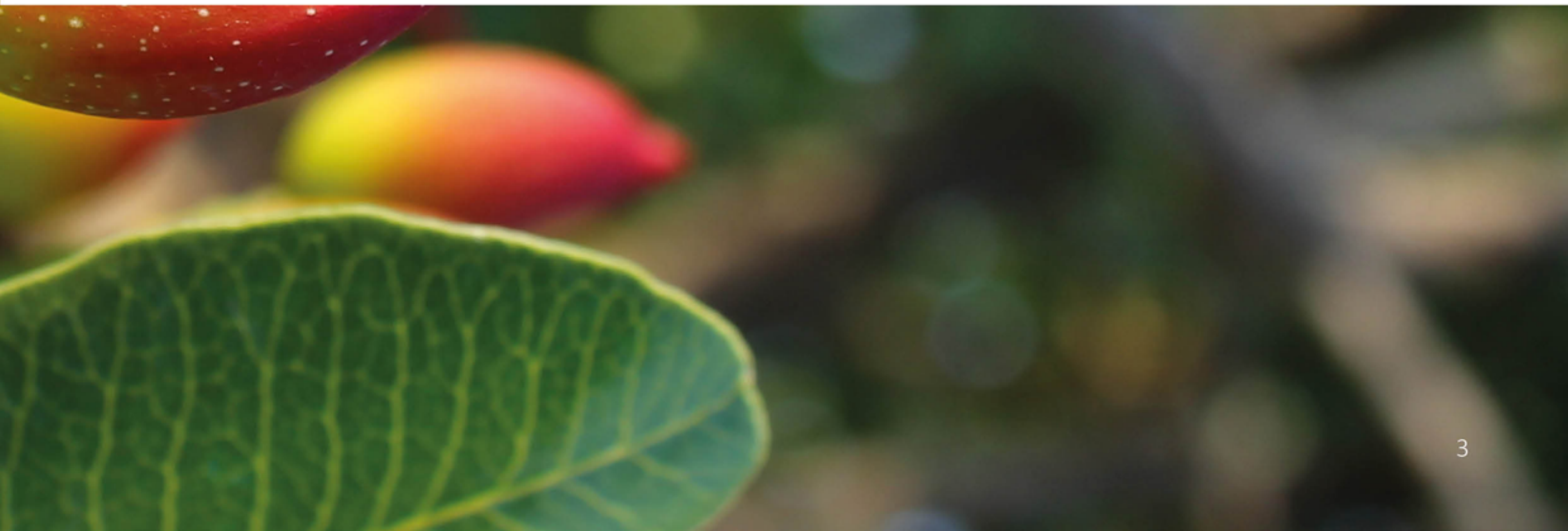


ALMOND

The almond (*Prunus dulcis*) is a tree native to central and southwest Asia. Almonds grow in temperate and subtropical regions and require low to medium cold units. Most varieties require 400 - 600 cold units. The temperature range for growth is 10 to 45°C with an optimum of 25°C. Almond trees' sensitivity to cold temperatures progressively increases from buds to small nuts, increasing the concern regarding the risk of cold temperatures during and after bloom. Almond frost damage begins when temperatures in orchards drop below approximately - 2°C. Almonds have a low tolerance to salinity and yield will decrease at a soil ECe greater than 1.6 ds/m. If the salt levels within the soil are high, they must be leached from the soil. This process is typically done with applications of water along with soil amendments during dormancy when evapotranspiration rates are low. An irrigation stress or deficit during the post-harvest period has also been shown to reduce bloom, fruit set, fruit load, and individual fruit weight. As the first round of harvesting is completed, the orchard must be irrigated.

Young almond trees require regular fertilizer applications throughout the growing season and they use nitrogen continuously. Mature almonds tend to take up most of their nitrogen requirement in early spring, and so require spring applications and a late summer application for next year's early growth. Almonds are most productive on irrigated light to medium well-drained, somewhat alkaline, loamy soils. However, to check the fertility requirements of almonds, healthy leaflets from non-fruiting spurs should be collected for tissue analysis during fruit development stages. Most of the nitrogen should be applied prior to kernel fill and before hull split, and the rest post-harvest, Applications of nitrogen in the post-harvest period have been promoted as a good farming practice. Potassium is preferably applied as sulfate or thiosulfate. Potassium uptake (as K_2O) is higher than the nitrogen uptake.

Almonds grow on trees that bloom from mid-February through March. These trees are not self-pollinating, so bees have an important role. For the trees to produce, at least two different almond varieties must be planted in alternating rows.

Almonds develop in a shell that is surrounded by a hull. Over the summer, as the nuts mature, the hull dries and splits open, revealing a shell that encases the nut. The nuts dry naturally in this shell before they are harvested.

Between mid-August and October, almonds are harvested by mechanical tree "shakers," which knock the almonds, still in their hulls, to the ground. The nuts are then gathered and delivered for processing, where the next stage of cleaning and grading occurs.

PISTACHIO

Pistachios (*Pistacia vera*) are one of the oldest flowering nut trees which are native to the Middle East. Pistachio trees grow best and produce the most nuts in hot-weather climates with long, dry, hot summers (above 37 °C) and low humidity. During the growing season, pistachio trees thrive on heat. Pistachio trees grow in almost all soils, however they grow better in deep, sandy loam soils and well-drained soils are needed for optimum growth. Pistachios are drought tolerant but for commercial crop production there must be adequate soil moisture during late winter, spring and early summer. Pistachio trees are in general highly tolerant to saline conditions but an eventual decline in tree growth and yield will eventually happen if the right nutrient and soil management do not take place.

Pistachio trees mature slowly and do not begin to bear fruit until at least seven years after planting. It is an alternate year bearing tree producing a large crop one year ('on' years) and very little the next ('off' years), therefore the fertilization is lighter during 'off' years and must be well designed for the 'on' years. Nutrients are best applied to the root zone at the time of greatest need, which is typically early in the season. To achieve the best results, the fertilizer program must be established based on soil analysis, and after the application program is initiated, leaf analysis in late July/early August should be used to monitor it. Efficient and profitable nitrogen application demands that nitrogen be applied at the right rate, with the right timing and in the right location. For mature pistachio (> 10 years), nut yield in the current year is the primary determinant of nitrogen demand: kernel filling is the most demanding sink for nitrogen. Potassium uptake is also very high during kernel filling.

WALNUT

Common walnut (*Juglans regia L*) is an economically important nut species cultivated worldwide for its high-quality wood and nuts. It is a wind-pollinated, monoecious, long-lived, perennial tree that grows well in virtually all parts of the world with a temperate climate. In its Asian native range *J. regia* survives and grows spontaneously in almost completely isolated stands surrounded by arid continental lowland, mountain slopes and highland steppes. Common walnut prefers mild climates with dry continental air, but nevertheless requires warmth during the growing season (6 months with an average temperature ≥ 10°C). Resistant to drought, thanks to its tap root, walnut trees thrive in deep, sandy loam or clay loam, well drained, irrigated and rich in organic matter soil. Walnuts are known to be sensitive to soil salinity (especially high concentrations of sodium, chloride and boron) and salinity of irrigation water, and both yield and quality can be adversely affected if salt levels are too high. Walnut can tolerate a wide pH range (pH 5 to 8), but in commercial orchards it is recommend to fix pH at around 6.5 - 7.5.

Walnut will bear nuts normally 4 - 5 year after planting. For optimum production, it is better to plant walnut on rich soils. In general, walnut trees have significant nutrient needs mainly in nitrogen, and secondly in phosphorus and potassium. Nitrogen uptake is greatest between the onset of shoot growth and the latter stages of nut fill. To provide sufficient nitrogen for the period of high uptake, it is recommended to apply one half to two thirds of the nitrogen in spring so it is available during the main flush of spring shoot growth and the remainder in summer so it is available for tree uptake before nut fill is completed. It is important to monitor the growth of the previous year in order to manage the appearance of late season shoots because in excess they can limit floral induction. An excess of nitrogen fertilizer can cause excessive growth. Potassium soil applications are generally made in the fall to allow winter rains to move the potassium into the root zone, but split applications of potassium during the season is highly recommenced: walnut hulls contain a high concentration of potassium.

