Controlled Release Nutrition for

Strawberries

Haifa Chemicals Ltd.
Pioneering the Future

Controlled Release Nutrition for

Strawberries

(Fragaria x ananassa Duch.)
French: Fraisier; Spanish: Fresón; Italian: Fragola; German: Erdbeere

ROSACEAE, Rose Family

Contents:

1. Crop data

Fragaria x ananassa, with large fruit (10-40 g), is by far the most important cultivated species, but other species (e.g. *Fragaria vesca*, with small but better flavored fruits), may also be grown. Perennial but, as a crop, more frequently exploited for one year.
It is a typical rosette plant; the petiolate leaves and the inflorescence stalk originate from the short stem, rich in brownish scales (crown). Some axillary buds can develop into branches with long internodes (stolons) which produce a new leaf rosette and adventitious roots at the nodes. The stolons are used for propagation.

1.1 Root system

The root system is mainly located in the upper 20 cm soil layer.

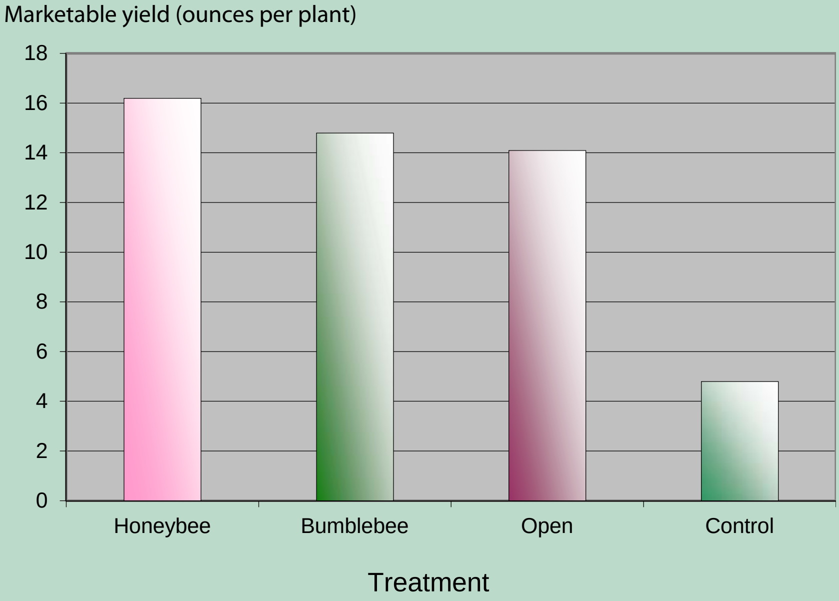
1.2 Flowers and fruits

Flowers and fruits are produced on a stalk that emerges from an axillary bud. Each flower is subtended by bracts and has five or more green sepals, five separate white petals, numerous stamens, and a domed receptacle (called a torus) that bears an indefinite number of pistils. The pistil (ovary plus style and stigma) develops into a one-seeded, dry fruit, called an achene; the achene is the hard structure found embedded on the fleshy receptacle, which becomes greatly enlarged. Therefore, this edible "fruit" is actually an aggregate fruit, which describes the situation in which two or more separate fruits (here, the numerous achenes) are formed within a single flower (here, borne on a fleshy receptacle of that flower).

1.3 Pollination

Strawberry flowers require some type of assistance to move pollen from the anthers to stigma. Bumblebees provide good pollination for strawberry plants. They perform much better than honeybees or hand pollination.

Figure 1: Evaluation of pollinators for high tunnel strawberry production.



1.4 Cultivars

Strawberry cultivars vary remarkably in size, color, flavor, shape, and degree of fertility, season of ripening, liability to disease and constitution of plant. Some vary in foliage, and some vary materially in the relative development of their sexual organs. In most cases the flowers appear hermaphroditic in structure, but function as either male or female.

Strawberries actually occur in three basic flowering habits: short day, long day, and day neutral. These refer to the day length sensitivity of the plant and the type of photoperiod which induces flower formation. Day neutral cultivars produce flowers regardless of the photoperiod.

In the Mediterranean area, short day cultivars are planted in summer or autumn; flowering occurs in winter and spring; harvest starts in spring.

Figure 2: *Fragaria* × *ananassa* 'Chandler,' a short-day commercial cultivar grown in California

2. Growing models

For purposes of commercial production, plants are propagated from runners and generally distributed as either bare root plants or plugs. Cultivation follows one of two general models, annual plasticulture or a perennial system of matted rows or mounds. A small amount of strawberries are also produced in greenhouses during the off season.
Fields using the plasticulture method – white and black plastic mulch.

Figure 3: Open-field grown strawberries on black plastic mulch.

Figure 4: Open-field grown strawberries on white plastic mulch.

2.1 Plasticulture system

The bulk of modern commercial production uses the plasticulture system. In this method, raised beds are formed each year, fumigated, and covered with plastic, which prevents weed growth and erosion, under which is run irrigation tubing. Plants are planted through holes punched in this covering. Runners are removed from the plants as they appear, to encourage the plants to put most of their energy into fruit development. At the end of the harvest season, the plastic is removed and the plants are plowed into the ground. However, because it requires a longer growing season to allow for establishment of the plants each year, and because of the increased costs in terms of forming and covering the mounds and purchasing plants each year, it is not always practical in all areas.

