Nutritional recommendations for

BANANA

Haifa

Pioneering the Future

Nutritional recommendations for

BANANA

Scientific name: *Musa acuminata* and *Musa balbisiana*
Common names in other languages: plátano, banane

Contents:

The recommendations appearing in this document should be regarded as a general guide only. The exact fertilization program should be determined according to the specific crop needs, soil and water conditions, cultivar, and the grower's experience. For detailed recommendations, consult a local Haifa representative.

1. Growing bananas

1.1 Description

The banana plant is a large perennial herb with leaf sheaths that form trunk-like pseudostems. The plant has 8 - 12 leaves that are up to 270 cm long and 60 cm wide. Root development may be extensive in loose soils, in some cases up to 9 m laterally. Plant height, bunch size and various other characteristics depend on the variety.

Flower development is initiated from the underground true stem (corm) 9 - 12 months after planting. The inflorescence (flower stalk) grows through the center of the pseudostem. Flowers develop in clusters ("hands") spirally around the main axis. In most cultivars, the female flowers are followed by a few "hands" of neuter flowers that have aborted ovaries and stamens. The neuter flowers are followed at the terminal ends by male flowers enclosed in bracts. The male flowers have functional stamens but aborted ovaries.

Fruits mature in about 60 - 90 days after flowers appearance. Each bunch of fruits consists of variable numbers of "hands" along a central stem. Each "hand" consists of two transverse rows of fruits ("fingers").

The fruit quality is determined by size (finger length and thickness), evenness of ripening, absence of blemishes and defects, and the arrangement of the clusters. Quality standards may differ in various markets.

1.2 Soil type

Bananas grow well over a wide range of soils. The ideal soil should be well drained but have good water retention capacity. Soil pH should be between 5.5 and 6.5. Soil must not be compact.

1.3 Varieties

Cavendish and Brazilians are the two major groups of dessert bananas. The Cavendish group includes 'Williams', 'Valery', 'Hamakua', 'Grand Nain', and 'Chinese' varieties. The Brazilian bananas are often, incorrectly, referred to as apple bananas. This group includes the 'Dwarf Brazilian'. The Bluefields group, which includes ‘Bluefields’ and 'Dwarf Bluefields', was the leading commercial variety. Currently, this group accounts for less than 1% of banana production in some countries due to its susceptibility to the Panama wilt disease. Starchy cooking bananas, or plantains, are also grown in some countries. Largo, Maia maole, and Popoulu are various plantain groups.

1.4 Climate

Bananas grow best in areas with 2,500 mm or more of well-distributed rainfall per year. Irrigation is needed if rainfall is inadequate or irregular. Banana plants do best in protected areas, because they are susceptible to wind damage. Average temperature of 27°C (81°F) and full sun are also beneficial for optimum plant development and yields.

The optimum conditions for ripening bananas are at temperatures of 20-21°C (68-70°F) and 90% relative humidity. As the fruit ripens, internal starch gradually turns into sugar.

1.5 Irrigation

Water is probably the most limiting a-biotic factor in banana production. The stringent water requirements of this crop can be evenly satisfied by effective rainfall and by irrigation. The use of these two sources varies widely throughout the world.
Banana is a plant with a rapid growth rate, high consumption of water, shallow and spreading roots distribution, roots with weak penetration strength into the soil, poor ability to draw water from drying soil, low resistance to drought, and rapid physiological response to soil water deficit.
These factors indicate that banana is sensitive to even slight variations in soil water content and that irrigation scheduling is critical. The water holding capacity of the soil, effective rooting depth of the plant, and the depletion percentage of total available water allowed before irrigation, determine the amount of water to apply, while crop coefficient together with the evapo-transpiration data determine the irrigation interval.
In Israel, where water scarcity is crucial, banana orchards are generally grown in net houses in order to reduce water losses by transpiration and reduce leaf tearing by the wind.

1.6 Planting density and expected yield

Banana plants are usually not planted closer than 2 - 3 m apart. Planting density depends on the banana varieties planted and the management practices. The number of suckers developing should be kept to a maximum of 4 or 5 per mat, depending on planting distance and other practices.
Yields of 15, 20 and up to 45 ton/ha can normally be obtained for the 'Brazilian', 'Bluefields' and 'Cavendish' varieties, respectively. Yields of 84 ton/ha have been reported under optimal conditions.

1.7 Plant nutrients consumption

Banana crop is a heavy potassium (K) feeder in comparison to many other crops (Table 1) and it has to be taken into account when a fertilization program is planned.

Table 1: Nutrients removal in fruit harvest by different crops

Fruit crop	Fruit yield (ton/ha)	N	P_2O_5	K_2O
		(kg/ha)		
Mango	15	100	25	110
Banana	**57**	**322**	**73**	**1,180**
Citrus	20	22	12	57
Pineapple	84	150	45	530
Papaya	80	225	60	180
Grape	20	160	40	180
Litchi	10	220	35	290

Table 2: Nutrients contents in various crops (kg/ha):

Fruit crop	Yield (ton / ha)	N	P_2O_5	K_2O
Corn	6	120	50	120
Wheat	6	170	75	175
Potatoes	40	175	80	310
Tomatoes	50	140	65	190
Peanuts	2	170	30	110
Sunflowers	3	120	60	240
Apples	25	100	45	180
Avocadoes	15	40	25	80
Citrus	30	270	60	350
Banana	**40**	**320**	**60**	**1000**

Potassium content in a banana leaf is rather high (Fig. 1), but in fruits it exceeds 50% of its dry weight (Fig. 2).

Figure 1: Relative contents of plant nutrients in banana leaves

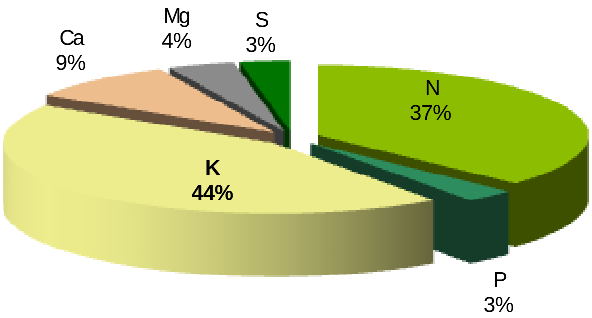
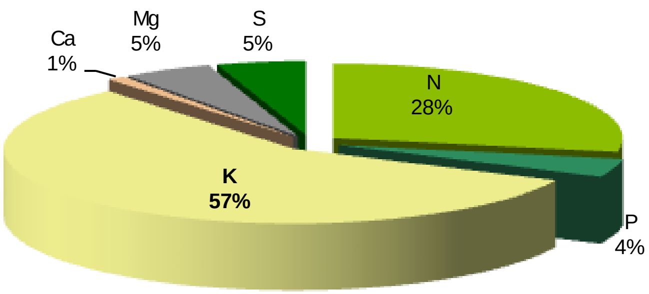
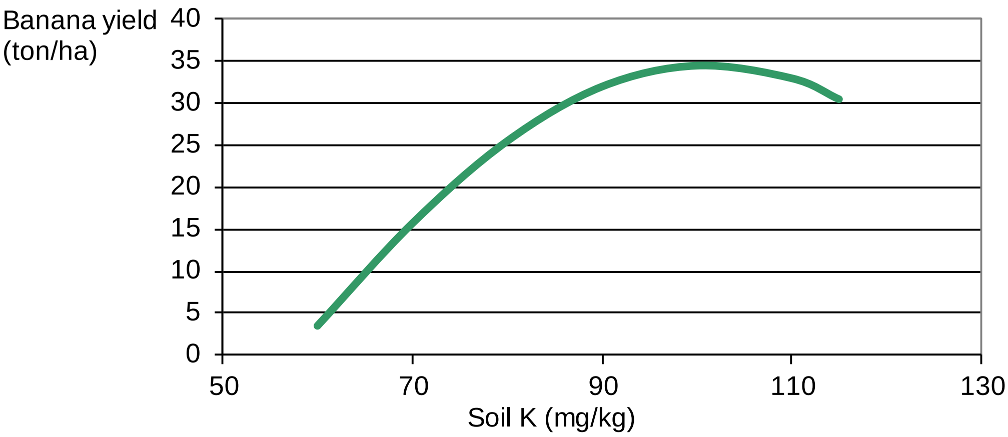


Figure 2: Relative contents of plant nutrients in banana fruits



Banana yields are highly responsive to the available K content in soil (Fig 3).

Figure 3: Relationship between soil K content (0 – 20 cm.) and banana yield
(B. L. Smith, South Africa, 1995.)



Potassium level in soil affects not only the yield, but also plant growth (Tab. 3). The higher the K level in soil, the larger foliage area is achievable.

Table 3: The effect of potassium levels, under sand culture conditions, on banana leaf size
(Lahav, 1972)

K level (ppm)	Length		Width		Area		Life span		Total foliage area	
	cm	%	cm	%	m^2	%	days	%	m^2	%
292	129	100	68	100	0.66	100	111	100	75	100
146	123	95	64	94	0.62	94	107	96	67	89
73	104	81	56	82	0.45	68	94	85	44	59
36	101	78	54	79	0.42	64	71	64	32	43
18	106	82	57	84	0.47	71	40	67	30	60
0	86	67	47	69	0.29	44	56	50	18	24
SE *(P = 0.01)*	5		4		0.06		4		6	

2. Plant nutrition

Low soil fertility is one of the major constraints to optimum crop growth and yield. Soils fertility can be managed by fertilization, but the grower must be fully aware of his nutrient problem(s) in order to arrive at the right decisions regarding the kind and rates of fertilizers to be applied. Numerous diagnostic techniques used in evaluating soil nutrient status and determining fertilizer requirement of the crop viz. nutrient deficiency symptoms, field and pot experiments, soil testing, and plant analysis

Banana yield and quality improvement due to balanced fertilization has been well documented. Information on improving fruit storage quality and the storage properties of banana fruit through proper nutrient use, is also crucial since large quantities of fruit are sold in remote markets.

- Banana root system spreads in the top 60 cm soil. Being an exhaustive crop, proper fertilizer application has to be resorted in order to obtain good yields.
- The choice of fertilizers, the dosage of nutrients, time of application etc., varies widely with respect to agro-climatic regions and varieties.

The effects of proper fertilization of bananas are

- Increase of the crop yield by the improvement of grading, or of weight of bunch,
- Reduction in time needed for maturation of the banana bunch
- Increase in the number of marketable, good quality bunches per hectare,
- Improvement in quality, in terms of physical and chemical characters, leading to high return to the growers.

