TESSENDERLO Kerley

POME FRUITS

In botany a pome is a specialty type of fruit produced by flowering plants in the *Maloideae*, sub-family of the *Rosaceae family*. The most well-known pome fruit are the apple, pear, loquat, nashi and quince. Apples represent the largest production and cropping area and have been cultivated for at least 2000 years with their origins tracing back to Eastern Europe and Western Asia. Pears are divided into European and Asian varieties with the latter cultivated for at least 3000 years in China. In general, pome fruit are adapted to the cool, temperate regions of the world. The fruits generally have a long storage life – up to a year for some apples. This allows an extended market season and the cultivation of only a few varieties. But there are large differences in yields from one country to another. The difference in yield partly depends on the fruit variety, but fertilization techniques as well as a comprehensive knowledge of orchard management are required to avoid costly errors.

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APPLE

The domestic or cultivated apple, *Malus domestica*, belongs to the rose family. The apple tree is the most commonly cultivated tree in the world, and as a wild tree it grew in Europe in prehistoric times. The native apple originated in southern Siberia and Asia, and the Greeks and Romans cultivated different varieties. Eastern Turkey and the Caucasus form the center of diversity of the genus *Malus*. The apple was originally grown there, from where it spread throughout Europe. By around the year 1600, almost 200 varieties of apples were already known. Shortly after this time the European colonizers transferred this fruit first to North and then to South America.

Enjoyed from prehistoric times, petrified apple slices have been discovered in 5000-year-old tombs. According to “pomology,” the science of apple and fruit growing, apple trees live about 200 years, taking about 4 or 5 years to first produce fruit. Apples have been linked to many health benefits, including improved gut health and reduced risk of stroke, high blood pressure, diabetes, heart disease, obesity, and some cancers. Apples are also a good source of fiber and vitamin C and can be consumed fresh, canned or as juice.

PEAR

The pear *(Pyrus communis L.)* is native to coastal and mildly temperate regions of the Old World, from Western Europe and North Africa east across Asia. The pear was also cultivated by the Romans, for consumption either raw or cooked. Apples and pears belong to the same family, *Rosaceae*, sub-family *Pomoideae*. They both have similar morphology and therefore share the same fertilization program as other pome fruit species. Pears come in many different varieties and around 100 types are grown worldwide. The Bartlett, Bosc, and D’Anjou varieties are among the most popular and fruits are consumed fresh, canned, as juice, or dried. Pears are rich in folate, vitamin C, copper, and potassium and are also a good source of polyphenol antioxidants.

OTHER POME FRUITS

Apples and pears are by far the most well know types of pome fruit but other plants producing fruit classified as a pome include nashi, quince and loquat.

Nashi or Asian pears *(Pyrus pyrifolia)* are totally different to the European pear, Nashi are a popular fruit with many Asian cultures, since they are extremely juicy, however their flavor is fairly bland. For this reason, they are often consumed primarily as a 'thirst quencher'.

The common quince *(Cydonia oblonga)*, originally from Asia, generally grows in cooler subtropical areas to cold temperate regions. The quince is very adaptable and grows well in a range of conditions. Its cultivation is similar to that of apples and pears. The fruit is used fresh, stewed, preserved, or made into jams and jellies.

THE POME FRUIT TREE GROWTH CYCLE

Each pome fruit goes through three basic stages of development. The first stage immediately after flowering is the accelerated cell division. At this stage, the final number of cells to be found in the mature fruit are formed. The second stage is the growth of the cell walls of the fruit. At this stage, the future size of the cells is determined. The third stage is the elongation of the cell walls with the entry of water in which the fruit reaches its final size.

The final size and quality of a pome fruit is influenced by many factors, which include the following:

The genetic information from seed

Each variety has the genetic characteristics of the variety in the seed. If the fruit contains a sufficient quantity of fertilized seed embryos, seeds, and auxins (growth hormones), then the manner and size of fruit development will be stronger and more pronounced. Gibberellins and cytokinins also play an important role. Therefore, the presence of bees to maximize the number of fertilized seed embryos is of great importance. As there are five seed embryos in each ovary, it is necessary to fertilize all 5 seed embryos with pollen.

The number of fertilized seeds and auxin production

Fruits with a very small number of fertilized seeds usually fall off. If part of the seeds are defective, genetic information from them can lead to deformation of the fruit.

The temperature during and after flowering

If temperatures during flowering and after are low, the division and multiplication of cells is weakened, and this may lead to a decrease in the number of cells in the future fruit. In such cases, spraying amino acids can help activate and speed up cell proliferation and division. It is also necessary to take care of the optimal nutrition of young fruits by providing the nutritional elements that the crop requires.

The number of cells in the fruit after the cell division phase

Immediately after flowering and fertilization, the fruit cell proliferation phase begins. It lasts a relatively short time, about a month after the end of flowering. At this stage, under the influence of hormones and auxins, the fruit cells divide, and a certain number of cells are formed in the future fruit. The more cells formed at this stage, the larger and firmer the fruit will be for storage later. Cell division, as mentioned earlier, depends on temperatures, the nutritional status of the vast majority of micro and macro elements, and the concentration of growth hormones and amino acids.

Thinning

Thinning has the greatest impact on the final fruit size at the cell division phase. Early thinning contributes to better nutrition of the rest of the fruit on the tree, resulting in increased cell division. After the cell division completion phase, the final fruit size is "recorded". In other words, the final size of the fruit is mostly already defined when the young fruits have a diameter of about 10-20 mm.
It has been reported in the scientific literature than foliar application of thiosulfates at precise doses (around 40 L/ha) can induce thinning in pome fruits trees. These reports also suggest that there is much less risk of leaf damage when using calcium thiosulfate. In addition the supply of calcium at this growth stage will also be beneficial to the trees.
Bio-stimulants, in addition to fertilizers, are an important part of modern apple growing technology. Regular application increases the resistance of apples to adverse agro-ecological conditions (low temperature, high temperature, drought, etc.), and also contributes to better nutrient uptake and higher yield and better quality of pome fruits. For cold weather or abundant fertility, spraying with amino acids can improve cell activity during division and multiplication.