HAZELNUT

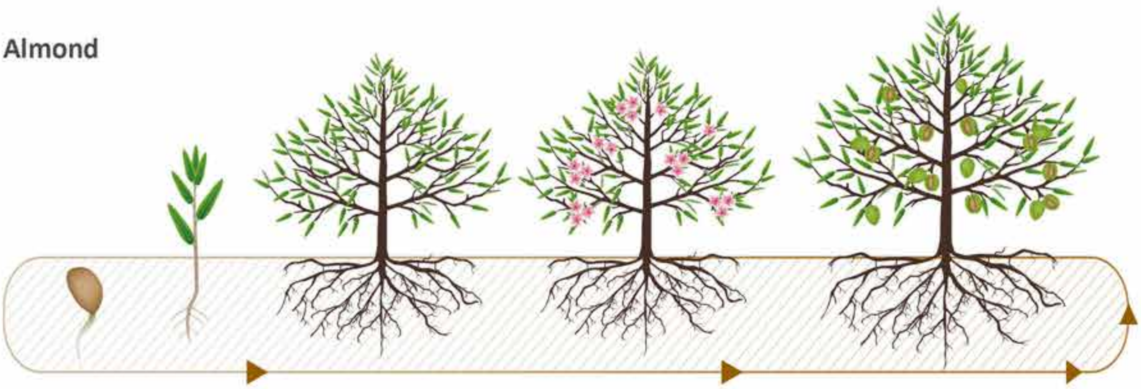
Hazelnut (genus *Corylus*), is native to Europe and Asia Minor and requires a mild climate to grow well and provide a bountiful harvest. Hazelnuts are monoecious, with separate male and female flowers. The plants are wind pollinated and self-incompatible. The staminate (male) flowers are catkins. Flowering and pollination occur from late autumn through to late winter. Hazelnut is a crop plant with hairy roots, which do not go deep into the soil. The tree preferably grows on light to medium soils with an optimum pH of 5-5.7. Hazelnuts are generally grown in humid conditions although irrigation is needed is dry summers. It is sensitive to soil salinity (tolerance to EC less than 2 dS/m).

Hazelnut has a higher tendency to develop stool. They develop abundantly on the roots of main branches every year. These stools compete for the soil nutrients, causing branches to become denser, preventing aeration and sunbathing. For these reasons, and in order to keep the number of main branches fixed during the production, these stools must be removed at least twice a year. In order to obtain good vegetative growth and high yield and quality, nitrogen and potassium application rate is of importance. High nitrogen rates increase shell thickness and reduce nut size and optimum potassium application reduces the proportion of empty nuts. Fertilizers should be applied based on soil analysis. Hazelnut kernels are high in potassium and an increase in kernel size has been recorded from applications of this element.

THE NUT TREE GROWTH CYCLE

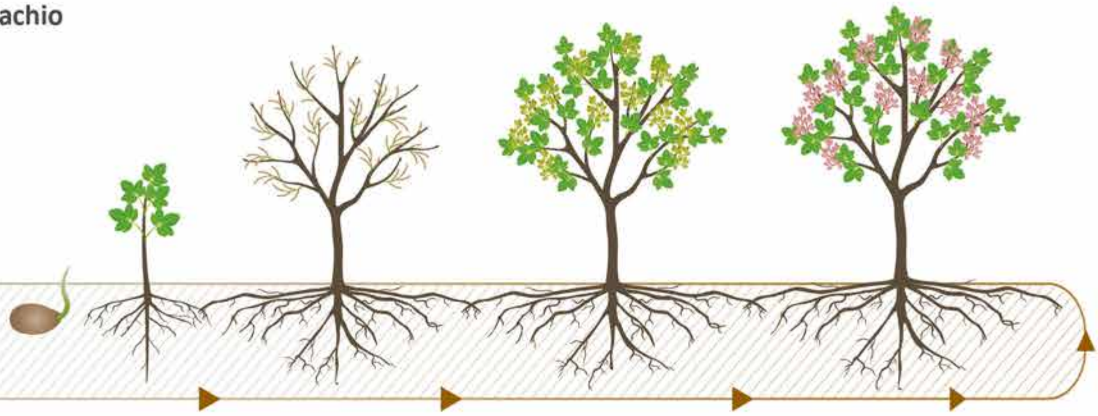
Many nuts are still cropped under traditional practices, although recent research demonstrates the benefits of balanced fertilization in modern nut production. Nevertheless, fertilizer rates and application timings will have to be adjusted according to the requirements of each species, and fertilizer doses will depend on the growth stage of the trees. The timing of fertilizer application has a significant effect on nut trees yields. Applying the right rate of fertilizer at the right growth stage increases nut yields and quality, reduces nutrient losses, improves nutrient use efficiency and prevents damage to the environment. Over-fertilizing trees can be even more harmful than not fertilizing at all. Excess fertilization of nut trees can result in too much rank, vegetative growth, reduced bloom and fruit set, as well as reduced nut quality. Therefore, the key to proper fertilization is a balance of nutrients applied at the right time. The requirements for nitrogen, phosphorus, potash, sulfur, calcium and magnesium are unique to each variety and these nutrients should be applied based on the results of soil analysis. This is also required in order to adapt fertilizer inputs to nutrients that are already present in the soil. Foliar analysis to demine the content of various nutrients in the leaves can also be a valuable tool to assist in defining the optimal fertilization program. It is worth noting that the method of fertilizer application will also have an impact on the nutrient use efficiency and hence the amount of fertilizer needed.

Almond



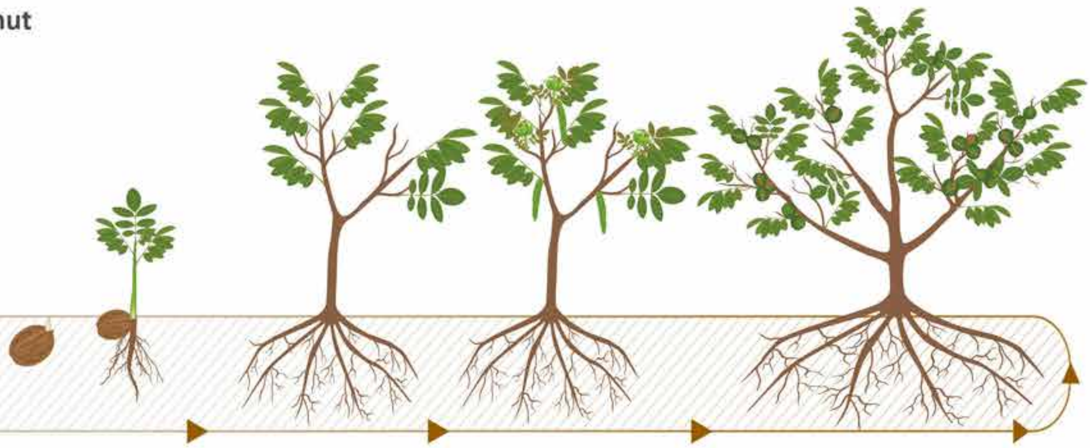
BUD DEVELOPMENT FOLIAGE GROWTH	BLOOM	KERNEL FILL	HULL SPLIT	HARVEST
BBCH 0-9 BBCH 10-59	BBCH 60-69	BBCH 71-79	BBCH 81-89	BBCH 91-99

