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SMALL FRUITS

The consumption of small fruits is widely appreciated in the form of fresh fruit, jams or cordials. Consequently, global production is on the increase thanks to a larger cropping area, new varieties and a better use of inputs, in particular fertilizers.

Strawberry is the most important small fruit crop and, for this crop, fertilization practices are well documented. However, for certain other small fruits, it may be more difficult to obtain specific information. As a general rule, however, they prefer neutral to acid soils of a loamy-sandy nature rather than sandy-clayey ones. Mineral nutrition can vary widely according to the cropping system and to the yield expectation, but it is important to remember that small fruit are chloride-sensitive crops, particularly gooseberries, currant varieties and strawberries. Consequently, chloride-containing fertilizers are best avoided in small fruit fertilization.

This guide provides information relating to the mineral nutrition of strawberries, blueberries, raspberries and blackberries grown outside in soil. The length of the growing season will depend upon the berry type, the cultivar and the climate of each unique growing region. For advice on how the recommendations should be adapted to your specific conditions or to other small fruits or under-cover cultivation using substrates or hydroponic conditions, please speak to one of our experts.

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STRAWBERRY

Fruits such as strawberry (*Fragaria × ananassa*) are characterized as being small and fleshy and are consumed in many countries. Most strawberries are enjoyed in the fresh form however they are also popular in processed products such as jam. Recently, consumers' interest in berries has grown dramatically due to their health benefits. Strawberries are very rich in antioxidants (associated with anticancer properties) and are also an excellent source of fiber, vitamins, folic acid, fatty acids, polyphenols and minerals. Strawberries need moderate levels of fertilization and irrigation, and thrive best on nearly neutral pH (6 - 6.5) soils. Strawberries on average take 30 days to mature from flower to fruit. The berries are generally picked every three days, and the fields must be re-planted every year.

One ton of strawberries contains 1 kg of nitrogen (N), 0.5 kg of phosphate (P_2O_5), 2 kg of potash (K_2O), 0.3 kg of calcium (CaO) and 0.2 kg of magnesium (MgO). As a function of the total nutrient exports in strawberry, the crop's fertilizer needs can be identified. As a general rule, the preferred formula for strawberries can be defined as: 1 N - 0.5 P_2O_5 - 1.5 K_2O - 0.2 MgO - 0.6 CaO.

BLUEBERRY

Blueberry (*Vaccinium sp.*) is currently the small fruit most requested by consumers thanks to its widely documented health benefits. Blueberry's exceptional richness in vitamins, mineral salts, fiber and polyphenols (oxoflavoids and anthocyanins in particular), is responsible for their recognized nutritional qualities. In addition, blueberries have a very high antioxidant power: only prunes and raisins do better. Blueberries are a deciduous fruiting plant, native to North America, and can live longer than 15 years before re-planting is necessary. Cultivated blueberries are generally of the 'highbush' variety, with larger berries growing on taller bushes. They prefer an acidic soil so ideally the pH should stay below 5.5 to avoid problems. If necessary soil pH can be adjusted (lowered) prior to planting or during establishment.

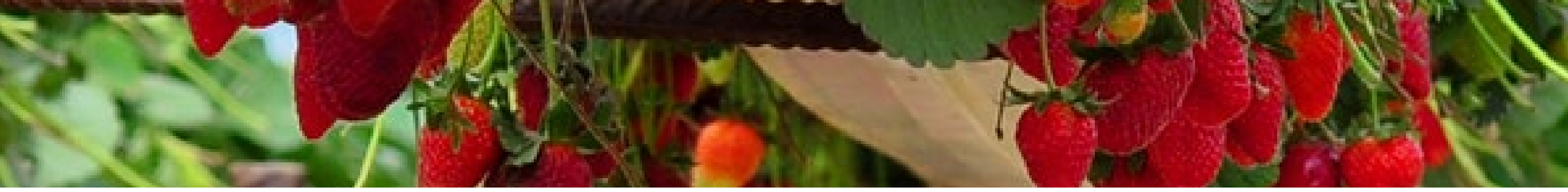
INITIAL SOIL PH	SOIL TYPE		
	SANDY	LOAMY	CLAY
	kg S/100 m^2		
5	2.0	5.9	9.0
5.5	3.9	11.5	17.6
6	5.9	17.3	25.7
6.5	7.4	22.6	33.9
7	9.4	28.6	41.7
7.5	11.9	29.3	43.0

Recommended sulfur application doses to decrease soil pH to 4.5

Blueberries are pale greenish at first, then, during the maturation process, they become reddish-purple, and finally turn dark purple when ripe. Mature berries have a sweet taste with variable acidity. Fruiting times are dependent on local conditions including the climate.

Fertilizer is usually applied to blueberries when growth begins in the spring, and also immediately after harvest, unless fertigation is being used. In this case, care is needed as blueberry plants are somewhat sensitive to highly soluble fertilizers. It is important to ensure sufficient water is applied during the fertigation process to limit the concentration of the fertilizers applied. Nitrate forms of fertilizer are best avoided as they may damage blueberries. Ammonium is the preferred source of nitrogen since it also has an acidification effect in the soil. The optimal balance for blueberry fertilization is around 1 N - 0.6 P_2O_5 - 0.75 K_2O.

In some cases blueberries may suffer from calcium deficiency problems due to the acidic soils, although this is not always the case. For this reason proper attention should be given to the correct supply of this important element,which also helps improve the availability to the crop of nitrogen in the ammoniacal form. Many blueberries are grown on low CEC soils which by nature will have a low calcium content. In these situations, calcium uptake could be a problem and calcium fertilization may be needed. Although rare, calcium deficiency symptoms included interveinal chlorosis of younger leaves and scorching of the margins of older leaves. Like in many fruit crops, a low calcium content often contributes to poor fruit storage quality.



RASPBERRY

Raspberries are an important commercial fruit crop, now widely grown in many temperate parts of the world. Interest in the health benefits of raspberries has grown dramatically in recent years. Red raspberries contain a variety strong antioxidants such as vitamin C, quercetin and gallic acid that can help protect against cancer as well as cardiovasclar disease. They have also been shown to have anti-inflammatory properties.

Raspberries grow best in well-drained, sandy loam soils, which are rich in organic matter and moisture retentive. They do not grow well in waterlogged soils and shallow chalky soils.

As far as cultivation is concerned, two types of raspberry are available. Summer-bearing cultivars (non-rising varieties) produce fruit only on second-year canes (the floricanes) and this occurs during a relatively short period during the summer. Such varieties are generally preferred in commercial production since labor associated with the harvesting is optimized. The other type are known as double or “ever-bearing” cultivars (rising varieties). As well as bearing fruit on the second-year floricanes in the summer, these also bear some fruit on first-year canes (primocanes) in the late summer and autumn. The fertilizer recommendations in this guide are for rising varieties. For non-rising varieties the amounts of fertilizer required by the plants may differ.

Raspberries prefer a soil pH in the range of 5.6 to 6.2, so soil pH may need to be adjusted by the application of acid or basic materials prior to planting.