Cell wall growth

The cell wall growth phase begins after the cell division phase. Calcium and potassium are especially needed at this stage. Calcium is a compound part of the cell wall. Since an pome fruit tissue cell can normally only grow to a certain size, not only is the number of cells important for the final size of the fruit, but the largest possible size and strength of an individual fruit cell is also important.
Calcium deficiency adversely affects cell growth and division, as well as their hardening.

Fruit nutrition

In order for the fruits to be able to pass through all phases normally, it is necessary that in each phase of the fruit’s development, the nutritional program is exactly matched with the elements that the trees need in that phase. In the cell proliferation phase, almost all macro and micro elements must be available at that time, so it is sometimes desirable to provide them by foliar feeding. In the phase of cell elongation and wall growth, the need for potassium, calcium, magnesium increases.

Number of leaves per fruit

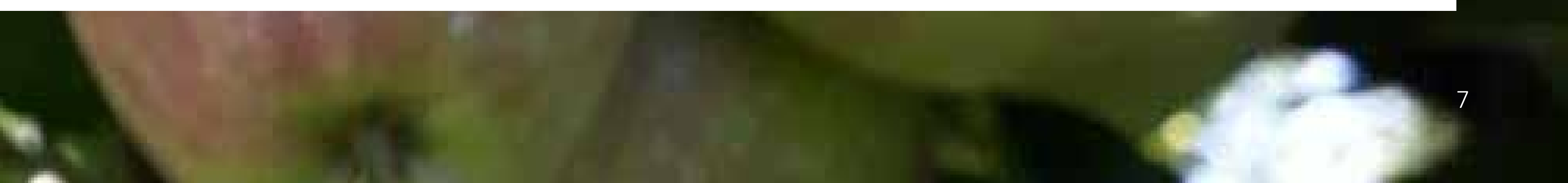
As for all fruit-bearing crops, the final result is usually dictated by the amount of healthy leaf area in relation to the number of fruits, berries and the like. The larger the healthy leaf area, the greater the production and accumulation of carbohydrates in the fruit. The state of nutrition depends not only on the amount and availability of nutrients but also on the amount of carbohydrates that the leaves produce by photosynthesis.

The amount of precipitation in the ripening phase

The amount of precipitation can both positively and negatively affect the final size of the pome fruit. If the amount of precipitation is properly distributed during the growing year, everything will be fine. However, if a rainy autumn occurs after a dry summer leading to a reduced number of cells in the fruit, the small number of fruit cells cannot receive huge amounts of water and the cells burst, turn brown and glassy, and in rare cases the whole apple fruit cracks on the tree.

The impact of alternate bearing

Alternate Bearing means an alternating cropping pattern of the pome fruit tree that is internally regulated by the plant. It results in alternating years of higher and lower fruit yields. This alternate bearing pattern is common in many of the perennial trees but is not universal. Alternate bearing in apples can be an serious economic problem for growers and is dependent on variety. ‘Golden Delicious’ are generally regarded as regular bearers whereas ‘Cox Orange Pippin’ are very much alternate bearers. The risk of alternate bearing can be reduced by planting orchards on carefully chosen sites with optimal climatic conditions, particularly minimal risk of frost damage.
Alternate bearing is natural phenomenon that is internally regulated by the tree, hence good orchard management practices are essential to minimize its occurrence. Nutrition, irrigation and pruning of the trees will provide optimal conditions for flower formation, but crop load management is perhaps the key to minimizing alternate bearing. The adjustment of crop load is critical for the regulation of yield both in the current season and the subsequent one. It can be done by a combination of pruning and thinning methods. Thinning can be accomplished either by hand, which is very labor intensive, or by the use of certain chemical thinners, including some thiosulfates according to the scientific literature (see earlier).



BUDDING

The age of the tree

It is known that the guarantee of a large proportion of first-class apples and large fruits is primarily the renewal of the native tree and the young native branches. An old vertebrate tree with numerous scars from past crops does not have a satisfactory “flow” of nutrition from the roots or leaves to the apple fruit. Therefore, ‘second class’ apples most often appear on old trees.

For apple and pear trees the pruning method is also a very important factor in the management of the wood, flowers and fruits. Crop nutrition will thus need to be adapted, depending on the type of pruning practiced.

One of the key elements for the fertilization of pome fruits is to take into account the differences that exist between different types of pome fruit trees that are grown. The objectives will differ for each species although in all cases growers will almost certainly be aiming for good yields of fruits that have good size and color, high levels of sugar and that are sufficiently firm to resist storage and transport. In certain cases earlier ripening can increase market value and hence this may become the principal objective of production. Fertilizer rates and application timings will have to be adjusted according to the requirements of each species. 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, nutrient removal and production practices. This is also required in order to adapt fertilizer inputs to nutrients that are already present in the soil. Regular tissue analysis is important to determine the content of various nutrients in the tissue and assist in defining the optimal fertilization program.
Environmental stresses combined with inappropriate nutrition can cause flower and seed abortion at critical developmental stages. Excessive fertilization can also cause plant stress which may favor the development of pests and diseases, particularly sap feeding insects. In apples, too much nitrogen and not enough calcium will often lead to bitter pit. During flowering, the plant will adjust its fruit load (and thus yield) based on the number of flowers pollinated and the tree’s nutritional status. 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. It is worth noting that the method of fertilizer application and the nutrient form and balance will also have an impact on the nutrient use efficiency and hence the amount of fertilizer needed.