Pistachio



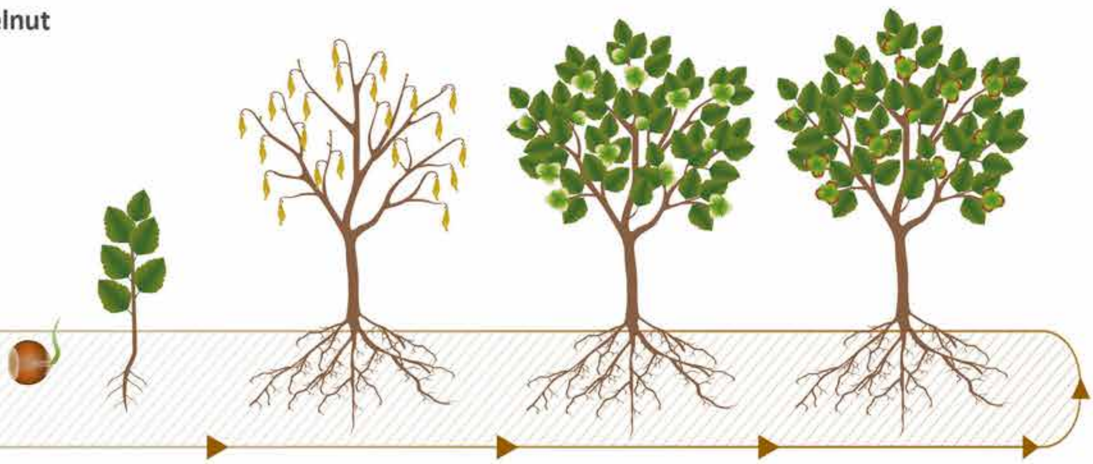
BUD BREAK	BLOOM	SHOOT GROWTH FOLIAGE	HULL EXPANSION SHELL HARDENING	NUT FILL SHELL SPLIT	HARVEST
BBCH 0-59	BBCH 60-65	BBCH 65-70	BBCH 71-79	BBCH 81-89	BBCH 91-99

Walnut



BUD BREAK BLOOM	SHOOT GROWTH/FOLIAGE HULL EXPANSION	NUT FILL SHELL HARDENING	HARVEST
BBCH 0-69	BBCH 70-79	BBCH 80-89	BBCH 91-99

Hazelnut



FERTILIZATION OBJECTIVES

Nuts are an important group of horticultural crops that have attracted attention for the health benefits they afford consumers. Successful nut production requires an adequate supply of essential nutrients to trees. Different types of nut trees have different nutrient requirements but it is generally accepted that all nut trees have high nitrogen and potassium demand during both early growth years and in the production years. Nut trees growing in deep, fertile soil may produce satisfactory crops with minimal fertilizer application, but like fruit trees, fertilization is considered one of the most effective practices to increase profits in nut trees. Therefore, annual fertilization is needed to achieve a high yield and quality in nuts. The key to proper fertilization is a balance of nutrients. The goal of any fertilizer management strategy is to ensure that adequate nutrients are available to supply the current demand of the plant.

The demand for different nutrients particularly in bearing trees, varies according to the stage of tree growth and the stage of nut development. When a nutrient is deficient there may be obvious visible signs such as leaf yellowing in the case of nitrogen deficiency (although leaf yellowing can be also caused by disease or inadequate moisture). To achieve the greatest benefits, small amounts of fertilizer should be applied regularly through the growing season. This reduces leaching and provides the tree with a continuous supply of nutrients: it has been shown that a continuous supply of potassium in almond can increase the yield by 12% compared to split application.

NUTRITIONAL REQUIREMENTS OF NUT TREES

1. Nitrogen (N)

Nitrogen is often regarded as the most important mineral nutrient, limiting crop production in many agricultural crops worldwide. Nitrogen is used by plants to synthesize amino acids and nucleic acids that are necessary for all functions of the plant. Therefore, it has a major effect on crop yield and quality. While increasing soil and plant nitrogen availability enhances tree growth and vigor, a shortage of nitrogen can reduce yield by preventing full fruit growth. Adding nitrogen in excess of the tree's demand does not increase yield and may result in loss of nitrogen to groundwater and a reduction in efficiency. Annual leaf tissue analysis can ensure that sufficient nitrogen is applied to meet the crop's needs without wasting money on unnecessary application. Nitrogen is mobile and new leaf production is at the expense of older leaves if nitrogen is deficient. In such cases, young leaves pale as older leaves turn yellow and drop from the tree early. Excessive leaf drop results in a tree with sparse foliage. The petioles and midribs of nitrogen deficient leaves become red. Nut yield will decrease with increasing nitrogen deficiency. An annual program of nitrogen fertilizer supply is needed to ensure the long-term productivity of nut trees by replenishing soil nitrogen. Proper rates and timings of nitrogen fertilizer adapted to the tree's nitrogen demand, in association with correct irrigation and pruning, are powerful tools for manipulating the delicate balance between vegetative and reproductive growth of nut trees. This contributes to enhancing the nitrogen use efficiency while minimizing nitrogen losses from the ecosystem. Optimal levels of leaf nitrogen in nuts are 2-3% of dry matter for mature trees. While nitrogen is required for all plant processes and in every organ, the development of the fruit represents by far the largest sink for nitrogen use in nut crops. In most of nut trees, limited application is needed during the spring flush and the remainder should be applied during late spring and early summer to meet the demands of nut fill.

2. Phosphorus (P)

Phosphorus is an essential nutrient both as a component of several key plant structures and as a catalyst in numerous key biochemical reactions in plants. Phosphorus is a vital component of adenosine triphosphate (ATP), the “energy unit” of plants. ATP forms during photosynthesis, has phosphorus in its structure, and is active from the beginning of seedling growth through to the formation of fruits and maturity.

Phosphorus is important for the general health and vigor of all plants including nuts. Some specific growth benefit that have been associated with phosphorus are: a stimulation of root development, increased branch strength, improved flower formation and nut production, improved crop quality, increased resistance to disease, and more vigorous development throughout the growth cycle.

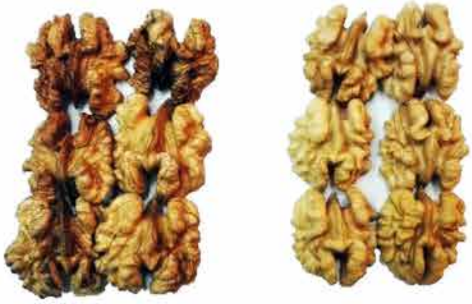
Leaf samples collected in mid-summer should have P values greater than 0.1% of dry matter. If values drop below 0.1%, the trees will almost certainly benefit from the addition of a phosphorus fertilizer. Phosphorus deficiency in young leaves of nut trees can be recognized by a dark green, purple, or bronze color with leaves looking stained. In severe cases, the edges of older leaves become dark brown and necrosis occurs, leading to early defoliation. Phosphorus is generally available to crops at soil pH of 6 and 7. When the soil pH is less than 6, P deficiency increases in most crops. If the phosphorus content of the soil is less than 20 ppm, mineral phosphorus fertilizers should be ploughed under and thoroughly cultivated in before planting, at a rate based on soil analysis. Phosphorus can also be applied in a NPK fertilizer on a regular basis (for example in fertigation).

3. Potassium (K)

Potassium is an extremely important nutrient in relation to transpiration, chlorophyll uptake, and the transport and storage of carbohydrates in the nuts. It is involved in regulation of nutrient uptake, water balance, sugar and protein synthesis. It also helps to promote the storage of reserves in different parts of the plants.

Potassium plays a role in orchard vigor and yield, and it contributes to the neutralization of formed organic acids. It also promotes respiration and activates growth. This is an important health factor for trees because it facilitates the proper distribution of reserves between different parts of the tree. It intervenes in the regulation of the opening and closing of stomata, it plays a role in improving drought resistance via better water use efficiency, ensuring an improvement in the functioning of the stomata. Potassium promotes the setting and advances the maturation of the nuts and play a major role in oil accumulation during nut fill and helps protect against frost.