The fruit is ready to harvest when it comes off the receptacle easily and has turned a deep color (which will depend on the species and cultivar). This is when the fruits are at their best. In new plantings, it is recommended not to apply all of the fertilizer at once but instead, to divide the total amount (of NPK) into three equal parts. The first part should then be applied 2 weeks after planting, the second 1 month later, and the third part third part one month after the second. The use of fertigation techniques can help the fractionation of the crop’s fertilizer requirement. The optimal balance for raspberry fertilization is around 1 N - 1.3 P_2O_5 - 2.4 K_2O.

BLACKBERRY

The blackberry (*Rubus fructicosus*) is a member of the family *Rosaceae*. It is a multidrupe that is comprised of small globules containing a tiny seed inside.

Blackberries are perennial plants, which produce biennial stems or canes from the root system. The blackberry plant itself is a scaly shrub with arched and prickly branches. The leaves have 3 or 5 elliptical and serrated edges, are arranged in a webbed form. Its flowers grow in compound clusters. Blackberries are reddish at the beginning of maturation and finally ripen to give a shiny black fruit.

Cultivated blackberries are notable for their significant content of important nutrients including potassium, magnesium and calcium, as well as vitamins A, C, E and B vitamins. Blackberries also contain fiber as well as manganese and folic acid. In addition, they are a rich source of anthocyanins, powerful antioxidants that give blackberries their deep purple colour.

When it comes to fertilization, applications of fertilizers with a higher proportion of phosphorus (1-2-1 ratio) in the first two years after planting should be beneficial. On newly established blackberry plantings, a more balanced fertilization is recommended. Soil-applied fertilizer should be placed about 30 cm to the side of and slightly lower than the plants. Applying fertilizer in the furrow where the crop is planted may lead to crop injury.

For soil application, around two thirds of the fertilizer should be applied as a side dressing just before bud swell in the spring on established berry plantings. A second application (one third of the total fertilizer requirement) should be made post harvest. Typically, rates are around 60 - 80 kg per hectare each of N; P_2O_5 and K_2O.

THE GROWTH CYCLE OF SMALL FRUITS

Strawberry

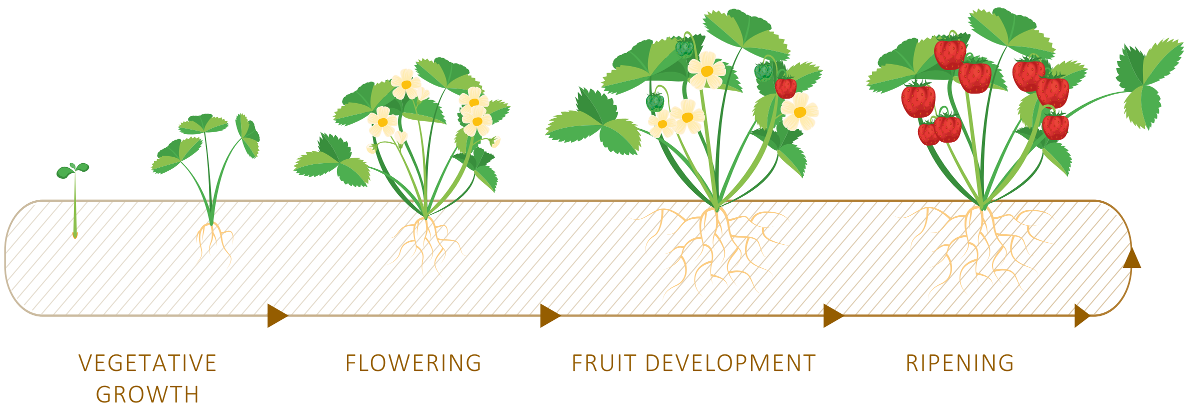
The strawberry production cycle is characterized by its annual nature. In the spring, buds appear in the axils of newly formed leaves. Some of these buds remain dormant during the summer, while the others usually develop into stolons. In winter, these buds develop either in crowns or in flower buds. A period of short days (critical duration of 11 to 13 hours) stimulates the vegetative apices of most varieties to turn into flower buds.

Depending on their sensitivity to the length of the day, the strawberry varieties can be classified into three groups: short day varieties, rising varieties and non-photoperiodic varieties.

In short day varieties, the initiation of budding generally occurs during the fall when the length of the day is below the critical duration of approximately 13 hours. These varieties form flower buds in winter when the days are short and temperatures are low. They then flower and produce in spring.

Rising varieties produce their inflorescences when the daylight duration is 11 to 17 hours. The number of inflorescences produced increases as the length of day gets longer. Induction begins in August and the development of the first stems is before winter.

The cultivars of non-photoperiodic strawberries are different from short-day strawberries that produce their fruit in June (northern hemisphere) or later in the summer, because they are not dependent on the photoperiod to initiate their inflorescences. This means they can flower and produce fruit continuously. These cultivars will continue their growth as long as temperatures allow.



Blueberry

Growth of blueberry is first visible in the spring with the onset of "bud swell" on 1-year-old wood (last year's growth). This wood has vegetative buds (small, scale-like buds that will only produce a shoot with leaves). Shoot growth occurs rapidly in the spring and begins to slow in midsummer.

Flowering occurs in spring when floral buds swell and open ("bud break"). Floral buds near the tip of 1-year-old shoots open first, followed by the buds below. Timing and duration of bloom vary by cultivar and prevailing weather conditions. The flowers of blueberry are urn-shaped and consist of:

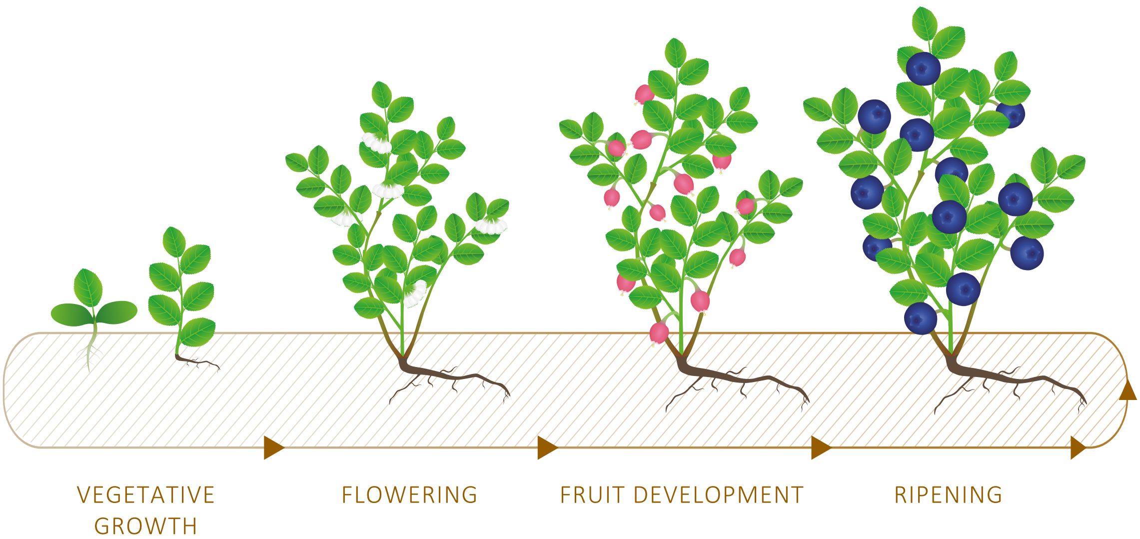
- The calyx, which ends up at the tip of a berry
- The corolla, or fused petals
- About 10 stamens that each have a pollen-containing anther at their tip
- A pistil, with an ovary at the base containing many ovules (which become seeds if they get fertilized by pollen)