Growth stages of appels

BBCH

Growth stages of pears

BBCH

BLOOM	FRUIT SET	FRUIT GROWTH	MATURATION	HARVEST
full bloom, 50% of open flowers	beginning of ovary growth	fruits about 90% of final size	beginning of fruit coloring	
BBCH 65	BBCH 71	BBCH 79	BBCH 81	BBCH 91

full bloom, 50% of open flowers	beginning of ovary growth	fruits about 90% of final size	beginning of fruit coloring	
BBCH 65	BBCH 71	BBCH 79	BBCH 81	BBCH 91

FERTILIZATION OBJECTIVES

Fertilization of apple and pear trees is one of the most important practices on which the growth and yield of fruit trees depends. Macro-elements are particularly necessary for normal growth and fertility of fruit trees: nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, but microelements are also essential for optimal productivity: boron, zinc, copper, iron, molybdenum, manganese and others. Through fertilization, these elements are usually introduced into the soil to maintain them in optimal quantities accessible to the plant, or alternatively the technique of foliar fertilization is used to introduce certain minerals directly into the plant through the leaves (thus avoid any potential immobilization of nutrients in the soil). Nitrogen is very important for the vegetative development of fruit trees, but also for the formation of generative organs. Late fertilization with large amounts of nitrogen affects the lush growth of young shoots and larger fruits. Such young trees are often prone to freezing. In the case of nitrogen deficiency, the shoots are of weaker growth and less flower buds are formed. Phosphorus affects the formation of flower buds, germination and normal fruit development, as well as the presence of color and aromatic substances in the fruit. Potassium affects the fertility of fruit trees as well as the quality and color of fruits.

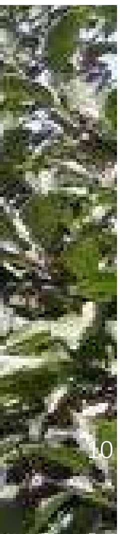
In order to be able to fertilize the orchard effectively, it is necessary to know the amount and accessibility of these elements in the soil and plants. Therefore, it is highly recommended to do a foliar and soil analysis every year to know what amounts of nutrients should be added to the soil. For apples and pears it also important to do fruit analysis as these fruits are often intended for storage. The fertilization program may also have to be tailored to the root stock of the trees.

Proper nutrition of apple and pear trees is one of the very important factors for successful production. Nutrition starts from planting, which helps the growth and development of young fruit trees. It enables normal growth of young shoots, and quality differentiation of mixed buds which, depending on the category of planting material, give a significant yield in the second year. In the years of growing fertility, and above all at full fertility, fruit trees are looking for significant amounts of nutrients. Of course, it is necessary to be aware of the trees' nutritional requirements, and perhaps it is even more important to understand when these nutrients should be added and in what way. Therefore one must know the pheno-phases of plant development as the basis for proving the crop with the necessary nutrients in a timely manner. Apple and pears consume significant amounts of N, P, K, Ca, Mg and S. The annual nutrition of pome fruits trees does not end at harvest, but when the trees are dormant in winter.

NUTRITIONAL REQUIREMENTS OF POME FRUIT TREES

Nitrogen (N)

Nitrogen is an essential component of the organs and tissues of apple and pear trees. It is differently represented in certain organs and tissues. Leaves, flower buds, fruits and seeds have the most nitrogen.
The role of nitrogen in the life of apple and pear trees is multiple. The beneficial effect of nitrogen is reflected in the increase of photosynthesis, growth of leaves, shoots, fruits and other organs of fruit trees and in the increase of flower buds. Nitrogen affects the overall development of the fruit, especially the abundance and quality of growth.
Nitrogen deficiency is reflected in reduced growth of young shoots, smaller leaves, reduced germination of flower buds, weaker flowering, increased decline of already germinated fruits and generally weaker fruit development. In general, whole trees remain less developed, stunted and decay faster. However, excess nitrogen can also have an adverse effect on apple and pear trees. The form of nitrogen applied may also have an impact on the trees. Excessive application of nitrates may lead to an increase in plant redox potential, which could lead to crop health issues.
If the soil is too rich in nitrogen, then the young shoots, leaves and roots grow very abundantly. Growth continues until late autumn, the young do not ripen enough but remain with green and soft tissue, so they freeze easily. At the same time, sensitivity to diseases and pests increases, and some physiological changes occur. Due to the excess of nitrogen, the ripening time of fruits is prolonged, and their duration is shortened. One of the most important issues resulting from an excess of nitrogen can be the imbalance with K, Ca and Mg and the subsequent increase in the incidence of bitter pit. Timely application of nitrogen fertilizers to the soil is also very important. Too late application of nitrogen fertilizers causes prolonged vegetation. On the other hand, nitrogen fertilizers are easily soluble and mobile, so there are bigger losses if everything is applied in the fall, because there is usually a lot of precipitation in the fall and winter.



Due to the intensive growth of roots in the fall, which requires a lot of nitrogen, it is important to apply nitrogen fertilizers in the fall , before the risk of frost. In the spring, intensive root growth begins again, followed by flowering, fertilization, growth of young shoots and fruits, and a lot of nitrogen is needed for the growth of these organs. So, it should be fertilized with nitrogen in the spring as well. At the beginning of the summer, flower buds are planted for the next year, young shoots and fruits grow profusely, so again a lot of nitrogen is needed.

Phosphorus (P)

Phosphorus has a positive effect on the color of the fruit, increasing the production of the enzyme involved in the production of anthocyanins, a natural plant pigment that plays a key role in the red color of the fruit. It is important to apply phosphorus in the right form and at the right time: in case of the need to improve the color of the fruit, foliar application is very effective after flowering and at early maturity. If this element is missing, the fruits will be spongy, and its excess can affect the amount of zinc.

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 vigour of all plants. Some specific growth benefit that have been associated with phosphorus are: a stimulation of root development, increased branch strength, improved flower formation and fruit production, more uniform and earlier ripening, improved crop quality, increased resistance to disease, and more vigorous development throughout the growth cycle.

Phosphorus is an essential nutrient for all parts of the tree as it is required for membranes, energy molecules and nucleic acids. In cases of phosphorus deficiency, the fruit are more highly colored and ripen earlier but exhibit surface defects and poor flavor.