Adequate potassium is critical to sustain yields in nut tree orchards. In cases of potassium deficiency, nut productivity and quality are negatively affected. Potassium deficient trees appear pale in color and the tree slows down in growth and produces smaller-sized leaves. Perhaps the most obvious symptom of potassium deficiency appears in older leaves where chlorosis starts at the tip and progresses down the leaf margins, the area widening with time. Black walnut kernels are sometimes linked to potassium deficiency (fig. 1) and to improve the kernel color, potassium in the sulfate or thiosulfate form is preferable to the other forms. Muriate of potash (MOP) often causes drawbacks during drying. In other nuts it has been reported that potassium deficiency can lead to poorly filled nuts and excessive nut drop. The causes for K deficiency are primarily: limited use of potassium fertilizers, increased yield, which removes more potassium from the soil, strong soil fixation reducing soil potassium availability and excessive use of nitrogen fertilizers, particularly in the ammonium form that tends to acidify the soil and inhibit potassium uptake. If potash fertilizers are not adequately applied to replenish the soil potassium pools, deficiency will increase in severity and extent in nut trees. Like nitrogen the annual demand and removal of potassium by nut trees are high. For example, several studies show that the use of potassium in pistachio orchards increases individual nut weight (improved ounce rate), total yield per hectare, split percentage, and percentage of filled nuts and therefore reduced blanking percentage. Potassium deficiency increases the sensitivity of pistachio nuts to sunburn.



- K   + K

Potassium deficiency in walnut kernel and leaf

Uptake of potassium occurs primarily during nut fill, when nutrients are allocated largely to embryo development. Optimal potassium nutrition is essential for optimal production: the adequate leaf potassium range for nut trees is 0.8 - 3% dry matter. Mid-summer leaf samples are the most reliable way to assess the potassium status in nut trees.

4. Sulfur (S)

Sulphur (S) is recognized as the fourth major plant nutrient. It is an essential nutritional element for promoting healthy tree growth and development needed for top nut yields The uptake and availability of sulfur is less influenced by soil pH and this nutrient is thus usually taken up readily across a range of orchard soil conditions. In the tree, it is incorporated into certain amino acids (cysteine, methionine) and subsequently becomes part of certain enzymes, vitamins, and oils. Once in these complex molecules, sulfur is not easily mobilized within the plant. Deficiency symptoms, therefore, will occur in the young tissues first.

Senescing leaves efficiently retrieve sulfur. As complex molecules are broken down, sulfur is converted into sulfate (SO_4^{2-}), which is readily transported out of the leaf and into the rest of the plant.

All proteins (and therefore enzymes) need sulfur to function, as disulfides bonds stabilize their structures. Sulphur also plays a key role in nitrogen metabolism. Sulfur plays a role in the aroma of certain fruits through volatile sulfur compounds.

A large body of evidence indicates that sulfur must be an integral part of balanced fertilization for obtaining optimum crop yields of high quality (oil, protein, fatty acids, and reduced nitrates in foliage). Sulfur fertilization is a good means of enhancing the uptake and fertilizer-use efficiency of nitrogen, phosphorus, potassium and also zinc, because of the sulfur's synergistic relationships with these elements. The adequate leaf sulfur range for nut varies from 0.18% in walnut to 0.6% in almond.

5. Calcium (Ca)

Calcium is another essential macronutrient that fruit and nut trees thrive on: it improves both leaf and fruit quality. Calcium is involved in many plant processes, including cell elongation, cell division, germination, pollen growth, and senescence. One of its most important functions is the maintenance of membrane permeability and cell integrity. When it is deficient, cells become permeable and lose control over the import and export of nutrients, leading to tissue breakdown.

When calcium supply is inadequate or transport is disturbed, local calcium deficiencies will result. This can lead to physiological disorder like a reduction in leaf size, and the appearance small and yellowish leaves, which show mottling and bronzing. Trees growing on calcium deficient soils are generally damaged by rotting of the root collar and bark.

Calcium (as the ion Ca^{2+}) is also an intracellular secondary messenger involved in many signal transduction pathways in nut trees. Its irreplaceable function in this role and in cell wall polysaccharide interactions is undisputed. It is through these processes that calcium is central to stress responses, cell wall growth and remodeling, and to plant tissue development. Since Ca^{2+} is such a biologically active ion, its concentration and transport must be tightly controlled within plant tissue down to the level of cellular and extracellular compartments.

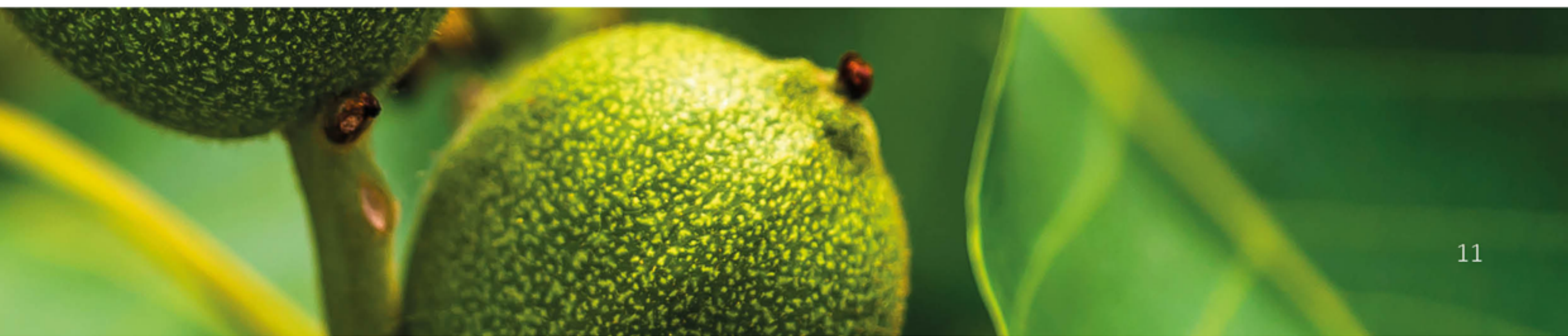
Calcium has an impact on the interior quality of nuts, and fertilization may have a positive or negative effect on the availability of calcium and its uptake from the soil. Fertilization in calcium deficient soils is a necessity, and this is very important in acidic soils. Calcium's immobility in the plant requires periodic supplementation to maintain adequate levels in the upper canopy.

Calcium can be very helpful to reduce the impact of high heat on flowers, which, during flowering, can lead to pollination failure. Severe heat stress will also result in increased bud drop. After successful pollination and fertilization, the ovaries develop into the fruit and the ovules develop into the seeds, two additional processes that each have specific chemical and nutritional requirements that a pollination complex can provide. The adequate leaf calcium range is from 2% in almond up to 4% in pistachio.

6. Magnesium (Mg)

Magnesium is a component of chlorophyll that intervenes in carbohydrate synthesis. In the fertilization of nut trees, magnesium contributes to the absorption and migration of phosphorus, and it improves the capturing of iron in nut trees.

Its deficiency appears as chlorosis on the old leaves at the base of branches, which can fall prematurely and cause the appearance of secondary branches. Symptoms are more pronounced on leaves situated close to fruit clusters. Deficiency occurs by impairment, as well as by antagonism, with calcium and potassium. Magnesium deficiency can occur with light, acidic soils that are prone to leaching or in soils that have received high rates of potassium fertilizers. In unbalanced soils, magnesium can limit the uptake of potassium and vice versa. Foliar sprays of magnesium are recommend in nut tree orchards during late May/early June (northern hemisphere) where required. The adequate leaf magnesium range for nut varies from 0.3% in almond to 1.2% in pistachio.