2.1 Main functions of plant nutrients

Table 4: Summary of main functions of plant nutrients:

Nutrient	Functions
Nitrogen (N)	Synthesis of proteins (growth and yield).
phosphorus (P)	Cellular division and formation of energetic structures.
Potassium (K)	Transport of sugars, stomata control, cofactor of many enzymes, reduces susceptibility to plant diseases.
Calcium (Ca)	A major building block in cell walls, and reduces susceptibility to diseases.
Sulfur (S)	Synthesis of essential amino acids cystin and methionine.
Magnesium (Mg)	Central part of chlorophyll molecule.
Iron (Fe)	Chlorophyll synthesis.
Manganese (Mn)	Necessary in the photosynthesis process.
Boron (B)	Formation of cell wall. Germination and elongation of pollen tube. Participates in the metabolism and transport of sugars.
Zinc (Zn)	Auxins synthesis.
Copper (Cu)	Influences in the metabolism of nitrogen and carbohydrates.
Molybdenum (Mo)	Component of nitrate-reductase and nitrogenase enzymes.

2.2 Nutrients functions and deficiency symptoms in banana

Table 5: Role of specific nutrients

	N	P	K	Mg	Ca	S	B	Cu	Fe	Mn	Zn
Yield parameters											
Yield	+	+	+	+	+	+	+	+	+	+	+
Bunch weight	+	+	+	+			+	+			
Hands / Bunch	+		+					+			
Fruit/Hand			+								
Fruit number			+								
Fruit weight			+				+	+			+
Fruit diameter			+				+	+			+
Fruit length			+								
Quality parameters											
Starch	+	+	+								
Sugars			+				+				+
Acid	+						+				+
Sugar / Acid ratio			+								+
Total Soluble Solids	+		+				+	+			+
Ascorbic Acid (Vit. C)			+				+	+			+
Peel Disorders					-						

Nutritional deficiencies hinder the growth of banana plant (Table 6). It can be noted that potassium deficiency has marked negative effects.

Table 6: Number of leaves produced in 158 days and intervals between emergence of leaves ("*Dwarf Cavendish*" on sandy soil)

Nutrient deficiency	No. of Leaves	Days between leaves emergences
Control, no deficiency	16.6	9.5
- K	7.0	22.6
- P	13.0	12.1
- K	11.5	13.8
- Ca	13.5	11.7
- Mg	14.5	10.9

2.2.1 Nitrogen (N)

Function: Nitrogen is one of the primary nutrients absorbed by banana roots, preferably in form of the nitrate (NO_3^-) ion. Nitrogen is a constituent of amino acids, amides, proteins, nucleic acids, nucleotides and coenzymes, hexosamines, etc. This nutrient is equally essential for good cell division, growth and respiration.

- Nitrogen is the chief promoter of growth. It induces the vegetative growth of the pseudostem and leaves giving them desirable healthy green color.
- A healthy robust vegetative frame is an essential pre-requisite for high yields, and nitrogen is mainly responsible for such a vegetative frame. Banana plants, poorly nurtured with N, produce only seven leaves versus 17 leaves produced by banana plants supplied with adequate N.
- If N is deficient in bananas the leaves take 23 days for unfolding versus 10 days for the leaves of banana supplied with adequate N.
- Nitrogen deficiency causes slow growth and paler leaves with reduced leaf area and rate of leaf production. N positively influences the longitudinal growth of petioles.
- It was observed that the greater the number of large, healthy leaves, produced during the first 4-6 months, the larger will be the size of the fruit bunch.
- Nitrogen increases the bunch grade, and sucker production.
- Lack of N produces thin, short and compressed leaf petioles, thin and profuse roots, and lesser number of suckers, .. Phosphorus uptake is higher due to N deficiency.

Table 7: Nitrogen (N) in the banana plant

Deficiency	Poor vegetative growth
Optimal N rate	High content of dry matter Larger bunches are produced at optimal N:K ratio
Excess	Bunches break before maturation

Table 8: Optimal rate of nitrogen for plant growth* - Cv. Pioneira (2 x 3 m)

I – First cycle

	140 days after planting		240 days after planting	
N rate (g/plant)**	**Plant height (cm)**	**Basal girth (cm)**	**Plant height (cm)**	**Basal girth (cm)**
0	82	8.3	114	13.3
80	102	11.1	128	15.7
160	106	11.5	127	14.3
240	92	10.2	112	13.2

II – Second cycle

N rate** (g/plant)	Bunch weight (kg)	Total hand weight per bunch (kg)	Fingers/ bunch	Hands/ bunch
0	4.58	4.13	54.2	5.11
80	5.00	4.50	59.7	5.49
160	5.96	5.40	63.1	5.76
240	5.88	5.22	67.2	5.87

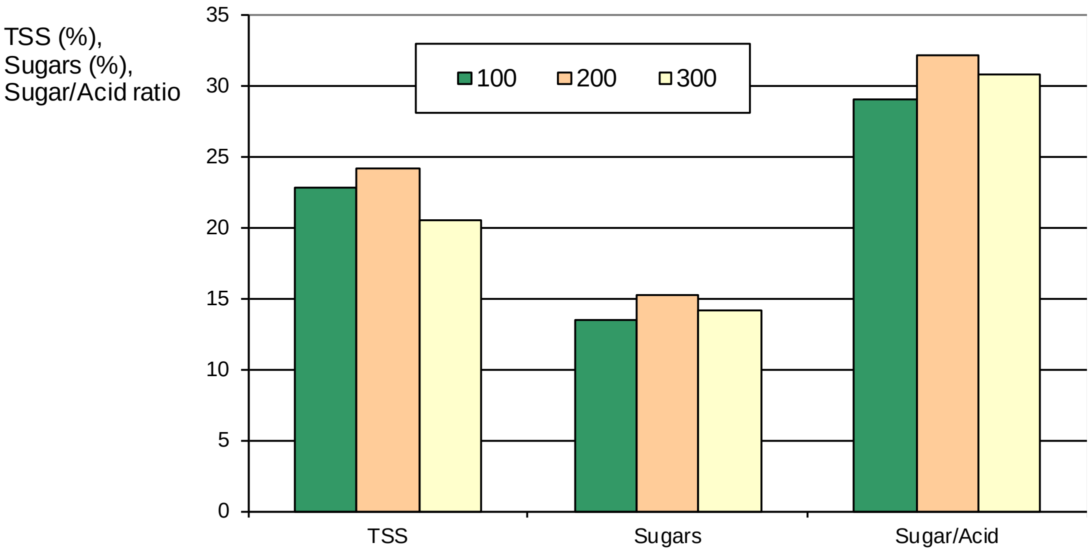
**** - Fertilization:** P and K, dolomite lime. N split (35, 75, 115, 155 days after planting).

Soil: pH 5.4; P 2 ppm; K 0.5 meq/l; Ca+Mg 7 meql/l; Al 1 meql/l

** Brasil et al. (2000) Brazil*

Figure 4: Nitrogen effects on TSS, Sugars and Sugar/Acid ratio (Uniform rates of P and K)

Babu (1999) India



Deficiency Symptoms:

Typical symptoms of nitrogen deficiency in banana are general yellowing of leaves, rose colored tints on petioles (Figs 5, 6) and leaf sheaths, stunting, resetting, slender pseudostem, small petioles and leaves, and reduced life span of leaves. Banana is more sensitive to a lack of nitrogen than any other element, and. Nitrogen deficiency causes notable reduction in yield.

Figure 5: Severe nitrogen deficiency symptom in banana

Figure 6: Nitrogen deficiency symptoms: petioles turn pink to violet, and distance between them becomes extremely short

Figures 7: Severe nitrogen deficiency symptom on banana petioles

Figure 8: Nitrogen excess: Severe scorching of banana laminae due to excessive application of urea (damages build up near the mid-rib).

2.2.2 Phosphorus (P)

Function: Phosphorus helps to produce healthy rhizome and a strong root system. It also influences flower setting and general vegetative growth. It is one of the three primary nutrients and is absorbed by banana roots mainly in the form of orthophosphate ($H_2PO_4^-$). It is a component of sugar-phosphates, nucleic acids, nucleotides, coenzymes, phospholipids, phytic acid, and more. It plays a key role in reactions involving ATP. This element is necessary for many life processes such as photosynthesis, metabolism of carbohydrates, and the transfer of energy within the plant. It helps plants store and use energy from photosynthesis, develop roots, speed-up the maturity, and resist stresses.

Deficiency Symptoms: Phosphorus deficiency symptoms show on the old leaves as chlorosis of their margins. Purplish brown flecks develop there as well. With severe deficiency, the affected leaves curl, the petioles break, and the younger leaves have a deep green color. P deficiency causes complete cessation of elongation, at a height of about two feet rosetting of leaves with older leaves becoming increasingly irregularly necrotic, leaf production is reduced and marginal chlorosis and in severe cases premature death follows.

Figure 9: Severe phosphorus deficiency, symptom on banana laminae (cv. Dwarf Cavendish). Laminae edges become necrotic

2.2.3 Potassium (K)

Due to the very high K contents in the banana fruit and leaves (see Fig. 1, page 5) K is considered the most important plant nutrient in banana production.
The amount of K taken up from the soil and removed from the field in harvested bunches is very high. Estimated annual soil losses through fruit removal alone can be 400 kg of elemental K (equivalent to 480 kg of K_2O) per ha with a production of 70 tons of fruit. For this reason, banana requires a good K supply, even in soils where K levels are considered high.

Function: Potassium is required as a cofactor for over 40 enzymes. It has a role in stomatal movements by maintaining electro-neutrality in plant cells. It is required for many other physiological functions, such as: formation of sugars and starch, synthesis of proteins, normal cell division and growth, neutralization of organic acids, involvement in enzymatic reactions, regulating carbon dioxide supply by control of stomatal opening and improving efficiency of sugar use, increasing plant resistance to biotic and abiotic stresses, such as: frost tolerance by decreasing the osmotic potential of cell sap due to higher ratio of unsaturated/saturated fatty acid, drought tolerance, regulation of internal water balance and turgidity, regulating Na influx and/or efflux at the plasmalema of root cells, chloride exclusion through selectivity of fibrous roots for K over Na, and imparting salt tolerance to cells by increasing K holding capacity in the vacuole against leakage when Na incurred in external medium.
Potassium does not play a direct role in the plant's cell structure, but it is fundamental because it catalyzes important reactions such as respiration, photosynthesis, chlorophyll formation, and water regulation. The role of K in the transport and accumulation of sugars inside the plant is particularly important since these processes allow fruit fill and, therefore, yield increase.