Phosphorus is not always fully available, so it is very important to have a soil phosphorus analysis and to adapt the phosphorus fertilization accordingly. Growers should also take into account that Phosphorus can be immobilized in calcareous soils or acidic soils containing iron.

Comparing to nitrogen and potassium, phosphorus deficiency in apples and pears is difficult to diagnose. Some of the symptoms include poor root growth and stunned growth of the trees, purple coloration of leaves, reduced flowering and seed formation and fruit set, reduced leaf and shoot growth, reduced fruit size and lesser fruit color and delayed fruit maturity.

Potassium (K)

Potassium is an extremely important nutrient in regard to transpiration, chlorophyll uptake, and the transport and storage of carbohydrates in the fruits, helping to increase sugar content. Potassium also helps to promote the storage of reserves in different parts of the plant and hence it is important to apply adequate amounts of this element during the autumn. 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.

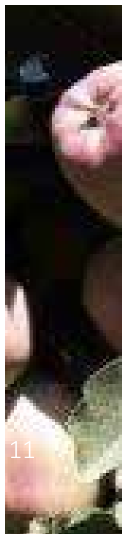
Potassium promotes the setting and advances the maturation of the fruits. In addition, it helps protect against frost. Potassium deficiency causes the appearance of small leaves, narrow and yellowish green, which is later dark (reddish-brown) along the rim, wrinkled in the middle. The dried part of the leaf is twisted towards the face of the leaf, and then it curls and falls off. Extinction starts from the top. The fruits are smaller, less colored and with less sugar. The flesh of the fruit is spongy or woody. Resistance to frost, diseases and pests is reduced.

Sulfur (S)

The uptake and availability of sulfur is not influenced by soil pH and this nutrient is thus 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 all enzymes and proteins and certain 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.

Calcium (Ca)

Terblanche et al. (1979) reported that the roots contained 18%, wood 40%, bark 11%, leaves 13% and fruit 18% of the total Ca content of apple. Calcium (Ca) is an important element in pome tree fertilization and is directly related to fruit quality. Due to the lack of calcium (Ca), bitter spots (Bitter Pit) appear in apples and cork spots in pears. In cases where insufficient calcium (Ca) is supplied, there is a higher risk of bitter spots (Bitter Pit) appearing in apples and cork spots in pears. The correct supply of calcium will reduce the their incidence. There are many reasons for the appearance of bitter pit, and in modern pome growing it is necessary to consider all the factors that limit the absorption of calcium. Proper fertilization and selection of calcium-based fertilizers can significantly reduce the appearance of bitter pit in apples.
Cork spot is one of the most damaging physiological disorders in pear. However, the mechanism of cork spot is unclear. Calcium deficiency is considered as the major factor leading to cork spot. In some studies, it has been found that pears located in lower half of the tree crowns showed a significantly higher calcium concentration resulting in lower K:Ca ratio than those from the upper half. On the other hand, pears with cork spot show a significantly higher potassium and magnesium and significantly lower calcium content.
Calcium uptake takes place passively in the form of Ca^{2+}ions via the root tips. The uptake depends on the root growth, soil temperature, soil moisture content and soil texture. Most of the annual amount of calcium required by the tree is taken up from the soil and, only whilst only a relatively small amount originates from reserves in the wood this part is vital for healthy tree growth. The fruits are mainly supplied with calcium during the cell division phase, in other words during the first six weeks after blossoming. Adequate amounts of potassium are key for efficient calcium uptake. For calcium fertilizer applied to the soil uptake via the roots is stimulated by a moist soil and by sufficiently high transpiration and is negatively influenced by a dry, cold soil. Calcium is also very important for optimal nitrogen use efficiency.
The transport of calcium over large distances in the tree takes place almost excursively via the xylem vessels, i.e. in the transpiration flow. As their transpiration rate is much higher (ratio 1:10), leaves are supplied far better with calcium than the fruits. Due to the poor mobility of calcium in the phloem vessels no calcium travels from the leaves to the fruits. Transport over short distances from cell to cell is driven by a so-called ‘auxin pump’ mechanism. The auxin producing tissues in the plant have a hormonal sink effect and therefore have priority in the supply of nutrients and water. This mainly concerns young leaves found in the shoot tips and close to the fruits (rosette leaves) and the flowers and seeds in young fruits.
Trees that blossom well and exhibit a good fruit set and healthy, well developing leaves absorb more calcium in total than trees that flower badly which have low production and poor leaf quality. To a certain extent shoot growth is useful in supplying the entire plant and so the fruits, too, with calcium via the transpiration flow.
In the summer the young leaves, compete directly with the fruit close to the shoots for the supply of calcium. If growth is too strong and too prolonged, this may cause calcium to be diverted from the fruits in favour of the shoot tips. Even and balanced growth and production and halting growth at an early stage are the most important aspects in creating a good distribution of calcium throughout the tree.

Magnesium (Mg)

Magnesium is part of chlorophyll, and is an important activator of enzymes, participating in energy transfer processes in plants and many other metabolic processes. Magnesium is mobile in plants, so the symptoms of deficiency appear on the lower leaves during the intensive growth of fruits.

Inadequate levels of magnesium cause a yellowing of tissue along leaf margins and between the main veins. Symptoms may initially develop along leaf margins, similar to potassium deficiency symptoms. As the deficiency progresses, the yellow regions turn brown and die, leaving a Christmas tree-shaped green area along the main veins in the middle of the leaf.

Magnesium deficiency can occur with light, acidic soils that are prone to leaching or in soils that have received high rates of potassium fertilizers.

Tissue Analysis

Regular tissue analysis of apple and pear leaves can give measure of tree nutritional status. Sampling at regular intervals is useful for monitoring nutrient levels in the crop and determining whether supplemental fertilization is needed. Optimum and deficient leaf nutrient content will vary according to pome fruit variety hence the figures in the table are given for indicative purposes only.