NUTRITIONAL REQUIREMENTS OF ALMOND					
	KG PER ONE TON IN-SHELL NUT YIELD	BLOOM FOLIAGE GROWTH	FRUIT SET AND ENLARGEMENT	KERNEL FILL MATURITY	EARLY POST HARVEST
	kg/ha	%			
N	45	20	30	30	20
P_2O_5	5	30	35	30	5
K_2O	49	20	30	40	10
SO_3	1.6	20	45	35	0
CaO	4	15	40	35	10
MgO	2.7	30	30	30	10

NUTRITIONAL REQUIREMENTS OF PISTACHIO					
	KG PER ONE TON IN-SHELL NUT YIELD	BUD BREAK BLOOM	FRUIT SET AND ENLARGEMENT	KERNEL FILL	HULL SPLIT HARVEST
	kg/ha	%			
N	25.6	15	25	40	20
P_2O_5	7	30	15	35	20
K_2O	22.8	10	30	50	10
SO_3	2.3	30	30	30	10
CaO	2	50	15	15	20
MgO	2.2	40	15	25	20

NUTRITIONAL REQUIREMENTS OF WALNUT						
	KG PER ONE TON IN-SHELL NUT YIELD	BUD BREAK BLOOM	SHOOT GROWTH FOLIAGE HULL EXPANSION	SHELL HARDENING	NUT FILL	POST HARVEST
	kg/ha	%				
N	31	30	20	20	30	0
P_2O_5	10	70	10	10	10	0
K_2O	25	20	40	20	20	0
SO_3	1.8	30	30	30	10	0
CaO	2.7	40	10	10	30	10
MgO	3	50	10	20	20	0

NUTRITIONAL REQUIREMENTS OF HAZELNUT					
	KG PER ONE TON IN-SHELL NUT YIELD	FLOWER INITIATION	FLOWERING AND ROOT GROWTH	NUT SET AND GROWTH	MATURE NUTS DROP
	kg/ha	%			
N	12.3	15	35	35	15
P_2O_5	1.7	30	20	20	20
K_2O	25	10	30	40	20
SO_3	3.2	20	30	30	20
CaO	2.8	30	20	20	30
MgO	2	20	30	30	20

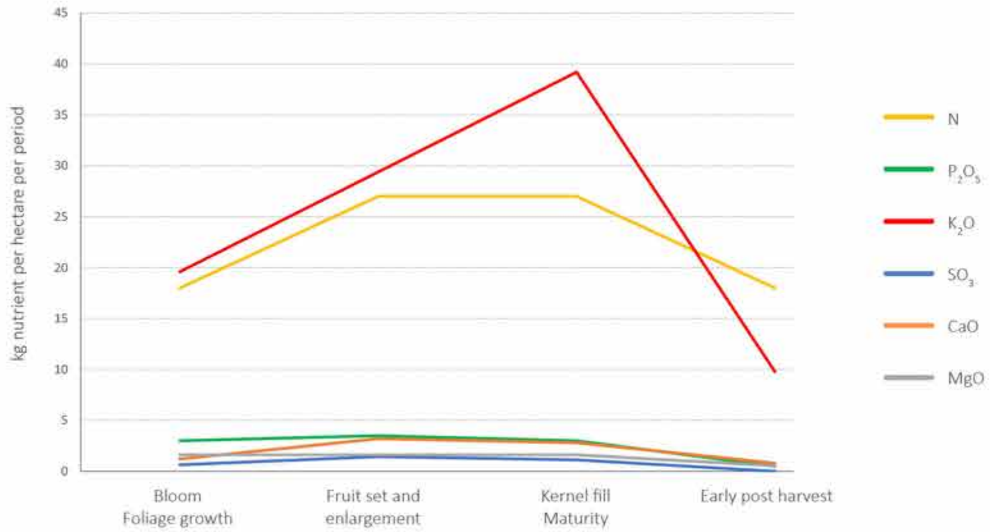
ABSORPTION OF NUTRIENTS

In order to supply a balanced concentration of micro and macro nutrients in crops, it is important to monitor the nutrient availability status of the soil as well as the tree's nutrient status (tissue analysis) during the season. The absorption of nutrients by nut trees depends considerably on the type of nut that is grown. The nutrient uptake is affected by several factors: soil parameters such as soil type and texture, soil pH, soil oxidation-reduction potential (Eh), and electrical conductively (EC), soil moisture and temperature, and plant factors including root growth and distribution, development of root hairs and density, fruit load and shoots. The initial nutrient concentration in the soil solution also influences the nutrient absorption. Since all nutrients should be supplied as dissolved ions at an optimal concertation rate in the water flow to roots, poor irrigation practices can lead to improper soil water content, consequently reducing the availability of nutrient to plants.

Plants uptake their nutrient needs based on the various growth stages during the season. This means that, depending on the growth stage, there will be precise demand for a specific combination of nutrients. Therefore, the seasonal pattern of nutrient uptake is a fundamental part of the fertilizer program calculation in nut orchards. The correct balance between the growth stage and fertilizer application rate within the plant's nutrient demand will ensure maximize yield and quality and also increase nutrient-use efficiency. For example in tree crops, the need for nitrogen arises after bud break. Calcium improves the absorption of nitrogen and therefore calcium fertilizer should be provided to trees in anticipation of nitrogen. For phosphorus, the main inputs will take place between bud break and flowering. However, in some cases, assimilation may also take place during maturation. With respect to potassium, generally speaking, the nut tree needs potash fertilization from flowering until maturation, especially during fruit development and nut fill, when over 90% of the potassium needed by the trees is taken up. Sulfur is regularly absorbed throughout the growth cycle. Finally, in terms of magnesium, whilst the need is never very high, it remains a much-appreciated nutrient during the entire cycle of the nut tree. Its absorption is stronger from bud break until the beginning of maturation. All the nutrients that have been taken up and thus have been removed by harvest from the soil should be replenished by a proper fertilizer program.

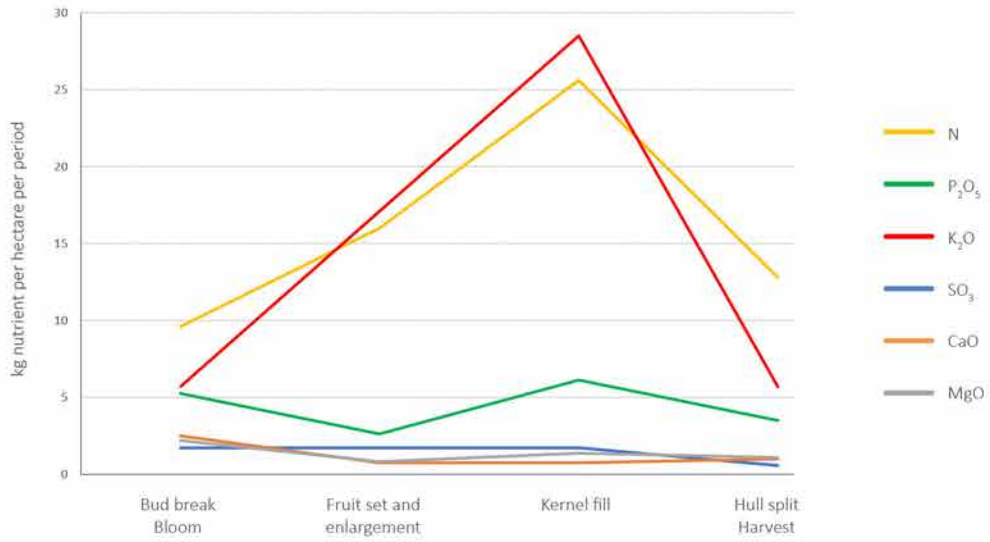
LEAF ANALYSIS DATA (OPTIMUM SUPPLY) OF NUT CROPS - MACRONUTRIENTS								
PLANT PART	STAGE OF GROWTH	CROP	% OF DRY MATTER					
			N	P	K	S	Ca	Mg
Mid-terminal compound leaves	At the end of July- early August	Almond	2.2-2.8	0.1-0.3	3	0.3-0.6	>2	0.3-0.4
		Pistachio	2.2-2.9	0.14-0.17	1.8-2.2	0.2-0.4	2.1-4	0.5-1.2
		Walnut	2.3-2.8	0.15-0.21	1.7-2.5	0.18-0.22	2.5-3	0.3-0.6
		Hazelnut	2-2.5	0.14-0.45	0.81-2	0.21-0.5	2.5-3	0.5-1