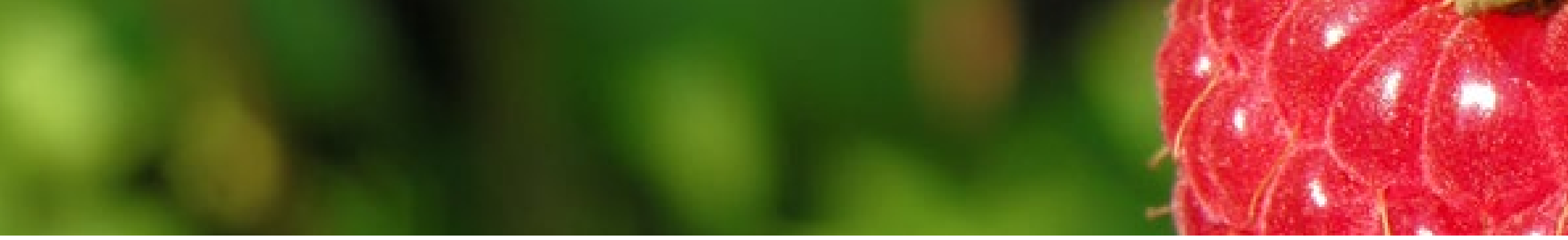
Flowers are receptive to pollination and seed set for 3 to 5 days after opening. Flowers need a large number of visits from bees or other pollinators for good fruit and seed set. Fruit set may be lower in regions that get a lot of rain or cold weather during bloom, which reduces bee activity.

After pollination and fruit set, the berry goes through three phases of growth:

1. Cell division, where the berry increases in size but is still green
2. Embryo development, where the berry does not increase in size much
3. Cell expansion, where each cell increases in size

The development of pink and then blue color starts at the end of the second phase of berry growth. Sugars increase and acids decrease during phase three. Berry weight is dependent on cultivar, crop load (severe pruning will increase berry size), stage of development (berries increase in size after turning fully blue), and the number of seeds per berry (in most cultivars). Berry firmness is mainly affected by cultivar but is also impacted by ripeness, cultural practices and weather.

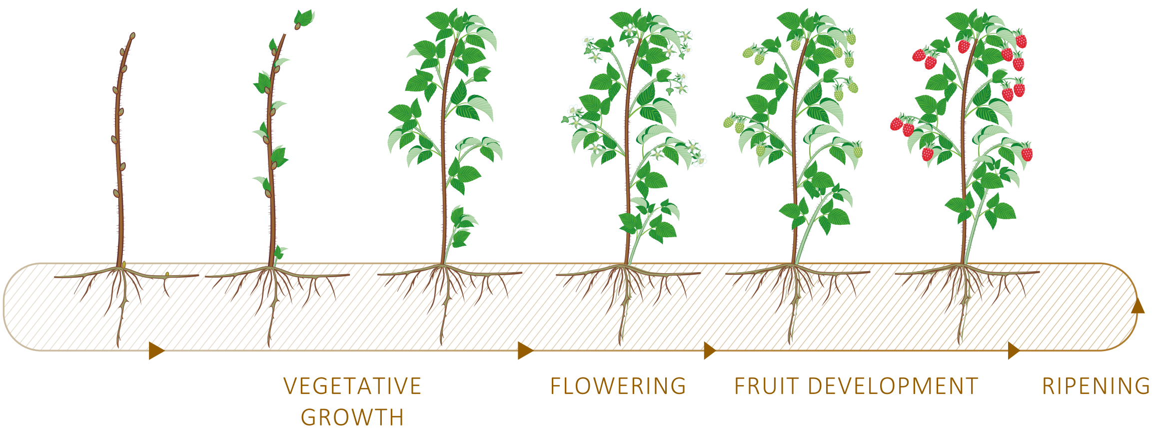




Raspberry

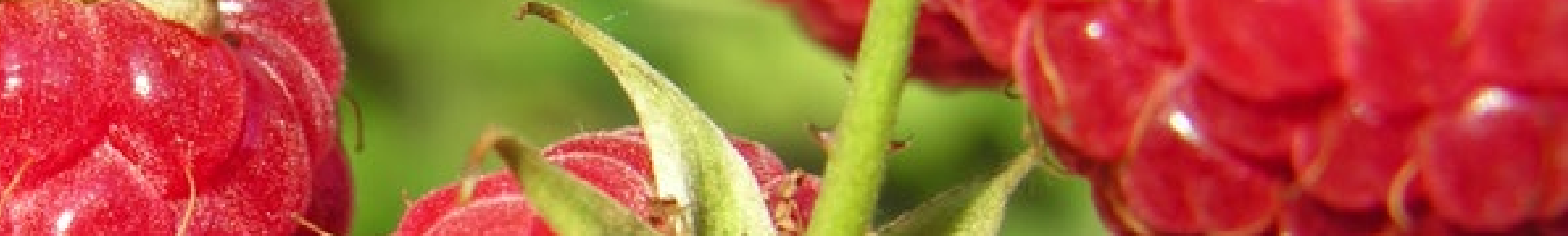
Raspberry adjusts to the climatic conditions of the cultivation country, which can allow up to two harvests per year in countries with climates that favor the cultivation.

The crowns and roots of raspberry plants are perennial in nature, but individual canes live for two years. The production cycle generally begins when plants produce new canes (suckers) each spring from shoots at the crown and underground lateral stems. These canes only grow in a vegetative manner during the first season: the fruit is formed during the summer of the second year, but for countries with favorable climate, in the case of rising varieties, the fruit will be formed in the autumn of the same year. At the same time, the cycle continues and new canes emerge to provide the following year's harvest. Second-year rods die shortly after fruiting. Pruning is a vital part of maintaining a healthy raspberry plantation that helps improve the quality and performance of the fruit. During the summer months, all new canes that emerge outside the desired row of plants should be removed regularly. Before buds break, all old canes must be removed. Summer raspberries generally start blooming in conditions of low temperatures and short days. This varies according to the fruiting season. Generally, it takes about a week of proper conditions to start flower buds. For countries with a favorable climate, for cultivation after the first harvest, plants are pruned between 60 and 70 centimeters in height to once again favor the development of new canes. These will generate the second harvest, and then after the second harvest they will be pruned at ground level to favor the growth of new poles and start the second year of production. Raspberry plants in commercial production generally require a new planting every two to three years, especially with companies that license their developed varieties.