2.2 Perennial system

The other major method, which uses the same plants from year to year growing in rows or on mounds, is most common in colder climates. It has lower investment costs, and lower overall maintenance requirements. Yields are typically lower than in plasticulture.

2.3 Harvesting

The harvesting and cleaning process has not changed substantially over time. The delicate strawberries are still harvested by hand. Grading and packing often occurs in the field, rather than in a processing facility. In large operations, strawberries are cleaned by means of water streams and shaking conveyor belts.

3. Monitoring Nutrients

3.1 Leaf and petiole analyses

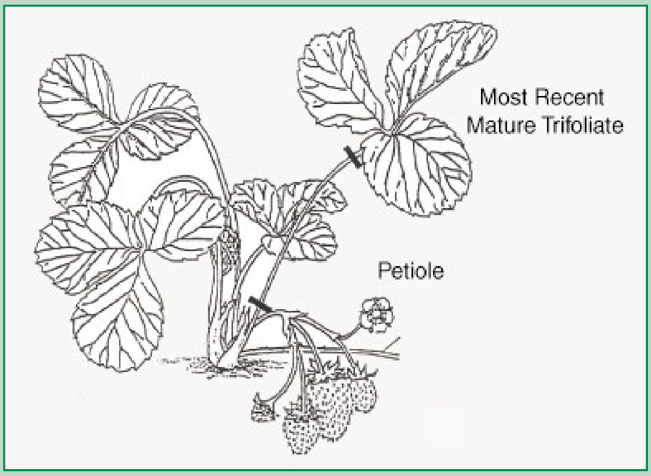
Leaf and petiole analyses provide the best means of monitoring nutritional status and correcting deficiencies that may occur. They not only ensure that yield and quality are optimized but protect against applying excess nutrients in the environment and incurring unnecessary expense. The most recent mature trifoliate is the best indicator of the status of most elements essential for plant growth. These include the major elements P and K, the secondary elements Ca, Mg, and S, and the micronutrients Fe, Zn, Cu, and B. The petiole from this same trifoliate is the best indicator of N status.

3.2 Sampling

Two approaches are used for tissue testing of a strawberry crop:

1. Analyzing the petiole through the season, in particular to monitor the nitrogen status.
2. Leaf blade analysis at fruiting, to evaluate the status of all plant essential nutrients.

Figure 5: Proper leaf and petiole sampling parts



Varieties differ in their ability to utilize nitrogen, primarily because of differences in growth habits, fruit production and foraging power of the roots for soil nitrogen. Consequently, different varieties should be sampled separately.

3.2.1 Blade

Sampling Time:	During fruiting, preferably at first harvest
Plant Part:	Leaf blades (excluding petioles)
Collect From:	Youngest mature leaves
Quantity per Sample:	30-50
Comments:	Deficiencies are more likely to arise during fruiting, when substantial nutrient uptake is occurring.

3.2.2 Petioles

Sampling Time: Through the growing season
Plant Part: Petioles
Collect From: Youngest matured leaves
Quantity per Sample: 50

Comments: Petiole analysis is recommended for monitoring the status of nitrogen, which is a key nutrient in strawberry production
It can also be useful to analyze the petioles for P, K, Mg and Cl.
Approximately 50 youngest mature leaves should be selected at random throughout the area and separated from their petioles. Nutrient concentrations are listed in Table 1.

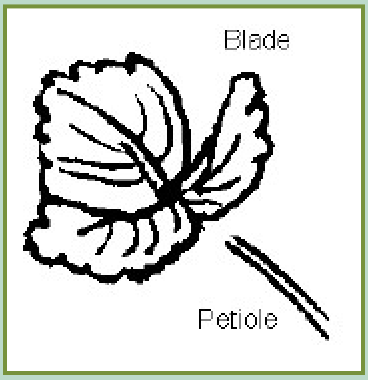


Table 1: Standard concentrations for foliar analysis of strawberries.

Element	Deficient	Optimum	Excess
Macronutrients (%)			
Nitrogen	< 2.0	2.6 - 3.5	-
Phosphorus	< 0.20	0.25 - 0.35	-
Potassium	< 1.0	1.0 - 2.0	-
Calcium	< 0.5	0.7 - 1.5	-
Magnesium	< 0.10	0.25 - 0.40	-
Sulphur	< 0.10	0.15 - 0.35	-
Sodium	< 0.01	0.02 -0.10	> 0.10
Chloride	-	-	> 0.50
Micronutrients (ppm)			
Manganese	< 20	200 - 500	-
Iron	-	100 - 200	-
Zinc	< 15	30 - 80	-
Copper	-	5 - 12	-
Boron	< 20	30 - 100	> 250

Analysis of Petioles and Leaves

Leaf analysis provides N-P-K concentrations in the plant, while petiole analysis provides the state of the nitrate not yet assimilated. Petiole analysis is more sensitive to changes in soil nitrate, while leaf analysis gives the nutritional state of the plant. Petiole analysis will also be affected by changes in temperature, solar radiation and soil moisture.