Almond



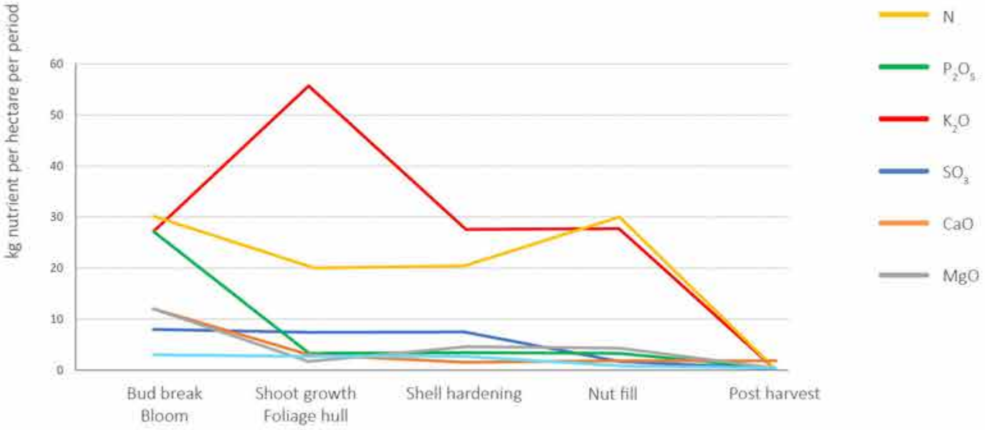
Almonds nutrient uptake curve for in-shell nut yield of 2 t/ha

Pistachio



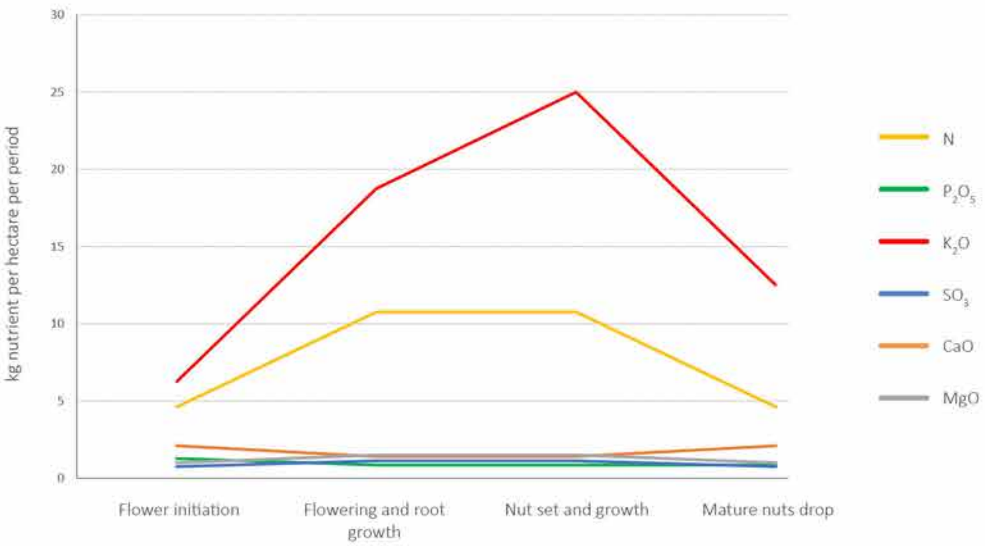
Pistachios nutrient uptake curve for in-shell nut yield of 2.5 t/ha

Walnut



Walnuts nutrient uptake curve for in-shell nut yield of 4 t/ha

Hazelnut



Hazelnuts nutrient uptake curve for in-shell nut yield of 2.5 t/ha

PRODUCTS

TESSENDERLO KERLEY FERTILIZERS

PRODUCTS	BUD BREAK BLOOM	SHOOT GROWTH FOLIAGE HULL EXPANSION	SHELL HARDENING	KERNEL FILL MATURITY	EARLY POST HARVEST
Thio-Sul	Fertigation / Soil application liquids				
KTS	Fertigation	Fertigation	Fertigation / Foliar application	Fertigation / Foliar application	Fertigation / Soil application liquids
CaTs	Fertigation	Fertigation / Foliar application	Fertigation / Foliar application	Fertigation / Foliar application	Fertigation / Soil application liquids
K-Leaf			Foliar application	Foliar application	
SoluPotasse		Fertigation	Fertigation	Fertigation	
GranuPotasse	Soil application granules				

Legend:

Foliar application — Soil application granules — Soil application liquids — Fertigation

NUTRIENT CONVERSION FACTORS*		
TO CONVERT	TO	DIVIDE BY
CaO	Ca	1.40
MgO	Mg	1.66
K_2O	K	1.20
P_2O_5	P	2.29
SO_3	S	2.50
SO_4	S	3.00

* To convert elemental units to oxide units multiply by the same factors

THIO-SUL

Characteristics and advantages

- Sulfur and nitrogen source without chloride.
- The addition of Thio-Sul transforms UAN into a stabilized nitrogen fertilizer.
- Sulfur in the unique thiosulfate form is a highly effective sulfur source, which is partly available immediately, and which is partly available over a period of several weeks.
- The leachability is significantly lower than with sulfur in the sulfate form.
- Promotes thiobacillus stimulation and especially the microbiological activity in the soil.
- Releases nutrients that are present in the soil.

Specifications

Ammonium thiosulfate	
- N (w/w) as ammoniacal nitrogen	12%
- S (w/w)	26%

Typical properties

- Appearance/color	Clear, colorless to light yellow
- pH range	6.5 - 8.5
- Density range (at 25°C)	1.32 kg/l - 1.35 kg/l
- Density (at 25°C)	1.33 kg/l
- Salt Out Temperature (SOT)	+ 7°C
- SO_3 (w/w)	64.9%
- N (w/v) as ammoniacal nitrogen	16%
- S (w/v)	34.6%
- SO_3 (w/v)	86.3%
- N (g/l) as ammoniacal nitrogen	160
- S (g/l)	346
- SO_3 (g/l)	863
- Chemical formula	$(NH_4)_2S_2O_3$

APPLICATION	RATE PER APPLICATION	GROWTH STAGE	COMMENT
Soil	40 to 80 l/ha	Bud break	Apply early in the growing season for sulfur nutrition Avoid pruning roots during injection application
Fertigation	40 to 60 l/ha	Bud break Beginning of full leaf stage	Apply with irrigation water every 10 to 14 days as needed

KTS

Characteristics and advantages

- The concentrated liquid form is ideal for applications in low water volumes and for large areas.
- Active thiosulfate technology enhances the uptake of phosphorus and micronutrients present in the soil or from fertilization.
- The neutral pH level is ideally adapted to tank mixtures with acid or base sensitive materials.
- KTS contains the two key crop nutrients potassium and sulfur, and it is chloride and nitrate free.
- Available in bulk and in 1,000 l containers.
- Can also be applied to the soil as a starter fertilizer (with P-Sure®) and in overhead pivots and sprinklers.
- The thiosulfate form of potassium is taken up rapidly by the leaves.

Specifications

Potassium thiosulfate	
- K_2O (w/w)	25%
- S (w/w)	17%
- pH range	6.8 - 8.5
- Density range (at 25°C)	1.45 - 1.49

Typical properties

- Appearance/color	Clear and colorless
- Density (at 25°C)	1.47 kg/l
- Salt Out Temperature (SOT)	- 10°C
- SO_3 (w/w)	42.4%
- K_2O (w/v)	36.8%
- S (w/v)	25%
- SO_3 (w/v)	62.4%
- K_2O (g/l)	368
- S (g/l)	250
- SO_3 (g/l)	624
- Chemical formula	$K_2S_2O_3$

APPLICATION	RATE PER APPLICATION	GROWTH STAGE	COMMENT
Flood and in furrow	45 to 110 l/ha	Starting at bud break	Apply once every 2 to 3 weeks starting at full leaf
Fertigation (drip irrigation)	Young trees 30 to 45 l/ha Mature trees 45 to 95 l/ha/ application	Shoot growth up to harvest	Depending on soil analysis, start at full leaf Apply once every 3 to 4 weeks
Fertigation (sprinkler/pivot)	45 to 75 l/ha/ application	Shoot growth up to harvest	Repeat every 10 to 14 days based on crop requirements
Foliar	5 to 15 l/ha	Fruit set and nut fill	In minimal 1000 liters of water spray solution For concentrated sprays of less than 1000 liters per hectare, reduce the rate of KTS to stay within the recommended solution ratio

CATS

Characteristics and advantages

- CaTs is a neutral to basic, chloride and nitrate free, clear solution.
- CaTs may be applied by drip, sprinkler, or flood irrigation.
- It may be blended with other fertilizers or applied as a foliar treatment on selected crops.
- When used as a foliar fertilizer, CaTs should first be diluted with water before application.
- Blends of CaTs should not be acidified below a pH of 6.0.
- CaTs may be used as a fertilizer for the correction of calcium deficiency.
- CaTs is an effective water soluble source of calcium and thiosulfate sulfur which assists in the correction of these nutrient deficiencies in crops.
- CaTs may be used to improve water infiltration and assists in terms of leaching of harmful soil salts.
- CaTs is compatible with most fertilizer solutions.
- CaTs is not compatible with phosphate, sulfate and ammonium thiosulfate fertilizers.