Potassium improves yield

Table 9: The effect of K on yield** - (*Cv. Grand Naine*, 3 x 4 m)

K_2O rate* (g/plant)	Bunch weight (kg)	Hands/bunch	Finger/bunch
400	25.0	12.4	217
600	26.7	12.8	220
800	29.0	13.2	225
1000	29.4	13.9	226

K_2O rate* (g/plant)	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Pulp (%)
400	95.3	18.4	3.91	70.6
600	101.6	18.5	4.30	71.4
800	108.4	18.5	4.67	72.1

* Fertigation: Daily K & N (total 400 g/plant) for 6 months, P, Mg, S weekly (4 months), Zn, Mn weekly (3 months)

** *Saad & Atawia (1999): Egypt*

Table 10: The effect of K on yield** - *Cv. Giant Governor (Cavendish)*

K_2O rate* (g/plant)	Yield (t/ha)	Fingers/ hand	Hands/ bunch	Fruit weight (g)	Fruit dimensions (cm)	
					length	diameter
100	29.3	12.2	7.0	103.2	16.6	3.53
200	37.0	13.5	7.5	115.2	17.1	3.55
300	42.4	13.8	7.3	129.7	19.5	3.72
400	50.7	14.6	7.3	132.7	19.0	3.76
500	59.3	15.4	6.7	140.3	19.9	3.95
600	55.9	15.6	8.7	138.8	19.8	3.89

* - N 250 g/plant, P_2O_5 125 g/plant; N & K in 3 split doses

*** Abu Hasan et al. (1999) India*

Table 11: The effect of K on yield** - Cv Pioneira (2 x 3 m)

I – Second cycle

K_2O rate* (g/plant)	Bunch weight (kg)	Total hand weight per bunch (kg)	Fingers/ bunch	Hands/ bunch
0	3.30	2.95	54.5	5.11
150	5.35	4.55	59.8	5.44
300	6.05	5.50	63.2	5.76
450	6.50	5.80	67.2	5.83

II - Third cycle

K_2O rate* (g/plant)	Bunch weight (kg)	Total hand weight per bunch (kg)
0	4.00	3.50
150	5.80	5.15
300	5.90	5.25
450	6.15	5.30

* Fertilization: P and N, dolomite lime. K split (35, 75, 115, 155 days after planting)

Soil: pH 5.4; P 2 ppm; K 0.5 meq/l; Ca+Mg 7 meql/l; Al 1 meql/l

*** Brasil et al. (2000) Brazil*

Table 12: The effect of K on yield and quality*

K_2O rate* (g/plant)	Bunch weight (kg)		Yield (t/ha)		Total sugar (%)		TSS (%)		Acidity (%)	
	Plant crop	Ra-toon	Plant crop	Ra-toon	Plant crop	Ra-toon	Plant crop	Ra-toon	Plant crop	Ra-toon
0	12.0	12.1	30.0	30.2	11.0	11.9	15.9	16.0	0.59	0.59
240	13.4	14.2	33.5	35.5	12.6	12.6	16.5	16.4	0.55	0.55
480	15.2	15.3	38.0	38.2	13.1	13.1	17.0	17.0	0.53	0.52

** Bhargava et al. (1993)*

Table 13: Effect of soil applied K on yield*

Soil application		Bunch Weight (kg)
g K_2O / plant / year	kg K_2O / ha / year	
0	0	21.9
240	432	26.7
480	864	30.4
720	1296	31.7

* at plant population of 1800 plants / ha

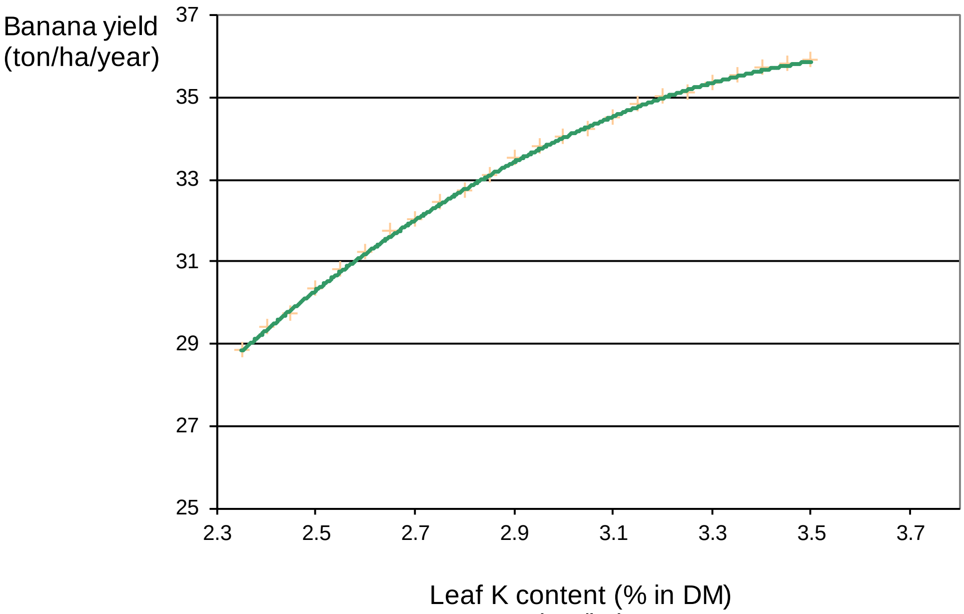
Dynamics of K Uptake:

- Intensive K uptake in first vegetative phase
- Overall decrease of K concentration in plant from sucker to fruit
- High K in soil allows large uptake also at latter phase
- K uptake is leveling off after bunch emergence
- Low K supply, limits transfer of mineral nutrients (N, P, Ca, Mg, Cu, Zn) in xylem
- Low K supply, limits transfer of carbohydrates

Table 14: Effect of Multi-K® application on banana quality
(Jambulingam et al. 1975)

Soil Application (g K_2O/plant/yr)	K in Leaves (%)	Total Soluble Solids/ Acids	Reducing Sugar (%)	Non-Reducing Sugar (%)
0	3.64	70	13.73	4.11
180	3.98	76	14.70	4.43
270	4.3	79	16.05	5.20
360	4.53	80	16.61	6.00

Figure 10: The effect of leaf K content on yield when applying Multi-K® by dripper.



Deficiency Symptoms: Potassium deficiency symptoms in banana are quickly evident when it is not continuously applied under intensive banana cultivation.
Classic symptoms of K deficiency are:

Leaves

- Chlorosis of the leaves: The most characteristic symptom of plants lacking in K is the yellowing of the tip of the older leaves (Figs. 11 - 12). The yellowing and necrosis spread rapidly towards the leaf base, until the whole leaf has withered standing in a normal position.
- Rapid yellowing of oldest leaves, which then turn orange and dry-up; leaves may become tattered and fold downward; leaves are crumpled in appearance Splits develop parallel to the secondary veins and the lamina folds downwards, while the midrib bends and fractures, leaving the distal half of the leaf hanging.

Figure 11: Mild potassium deficiency: old leaves become yellow-orange

Figure 12: Moderate potassium deficiency: necrosis starts at leaf margins

Figure 13: Severe potassium deficiency: necrotic stripes reach leaf midrib

Figure 14: Extreme potassium deficiency: most of the leaf desiccates and typical curling starts

Figure 15: Lethal potassium deficiency: necrosis and bending of a large part of the leaf

- As time progresses, leaves curl inward and die soon after (Fig. 16).

Figure 16: Potassium deficient banana; older leaves become chlorotic, then necrotic, and the tip of the midrib bends downward.

- Purplish brown patches appear at the base of the petioles and in severe cases the center of the corm may show areas of brown, water soaked disintegrated cell structures.

Fruit

- Bunch deformation: fruit bunches on K-deficient plants are short, slim and deformed because of poor fruit filling, bunches are poorly filled.
- Fruits are badly shaped, poorly filled and unsuitable for marketing.

Figure 17: Fruits are badly shaped, poorly filled and unsuitable for marketing.

Plant growth

- Stunted growth: It is common for K-deficient banana plants to exhibit slow growth, shortened internodes and a sturdy appearance.
- Longer than usual intervals between the emergence of new leaves, leaves are profusely smaller, premature yellowing of plant.

Excessive potassium

High Potassium levels:

- create an imbalance of MgO/K_2O ratio in soil
- Symptoms: "blueing"
- Magnesium deficiency
- Calcium deficiency

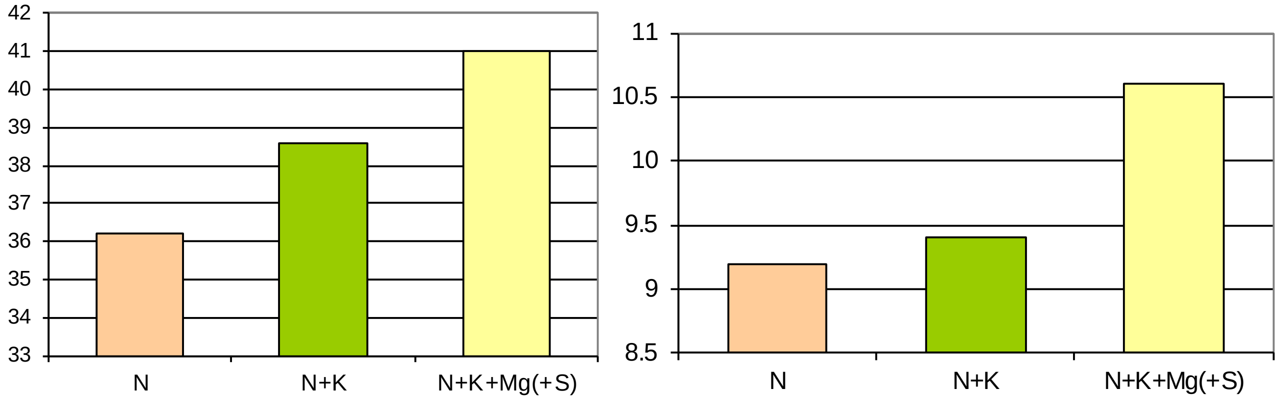
Figure 18: Symptoms of excessive level of potassium

2.2.4 Magnesium (Mg)

Function: Magnesium is a secondary macronutrient absorbed as Mg^{2+}. Magnesium is a crucial constituent of the chlorophyll molecule. It is required, nonspecifically, by a large number of enzymes involved in phosphate transfer. It is involved in photosynthesis, carbohydrate metabolism, synthesis of nucleic acids, related to movement of carbohydrates from leaves to upper parts, and stimulates P uptake and transport, in addition to being an activator of several enzymes.