OPTIMUM AND DEFICIENT LEVELS OF NUTRIENTS IN POME FRUIT TREE LEAVES

	APPLES		PEARS	
NUTRIENT	OPTIMUM RANGE	DEFICIENT LEVEL	OPTIMUM RANGE	DEFICIENT LEVEL
N (%)	1.8-2.6	2.0	2.0-2.5	2.0
P (%)	0.16-0.30	0.6	0.15-0.30	0.9
K (%)	1.3-1.5	1.0	1.2-1.5	1.0
Ca (%)	1.1-1.6	0.5	1.1-1.7	0.5
Mg (%)	0.30-0.50	0.2	0.25-0.45	0.2
B (ppm)	25-50	25	25-50	25
Cu (ppm)	10-20	4	5-30	4
Fe (ppm)	150-250	25	50-250	20
Mn (ppm)	50-80	20	30-130	20
Zn (ppm)	20-40	15	20-100	15

NUTRITIONAL REQUIREMENTS - APPLES AND PEARS

	TOTAL PER MT OF YIELD*	BUDDING	BLOOM	FRUIT SET	FRUIT GROWTH & MATURATION	POST-HARVEST
	kg/ha	%				
N	0.74	30	25	5		40
P_2O_5	0.28	20	25	15		40
K_2O	1.61	10	20	40	10	20
SO_3	0.15	15	40		15	30
CaO	0.74	30	25	30	15	
MgO	0.27	25	30	30	15	

*Based on target yield 84 mT/ha (Cornell University, Dr Cheng)

FRUIT NUTRIENT REMOVAL (KG/HA) AT HARVEST IN RELATION TO YIELD - APPLES AND PEARS

YIELD (T/HA)*	N	P	K	CA	MG	S
34	9.6	2.5	31.0	2.0	1.6	0.8
50	14.5	3.7	46.5	2.9	2.5	1.1
67	19.3	4.9	62.0	3.9	3.1	1.5
85	24.0	6.7	77.5	4.9	3.9	1.8
100	28.8	7.4	93.0	5.9	4.7	2.2
118	33.7	8.6	108.5	6.8	5.5	2.6

*Gala on M26 (Cornell University, Dr Cheng)

ABSORPTION OF NUTRIENTS

If apple and pear orchards are to be profitable it is essential that a high proportion of the harvested produce should fall into the first-class category with regards to quality. Production of a high-quality crop requires both sufficient amounts and a correct balance of the nutrients required for plant growth. On the other hand, crop load optimizing is important for fruit quality, which has an impact on profit. At lower crop loads, the apples and pears often have improved quality; they ripen earlier, are sweeter, often firmer and have higher levels of dry matter.

Colour management is an extremely important part of the pome fruit production process. Apple and pear peel colour determines market acceptance and colour branding has been incorporated into the grading standards of many varieties of apples. Red skin varieties of pears become more and more popular. High nitrogen rates reduce red coloration by increasing foliage and thereby reducing light penetration into the canopy. Potassium fertilization enhances anthocyanin accumulation and red coloration of apples and some varieties of pears by compensation of some of the negative effects of higher nitrogen rates.

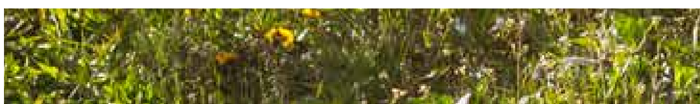
Calcium has an important role in cell wall development. When calcium is in short supply, cell wall integrity is lost, resulting in these symptoms, which vary slightly between varieties. Calcium nutrition is directly linked to bitter pit development. Excessive nitrogen causes large fruit that result in a dilution of calcium in the fruit and more serious bitter pit. Excessive potassium fertilizer applications can also depress calcium in the fruit, particularly when calcium levels are low. Boron is involved in the movement of calcium to the fruit. If boron is low, calcium disorders such as bitter pit may develop.

Young, non-bearing trees have higher requirement in nitrogen comparing to bearing trees. In the fertilization program of young trees it is important to provide adequate levels of nitrogen so they could produce wood, while the goal with bearing trees is higher yields of top quality fruit. Fruit color development in mature trees is delayed in the case of high nitrogen levels: for each 0.1% increase of nitrogen in the leaf, the percentage of red color is reduced by about 5%. Almost half the recommended nitrogen should be applied during the post-harvest period, to be stored and used early in the following season. The other half should be applied at bud burst and after bloom.

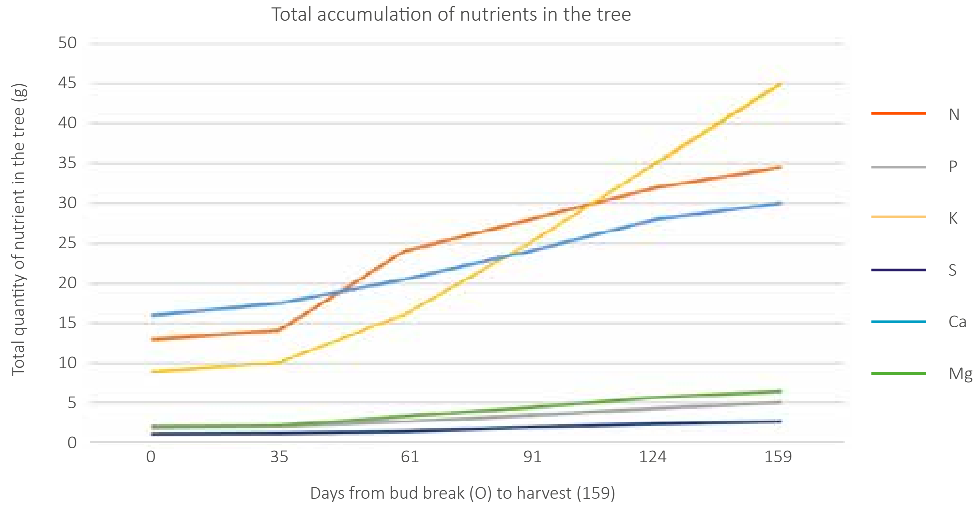
Pome trees also absorb phosphorous over a long part of the year. Phosphorous has very low mobility in the soil, it will not move down the soil profile more than 2 to 3 centimeters per year, and it is very difficult to determine orchard phosphorus status with standard methods. While the extensive root system of pome trees tends to absorb enough soil phosphorus it is important to provide enough of this nutrient throughout the season.