PLANTATION	DEVELOPMENT	FLOWERING TO HARVEST	HARVEST	CUT CANES	WINTER DEVELOPMENT	FLOWERING TO HARVEST	HARVEST	PRUNED TO THE GROUND
1^{st} cycle				To height of 60-70 cm	2^{nd} cycle			3^{rd} cycle
Day = 0	60 days	40 days	70 days	Day 0	20 days	40 days	70 days	Day = 0

The raspberry growth cycle

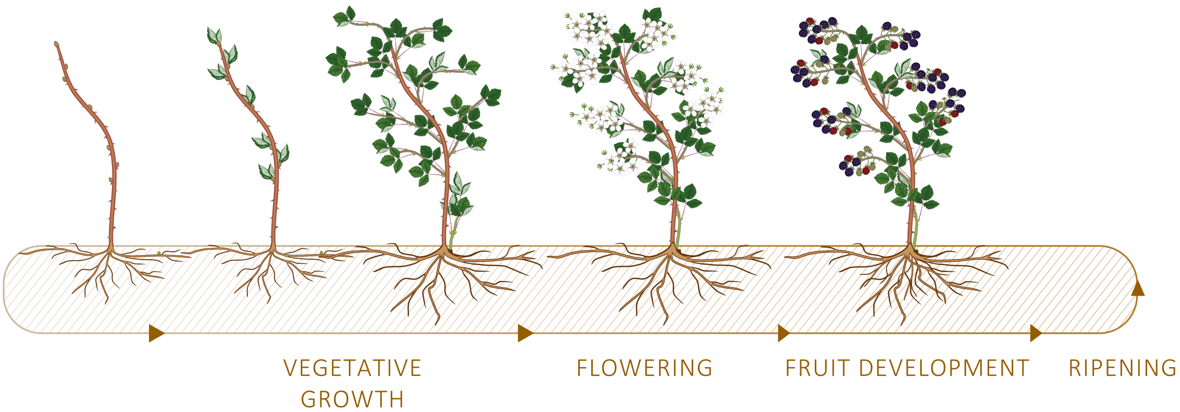


Blackberry

Growers should select a variety suitable for the fresh or processing market and for the climatic and soil conditions in the area. Blackberry is a perennial crop that can have a useful life of 10 years or more with good agronomic management, although a short-term renovation is currently proposed, which should evaluate growing conditons and profitability. For varieties under licensing scheme, it is suggested to replace plants every 2 or 3 years.

The growth cycle of blackberries depends mainly on the selected variety and the country where it is cultivated. When planting begins, proper management and fertilization must be given to generate main stems that support lateral branches where the fruit will be established. In cold climates certain varieties need cold hours (hibernation) to induce flowering in spring and for varieties that produce two harvests per year (for a second cycle), blackberries must be cut between sixty to approximately 1.2 meters to have the growth tips of the new pinched bars. This will encourage the poles to form lateral branches, which will bear fruit in the following year or cycle as appropriate. For the following year of production, all the sticks that fruited must be removed after harvest. In early spring, thin the remaining posts, leaving only five to seven of the toughest per crown. Cut the side branches back to 12 shoots (usually about 12 inches long) and tie the posts to the wire or pole for support.

The most productive blackberry plants require a new planting every five or six years.



PLANTATION	DEVELOPMENT	DEFOLIATION	DEVELOP OF SPROUT AND BRANCHES	FLOWERING TO HARVEST	HARVEST	PRUNED TO 30-60 CM	DEVELOP OF NEW CANES TO FLOWERING	HARVEST	PRUNED TO THE GROUND
1st year		To control dates for harvest window							Start 2nd year
Day = 0	60-90 days	Day = 0	20 days	80 days	70-90 days	Day = 0	60 days	60-90 days	Day = 0

The blackberry growth cycle

FERTILIZATION OBJECTIVES

Depending on the type of berry, the fertilizers applied to the crop should be chosen in relation to the chemical properties of the soil, development and yield of the crop. Therefore, the fertilization program for each season must be specific for each berry. Lack or excess of any nutrient will directly affect the productivity and the quality of the fruit. The use of soil analysis can helps to calculate a more efficient fertilization according to the actual situation and needs of each crop (within the same type of berry there are nutritional differences depending on the variety). With soil analysis, savings can be made on some nutrients (fertilizers) allowing a greater focus and investment on other nutrients that are not at a sufficient level.

NUTRITIONAL REQUIREMENTS OF SMALL FRUITS

1. Nitrogen (N)

Nitrogen, along with water, is the key factor in successful growth of berries. Nitrogen is the nutrient that promotes the growth and vigor of the plants. It is one of the fundamental elements of plant nutrition, since it is included in the composition of chlorophyll.

Small fruit plants will continuously absorbs nitrogen from vegetative growth through to the beginning of ripening. Nitrogen can be absorbed by plant roots in two different forms: the ammoniacal form (NH_4^+) and the nitrate form (NO_3^-). In the soil, ammoniacal nitrogen is gradually transformed into nitrate nitrogen by nitrification in moist soils.

During the vegetative stage up to flowering, the optimal growing temperature for small fruits is around 25°C, and the two sources of nitrogen (NO_3^- and NH_4^+) should be in balance. Although the small fruits generally prefer ammonium to nitrate in their nutrition, the presence of ammonium can become harmful at certain growth stages. Nitrogen in the ammoniacal form generally becomes available to the plant over a period of time. This is not ideal in cases where the supply of nitrogen needs to be 'switched off' quickly during fruit maturation. Although nitrate is a slightly toxic anion for small fruits, it is also very mobile and can be transported to all parts of the plant. Nitrates (NO_3^-), having a negative charge, act as a "transporter" of cations to the organs (leaves, flowers, fruits), where all the elements can then perform their roles.

N deficiency symptoms generally appear on adult leaves first. With limited nitrogen availability, plants stop growing and are weak. Nitrogen deficiencies are observed as a reduction in the leaf area and a yellowing of older leaves, which may fall prematurely. The growth of the roots is also reduced and its branching is restricted in such a way that the stem to root ratio is increased. Consequently, both crop yield and quality are significantly reduced.

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 small fruits. Some specific growth benefit that have been associated with phosphorus are: a stimulation of root development, increased shoot and 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 plant as it is required for membranes, energy molecules and nucleic acids. The role of phosphorus in promoting root development means it is an essential factor in terms of successful establishment of the plants. A lower soil pH, such as that required for the cultivation of blueberries, may reduce phosphorus availability in the soil.

Phosphorus deficiency manifests itself as a reduction in plant size, accompanied by poor root growth and the coloration of the adult leaves is purple. In soils where levels of below 3 ppm of P are found, approximately 110 kg/ha of phosphorus should be applied before transplanting. In established plantations around 80 kg/ha of phosphorus should be applied during in the plant development stage (preferably using fertigation).

3. Potassium (K)

Potassium is involved in several metabolic processes such as photosynthesis, protein synthesis and enzymatic activities It is also involved in the membrane transport processes, in charge balance, in the generation of turgor pressure, in the plant transpiration and in cell elongation.

The demand for potassium fluctuates throughout small fruit growth production. Potassium generally accumulates in the tissues of the stem during the vegetative stage and its content then decreases as the plant grows. However, the absorption of potassium peaks during flowering and during fruit ripening. At this time, the concentration of potassium in the leaves is low. The plant's response to potassium fertilization obviously depends on the time of its application. In fertigation, potassium applications during the vegetative stage are less likely to have a positive impact on the crop yield. In contrast later applications of potassium during the flowering period and as the fruits start to form will usually significantly increase the yield and also the number of flowers produced. Complimentary foliar applications of potassium from flowering onwards can provide a valuable potash boost to the plants when the need for this nutrient is at its highest. In cases where insufficient potassium is available, deficiency symptoms will appear as a light green to yellow color around the margins and tips of adult leaves, which later evolve into necrosis (leaf "burn"). Potassium deficient plants are often more sensitive to diseases and more vulnerable under conditions of stress.