Figure 19: The effect of magnesium on banana yield.

A. Tons per hectare. B. Hands per bunch.



N: 276 kg/ha, K_2O: 585 kg/ha, MgO: 122 kg/ha (+ S: 96 kg/ha)

Source: REF: Kali & Salz (2002) Ecuador

Deficiency Symptoms: Magnesium deficiency is expressed by yellowish chlorosis of the central zone of the lamina while the margins and midrib area remain green; other symptoms are purple mottling of the petioles and separation of leaf sheaths from the pseudostem.

Deficiency:

- Common in bananas
- Occurs in old plantations which have had little Mg applied
- OR where excessive potassium is applied
- Marginal yellowing (Fig. 20).
- Bluish - purple mottling of petioles ('blue sickness')
- Separation of leaf sheath from stem

Result

- Lower yields
- Poor plant growth
- Poor uptake of potassium and calcium

Figure 20: Magnesium deficiency symptoms

2.2.5 Calcium (Ca)

Function: Calcium is another secondary plant nutrients, absorbed by plant roots as Ca^{2+}. Calcium is a constituent of the middle lamella of cell walls as Ca-pectate. Calcium is required as a cofactor by some enzymes involved in the hydrolysis of ATP and phospholipids. It is an important element for root development and functioning; a constituent of cell walls; and is required for chromosome flexibility and cell division.

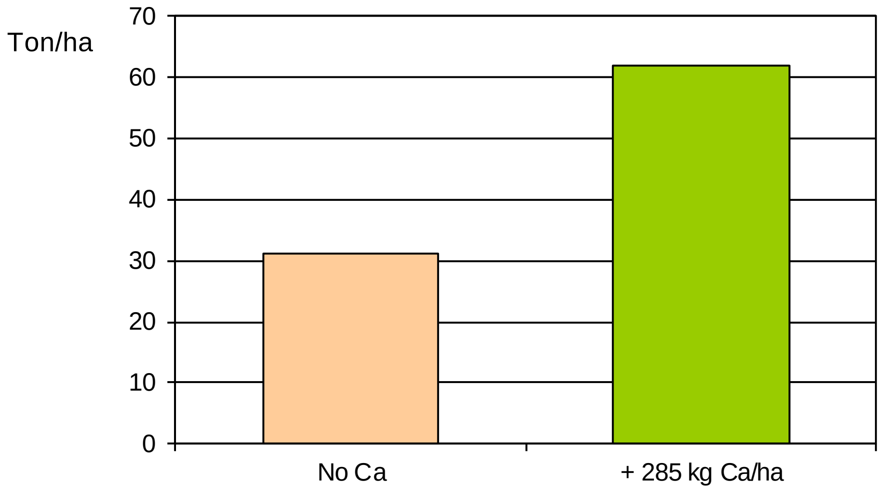
Calcium deficiency is a widespread problem in banana crops and significantly reduces fruit quality. Moisture stress is the major cause of calcium deficiency as it interrupts the root uptake of calcium and leads to localized deficiencies in fruit. Boron is required for the maintenance of transpiration (water uptake) and therefore also calcium uptake. Over-use of nitrogen fertilizers and excessive plant vigour also compound calcium deficiencies. Calcium and boron are also essential for plant strength and therefore deficient plants are more likely to suffer from fungal diseases and environmental stresses. Calcium deficiencies are common in both acid and alkaline soils even when exchangeable soil calcium levels are high. This is largely due to the low mobility of soil calcium and competition with other nutrients such as ammonium nitrogen, potassium and magnesium

Calcium deficiency caused by:

- Low transpiration – e.g. at high humidity
- Fruit has a low transpiration rate:
  a) Reduced Ca uptake in maturating fruits may result in Ca deficiency
  b) Maturity spots of banana (e.g. aggravated by plastic bags on bunch)
- Rapid leaf growth may cause a Ca shortage
- Cold winters in subtropics
- Imbalances with K and Mg
  a) high rates of K, Mg or NH_4^+ will reduce Ca availability
  b) optimum Ca uptake at soil Ca:(K+Ca+Mg) ratio of 0.7

Source: Lahav & Turner (1989 - IPI-Bulletin No 7), C.B.I Banadex (1998 –AIM database)

Figure 21: The effect of calcium application on banana yield



N rate: 200 kg /ha, K rate: 498 kg/ha

Source: Moreno et al. (1999) - Venezuela

Deficiency Symptoms

Typical symptoms indicating calcium deficiency in banana are: general dwarfing, reduced leaf length, reduced rate of leaf emission; leaves are undulated; tissue near midrib thickens, may turn reddish-brown. In sub-tropical growing areas, calcium deficiency, generally, appears in early summer after spring flush. It reveals as typical chlorosis and necrosis and "Spike-Leaf" in severe cases.

Leaf:

- The symptoms are found on the youngest leaves causes the spike leaf in which the lamina in new leaves is deformed
- Black Sigatoka *(Mycosphaerella fijiensis)* disease is worse
- Interveinal chlorosis near leaf margins
- Creates 'spike leaf' appearance where lamina of new leaves is deformed or absent
- Symptoms appear in after a flush of growth
- OR where high levels of potassium are applied

Plant:

- It causes heart rot to newly planted tissue culture plantlets.

Fruit:

- Peel splits when fruit ripe
- Fruit curls – scratching others in bunch
- Fruit weight and diameter is reduced
- The fruit quality is inferior and the peel splits during the ripening.

Figure 22: Calcium deficiency symptoms

Figure 23: Early foliar symptoms (yellow stripes parallel to leaf midrib)

Figure 24: Chlorotic (white) and/or necrotic heart leaf.

Figure 25: Early foliar symptoms of Calcium-Boron deficiency (crinkled leaves)

2.2.6 Sulfur (S)

Function: Sulfur, also a secondary plant nutrient, is essential for protein formation, as a constituent of the three amino-acids cystine, cysteine and methionine.
Sulfur is required for the formation of chlorophyll and for the activity of ATP - sulfurylase. These essential functions permit the production of healthy and productive plants, which are a precondition for high yields and superior quality.

Deficiency Symptoms:
Leaves are chlorotic and reduced in size, with a thickening of secondary veins; undulating leaf edges; necrosis along edge of lower leaves.
Sulfur deficiency is rare, as sulfur is often supplied with fertilizers containing sulfur:
$(NH_4)_2SO_4$, Superphosphate or $MgSO_4$

Leaf:
- Symptoms appear in young leaves
- Leaves become yellowish-white
- If severe, necrotic patches appear in the leaf margins
- Leaf veins are thickened

Fruit:
- Bunches are small or 'choked'
- Yields may be reduced

Figure 26: Sulfur deficiency

Figure 27: Sulfur deficiency, Yellowing of the entire lamina

2.3 Micro-nutrients

The availability of micro-nutrients is markedly influenced by soil pH

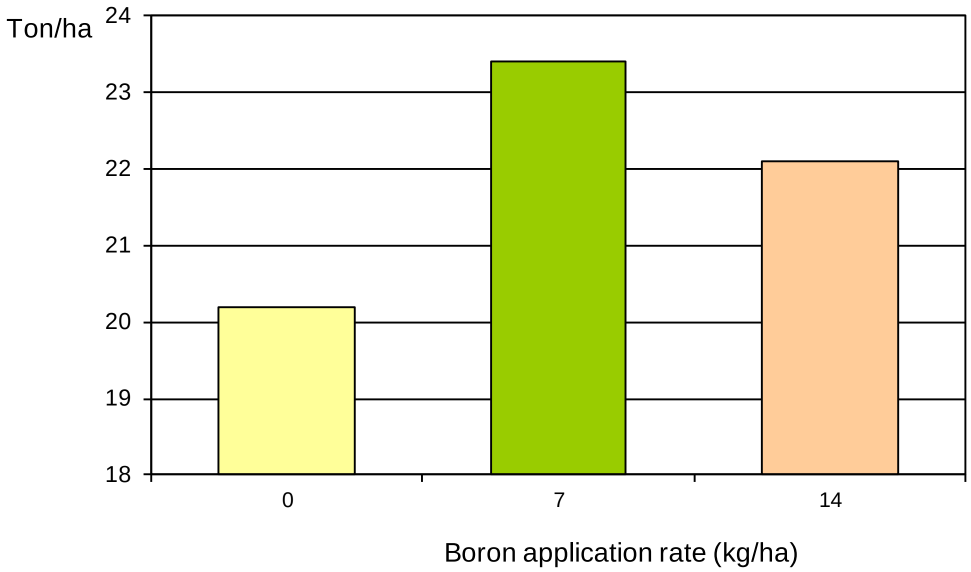
- Above pH 7 there is a clear reduction in the uptake of Fe, Mn and Zn
- Below pH 5 there is a clear reduction in the uptake of Mo and P and an increase in the uptake of Mn and Al.

High Na and Mg contents in soil reduce uptake of micro-nutrients

2.3.1 Boron (B)

- Boron deficiency is not common in bananas. It does occur, though in some Latin American countries (e.g. Ecuador)
- Boron deficiency is common in acid soils
- Boron deficiency symptoms:
  - Curling and deformation of leaf
  - White strips perpendicular to veins on underside of lamina
- B uptake rate in field is constant from sucker to harvest – 40 mg/plant/month

<u>Figure 28</u>: Effect of various Boron rates on yield



Planting density: 2123 plants/ha

Fertilization [kg/ha]: N 224, P 35, K 336, Mg 62, Zn 24

Source: Silva (1973), Puerto Rico Plantains

Boron deficiency symptoms include: Chlorotic streaking of leaves, oriented perpendicular to and crossing the primary veins (Fig. 29); leaf malformation (Fig. 30), interveinal chlorosis. This deficiency can develop slowly over time.
Boron deficiency may results in reduction in weight and size of the bunch and in proper filling of the individual fruit units.

Figure 29: Boron deficiency - whitish parallel streaking of the entire width of central part of the leaf.