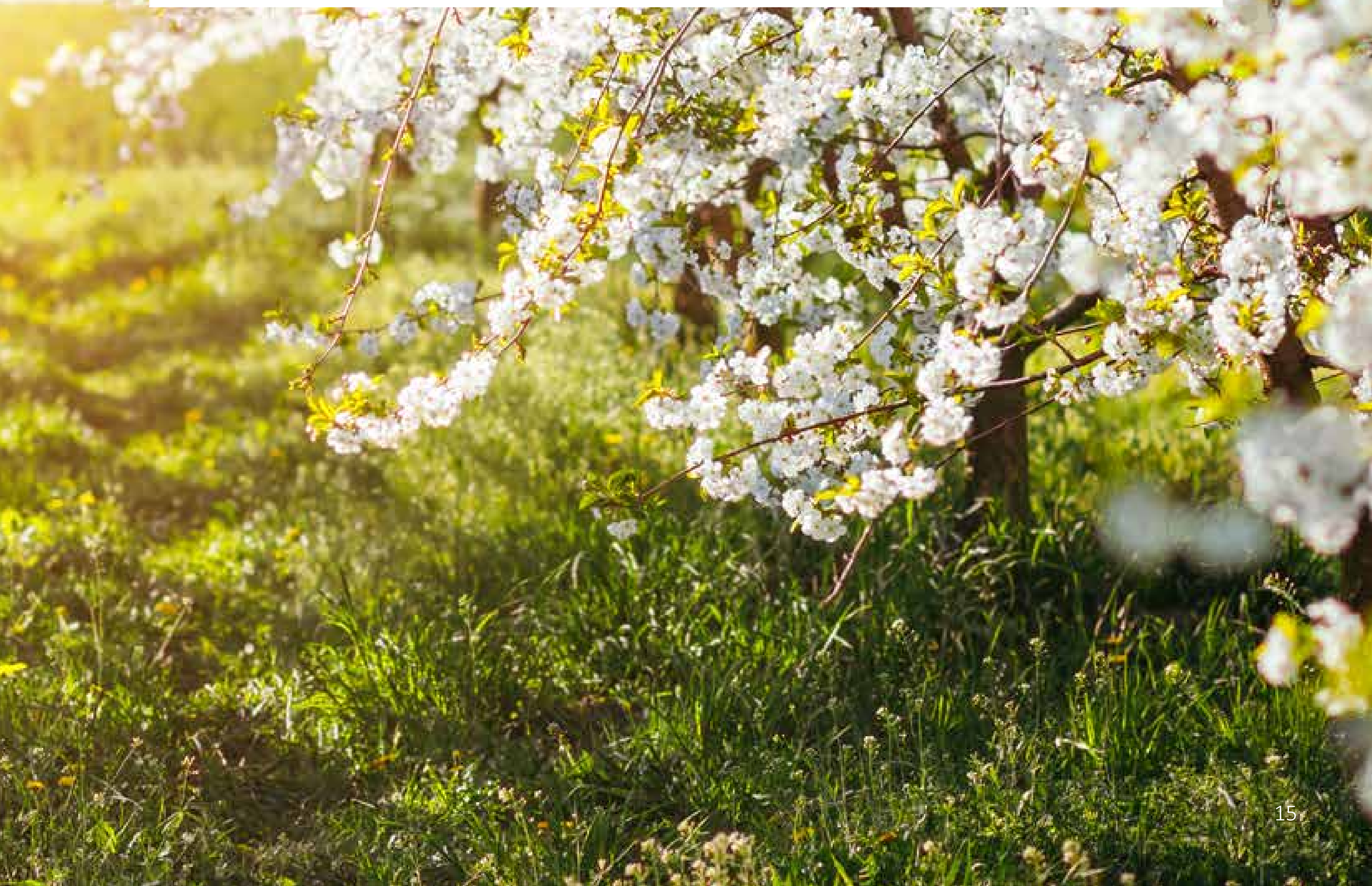
Potassium is one of the major essential nutrients and plays an important role in promoting synthesis of photosynthates and their transport to fruits, formation of starch, and protein synthesis. It is believed that the apple and pear tree needs potassium even more than nitrogen. The proper fertilization with potassium can stimulate a significant yield increase. On the other hand, the application of excessively high rates of potassium can reduce the availability of soil calcium. The potassium fertigation rate must meet the apple and pear tree's requirements and crop load, which can vary significantly in different years. The main need for potassium absorption begins during the growth and development of the fruit. Potassium has a role in water regulation and uptake in plants under water stress as it facilitates the turgor pressure of guard cells during opening and closing of stomata.

Sulfur is essential for the growth and development of apple and pear trees and has some key functions in plants such as formation of chlorophyll, protein production (sulphur is a constituent of three S-containing amino acids (cysteine, cystine and methionine), oil synthesis and activation of enzymes. Sulfur in the sulfate (SO_4^{2-}) form is immediately available to the crop whereas elemental sulfur (S) is oxidized in the soil for uptake by the trees later in the season. There is now evidence that plants can also directly take up sulfur in the thiosulfate form ($S_2O_3^{2-}$). Prior to its assimilation sulfur in the sulfate form needs to be reduced and cysteine is the primary precursor or 'sulfur donor' for other plant sulfur metabolites. Thiosulfate is a reduced form of S and it is used as a source of electrons for energy generation in photosynthetic and respiratory systems of a wide variety of bacteria. Thiosulfate sulfur is unique in that it exists in two oxidation states. This gives it enhanced pathways of availability more suitable to the sulfur uptake patterns of most plants, making thiosulfates a more energy efficient form of sulfur for the tree.