4. Sulfur (S)

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 soil conditions. In the plant, it is incorporated into certain amino acids (cysteine, cysteine, methionine) and subsequently becomes part of certain enzymes (e.g. coenzyme A), vitamins (e.g. thiamine, biotin), and oils. Once in these complex molecules, sulfur is not easily mobilized within the plant. Hence in cases of deficiency, symptoms will occur in the young tissues first.

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 small fruits through volatile sulfur compounds.

Annual fertilization must include at least 17 at 23 kg/ha of sulfur (S) otherwise there is a risk of deficiency. Leaf sulfur deficiency in small fruits shows up as yellowing accompanied by purple dots on the young leaves.

5. Calcium (Ca)

Calcium is responsible for maintaining cell structure and tissue rigidity. Calcium is also important for the stability of the cell membrane and the maintenance of fruit quality. Calcium also plays an important role in the plant's defense by enhancing resistance to biotic and abiotic stress.

Calcium is a slowly mobile element. It is mainly absorbed by the young roots of the plant and is then transported by the flow of transpiration to the aerial parts. In fact, calcium is rather immobile in the phloem and quantities contained in the leaves will not be remobilized towards the fruits. All calcium found in the fruit reaches it through the xylem.

The peak of calcium absorption takes place during the vegetative stage, and absorption generally decreases during fruiting. Furthermore, flowers contain a significant amount of calcium, but from fruit set, the concentration decreases rapidly, probably due to the influx of photosynthates to the fruits. The concentration of calcium in the leaves, however, remains constant during the fruit development and ripening. Calcium deficiency occurs first in the apical meristems and young leaves because of the low mobility of calcium. Deficient leaves are chlorotic, and at later stages, they show signs of necrosis at the margins. Temporary calcium deficiencies can occur when the levels of this element in the xylem are low, due to the reduction in the rate of transpiration caused by high relative humidity, cloudy days or low water availability. Exogenous application of calcium will help prevent deficiency but it will not serve a corrective measure.

6. Magnesium (Mg)

Magnesium is absorbed and accumulated by plants in amounts less than for calcium or potassium but similar to those of phosphorus and sulfur. It plays an important role in the regulation of cellular pH and the anion-cation balance. Undoubtedly, the most important function of magnesium is as a constituent element of chlorophyll that intervenes in carbohydrate synthesis. It has an important role to play in energy metabolism (photosynthesis, glycolysis, Krebs cycle), since magnesium ions are crucial in the phosphorylation of protein kinases. Adequate levels of magnesium will increase the intensity in the green color of leaves and contribute to increase the performance of the plant (increased photosynthetic activity in the leaves). In addition, good levels of magnesium will improve the accumulation of reserves for next season

Application of magnesium is recommended when the concentration of this element in the soil is less than 1 meq/100 g. In such cases, an application of around 50 kg magnesium (Mg) per hectare is recommended. Magnesium deficiency can occur in light, acidic soils that are prone to leaching or in soils that have received high rates of potassium fertilizers. Deficiency generally shows up as internerval necrosis in the older leaves.

NUTRITIONAL REQUIREMENTS OF STRAWBERRY

	TOTAL	VEGETATIVE GROWTH	FLOWERING	FRUIT DEVELOPMENT	RIPENING
	kg/ha	%			
N	90 - 180	40	30	20	10
P_2O_5	55 - 110	40	25	25	10
K_2O	140 - 280	10	20	35	35
SO_3	45 - 90	20	20	30	30
CaO	40 - 75	25	25	25	25
MgO	20 - 45	25	25	25	25

FROM 1ST TO 3RD YEAR

APPLIED DURING VEGETATIVE GROWTH

	TOTAL
	kg/ha
N	40
P_2O_5	30
K_2O	-
SO_3	50*
CaO	-
MgO	-

NUTRITIONAL REQUIREMENTS OF BLUEBERRY (FROM THE 3RD YEAR ONWARDS)

	TOTAL	VEGETATIVE GROWTH	FLOWERING	FRUIT SET	FRUIT FORMATION	RIPENING
	kg/ha	%				
N	50 - 100	20	25	25	15	15
P_2O_5	25 - 50	14	20	26	24	16
K_2O	100 - 200	15	20	25	25	15
SO_3	45 - 90	15	20	25	25	15
CaO	5 - 10	15	20	20	30	15
MgO	20 - 40	15	20	20	30	15

*Sulfur is added to decrease soil pH- quantity indicated is based on a loamy soil with initial pH of 5 (see table on page 4)

NUTRITIONAL REQUIREMENTS OF RASPBERRY

	TOTAL	VEGETATIVE GROWTH	FLOWERING	FRUIT DEVELOPMENT	RIPENING	POST HARVEST (PRUNING/DEFOLIATION)
	kg/ha	%				
N	80 - 120	15	20	25	25	15
P_2O_5	60 - 90	20	20	20	15	25
K_2O	120 - 180	15	25	30	30	0
SO_3	50 - 75	15	20	25	30	10
CaO	80 - 120	10	20	30	40	0
MgO	20 - 40	25	25	25	25	0

NUTRITIONAL REQUIREMENTS OF BLACKBERRY

	TOTAL	VEGETATIVE GROWTH	FLOWERING	FRUIT DEVELOPMENT	RIPENING	POST HARVEST (PRUNING/DEFOLIATION)
	kg/ha	%				
N	80 - 100	50	30	5	5	10
P_2O_5	80 - 100	35	35	15	5	10
K_2O	100 - 150	25	25	25	25	0
SO_3	50 - 75	15	20	25	30	10
CaO	30 - 45	25	25	25	25	0
MgO	45 - 65	50	20	15	15	0