Specifications

Calcium thiosulfate	
- Ca (w/w)	6%
- S (w/w)	10%
- pH range	6.5 - 8.8
- Density range (at 25°C)	1.22 - 1.26

Typical properties

- Appearance/color	Clear and colorless
- Density (at 25°C)	1.25 kg/l
- Salt Out Temperature (SOT)	0°C
- CaO (w/w)	8.4%
- SO_3 (w/w)	25%
- Ca (w/v)	7.5%
- S (w/v)	12.5%
- CaO (w/v)	10.5%
- SO_3 (w/v)	31.2%
- Ca (g/l)	75
- S (g/l)	125
- CaO (g/l)	105
- SO_3 (g/l)	312
- Chemical formula	CaS_2O_3

APPLICATION	RATE PER APPLICATION	GROWTH STAGE	COMMENT
Flood and in furrow	100 to 200 l/ha	Shoot growth up to harvest	To improve water infiltration and to reduce runoff Apply as needed during the growing season
Fertigation (drip irrigation)	50 to 150 l/ha	Shoot growth up to harvest	Repeat four or five times during the growing season or as needed
Fertigation (sprinkler/pivot)	45 to 95 l/ha	Shoot growth up to harvest	Repeat as required
Foliar	5 to 10 l/ha	At bloom and nut fill	Repeat applications as required Up to 4 or 5 applications at 10 days intervals

K-LEAF

Characteristics and advantages

- The highly soluble potash booster is suitable for foliar applications using regular spray volumes.
- K-Leaf is well suited for foliar application at higher potash rates per hectare.
- K-Leaf dissolves three times as fast as regular water soluble SOP, leaving no residues.
- The acidification effect may in some cases have a beneficial impact on absorption of tank mix partners.
- K-Leaf is a cost-effective source of potassium and sulfur and is chloride and nitrate free.
- Available in 20 kg bags.
- K-Leaf can be applied at higher rates than certain other foliar potassium fertilizers.
- K-Leaf has now been verified as compliant for use in organic agriculture according to EC Regulation no. 834/2007.

Specifications

Potassium sulfate	
- K_2O (w/w)	Min. 51.5%
- Cl (w/w)	Max. 0.5%
- S (w/w)	18.7%

Typical properties

- Appearance/color	Fine white powder
- Bulk density (struck/loose)	1.53 kg/l / 1.25 kg/l
- Angle of repose	35°
- pH (1% solution)	2.9
- Residues (5% solution)*	0.03%
- Solubility at 25°C	120 g/l pure water
- Dissolved after 1 min with stirring	90%
- K_2O (w/w)	52%
- Cl (w/w)	0.2%
- SO_3 (w/w)	47%
- H_2O (w/w)	0.07%
- Chemical formula	K_2SO_4

* After stirring for 10 minutes at 25°C

APPLICATION	RATE PER APPLICATION	GROWTH STAGE	COMMENT
Foliar	8 to 16 kg/ha	Fruit set and nut fill	Spray volume base: 800 l/ha Repeat 2 to 3 times with two weeks interval

SOLUPOTASSE

Characteristics and advantages

- SoluPotasse is a cost-effective source of potassium and sulfur and is chloride and nitrate free.
- SoluPotasse provides a high concentration of these important crop nutrients.
- SoluPotasse dissolves rapidly and completely, leaving no residues.
- SoluPotasse has an extremely low salt index and is ideal for use in chloride sensitive crop or regions at risk from salinity.
- The acidification effect ensure optimal uptake of all nutrients and helps prevent clogging of the drippers.
- SoluPotasse is of a consistently high quality and is the market leading water soluble SOP for fertigation.
- Available in 25 kg bags and big bags (1000 kg or 1200 kg).

Specifications

Potassium sulfate	
- K_2O (w/w)	Min. 51%
- Cl (w/w)	Max. 1%
- S (w/w)	18.7%

Typical properties

- Appearance/color	Fine white powder
- Bulk density (struck/loose)	1.46 kg/l / 1.21 kg/l
- Angle of repose	40°
- pH (1% solution)	2.9
- Residues	0.03%
- Solubility at 25°C	120 g/l pure water
- Dissolved after 3 mins with stirring	90%
- K_2O (w/w)	51.5%
- Cl (w/w)	0.6%
- SO_3 (w/w)	47%
- H_2O (w/w)	0.02%
- Chemical formula	K_2SO_4

APPLICATION	RATE PER APPLICATION	GROWTH STAGE	COMMENT
Fertigation	10 to 20kg/ha /week	At flowering	Based on weekly applications
	30 to 40kg/ha per week	At fruit set	
	30 to 40 kg/ha per week	Nut fill	
	20 to 30 kg /ha per week	Maturity	

GRANUPOTASSE

Characteristics and advantages

- GranuPotasse is a cost-effective source of potassium and sulfur, and it is chloride and nitrate free.
- GranuPotasse provides a high concentration of these important crop nutrients.
- GranuPotasse is virtually dust-free.
- GranuPotasse has a consistent granulometry that ensures uniform application, with a spreading range of up to 28 meters.
- GranuPotasse is suitable for both pre-emergence and post-emergence application during early stages of crop growth.
- GranuPotasse has excellent stability, which makes it ideal for producing a wide variety of NPK blends.
- Available in 25 kg bags or big bags (600 kg, 1,000 kg or 1,200 kg).

Specifications

Potassium sulfate	
- K_2O (w/w)	Min. 50%
- Cl (w/w)	Max. 2.5%
- S (w/w)	18%

Typical properties

- Appearance/color	Light grey to beige granules
- Bulk density (struck/loose)	1.40 kg/l / 1.27 kg/l
- Angle of repose	33°
- Sieve analysis	97% between 1.6 mm and 5 mm
- K_2O (w/w)	50.2%
- Cl (w/w)	2.3%
- SO_3 (w/w)	45%
- H_2O (w/w)	0.2%
- Chemical formula	K_2SO_4

APPLICATION	RATE PER APPLICATION	GROWTH STAGE	COMMENT
Soil application	150 to 300 kg/ha	Prior to planting or during the winter rest period	Apply either soil incorporated prior to planting or apply annually as a basal dressing

FERTIGATION RECOMMENDATIONS

FERTIGATION RECOMMENDATIONS

The fertigation recommendations presented are for illustrative purposes only. Many different products are available for use in fertigation and the final product choice will depend on many different factors. Always consult a qualified agronomist beforehand.

FERTILIZATION FOR ALMOND BASED ON NUTRIENT REQUIREMENTS					
	TOTAL KG/HA ON MATURE TREES	BLOOM FOLIAGE GROWTH	FRUIT SET AND ENLARGEMENT	KERNEL FILL MATURITY	EARLY POST HARVEST
Nitrogen (kg N/ha)	150-250	30-50	45-75	45-75	30-50
Phosphorus (kg P_2O_5/ha)	50-80	15-24	17.5-28	15-24	2.5-4
Potassium (kg K_2O/ha)	200-250	40-50	60-75	80-100	20-25
Sulfur (kg SO_3/ha)	50-80	10-16	22.5-36	17.5-28	0
Calcium (kg CaO/ha)	40-60*	6-9	16-24	14-21	4-6
Magnesium (kg MgO/ha)	60-120	18-36	18-36	18-36	6-12

Based on the quantity of nutrients mobilized – *except calcium (quantity exported)

TESSENDERLO KERLEY FERTIGATION RECOMMENDATIONS FOR ALMOND				
	BLOOM FOLIAGE GROWTH	FRUIT SET AND ENLARGEMENT	KERNEL FILL MATURITY	EARLY POST HARVEST
LIQUIDS (per period)				
KTS (l/ha)	60-80	80-100	180-200	30-40
CaTs (l/ha)	45-55	120-150	70-80	45-50
WATER SOLUBLES (per period)				
SoluPotasse (kg/ha)	40-60	100-120	200-240	20-30

GranuPotasse, as a solid fertilizer, can be applied on soil as a potassium and sulfur source.
K-Leaf can be applied as a foliar spray to provide a potash boost at key growth stages.