3.3 Soil Testing

Sampling Time: Prior to crop establishment
Core Depth: 15 cm
Collect From: From the rooting zone of the plants
Quantity per Sample: 12 - 20 cores

Comments: Separate samples should be taken from blocks that differ in age, cultivar types, vine performance, soil types, topography, and fertilizer history.

If trying to diagnose a problem with crop growth and yield, samples should be collected from the rooting zones of the worst affected plants. In these circumstances, a second sample taken for comparative purposes from the rooting zones of normal plants may be useful.

Table 2: The desirable N, P and K levels in sampled soil solution and required daily N

	Nitrogen	Phosphorus	Potassium
	1.5-2.5 kg N/ha/day		
Soil solution	Nitrate-N 20-30 ppm all times	P kept at 20-30 ppm (Olsen)	K kept at 1-2 mEq/liter

3.4 Time of sampling

Both leaf and soil samples should be taken in the fall if questions arise concerning plant establishment vegetative growth and crown development. The best procedure is to take leaf samples from good and bad plants for comparison. A soil core should be taken from the root zones of plants sampled in each of these respective areas.
Spring sampling for monitoring should when spring growth begins, and continue at two-week intervals throughout the growing season. A total of 6-8 samples should be taken in each field during the growing season.

3.5 Best Indicator Sample

The most recent mature trifoliate and the associated petioles are the best indicators of nutritional status. This is the trifoliate that is fully expanded but is not dull from age nor slick with a light green sheen associated with immaturity.

3.6 Plant analysis data

A concentration in the petioles in the range 3000-10000 ppm nitrate N (on a dry matter basis) indicates an optimal nutritional status.
Strawberries grow well in soils with a pH range between 5.3-6.5. A pH around 6.5 is best with sandy textured soils whereas for finer textured soils a pH closer to 5.3 is preferable. Soil pH has a strong influence on nutrient availability, and should be regularly monitored and corrected as needed. A low pH or acid soil will have reduced availability of nitrogen, phosphorus, potassium, magnesium and molybdenum, while a high pH or alkaline soil will have reduced availability of zinc, boron, iron, manganese, and copper.

Table 3: Desirable Range of pH and Organic Matter from Soil Test for Strawberries.

pH	5.8 to 6.5
Organic Matter	2 to 3%

3.7 The role of plant nutrients

3.7.1 Nitrogen (N)

Nitrogen is an essential component in the synthesis of amino acids and proteins in the plant. As a fertilizer, it stimulates vegetative growth, such as leaves, petioles and shoots. Heavy applications are not recommended because excess vegetative growth as it will result in dense leaf canopy that will cover developing fruit and encouraging the development fruit rot such as gray mold.

3.7.2 Phosphorus (P)

Phosphorus is important in order for the plants to store energy, and plays a role in fruit development. It is often present in adequate amounts for good strawberry growth, but much of it is not readily available to the plants because it gets tied up in both the mineral and organic fractions of the soil. As a result, it does not tend to move through the soil or leach very easily.

Strawberries don't have a very high phosphorus demand. Availability is reduced if the soil pH is too low, or other nutrients, such as calcium are out of balance. Soil tests should read 20 to 30 ppm for optimal phosphorus uptake.

3.7.3 Potassium (K)

Potassium is an important component of strawberry fruit and helps the plants regulate water movement and enzymatic reactions. Potassium may compete with magnesium for uptake by the roots and must therefore be kept in an appropriate ratio (4:1, K: Mg) in the soil to prevent one of these nutrients from overriding the other and creating a deficiency.

3.7.4 Calcium (Ca)

Calcium is the first of what are known as the "secondary" nutrients needed by the plant. Levels of calcium are usually adequate in the soil if the pH is in the appropriate range (6.0-6.2). Soils with a low pH may become calcium deficient. Soil test levels of 1000 to 1500 ppm being optimal. Calcium is essential for building cell walls and membranes in the plant. It is not very mobile in the soil, or in the plant tissue. It should be worked into the soil to improve uptake.

3.7.5 Magnesium (Mg)

Magnesium soil test levels of 120-180 ppm should provide optimal growth for strawberries. Availability of magnesium is reduced under low soil pH. Potassium can compete with magnesium for root uptake, and should therefore be kept in an appropriate balance (4:1, K: Mg) to prevent one from causing a deficiency of the other.

3.7.6 Micro-nutrients

The most important micro-nutrients in terms of strawberries include boron (B) and zinc (Zn). Others include iron, manganese, copper and molybdenum.

Boron (B) is essential for good root growth and pollination of the flowers. It is easily leached from the soil. Although boron is often recommended as a nutrient supplement for strawberries, excessive levels can be toxic to the plants, so care must be taken to make sure that the plant has enough, but never too much.

Zinc (Zn), although needed in very small amounts by strawberry plants, is very important in biochemical processes and fruit development. Zinc in the soil is more available to plants under low pH conditions. Heavy applications of lime and/or phosphorus can reduce the availability of zinc to the plants. The optimal level of zinc in leaf tissue is 35 ppm.