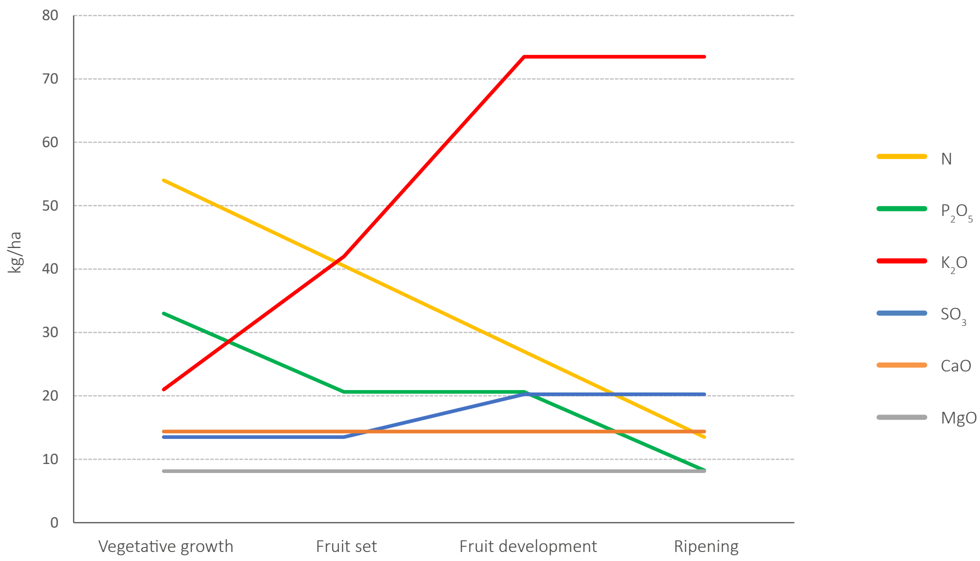
ABSORPTION OF NUTRIENTS

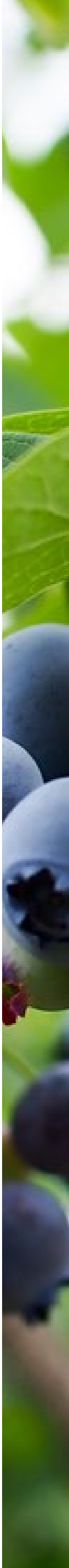
Small fruits require a continuous supply of N and Ca for growth and 50 % of nitrogen eventually accumulates in the fruit. Excessive amounts in the leaf, and available at later stages, can soften the fruit and delay ripening. Best practice is to ensure regular applications throughout the growing season.

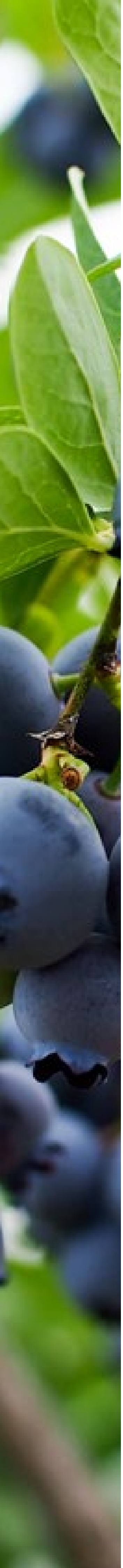
Phosphorus is important at early stages of crop development to ensure good rooting and leaf growth. During fruit development, the P concentration in other plant organs decreases, indicating a redistribution of P to the fruits with around 40 % of total uptake ending up in the berry.

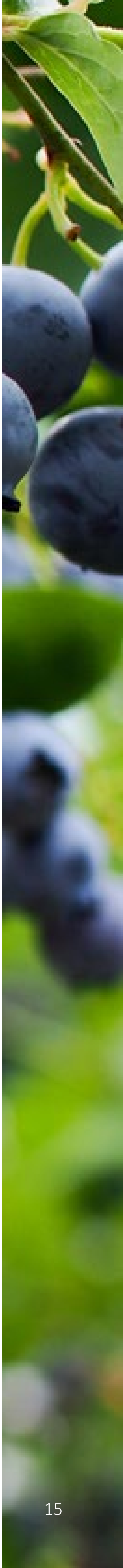
Potassium is needed in large quantities - at levels above those of nitrogen. Almost 60 % of the potassium is found in the fruit at harvest. Peak K demand is from early fruit formation through to maturity, when uptake is faster than for any other nutrient.