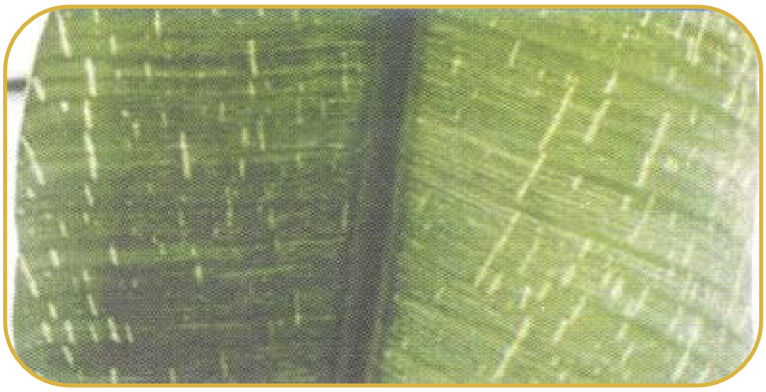


Figure 30 a-c: Boron deficiency – deformed foliage

Boron deficiencies occur on a wide variety of soils, however, boron availability reduces as pH increases. Boron is essential for flowering, fruit set and the translocation of sugars. Boron is required for calcium uptake and movement, and calcium deficiencies can be significantly reduced by boron application. Boron plays a similar role to calcium in plant nutrition, which makes it essential for quality factors such as skin strength, fruit firmness and storage life. Because boron is required for root development and plant strength, deficiencies often increase the likelihood of fungal diseases and reduce the plant's tolerance to various environmental stresses.

2.3.2 Iron (Fe)

Function: Iron is a constituent of cytochromes, nonhaeme iron proteins, it is involved in photosynthesis, and N_2 fixation and respiratory linked dehydrogenases. Iron is also involved in the reduction in nitrates and sulfates, and in reduction processes by peroxidase and adolase.
Total amount of iron uptake by healthy plants is only about 1-3 g. 80% of this is absorbed during the first half of plant's life.

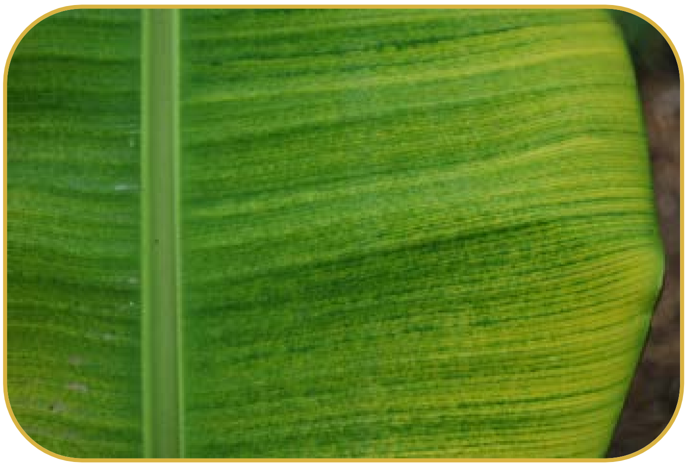
Deficiency Symptoms: General chlorosis of entire lamina mainly of young leaves; retarded plant growth; small bunches. Leaf color becomes yellow-white.

Iron deficiency is mainly observed on:

- Calcareous soils
- Soils with high water tables
- Soils with high Manganese

Lahav & Turner (1989 - IPI-Bulletin No 7)

Figure 31: Iron deficiency symptoms.



2.3.3 Manganese (Mn)

Function: Manganese is one of the micronutrients, absorbed by the plant roots in the form of Mn^{2+}. It is required for the activity of dehydrogenases, decarboxylases, kinases, oxidases, peroxidases, and non-specifically by other divalent cation activated enzymes. It is required for photosynthetic evolution of O_2, besides involvement in production of amino acid and proteins. Manganese has equally strong role in photosynthesis, chlorophyll formation and nitrate reduction. A metallo-enzyme peroxidase concentration is considered to be the marker of Mn deficiency.

Deficiency Symptoms: Manganese deficiency at its mild form is expressed as "comb-tooth" chlorosis, which starts on the leaf margins and spreads along the veins towards the midrib of the leaf with occasional narrow green edge. Chlorosis first appears on second or third youngest leaf.

Figure 32: Manganese deficiency symptoms.

Toxicity: Manganese toxicity is a known problem in acid soils. In severe cases, leaf Mn levels may reach 6000 ppm. Hi Mn levels reduce calcium uptake by 30%, magnesium uptake by 40% and zinc uptake by 20%, and may enhance the occurrence of disorder known as 'mixed ripe'.

2.3.4 Zinc (Zn)

Function: It is an essential constituent of alcohol dehydrogenase, glutamic dehydrogenase, lactic dehydrogenase, carbonic anhydrase (regulating carbon dioxide metabolism), alkaline phosphatase, carboxypeptidase, and other enzymes such as dehydropeptidase and glycylglycine dipeptidase active in protein metabolism. It also regulates water relations, enhances cell membrane integrity, and stabilizes sulflahydryl groups in membrane proteins involved in ion transport. Under low Zn availability bunch mass will quadruple in response to increasing Zn rate. At high concentration Zn features low mobility rate in the phloem from the leaves to the fruits.

Deficiency Symptoms: Zinc deficiency is a very common problem in banana, observed in all growth regions. It is more common on young plants with no mother plant to act as a nutrient reservoir. Symptoms may appear in one year without affecting yield, but reduce fruit yield in second or third year. Zinc deficiency is found in banana when it grows in zinc-deficient soils, symptoms may be severe mainly in sandy soils and on high pH soils due to fixation, or on weathered, acidic soils, were Zinc content is low. Zinc may leach under acidic conditions. Also, zinc is inactivated at high concentrations of phosphorus in the soil.

In leaf:
- Leaves become narrow
- Yellow to white strips appear between the secondary veins
- Oblong brown necrotic patches appear in the yellow stripes
- It shows as narrow pointed and chlorotic young leaves, strap-shaped leaves, leaf chlorosis in strips or patches;.
- A zinc deficient leaf is significantly smaller in size than a normal leaf and high concentration of anthocyanin pigmentation is developing on its lower side.

Suckers:
- Become very thin
- Bunches have small twisted fingers
- Bananas have a characteristic light green tip
- Plant growth shows stunting and resetting.

2.3.5 Copper (Cu)

Function: Copper plays an active role in enzyme performing key functions like respiration and photosynthesis, and Cu-proteins have been implicated in lignification, anaerobic metabolism, cellular defense mechanism, and hormonal metabolism. Known forms of Cu in the plants comprise: cytochrome oxidase, diamine oxidase, ascorbate oxidate, phenolase, leccase, plastocyanin, protein having ribulose biphosphate carboxylase activity, ribulose biophosphate oxygenase activity, superoxide, dismutase, plant acyanin, and quinol oxidase. Copper proteins exhibit electron transfer and oxidase activity. Copper is also a constituent of cytochrome oxidase and heme in equal proportions. It also acts as a terminal electron acceptor of the mitochondrial oxidative pathway**.**

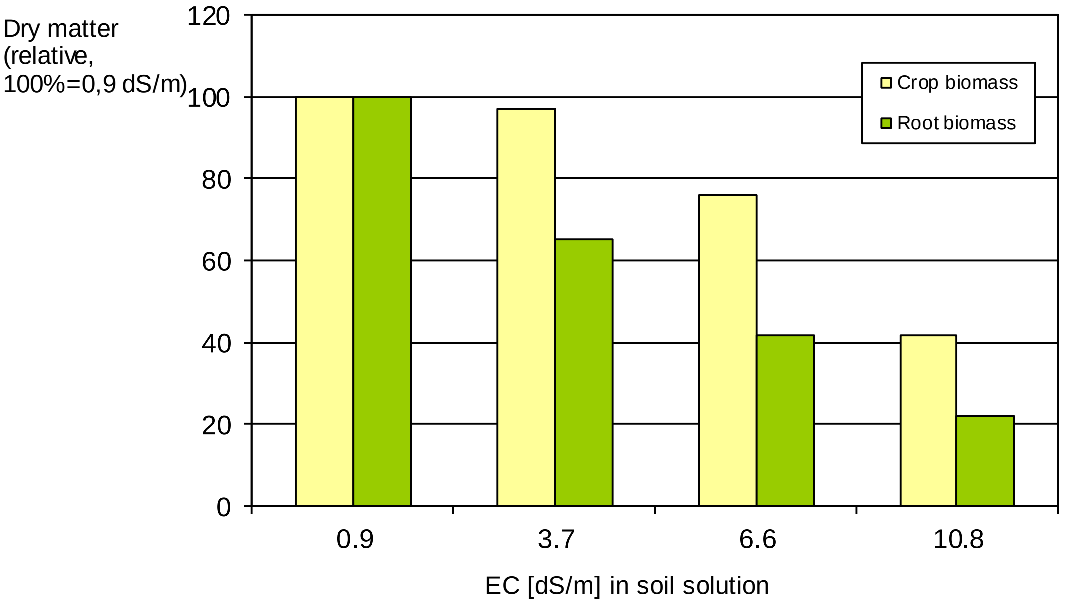
Deficiency Symptoms: Midrib and main veins bend backwards giving plant an umbrella appearance. Leaves turn a yellow bronze color.
Cu toxicity is possible, in particular where Bordeaux mixture is still in use for plant protection.

2.4 Salt sensitivity

- High salt levels in soil or water can cause stress.
- Salinity stress results in marginal leaf chlorosis, stunted growth and thin, deformed fruits.
- Dessert bananas of AAA type (e.g. Cavendishs) are more sensitive than plantains (AAB/ABB types).
- 100-500 ppm total soluble salts in soil is satisfactory with banana growth. At levels of 500-1000 ppm, plants and fruits are visibly affected. When total concentration of soluble salts exceeds 1000 ppm, plants are stunted or dead.
- Salinity problems occur in Carribean area, Latin America, Israel, Canary Islands.
- Sodium and Chlorine are not considered essential nutrients for banana growth
- Bananas seem to be more sensitive to Na than to Cl. (E.g. bananas still grow at up to 600 ppm Cl in irrigation water) (Israel).
- At high Na levels, Na contents in roots can rise up to 1.5% (3 x normal value), especially when K is deficient.
- Excessive Na causes nutrient imbalances
  - Na (or Mg) present at high amounts in irrigation water, reduce K uptake, even if soils contain high K levels.
  - High Na and Mg also reduce uptake of micronutrients.
- When Cl is excessive - sucker growth is restricted and fruit will not fill.