3.8 Nutritional Disorders

The most likely disorders encountered in strawberry production are deficiencies involving K, P, Mg and N. The first symptoms of **K deficiency** (K <1.0%) appear on the upper leaf margins of the older leaves. The serration tips redden, the injury gradually progressing inwards between the veins until most of the leaf blade is affected. This is accompanied almost simultaneously by a symptom which appears to be unique to strawberries. The rachis (extension of the petiole to the central leaflet) darkens and dehydrates. The blade area either side of this tissue is similarly affected. Few runners are produced on K deficient plants. Those that are tend to be short and thin with few plants. Fruit are insipid, colorless, and pulpy.

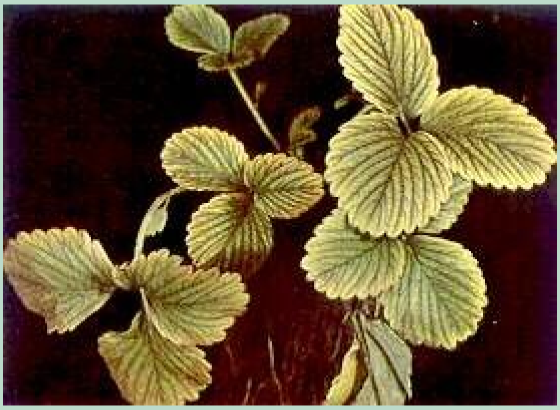
P deficiency (P <0.1%) can be recognized by the dark green colour and black metallic-like sheen on the upper surface of leaves. The lower leaf surfaces may develop a reddish-purple tint which becomes evident on the upper surface of some varieties as the leaves become older.

Symptoms of **Mg deficiency** (Mg <0.1%) are similar to those for other crop species; tissue in the interveinal regions of older leaves which has an initial chlorosis eventually becomes necrotic as the deficiency progresses. In some instances, a marginal scorch forming a halo pattern can be observed near the base of the serrations on the older leaves.

Plants with mild **N deficiency** (N <2.0%) have small chlorotic older leaves. More severe deficiencies cause shortening of the petioles, which turn red and become brittle. Frequently, as the leaves and fruit age, they also become reddish, the leaves particularly.

Figure 6: Manganese deficiency somewhat faint intervenal chlorosis beginning at margins and progressing towards midrib; where severe, chlorotic areas yellowish appearance

Figure 7: Iron deficiency, leaves severe chlorosis; green network of fine veins distinct in early stages.



4. Controlled release nutrition of Strawberries

4.1 Multicote™ Agri Controlled Release Fertilizers

Multicote™ Agri is a controlled-release fertilizer, designed to release available nutrients to the soil solution slowly and continuously over months. **Multicote™ Agri** is based on polymer-coated fertilizer granules. Following application, the granules start absorbing soil moisture that dissolves the urea inside the granules. The dissolved urea then diffuses, slowly and continuously, into the root zone.
The release rate depends upon and is dictated solely by the soil temperature. The release rate increases as temperature rises, just as happens with plant uptake rates.
Other factors, such as soil type, humidity, pH, and microbial activity do not affect the release rate.
Multicote™ Agri products also contain non-coated, readily available nutrients, for establishment and initial growth.