Nutrition uptake curve of strawberry

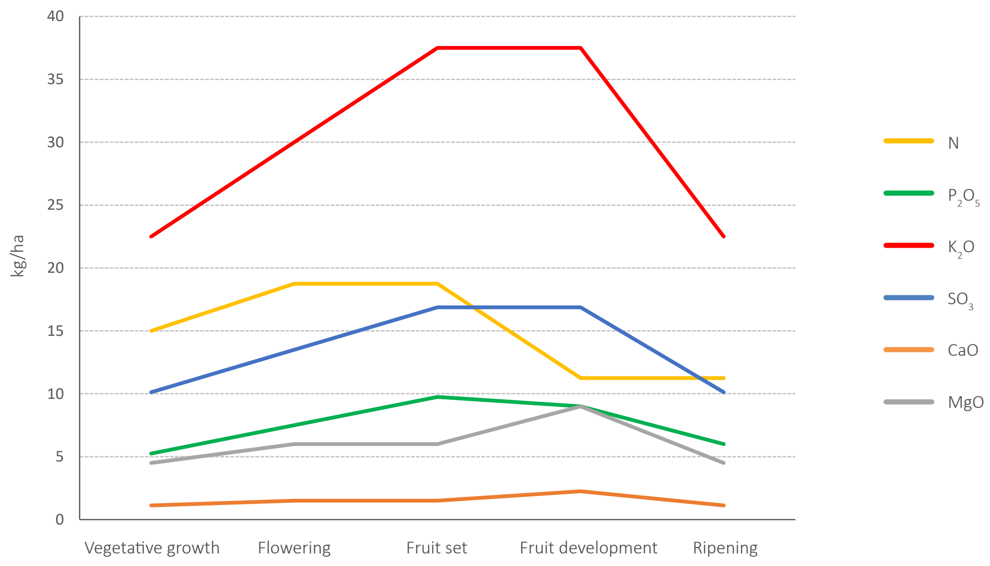




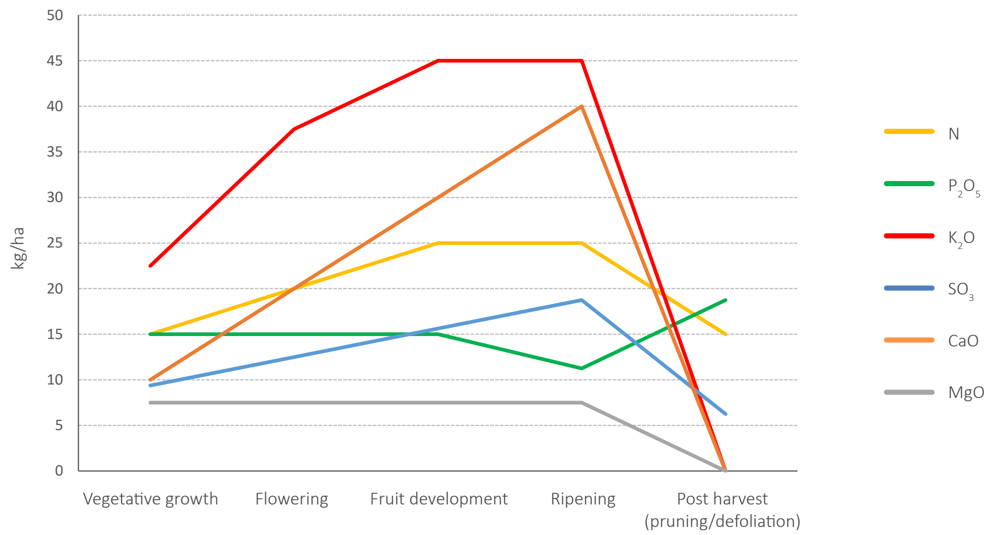




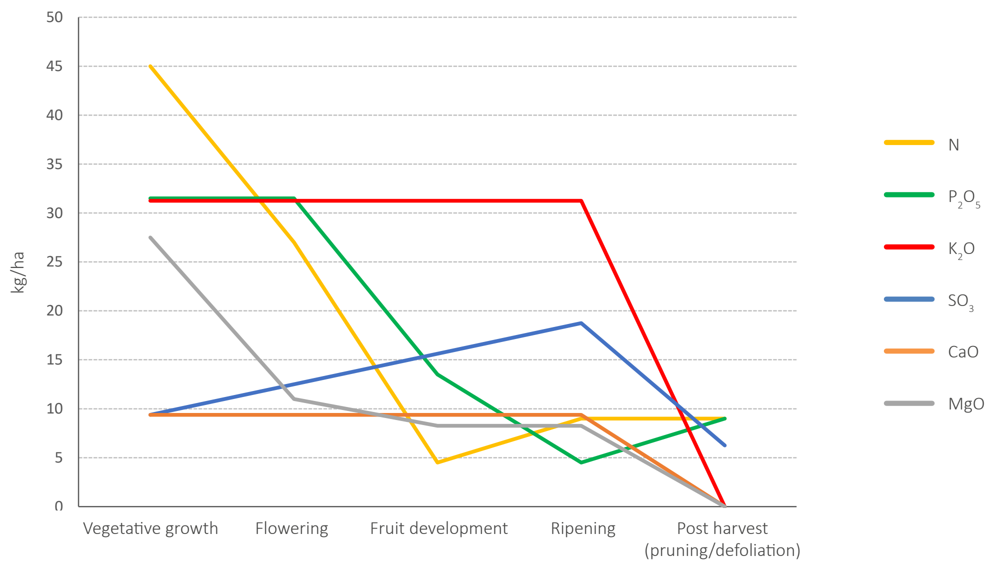
Nutrition uptake curve of blueberry



Nutrition uptake curve of raspberry



Nutrition uptake curve of blackberry



PRODUCTS

TESSENDERLO KERLEY FERTILIZERS

PRODUCTS	VEGETATIVE GROWTH	FLOWERING	FRUIT SET	RIPENING
Thio-Sul	Fertigation / Soil application liquids	Fertigation	Fertigation	Fertigation
KTS	Fertigation / Soil application liquids	Fertigation	Fertigation	Fertigation
CaTs	Fertigation / Soil application liquids	Fertigation / Foliar application	Fertigation / Foliar application	Fertigation / Foliar application
K-Leaf		Foliar application	Foliar application	Foliar application
SoluPotasse	Fertigation	Fertigation	Fertigation	Fertigation
GranuPotasse	Soil application granules			

Legend:

Foliar application

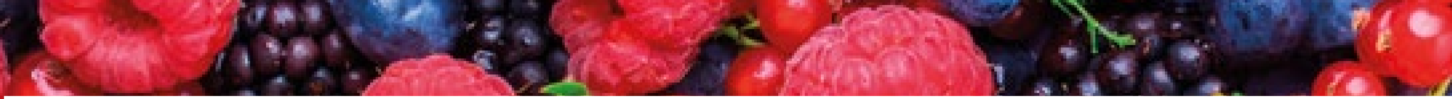
Soil application granules

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 application (side dressing) - injection and surface banding	55 to 110 l/ha	Apply during vegetative growth	If injection applications are made close to the row (less than 30 cm), reduce application rate by approximately half (25 to 50 l/ha). Avoid root pruning when injecting.
Fertigation (flood and in-furrow)	45 to 90 l/ha	Apply as needed during the growing season	
Fertigation (sprinkler/pivot)	10 to 30 l/ha	Wait until the crop is at the 3rd or 4th leaf stage	Repeat as needed every 7 to 14 days.
Fertigation (drippers and mini-sprinklers)	10 to 20 l/ha	Wait until the crop is at the 3rd or 4th leaf stage	Apply with full irrigation. Repeat application, as needed, every 7 to 10 days

Application of Thio-sul should be followed by 1 to 2 hours additional irrigation to reduce the possibility of crop injury. Always apply with full irrigation and avoid application at midday or with high temperatures.

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
Soil application (side dressing) - injection and surface banding	30 to 80 l/ha	Apply during vegetative growth	Apply once every two to three weeks
Fertigation (flood and in-furrow)	45 to 95 l/ha	Beginning at the 3rd-4th leaf stage	Apply once every two to three weeks
Fertigation (sprinkler/pivot)	30 to 55 l/ha	Beginning at the 3rd-4th leaf stage	Apply every 7 to 10 days
Fertigation (drippers and mini-sprinklers)	10 to 50 l/h	After plants are well established	Apply once every 10 days but no more than 3 times per month Application should be during second third of watering

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 application (side dressing) - injection and surface banding	50 to 150 l/ha	Apply as needed either at the beginning of the growth cycle or after harvest	
Fertigation (flood and in-furrow)	50 to 140 l/ha	Apply as needed during the growing season	
Fertigation (sprinkler/pivot)	45 to 95 l/ha	Repeat applications as required during the season	Allow 7 to 8 days between applications
Fertigation (drippers and mini-sprinklers)	15 to 25 l/ha 30 to 45 l/ha	Vegetative growth to flowering Flowering onwards	Allow 15 days between applications Allow 7 days between applications Apply 4 to 5 times in total during the growing season as required
Foliar	5 to 10 l/ha	Up to 4 or 5 applications at 10 days intervals Repeat applications as required during the season	When blending with micronutrients and pesticides, trial blends should be conducted before beginning large scale mixing.

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	5 to 13 kg/ha	From flowering to ripening	3 applications It is not recommended to exceed a concentration of 3% of K-Leaf (w/w) 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).

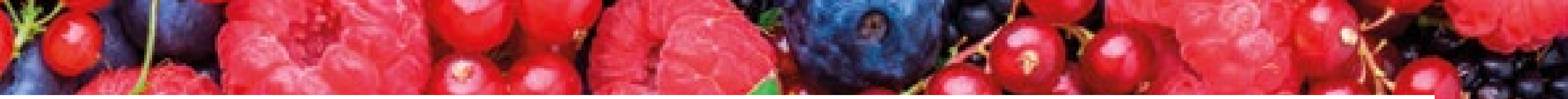
Specifications

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 (with basal dressing of potash)	15 to 30 kg/ha/week	From flowering to harvest	Assumes a basal dressing of 100-150 kg K_2O/ha before planting Based on weekly fertigation
Fertigation (without basal dressing of potash)	30 to 60 kg/ha/week	Based on weekly fertigation	



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	100 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

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 STRAWBERRY BASED ON NUTRIENT REQUIREMENTS					
	TOTAL	VEGETATIVE GROWTH	FLOWERING	FRUIT DEVELOPMENT	RIPENING
Nitrogen (kg N/ha)	90 - 180	35 - 70	25 - 55	20 - 35	10 - 20
Phosphorus (kg P_2O_5/ha)	55 - 110	25 - 45	15 - 30	10 - 25	5 - 10
Potassium (kg K_2O/ha)	140 - 280	15 - 25	25 - 55	50 - 100	50 - 100
Sulfur (kg SO_3/ha)	45 - 90	10 - 20	10 - 20	15 - 25	10 - 25
Calcium (kg CaO/ha)	40 - 75	10 - 15	10 - 20	10 - 20	10 - 20
Magnesium (kg MgO/ha)	20 - 45	5 - 10	5 - 10	5 - 15	5 - 10