Apples


Total accumulation of nutrients in the tree
Total quantity of nutrient in the tree (g)
50
45
40
35
30
25
20
15
10
5
0
0
35
61
91
124
159
Days from bud break (O) to harvest (159)
N
P
K
S
Ca
Mg



PRODUCTS

TESSENDERLO KERLEY FERTILIZERS

PRODUCTS	BUDDING	BLOOM	FRUIT SET	STONE HARDENING	MATURITY	POST HARVEST
Thio-Sul	Soil application liquids	Soil application liquids	Soil application liquids	Soil application liquids	Soil application liquids	Soil application liquids
KTS			Foliar application	Fertigation / Foliar application	Fertigation / Foliar application	Fertigation / Soil application liquids
CaTs	Foliar application	Foliar application	Fertigation / Foliar application	Fertigation / Foliar application	Fertigation / Foliar application	Fertigation / Soil application liquids
K-Leaf			Foliar application	Foliar application	Foliar application	
SoluPotasse			Fertigation	Fertigation	Fertigation	
GranuPotasse	Soil application granules					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%

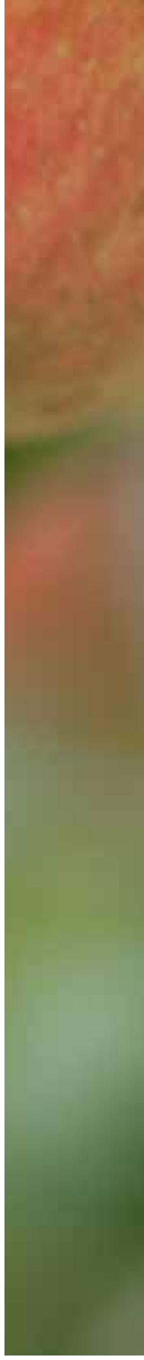
Typical properties

- 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 application – soil injection and surface banding	45 to 90 l/ha	Early in the growing season for sulfur nutrition	Take care to avoid damaging roots during injection application
Soil application – broadcast (mature trees)	95 to 110 l/ha	Early in the growing season for sulfur nutrition	Spray alone or mixed with water and/or other liquid fertilizers. Prevent spray and drift from contacting foliage and tree bark.
Soil application – broadcast (young trees)	45 to 75 l/ha	Early in the growing season for sulfur nutrition	Spray alone or mixed with water and/or other liquid fertilizers. Prevent spray and drift from contacting foliage and tree bark.
Flood and in furrow	45 to 90 l/ha	Starting at full leaf	Apply with the irrigation water

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 in overhead pivots and sprinklers.
- The thiosulfate form of potassium is taken up rapidly by the leaves.



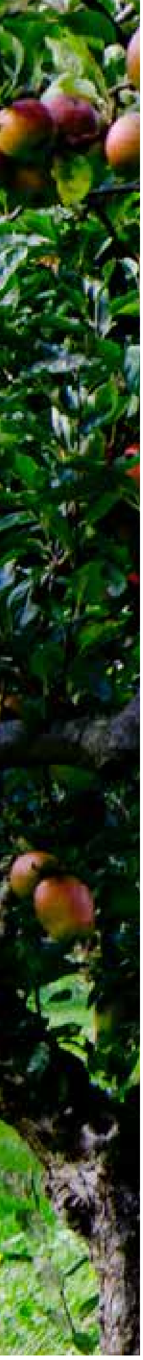
Specifications

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
Fertigation (flood and in furrow)	50 to 150 l/ha	Starting at bud break	Apply once every 2 to 3 weeks
Fertigation (sprinkler/pivot) – under canopy	45 to 75 l/ha	Shoot growth up to harvest	Apply every 10 to 14 days based on crop requirements
Fertigation (sprinkler/pivot) – overhead	30 to 45 l/ha	Shoot growth up to harvest	Apply every 10 to 14 days based on crop requirements
Fertigation (drip) – young trees	30 to 45 l/ha	Shoot growth up to harvest	Depending on soil analysis, start at full leaf; apply once every 3 to 4 weeks
Fertigation (drip) – mature trees	45 to 95 l/ha	Shoot growth up to harvest	Depending on soil analysis, start at full leaf; apply once every 3 to 4 weeks
Fertigation (micro-sprinkler) – young trees	Young trees: 30-45 l/ha	Shoot growth up to harvest	Repeat every 10 to 14 days based on crop requirements
Fertigation (micro-sprinkler) – mature trees	Mature trees: 50 to 120 l/ha	Shoot growth up to harvest	Repeat every 10 to 14 days based on crop requirements
Foliar	5 to 15 l/ha	Fruit set onwards	Apply in a minimum of 1000 liters of water spray solution. For concentrated sprays of less than 1000 liters per hectare, reduce the rate of KTS so as not to exceed the maximum spray solution concentration of 1.5%. See also caution on page 26



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.

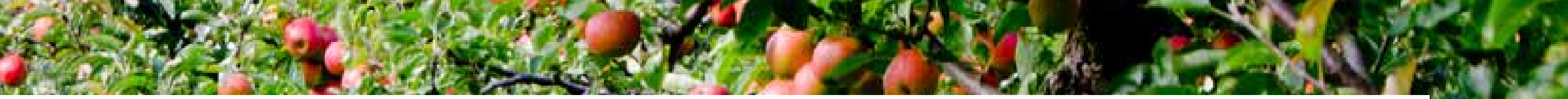
Specifications

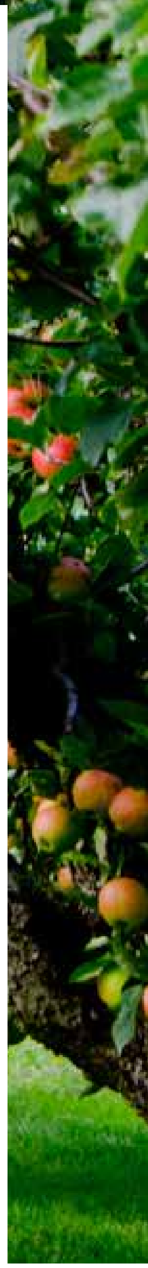
Calcium thiosulfate	
- Ca (w/w)	6%
- S (w/w)	10%
- pH range	6.5 - 8.8
- Density range (at 25°C)	1.22 - 1.26