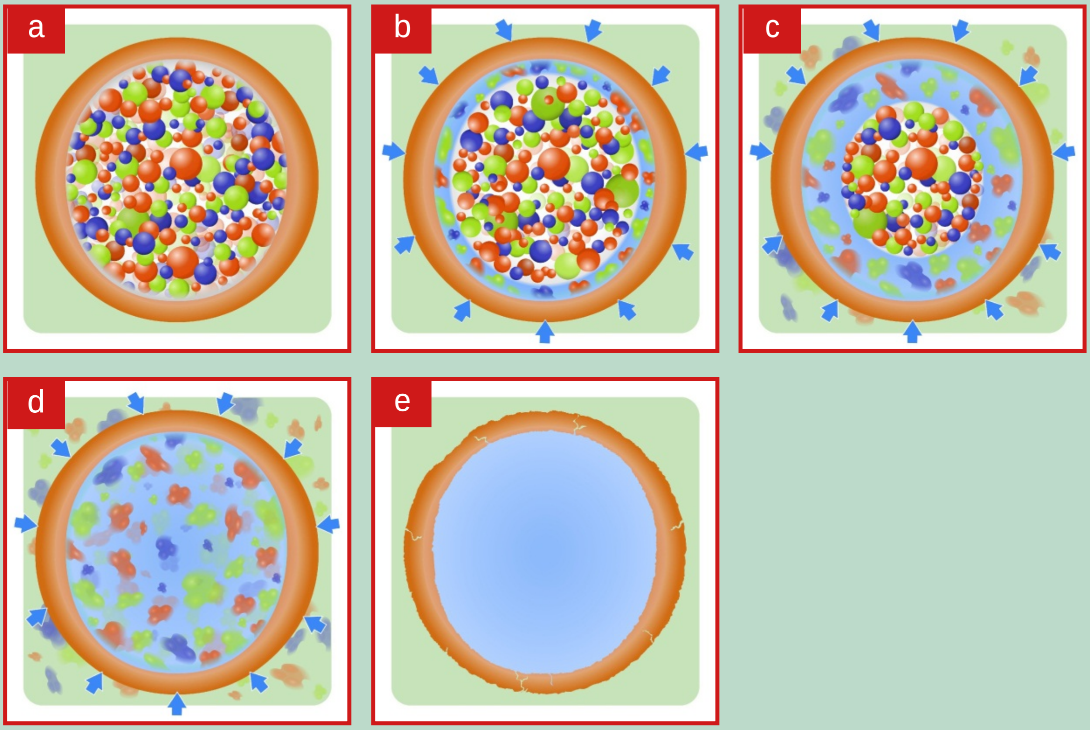
4.1.1 The advantages of Multicote™ Agri

- Nutrients are supplied in accordance with plant needs, for optimal development and best yields
- Single application per season – which results in a drastic reduction of field labor and application costs, as well as considerably less soil compaction
- Minimized losses through leaching, volatilization or fixation in the soil
  - Availability of nutrients throughout the growth cycle is ensured
  - More efficient use of fertilizers without wastage enables reduced application rates
  - Ecologically superior (no soil or air pollution)

4.1.2 Multicote™ Agri release mechanism

Multicote™ Agri is based on polymer-coated fertilizer granules. During the production process, water-soluble nutrients are encapsulated in a polymeric shell. This shell prevents the immediate dissolution of the fertilizer when applied to the soil. The thickness of the shell determines the longevity of nutrients release (Fig. 8a).
Following application, soil moisture slowly penetrates through the coating. This moisture starts a gradual dissolution of the nutrients inside the granule (Fig. 8b).
The dissolved nutrients diffuse through the coating to the root zone, providing the plant with available nutrients at measured portions – according to its growth needs (Fig. 8c).
The rate of diffusion – the actual release rate depends upon and is dictated solely by the soil temperature. The release rate increases as temperature rises, just as happens with plant uptake rates.
Other factors, such as soil type, humidity, pH, and microbial activity do not affect the release rate.
While nutrients are released to the root zone, further penetration of moisture dissolves more of the solid fertilizer. At a certain stage, the entire content of the granule is dissolved, ready for diffusion and release. From this stage the release rate slows down (Fig. 8d).
After the release is complete, the empty shell ruptures and degrades, leaving no residues in the soil (Fig. 8e).

Figure 8 a-e: Multicote™ Agri release mechanism



4.2 Multicote™ Agri for strawberries

Haifa offers strawberry growers worldwide **Multicote™ Agri** formulae specially tailored to suit local cultivars and growth conditions. **Multicote™ Agri** products are based on polymer-coated, controlled release fertilizers, designed to release plant nutrients steadily and continuously throughout the growth season. **Multicote™ Agri** formulae for strawberry may consist of either 100% polymer coated fertilizer granules, or, for cost saving reasons and/or to meet the local specific plant nutrient requirements, it may partially contain also non-coated, readily available fertilizers.
The versatile controlled release characteristics of **Multicote™ Agri** give growers the power to apply a cost effective fertilizer, a suitable product for each strawberry growth area. **Multicote™ Agri** minimizes nutrient loss, gives strawberries the right amount of nutrients, and helps strawberry growers maximize profitability.

5. Nutrient management for strawberry production

Table 4: Uptake and removal of macro-nutrients by strawberry crop

	N	P_2O_5	K_2O
Removal (kg per ton fruits)	6-10	2.5-4.0	10 or more
Uptake (kg/ha)	200-250	100-150	400

N-P_2O_5-K_2O ratio required by strawberry is about 2.5:1.0:3.5

Table 5: Maintenance fertilizer program for annual replant strawberries and estimated nutrient removal in a 30 ton/ha crop.

Element	Soil Parameters	Crop Removal (kg/ha)	
		Fruit	Plant
N	Ex pasture Replant	30	27
P	Replant; low P retentive soil Replant; high P retentive soil (volcanic ash)	5.5	4.0
K	Low P in soil, or P deficiency Replant	40	23
Mg	Low K in soil or K deficiency Replant	3.0	5.0
Ca	Low Mg in soil, Mg deficiency Ca deficiency	5	27

Factors to be taken into account:

- The root system is rather weak and shallow (70 % in the upper 7 cm soil layer), just below the surface in mulched crops;
- The plant prefers light, rather sub-acid soil (pH 5.5-6.5) and suffers from brackish water and/or soil (from both Cl and Na);

Correct practice normally involves:

- Application of 100 kg N/ha, 100 kg P_2O_5/ha and 200 kg K_2O /ha before planting
- Top-dressing with N and K_2O (50-100 kg/ha)

Nitrogen requirement on sandy soils, about 135 kg N/ha is optimum for 'Chandler' strawberry production under plastic culture. This rate of N includes reduced vegetative growth and firmer fruit without sacrificing market yield. The optimum N rate probably will vary among soils and may even be lower for heavier-textured soils.
The recommended rate for K_20 is: 135 kg/ha.