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

FERTIGATION RECOMMENDATIONS FOR STRAWBERRY				
	VEGETATIVE GROWTH	FLOWERING	FRUIT DEVELOPMENT	RIPENING
LIQUIDS (doses per week during the period indicated)				
Thio-Sul (l/ha)	5 - 10	5 - 10	15 - 20	5 - 10
KTS (l/ha)	10 - 20	20 - 40	20 - 40	20 - 40
CaTs (l/ha)	15 - 25	30 - 45	30 - 45	30 - 45
WATER SOLUBLES (doses per week during the period indicated)				
SoluPotasse (kg/ha)	10 - 25	15 - 30	15 - 30	15 - 30

FERTILIZATION FOR BLUEBERRY BASED ON NUTRIENT REQUIREMENTS						
	TOTAL	VEGETATIVE GROWTH	FLOWERING	FRUIT SET	FRUIT DEVELOPMENT	RIPENING
Nitrogen (kg N/ha)	50 - 100	10 - 15	10 - 20	10 - 25	15 - 25	5 - 15
Phosphorus (kg P_2O_5/ha)	25 - 50	5	5 - 10	5 - 15	5 - 15	5
Potassium (kg K_2O/ha)	100 - 200	15 - 30	20 - 40	25 - 50	25 - 50	15 - 30
Sulfur (kg SO_3/ha)	45 - 90	5 - 15	10 - 15	15 - 25	10 - 20	5 - 15
Calcium (kg CaO/ha)	5 - 10	1-2	1 - 2	1 - 2	1 - 2	1 - 2
Magnesium (kg MgO/ha)	20 - 40	5	5 - 10	5 - 10	5 - 10	0 - 5

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

FERTIGATION RECOMMENDATIONS FOR BLUEBERRY					
	VEGETATIVE GROWTH	FLOWERING	FRUIT SET	FRUIT DEVELOPMENT	RIPENING
LIQUIDS (doses per week during the period indicated)					
Thio-Sul (l/ha)	10 - 15	15 - 20	15 - 20	15 - 20	10 - 15
KTS (l/ha)	10 - 20	20 - 40	20 - 40	20 - 40	10 - 20
CaTs (l/ha)	5 - 10	10 - 15	10 - 15	10 - 15	10 - 15
WATER SOLUBLES (doses per week during the period indicated)					
SoluPotasse (kg/ha)	5 - 10	10 - 15	10 - 15	10 - 15	10 - 15

FERTILIZATION FOR RASPBERRY BASED ON NUTRIENT REQUIREMENTS						
	TOTAL	VEGETATIVE GROWTH	FLOWERING	FRUIT DEVELOPMENT	RIPENING & HARVEST	POST HARVEST PRUNING/DEFOLIATION
Nitrogen (kg N/ha)	80 - 120	15 - 20	15 - 25	20 - 30	20 - 30	10 - 15
Phosphorus (kg P_2O_5/ha)	60 - 90	15 - 20	10 - 15	10 - 15	10 - 15	15 - 25
Potassium (kg K_2O/ha)	120 - 180	20 - 25	30 - 45	35 - 55	35 - 55	0
Sulfur (kg SO_3/ha)	50 - 75	5 - 10	10 - 15	15 - 20	15 - 20	5 - 10
Calcium (kg CaO/ha)	80 - 120	10 - 15	15 - 25	25 - 35	30 - 45	0
Magnesium (kg MgO/ha)	20 - 40	5 - 10	5 - 10	5 - 10	5 - 10	0

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

FERTIGATION RECOMMENDATIONS FOR RASPBERRY					
	VEGETATIVE GROWTH	FLOWERING	FRUIT DEVELOPMENT	RIPENING & HARVEST	POST HARVEST PRUNING/DEFOLIATION
LIQUIDS (doses per week during the period indicated)					
KTS (l/ha)	10 - 15	15 - 20	20 - 30	20 - 30	5 - 10
CaTs (l/ha)	5 - 10	5 - 0	10 - 15	20 - 25	5
WATER SOLUBLES (doses per week during the period indicated)					
SoluPotasse (kg/ha)	5 - 10	5 - 10	10 - 15	10 - 15	0

FERTILIZATION FOR BLACKBERRY BASED ON NUTRIENT REQUIREMENTS						
	TOTAL	VEGETATIVE GROWTH	FLOWERING	FRUIT DEVELOPMENT	RIPENING & HARVEST	POST HARVEST PRUNING/DEFOLIATION
Nitrogen (kg N/ha)	80 - 100	40 - 50	0	0	0	40 - 50
Phosphorus (kg P_2O_5/ha)	80 - 100	60 - 75	0	0	0	20 - 25
Potassium (kg K_2O/ha)	100 - 150	25 - 35	25 - 35	25 - 40	25 - 40	0
Sulfur (kg SO_3/ha)	50 - 75	10 - 15	10 - 15	15 - 20	15 - 20	0 - 5
Calcium (kg CaO/ha)	30 - 45	5	5 - 10	10 - 15	10 - 15	0
Magnesium (kg MgO/ha)	45 - 65	25 - 30	10 - 15	5 - 10	5 - 10	0

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

FERTIGATION RECOMMENDATIONS FOR BLACKBERRY					
	VEGETATIVE GROWTH	FLOWERING	FRUIT DEVELOPMENT	RIPENING & HARVEST	POST HARVEST PRUNING/DEFOLIATION
LIQUIDS (doses per week during the period indicated)					
KTS (l/ha)	5 - 10	15 - 20	20 - 25	20 - 25	0
CaTs (l/ha)	5 - 10	10 - 15	25	25	0
Thio-Sul (l/ha)	10 - 15	15 - 20	10 - 15	0	5
WATER SOLUBLES (doses per week during the period indicated)					
SoluPotasse (kg/ha)	5 - 10	5 - 10	5 - 10	5 - 10	0

GranuPotasse, as a solid fertilizer, can be applied on soil as a potassium and sulfur source. Foliar sprays of K-Leaf potash booster can also complement fertigation.

FERTILIZATION OF OTHER SMALL FRUITS

For detailed advice on how to adapt our recommendations to other small fruits and berries, such as redcurrants, blackcurrants, cranberries and gooseberries, please speak to your Tessenderlo Kerley International agronomist.

FERTILIZATION OF SMALL FRUITS GROWN UNDERCOVER IN SUBSTRATE

The main berries grown in substrate are blueberry and strawberry. There are also some raspberry and red currants but these are relatively small amounts. The yield of strawberry cultivated in a greenhouse would be 12 kg/m² which is higher than yields in tunnels due to difference of temperature. Yield of blueberry is around 1.6 kg/m² when cultivated in a greenhouse. Since fertilizers are continuously applied by drip irritation in greenhouses, growers often prefer to refer to the amount of fertilizer per 1000 liter tank (which corresponds to 100,000 liters of fertigation solution, assuming a dilution of 1%).

For detailed advice on how to adapt our recommendations to small fruits grown undercover and in substrates or hydroponic conditions speak to your Tessenderlo Kerley International expert.

GUIDELINES

General

- Do not apply products to crops that are sensitive to the effects of sulfur.
- Use the correct type of spray nozzles 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 stone fruit 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.
- Do not apply 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.

- 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.

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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