FERTILIZATION FOR PISTACHIO BASED ON NUTRIENT REQUIREMENTS					
	TOTAL KG/HA ON MATURE TREES	BUD BREAK BLOOM	FRUIT SET AND ENLARGEMENT	KERNEL FILL	HULL SPLIT HARVEST
Nitrogen (kg N/ha)	150-200	22.5-30	37.5-50	60-80	30-40
Phosphorus (kg P_2O_5/ha)	50-100	15-30	7.5-15	17.5-35	10-20
Potassium (kg K_2O/ha)	150-250	15-25	45-75	75-125	15-25
Sulfur (kg SO_3/ha)	50-80	15-24	15-24	15-24	5-8
Calcium (kg CaO/ha)	30-40*	15-20	4.5-6	4.5-6	6-8
Magnesium (kg MgO/ha)	60-80	24-32	9-12	15-20	12-16

Based on the quantity of nutrients mobilized – *except calcium (quantity exported)

TESSENDERLO KERLEY FERTIGATION RECOMMENDATIONS FOR PISTACHIO				
	BUD BREAK BLOOM	FRUIT SET AND ENLARGEMENT	KERNEL FILL	HULL SPLIT HARVEST
		LIQUIDS (per period)		
KTS (l/ha)	40-50	75-100	180-230	40-50
CaTs (l/ha)	70-100	45-55	45-55	60-80
		WATER SOLUBLES (per period)		
SoluPotasse (kg/ha)	40-50	90-120	150-200	40-50

GranuPotasse, as a solid fertilizer, can be applied on soil as a potassium and sulfur source.
K-Leaf can be applied as a foliar spray to provide a potash boost at key growth stages.

FERTILIZATION FOR WALNUT BASED ON NUTRIENT REQUIREMENTS						
	TOTAL KG/HA ON MATURE TREES	BUD BREAK BLOOM	SHOOT GROWTH FOLIAGE HULL EXPANSION	SHELL HARDENING	NUT-FILL	POST HARVEST
Nitrogen (kg N/ha)	150-200	45-60	30-40	30-40	45-60	
Phosphorus (kg P_2O_5/ha)	60-80	42-56	6-8	6-8	6-8	
Potassium (kg K_2O/ha)	200-300	40-60	80-120	40-60	40-60	
Sulfur (kg SO_3/ha)	50-80	15-24	15-24	15-24	5-8	
Calcium* (kg CaO/ha)	40-60	16-24	4-6	4-6	12-18	4-6
Magnesium (kg MgO/ha)	20-40	10-20	2-4	4-8	4-8	

* in acidic soil (pH < 6.5) calcium can be applied as soil amendment at rate of up to 250 kg/ha

TESSENDERLO KERLEY FERTIGATION RECOMMENDATIONS FOR WALNUT					
	BUD BREAK BLOOM	SHOOT GROWTH FOLIAGE HULL EXPANSION	SHELL HARDENING	NUT-FILL	POST HARVEST
LIQUIDS (per period)					
KTS (l/ha)	70-90	100-150	90-110	90-110	
CaTs (l/ha)	80-120	45-50	45-50	60-80	45-50
WATER SOLUBLES (per period)					
SoluPotasse (kg/ha)	60-80	160-200	80-120	80-120	

GranuPotasse, as a solid fertilizer, can be applied on soil as a potassium and sulfur source.
K-Leaf can be applied as a foliar spray to provide a potash boost at key growth stages.

FERTILIZATION FOR HAZELNUT BASED ON NUTRIENT REQUIREMENTS					
	TOTAL KG/HA ON MATURE TREES	FLOWER INITIATION	FLOWERING AND ROOT GROWTH	NUT SET AND GROWTH	MATURE NUTS DROP
Nitrogen (kg N/ha)	200	30	70	70	30
Phosphorus (kg P_2O_5/ha)	50-100	15-30	10-20	10-20	10-20
Potassium (kg K_2O/ha)	150-200	15-20	45-60	60-80	30-40
Sulfur (kg SO_3/ha)	30-40	6-8	9-12	9-12	6-8
Calcium (kg CaO/ha)	25-35	7.5-10.5	5-7	5-7	7.5-10.5
Magnesium (kg MgO/ha)	30-40	6-8	9-12	9-12	6-8

TESSENDERLO KERLEY FERTIGATION RECOMMENDATIONS FOR HAZELNUT				
	FLOWER INITIATION	FLOWERING AND ROOT GROWTH	NUT SET AND GROWTH	MATURE NUTS DROP
LIQUIDS (per period)				
KTS (l/ha)	45-60	90-120	100-150	80-90
CaTs (l/ha)	60-80	45-55	45-55	60-80
WATER SOLUBLES (per period)				
SoluPotasse (kg/ha)	40-50	80-110	120-150	90-100

GUIDELINES

General

- Do not apply products to crops which are sensitive to the effects of sulfur.
- Use the correct type of spray nozzles that are recommended for foliar applications.
- Contact a representative of Tessenderlo Kerley International if you require any additional information.
- The purpose of this brochure is to provide information about fertilizer products and to make suggestions regarding their use in nut trees. The exact quantities of nutrients required by the crop will depend on local growing conditions including, but not limited to, soil type and nutrient content, climate conditions; crop variety, target yield, etc.
- Use of tissue and soil analysis to determine crop and soil nutrient status is recommended.
- Tessenderlo Kerley International recommends that you seek advice on your specific fertilization program from a qualified agronomist.

Liquids

- Do not apply products to soils that have a very low pH level.
- Avoid applying products as a foliar spray when the temperature exceeds 30°C. Ensure you apply products (preferably) early in the morning or in the evening. When mixing with other products, it is recommended to conduct a small-scale trial in order to check the compatibility of the mixture before operating on a larger scale and applying.

Water solubles

- Continuous agitation or stirring will speed up dissolution.
- The time required to dissolve the product, however, will also depend on the quality and temperature of the spraying water. Poor quality water may affect solubility.
- To get the best results from the products:

  1. Fill the tank with water to at least 2/3rds of its capacity.
  2. Add the product taking care not to exceed the maximum recommended concentration.
  3. Maintain stirring or agitation throughout the entire operation.
  4. Fill the remainder of the tank with water.
  5. Check that the product has dissolved completely before using the solution.
  6. The use of filters is recommended, as generally advised for most solid fertilizers when used in solution.

- Avoid applying products as a foliar spray when temperature exceeds 30°C - apply products preferably early in the morning or in the evening.
- Do not mix sulfates with materials containing calcium.
- When mixing with other products it is recommended to conduct a small-scale trial to check the compatibility of the mixture before operating on a larger scale.
- Store products in dry conditions, avoiding extreme heat or cold.

Always respect and comply with local legislation and regulation regarding the use of fertilizer products.

SUSTAINABLE CROP NUTRITION FOR AGRICULTURE

For over 100 years Tessenderlo Kerley International has demonstrated its commitment to nurturing crop life through innovation, research and the development of novel fertilizers for a more sustainable agriculture. Our diverse product portfolio addresses the challenges of modern agriculture by delivering essential nutrients in forms that protect soil health and optimize nutrient use efficiency.

We provide an extensive range of both liquid and solid/soluble fertilizers

KTS CaTs SoluPotasse Solucros

HIGH-PERFORMANCE LIQUIDS

HIGH QUALITY SOLID/SOLUBLES

MagThio Thio-Sul K-Leaf GranuPotasse

Our experts are familiar with your region and crops.
Their support includes:

- Agronomic advice
- Providing technical information
- Carrying out field studies that are specific to your issues
- Providing application and storage tips

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