5.1 Open field - pre plant fertilizers

The texture and nutritional status of the soil influence strawberry nutritional requirements. Lighter soils tend to leach Nitrogen and Potassium more easily than medium and heavier soils. The nutritional application program must be tailored accordingly to the type of substrate.

Pre-plant Fertilization Recommendation (kg/ha)

For extensive growth conditions

N	P_2O_5	K_2O	CaO	MgO
150	150	240	120	60

Note:

Pre-plant fertilizers may be applied either as inorganic straights or as an organic based/inorganic compound.

Table 6: Recommendation for field-grown strawberries in Israel when demand is maximal

	Nitrogen	Phosphorus	Potassium
	1.5 – 2.5 kg N/ha/day		
Soil solution	Nitrate-N 20-30 ppm all times	P kept at 20-30 ppm (Olsen)	K kept at 1-2 meq/liter

5.2 Outdoor grown strawberries

Plant Population: 35000 Plants/Ha

Expected yield: 40-50 T/Ha

Recommended average rates of nutrients for outdoor grown strawberries

kg/ha		
N	P_2O_5	P_2O_5
150-200	110-130	220-250

Application of foliar sprays with iron compounds may be of use in checking negative effects caused by immobilization of Fe.

6. Worldwide fertilization practices with Multicote™ Agri

6.1 Israel

Soil type: Light texture soil

Planting time: Early to Late Fall

Growing method: Mainly plasticulture; covered with mini or high tunnels. The expected yield grown until end of May, is 70 – 75 tons/ha in the mini tunnels and 75 – 80 tons/ha in the high tunnels.

Average Yield: The average yield and fruit quality varies during the growth period as it depends on the weather (Tab. 7).

Figure 9: Mini tunnel growing method

) during the growth period

			an.	Feb.	March	April	May	Total
Export quality	0	5,000	2,000	5,000	3,000	0	0	15000
Local market	0	3,000	3,000	7,000	10,000	12000	10000	45000
Total	0	8,000	5,000	12,000	13,000	12000	10000	60000

6.1.1 Fertilization

Recommended plant nutrients for 7-8 months growth period (kg/ha)

N	P_2O_5	K_2O	CaO	MgO
220 -250	120 - 130	350 - 370	200 - 250	100 - 120

Table 8: Required plant nutrients during different growth stages (kg/ha/week)

	Nov.	Dec.	Jan.	Feb.	March
N	7.5	11	7	11 - 14.5	11
K_2O	-	17.5	11	17.5 - 21	17.5

Pre-plant fertilization:

Nitrogen, after transplanting, will be supplied with the first fertigation.
Phosphorus: Applying 500-1000kg superphosphate (46% P_2O_5)/ha. P should be kept at 20-30 ppm (Olsen)
Potassium: Applying 500 kg. potassium chloride (60% K_2O)/ha. K should be kept at 1-2 meq/liter.

Side/Top-dressing:

In order to supply the required plant nutrients, **Multicote™ Agri (6) 17-8-27** or **Multicote™ Agri (6) 15-5-30** (90%-50%-90% polymer coated), at a rate of 800 – 1000 kg/ha, will ensure a continuous plant nutrients supply in the desired ratio. This **Multicote™ Agri** application results in higher yield of a better quality fruits.

There are three application methods:
1) Banding **Multicote™ Agri** between two planted rows, next to an irrigation line.
2) Broadcasting on the bed, before planting, and incorporating with a rototiller.
3) Broadcasting after plants are established, before mulching with plastic, and incorporating with a suitable cultivator. This method is the most popular type of application.

Nutrigation™ (fertigation):

The required level of plant nutrients raise from the planting stage through flowering, fruit setup and finally; harvesting. Plants at the pick of flowering stage consume high level of nutrients for the growth of plant and fruits development, therefore, the nutrient level should be: 2-2.5 kg N, 1-1.3 kg P_2O_5 and 3-4 kg K_2O /day/ha. During the harvesting period, the demand for plant nutrients slows down (Tab. 9).

Table 9: Daily plant nutrient rates (kg/ha) during different growth periods

Growth stage	N	P_2O_5	K_2O	CaO	MgO
Planting-January	1	1	1-1.6	0.8	0.4
February	1.5	0.6	2.3	0.8	0.4
March	2-2.5	1-1.3	3-4	0.8	0.4
April-May	1.5	0.6	2.4	0.8	0.4

Nitrogen: Excessive rates of nitrogen may increase the vegetative growth and delay flowering.
Soil solution should contain 20-30 ppm of nitrate-N at all times.

When proportional Nutrigation is used, the recommended concentration in irrigated water should be:

Plant Nutrient	N	P	K	Ca	Mg
Concentration (ppm)	80-100	50-60	120-140	80	40

Nutrigation™ with **Poly-Feed™**, a water soluble fertilizer, during different growth stages will supply the recommended plant nutrient. **Poly-Feed™ 20-20-20** or **Poly-Feed™ 18-18-18** is being applied by growers at the early growing stages. When the nutritional demand during flowering and fruit-set stage increases, **Poly-Feed™ 20-2-30** and **Poly-Feed™ 17-10-27** are the most common water soluble fertilizers growers will use from this stage onward by applying a rate of 7.5 kg/day/ha.