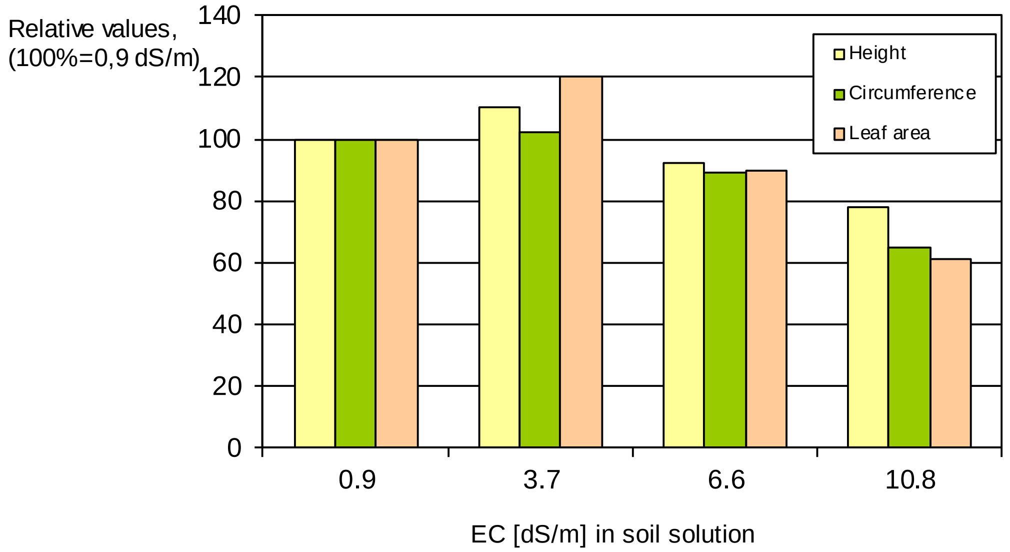
Figure 33: Salinity in soil causes crop and root biomass reduction
Salinity affects root growth before crop stress is visible

Nanicao (Cavendish-group) – Greenhouse trial



Source: Araujo Filho et al. (1995) - Brazil

Figure 34: Salinity reduces growth



Source: Araujo Filho et al. (1995) - Brazil

Bananas are sensitive to salinity and sodium toxicity

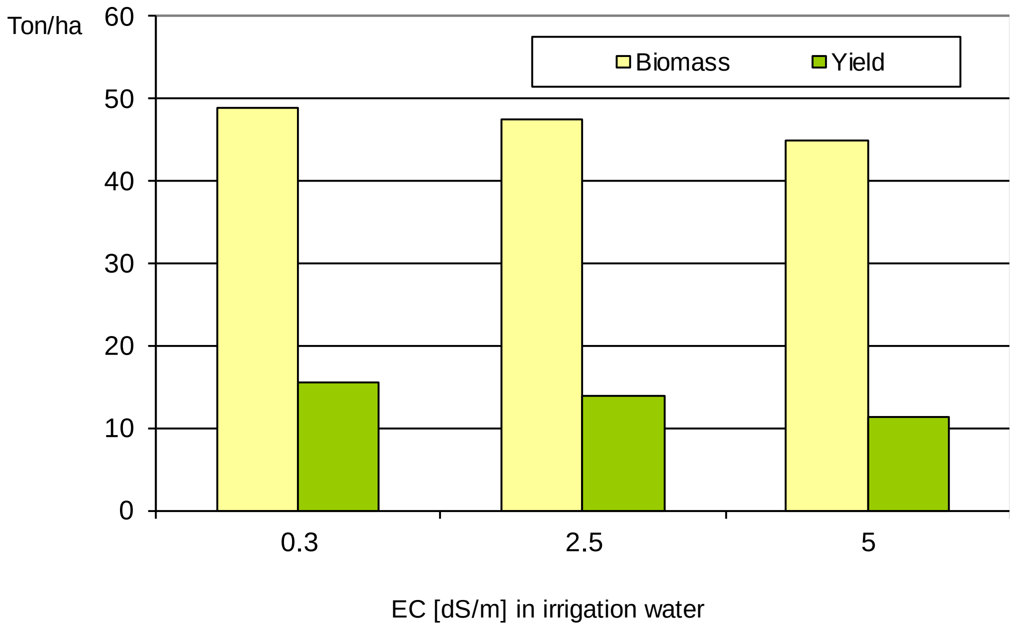
- Banana is sensitive to sodium (Na) and chloride (Cl)
- Salt problems occur when chloride concentration in the soil solution exceeds 500 ppm
- Cl toxicity reduces sucker growth and fruits will not fill
- Sodium (Na) toxicity causes chlorosis
- Na^+ interferes with K^+ uptake

Figure 35: Sodium toxicity

Salinity damages start showing in banana plants irrigated with water at a concentration of 500 mg Cl/ L. The problem escalates when recycled irrigated water is used. In such case, the use of Multi-K® potassium nitrate as a source of nitrate to suppress the uptake Cl by banana roots, is recommended.

Figure 36: Water salinity reduces crop production

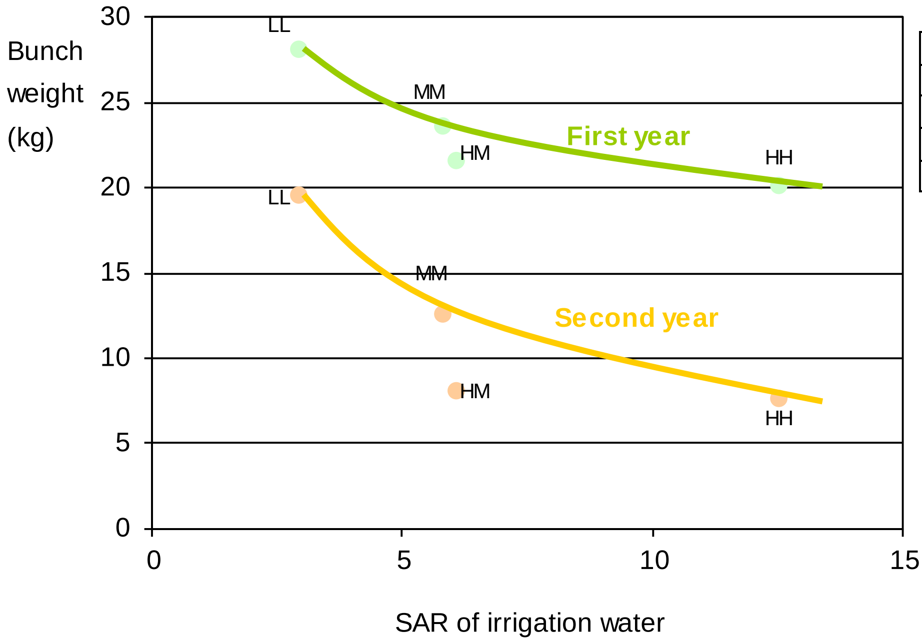
Monthan banana (ABB), India
Soil: sandy loam; pH 6.8, CEC 10.0 mol/kg, irrigation: 200mm



The effects of salinity (0, 50 and 100 mM NaCl) can be observed on many banana cultivars. With increased NaCl levels it shows injury symptoms, such as: chlorosis and marginal leaf necrosis with subsequent leaf death. The effects on leaves results in the reduction of up to 50% of leaf area and and 70% in dry matter.

Increased salinity in the irrigated water reduces yield (Figs. 37 - 40).

Figure 37: The relationship between bunch weight and sodium adsorption in the irrigation water



	Salinity	SAR
LL	Low	Low
MM	Medium	Medium
HM	High	Medium
HH	High	High

Figure 38: The effect of the E.C. of irrigation water on weight of bunches (two-year trial)
Israeli et al, 1986

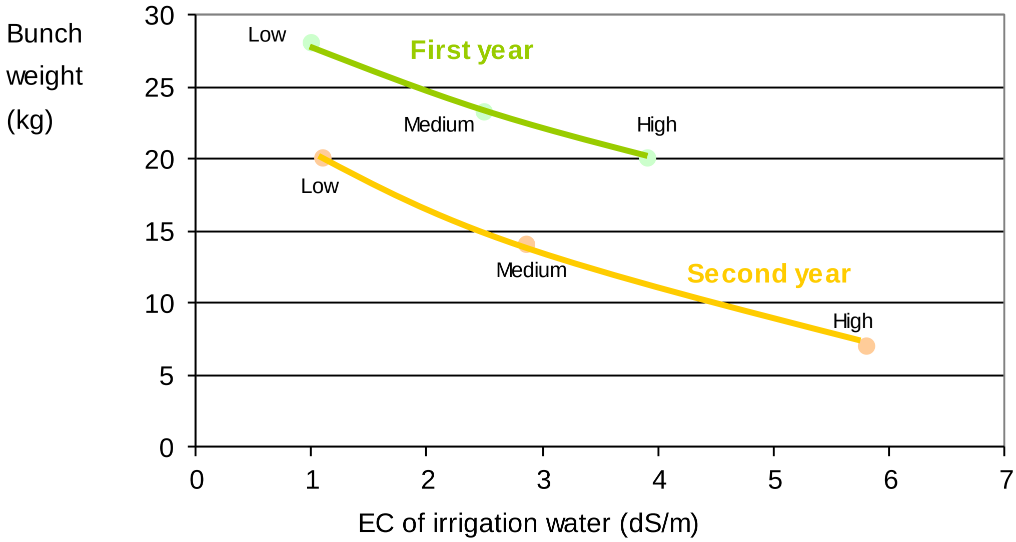


Figure 39: Salinity damage (reduction in water conductance) following the use of KCl
Source: Jones & Vimpany, 1999

Reduction in leaf water conductance (%)