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
Soil applied	100 to 200 l/ha	Shoot growth up to harvest	
Fertigation (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 (sprinkler/pivot)	50 to 150 l/ha	Shoot growth up to harvest	Repeat as required
Fertigation (Drip)	40 to 90 l/ha	Shoot growth up to harvest	Repeat four or five times during the growing season or as needed
Foliar	5 to 10 l/ha	At bloom and nut fill	Repeat applications as required (up to four or five applications at 10 days intervals). See also caution on page 26





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 24 kg/ha	Fruit set and development	Spray volume base: 800 l/ha Repeat 2-3 times with two weeks interval It is not recommended to exceed a concentration of 3% in the spray solution

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 20 kg/ha per week	Flowering	Based on weekly applications
	30 to 40 kg/ha per week	Fruit set	
	30 to 40 kg/ha per week	Fruit development	
	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	200 to 400 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

FERTILIZATION RECOMMENDATIONS

FERTIGATION RECOMMENDATIONS

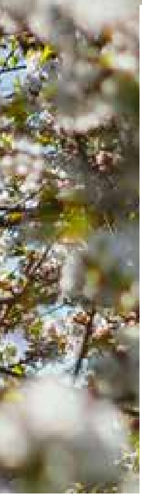
The fertigation recommendations presented are for illustrative purposes only. The application rates indicated in the table(s) below assume that all of the crop's requirement for the nutrient(s) will be delivered by the product listed in the table. The rates indicated are for use of either all KTS or all SoluPotasse – if a combination of these two products is used then the rates should be adjusted accordingly. 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 APPLES AND PEARS BASED ON NUTRIENT REQUIREMENTS						
	TOTAL KG/HA ON MATURE TREES	BUDDING	BLOOM	FRUIT SET	FRUIT GROWTH & MATURATION	POST HARVEST
Nitrogen (kg N/ha)	40-85	10-25	10-20	0-5	0	20-35
Phosphorus (kg P_2O_5/ha)	15-35	5-10	5-10	0-5	0	5-10
Potassium (kg K_2O/ha)	90-180	10-20	20-35	35-70	10-20	15-35
Sulfur (kg SO_3/ha)	10-20	0-5	5	0	0-5	5
Calcium (kg CaO/ha)	40-85	10-25	10-20	10-25	5-10	0
Magnesium (kg MgO/ha)	15-30	5	5-10	5-10	0-5	0

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

CROP VITALITY FERTIGATION RECOMMENDATIONS FOR APPLES AND PEARS					
	BUDDING	BLOOM	FRUIT SET	FRUIT GROWTH & MATURATION	POST HARVEST
LIQUIDS					
KTS (l/ha)	50-70	50-70	180-200	30-50	20-40
CaTs (l/ha)	80-100	80-100	80-100	40-60	40-60
WATER SOLUBLES					
SoluPotasse (kg/ha)	20-35	35-70	70-140	20-35	0

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 a key growth stages.



GUIDELINES

General

- Do not apply products to crops which are sensitive to the effects of foliar applied sulfur.
- Micronutrient blends should be jar tested first before mixing with thiosulfates. In most situations, micronutrient chelates of neutral pH are preferred for blending with thiosulfates. Strongly acidic and/or weak chelates do not blend well with thiosulfates. Blends of thiosulfates should not be acidified below a pH of 6.0. Do not mix CaTs with micronutrients in the sulfate form.
- Use the correct type of spray nozzles that are recommended for foliar applications.
- Use of tissue and soil analysis to determine crop and soil nutrient status is recommended.
- Contact a representative of Tessenderlo Kerley International if you require any additional information on the properties, benefits and use of the products in this guide.
- 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.
- 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.
- Do not apply products as a foliar spray when temperatures are, or will be, above 30°C or when humidity drops below 30%. Ensure you apply products (preferably) early in the morning or in the evening.
- **ALWAYS CONSULT WITH OUR EXPERTS** if intending to apply foliar thiosulfate with a crop oil spray, or shortly before and/or after an oil spray.

CAUTION: Foliar applications of thiosulfates may in some cases cause flower thinning in pome fruit trees

Blending of liquids

- The original salt out temperature (SOT) of each liquid in a blend can change when mixed with other liquid fertilizers or other liquid micronutrients and/or pesticides.
- When mixing with other products, and in the absence of specific recommendations and data, you are strongly advised to conduct a small-scale trial (jar test) in order to check the physical compatibility of the mixture before operating on a larger scale and applying.
- For blending the sequence should be to add:

  1. 50% of the total water volume
  2. Liquid fertilizers for other N and/or P sources
  3. Thiosulfate fertilizers
  4. Compatible micronutrients
  5. Pesticides
  6. Complete the filling of the tank with the remaining 50% of the water

- KTS is compatible with urea and APP in any ratio. When blending KTS with UAN, always have as much water, by weight, in the blend as the UAN solution. Potassium (from KTS) may react with nitrates to form potassium nitrate crystals. If this should happen the addition of water and/or gentle heating should bring it back to clear solution.
- CaTs is not compatible with phosphate, sulfate and ammonium thiosulfate fertilizers.
- The recommendations in this guide are for KTS, CaTs and Thio-Sul applied alone (not in blends). The addition of other products to the mix is the responsibility of the operator and not of Tessenderlo Kerley International. In case of doubt always consult a qualified agronomist.

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.

- Do not apply 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.

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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

HIGH-PERFORMANCE LIQUIDS

HIGH QUALITY SOLID/SOLUBLES

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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