6.2 South Africa

Soil type: Sandy, some cases sandy-loam.

Growing period: Planting in March/April (autumn)

Harvesting: from June to December

Expected yield: 40-50 tons/ha

Growing method: Multi-span tunnels and open field with mini tunnels (plastic coverings) during the winter months.

6.2.1 Fertilization

The seasonal plant nutrients requirement is about:

Plant nutrient	N	P_2O_5	K_2O
kg/ha	200	100	300

A pre-plant application of **Multicote™ Agri (6) 17-8.5-26** (80-100-100% polymer coated) @ 1100 kg/ha is made. Lime and / or Gypsum are also applied prior to soil preparation and are based on soil analysis. After planting Ca, in the form of $CaNO_3$, is applied on a continuous basis via fertigation at a rate of 40 ppm. The objective is to grow a good sized plant, not overly vegetative, that flowers continuously and sets its fruit. This is a base requirement and growers may adapt the fertigation depending on the weather and reaction of plants. The fertigation solution is adjusted during the season using soil solution and leaf analysis, as well as visual observations. Additional **Multi-K™** is applied in the final stages of the season to stretch the growing season and maintain fruit quality as long as possible. Whenever needed, **Multicote™ Agri** may contain also Mg and micronutrients.

Application method:

The fertilizer is band placed by a Monosem fertilizer applicator mounted on the ridger (Fig. 10-11).

A single band of fertilizer is placed between 2 rows of plants on each ridge. Irrigation is by means of single dripper line with a 35cm dripper-spacing.

Figure 10: **Multicote™ Agri** applied at the time of bed preparation.

Figure 11: 'Monosem' fertilizer applicator mounted on the ridger.

6.3 California, USA

Soil type: Sand/sandy loam to loamy clay soil

Growing period: Winter Berries grown froOctober to May; Summer berries grown from July to December.

Growing method: Open field, plastic mulch

6.3.1 Fertilization

A. Winter crop fertilization

Southern California - Recommended plant nutrients

kg/ha			Lbs/acre		
N	P_2O_5	K_2O	N	P_2O_5	K_2O
225	90	160	200	80	140

Expected yield: 67 ton/ha (30 ton/acre or 5000 trays per acre)

Pre-plant: applying 15-15-15 or 16-20-0 a rate of: 225-334 kg/ha (200-300 lb/acre), plus **Multicote™ Agri**: 900-1100 kg/ha (800-1000 lbs/acre), 100% polymer coated.

Northern California - Recommended plant nutrients

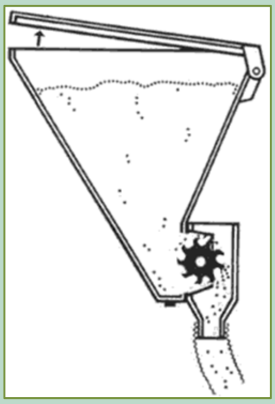
kg/ha			**Lbs/acre**		
N	**P_2O_5**	**K_2O**	**N**	**P_2O_5**	**K_2O**
110	45	70	100	40	60

Expected yield: 78 ton/ha (35 ton/acre or 5833 trays per acre)
Pre-plant: applying **Multicote™ Agri** rate of: 530 kg/ha (475 lbs/acre), 100% polymer coated.

Application method
Multicote™ Agri 22-8-13, applied in a tight band by 'Clampco' shank (Fig. 12-15), placed precisely in the fertilizer slot, at least 4 cm (1.5 inches) from the transplant roots (Fig. 16).

Figure 12: 'Clampco' Precision Applicator engineered angles that allow free flow of Multicote™ Agri

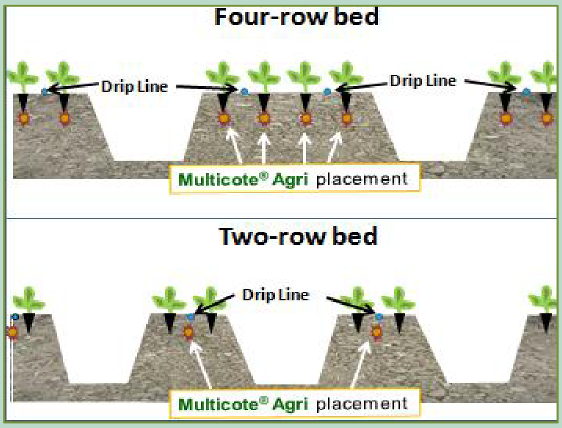
Figure 13: 'Clampco' hopper



Figures 14-15: Two-raw 'Clampco' applicator, banding **Multicote™ Agri.**

Figure 16: Multicote™ Agri field trials

Figure 17: Planting strawberry patterns and Multicote™ Agri placement.