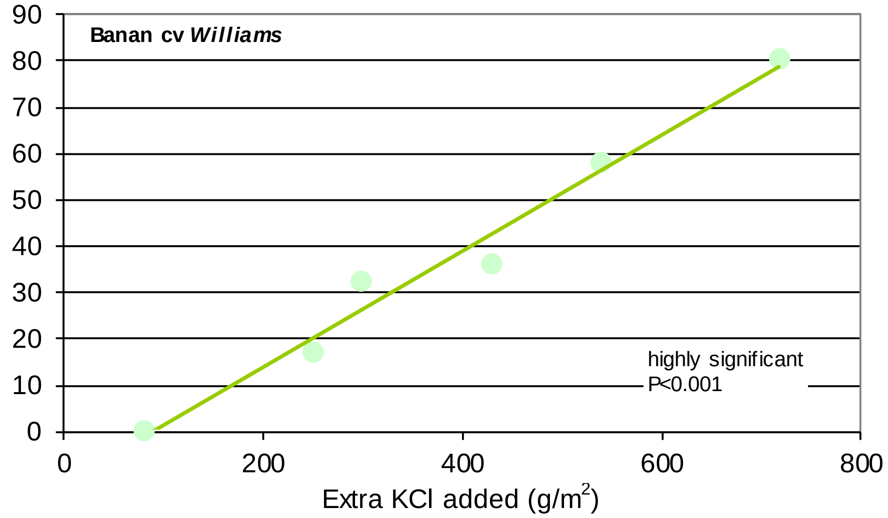
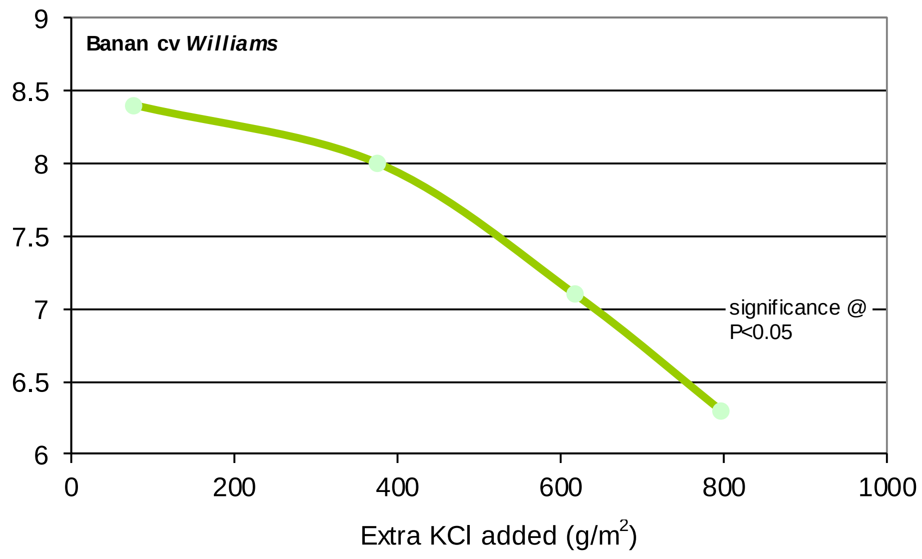


Figure 40: Salinity damage (growth suppression) following the use of KCl
Source: Jones & Vimpany, 1999

Number of new leaves



As a result to the fact that banana plant is sensitive to salinity, the source of fertilizers, as a potential contributor to salinity, should be selected carefully. Haifa's fertilizers are products of choice as a chlorine free source, either water soluble fertilizers or CRF (Controlled Release Fertilizers). For more details, see pages 60-70.

3. The proof is in Haifa's products performances

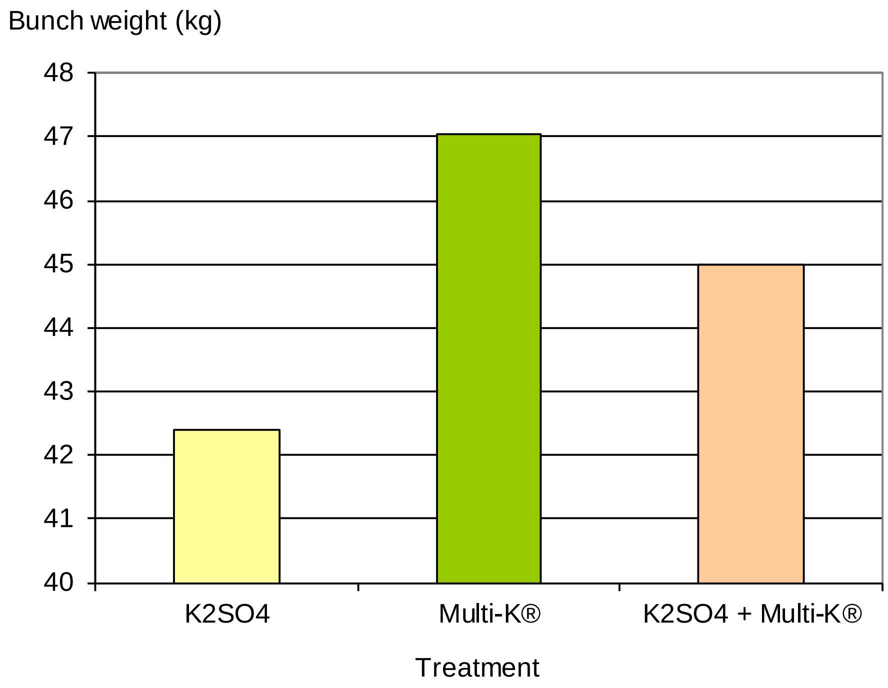
For many years, wherever banana crop is grown, growers acquired experience fertilizing with Haifa products. Methods of application vary from country to country while advantages of using Haifa fertilizers is always beneficial. Some of experimental results and field trials are shown in the following tables.

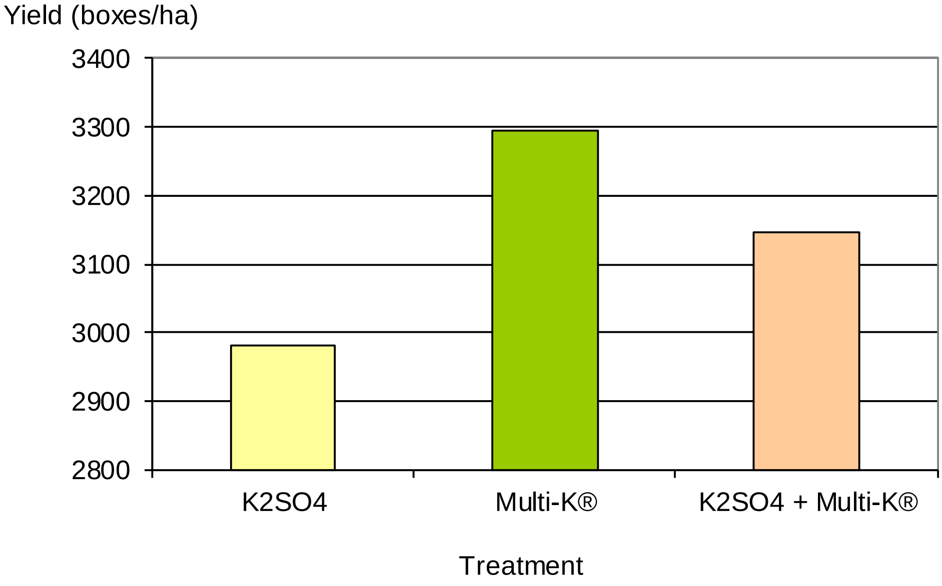
Soil application

Table 15: The effect of soil-applied Multi-K® on Banana yield (*Lahav, 1973*)

Multi-K® applied (kg/ha/year)	Mean bunch weight (kg)	No. of Bunches (per ha)	Yield (MT/ha/year)
0	23.3	1650	37.2
500	26.2	1910	47.2
1000	27.2	2000	50.5
2000	26.4	2140	51.5

Figure 41 a-b: Effect of different potassic fertilizers on banana yield (Guerrero and Gadban, 1996)





Foliar application

Figure 42: Effect of foliar feeding with Multi-K® on banana plants (Gran Enno)
(Guerrero & Gadban, 1992)

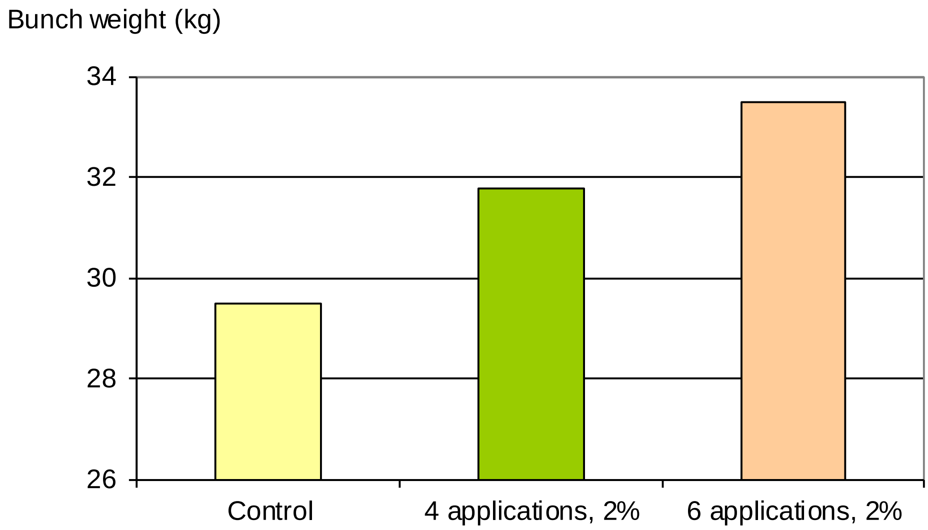


Table 16: The effect of foliar sprays with Multi-K® on banana yield
(Guerrero & Gadban, 1992)

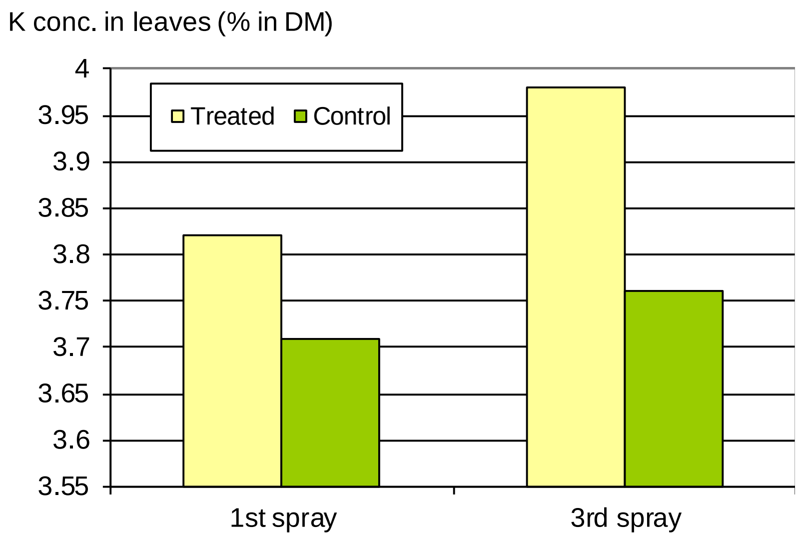
Treatment* (4 Sprays @ 2%)	Bunch Weight (kg)	Hands/Bunch	Fingers/Hand 2nd basal	Cost/Benefit ratio
Not sprayed	35.9	9.9	23.10	--
Multi-K® sprayed	37.9	10.5	23.25	13.5