B. Summer crop fertilization

Expected yield: 34 ton/ha (15 ton/acre).
No pre-plant fertilization.
Monthly application of CAN (15-17% N) rate: 280-470 L/ha (30-50 gal/acre).
During one and a half months after planting, also applying white phosphoric acid (75% P_2O_5) at a rate of 470 L/ha (50 gal/acre).
4 times a month, for the first two months, fertigating with liquid 4-10-10 + micronutrients, made from Multi-K™ (potassium nitrate) is a common practice. Standard rates are 4-11 kg N/application/ha (3 -10 lbs N/application/acre) or rate of 50-100 L/ha (5-10 gal/acre).
At the end of the season, 2-18-18 analysis, for juice and freezer berries, may be applied.
Liquid feed is also applied right after rain, depending on amount of rainfall.

Figure 18: Mulched strawberry in open-field

Figure 19: Drip lines under plastic mulched four-raw bed.

6.4 Mexico

6.4.1 Baja California

Soil type: Medium to light texture soils

Growing period: Transplanting - September to mid October – Harvesting till May.

Growing method: Similar to southern California; Two and four row beds covered with plastic mulch (Fig 20-21).

Fertilization: Base-dressing, similar to Californian practice. During bedding process, before transplanting, applying 800-1200 kg/ha **Multicote™ Agri (6) 22-8-13**.

Figure 20: Mulching and laying drip line

Figure 21: Plastic-mulched open field

Fruit quality:
Better quality harvested during December to February.
Local market quality harvested during March to June.

6.4.2 Inland (central part of the country)

Soil type: medium to heavy texture soils

A. Growing method: Open Field (practiced by 70% of growers)

Growth period: Start August / September – end of the harvest from April to May.

Inundation: In June, a common practice is to flood the field in order to control weeds and soil born pests (Fig. 24). The flood will continue for 1 to 3 months.

Soil preparation: In May bedding and may include base-dressing. Some growers will apply fertilizers only after transplanting in September.

Transplanting: In August and September, immediately after draining the flooded field.

Figure 22: Flooded field

Fertilization: Nutritional requirement of the plant.(Base)

kg/ha				
N	P_2O_5	K_2O	CaO	MgO
185	160	320	85	When needed

Application 1st option (traditional)
After transplanting two applications of common N-P-K fertilizers, such as: 12-11-17, 15-15-15, etc., are practiced. The 1st application takes place after 20 to 25 days and 2nd application after 60 to 65 days. Part of the required plant nutrients are applied also as base-dressing.

2nd option (advanced method)
In September/October, 20-25 days after transplanting, applying once only **Multicote™ Agri (8) 12-15-17** (30%-0%-30% polymer coated), either manually (Fig. 23) or with a mechanical applicator (Fig. 24), a rate of 500 kg/ha. This application method eliminates the need to top-dress at a later stage.

Figure 23: Multicote™ Agri application: manual

Figure 24: Multicote™ Agri application: mechanical

Fertigation: During all growing stages, strawberries will be fertigated with water soluble fertilizers.

Harvesting: Harvest is done until end of May. The highest production of best quality fruit is between February to April.

Expected yield: 45-55 MT/ha/harvest. The variability of yields depends on the variety. Strawberry harvest is done usually every 3 days, up to 60-70 harvests during the crop cycle.

B. Growing method: macro-tunnels (practiced by 30% of growers)

Field preparation: In May, soil preparation and base-dressing. After this operation, mulching beds with plastic.

Macro-tunnels installation and inundation: Tunnels are installed before the rainy season. In the past flooding of the field (Fig. 25) was a common practice to control hers and pests. Today, most growers use pesticides and herbicides for this purpose.

Figure 25: Flooded macro-tunnel

Figure 26: Macro-tunnel field treated with **Multicote™ Agri**

Growing period: Start August / September – end of the harvest March to mid May

Transplantation: The transplanting process starts after draining the flooded field, in August.

Fertilization: After bedding and mulching, applying **Multicote™ Agri (8) 15-15-15** (100%-0%-100% polymer coated) at a rate of 400 kg/ha (Fig. 26).

Expected yield: 65-75 MT/ha / harvest. The variability of yields depends on the variety. Strawberry harvest is done usually every 3 days, up to 60-70 harvests during the crop cycle.

6.5 Spain

Soil type: Sandy soil with high ph around 7-8.

Growing period: Planting in April and grown for about 6 months.

Growing method: Open field, with no mulch, irrigated by sprinklers (Fig 27-29).

6.5.1 Fertilization

Recommended plant nutrients for the entire growth period (kg/ha):

N	P_2O_5	K_2O
140	60	50

<u>Pre-pant fertilization</u>: Applying **Multicote™ Agri (4) 15-15-15+1,2 MgO** or **Multicote™ Agri (4) 18-11-11+4 MgO**, before planting, at a rate of 20-30 g/linear meter.

<u>Side-dressing</u>: 11 weeks after planting, from June to September, fertigating on a weekly basis with water soluble fertilizer, such as: Poly-Feed™ 22-0-10+3MgO+MAP.

Figure 27: Seeding and application of Multicote™ Agri

Figure 28: Initial growth stage

Figure 29: Sprinkle irrigated/fertigated strawberry field