* Soil application: 400 kg N + 600 kg K_2O ha / year

Table 17: Effect of foliar sprays with Multi-K® on nutrient content in banana leaves
(Guerrero & Gadban, 1992)

	Nutrient Content in Leaves (%)				
	N	P	K	Ca	Mg
Not sprayed	1.38	0.10	2.15	0.45	0.21
4 sprays @ 30 days intervals	2.02	0.12	2.85	0.65	0.31
6 sprays @ 30 days intervals	1.86	0.11	3.2	0.95	0.28

Figure 43: Effect of foliar sprays with Multi-K® on K content in leaves
(Aerial application of 2 kg Multi-K® in 20 L solution (10%) per ha, 2 weeks interval between applications)



Growers who successfully adopted fertigation systems used Multi-K® potassium nitrate in combination with other water-soluble fertilizers:

1. Santa Maria, Colombia - tropical conditions.
Plant density: 1200-1800 mat/ha
Expected yield: 45-60 MT/ha

Table 18: Fertilizing recommendations of banana crop in Colombia

Nutrient requirements (kg/ha)			Recommended fertilizers (kg/ha)		
N	P_2O_5	K_2O	Urea	MAP	Multi-K®
550	-	750	740	-	1630

* In addition to 2 MT/ha/Year of manure.
(Source: Guerrero and Gadban, 1993)

2. Canary Islands - subtropical conditions.
Plant density: 2000mat /ha
Expected yield: 45-60 MT/ha

Table 19: Fertilizing recommendations of banana crop in Canary Islands

Season	Nutrient requirements (kg/ha)			Recommended fertilizers (kg/ha)		
	N	P_2O_5	K_2O	AS**	MAP	Multi-K®
Spring* (Feb. – Jul.)	200	85	260	495	140	565
Autumn (Aug.- Jan.)	200	52	304	460	85	660

*Additionally, during springtime, once a week:
15 kg/ha - Calcium nitrate + 8 Lit/ha Nitric Acid (60% w/w).
**AS = Ammonium sulfate, 20-0-0

3. South Africa - subtropical conditions.

Table 20: Fertilizing recommendations of banana crop in South Africa

Nutrient requirements (kg/ha)			Recommended fertilizers (kg/ha)*		
N	P_2O_5	K_2O	AN	MAP	Multi-K®
185 - 250	--	655 - 850	-	-	1424 - 1880

* 19 applications of 45 *g/mat* Multi-K®, every two weeks (August through April).
(Source: Smith, 1991)

4. Fertilization recommendations

Banana plants need fertile soil and an abundance of soil moisture for best growth and production. The development rate the plant makes in its first 3-4 months determines the weight of the bunch and the number of hands. Consequently, it is essential to provide the best care during this period.

Placement - Soluble potassium, phosphorus and nitrogen fertilizers can be made easily available to the roots after planting. Application can be done in various forms:

1) Soil application broadcast or localized. Since banana roots quickly ramify away from the pseudostem, fertilizers should be rather broadcast than concentrated around the pseudostem.

2) Nutrigation™ (Fertigation- fertilizer placement via irrigation) is most efficient since nutrients are applied directly to the root zone

Timing - Fertilizing schedule should coincide with climatic conditions and phenological stages of the crop.

Frequency - Frequent applications are especially important where the soil is light and lacking in fertility and when rainfall is heavy. Because of its limited mobility in the soil, P fertilizers should be applied once or twice annually in the subtropics. N, K fertilizers are normally applied at short intervals via the irrigation system.
In humid tropics, intensive leaching due to extremely heavy showers dictates immediate fertilization via soil application in order to compensate for leaching losses.

Application frequency can be reduced significantly when **Multicote®**, controlled-release fertilizer, is used.

By using **Multicote®**, less leaching of plant nutrients, if any, will occur and less applications are required.

4.1 Nutrients uptake/removal

Uptake of macronutrients is in the following mass order:
Potassium (K) > Nitrogen (N) > Calcium (Ca) > Magnesium (Mg) > Phosphorus (P), see table 21.
Uptake of micronutrients is in the following mass order:
Manganese (Mn) > Iron (Fe) > Boron (B) > Zinc (Zn) > Copper (Cu).
N, P, K, Mg, and Cu have a high re-translocation rate compared to other nutrients.

Table 21: Nutrient removal by banana plants *(cv. Cavendish)**

Nutrient	Removal in fruit (kg/ha)	Removal in pseudo-stem (kg/ha)	Total (kg/ha)	Share of removal in fruit (%)
N	189	199	388	49
P	29	23	52	56
K	778	660	1438	54
Ca	101	126	227	45
Mg	49	76	125	39

* 50 ton/ ha of fresh fruit @ 2000 plants / ha

N:K ratio*

Critical leaf N:K ratio for optimum yields varies between 1:1 and 1:1.6, depending on method for leaf analysis.

Low N:K ratio results in

- "Finger Drop" (Dégrain) – a post-harvest problem of ripe banana bunches, called Finger Drop occurs during hot, wet seasons in tropics, if K supply is low, so that NH_4^+ accumulates.
- Delay in bunch emergence
- Widely spread hands, easily damaged during transport
- Fruit pedicles are fragile and when ripe, fruit fall from the bunch
- reduced wind resistance

Banana Nutrition (Lahav & Turner), IPI-Bulletin No 7 (1985), Irizarry et al. (1988), Garcia et al. (1980), Oschatz (1962)

On soils high in Sodium also Na^+ has to be considered for the optimum cationic balance e.g. problems with high Na:(K+Mg+Ca) ratio as in Canary Islands (*Banana Nutrition : Lahav & Turner) IPI-Bulletin No 7 (1985); Banano (ed.: Rosero Ruano); Godefroy-Lachenoud, 1978).*

Here again, Multi-K®, either water soluble or Multicote®, a coated CRF potassium nitrate, can not only be ideal source of K^+, but also due to the antagonistic cation (K^+) effect, can reduce or prevent the uptake of sodium.

4.2 Soil and leaf analysis

4.2.1 Soil test

Soil tests should be practiced to establish an effective, economical fertilizer program. The soil test for N is often considered an unreliable indicator of soil N status under banana, as close relationships between soil N test and banana response to applied N are difficult to obtain. Bananas perform best in soils with a pH of 5.0 (calcium chloride) or above. The table below provides a guide to preferred levels for bananas from a typical soil test.

Table 22: Guide to preferred levels for bananas from a typical soil test

Phosphorous (P)	80 ppm
Potassium (K)	0.5 meq/100 g
Calcium (Ca)	4 to 10 meq/100 g
Magnesium (Mg)	1 to 3 meq/100 g
Electrical conductivity (EC)	< 0.15 ds/m

As a result, soil test information is usually combined with local knowledge as variation occurs between areas (Tab. 24) to construct an optimal fertilization program.

Table 23: Soil analysis – critical values *(Godefroy and Dormoy (1988); Turner et al. (1989); Rosero Ronano (2000).*

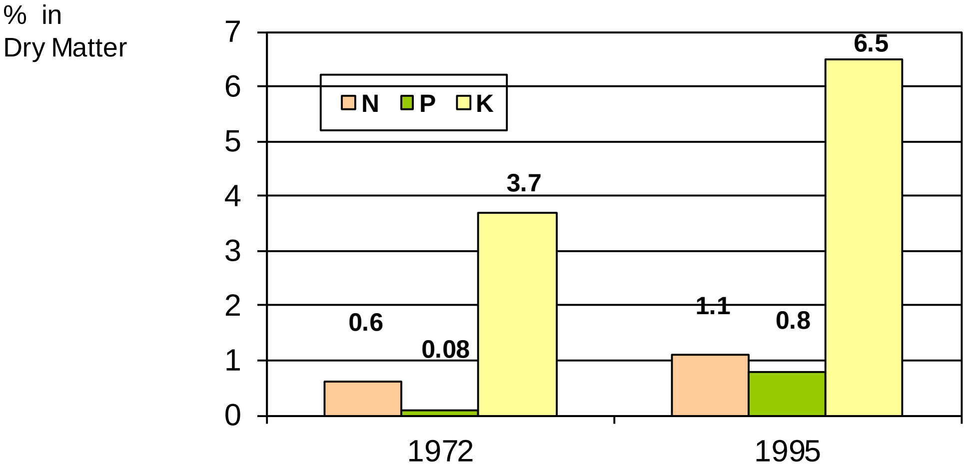
	P	K		Mg		Ca	
	mg/kg	mg/kg	meq/100g*	mg/kg	meq/ 100g*	mg/kg	meq/ 100g*
Carribean	40	156	0.4				
Martinique	25	200	0.5	122	1.0	600	3.0
Costa Rica	5-10	200-250	0.5-0.6	180-230	1.5-1.9	3-4000	15.0-20.0
Australia		546	1.4	608	5.0	3000	15.0

* millequivalent/ 100 g soil

4.2.2 Leaf analysis

For many years, leaf samples were taken from the 7th petiole and from the 3rd lamina. During these years hardly any changes took place in the laminae nutrient standards, while over the years, increased levels of N, P and K in the petioles, were adopted (Fig. 44).

Figure 44: Changes of N, P and K content in the 7th petiole over the years



Also, the vegetative mass of banana plants was increased, mainly due to better varieties, intensified fertilization schedules and rates. Consequently, nutrient content in plants increased as well (Tab. 24).

Table 24: Banana plants mass increased from the 1960s to the1990s
(*Lahav and Lowengart, 1998*).

Years	1960s	1990s
Average plant height (cm)	150	270
Average bunch weight (kg)	18	28
No. of bunches/ha	1700	2100
Average yield (ton/ha)	30	60

The third leaf from the top of the pseudostem of recently flowering (shot) plants is usually sampled for analysis.

Table 25: Recommended critical nutrient levels using the third leaf as sample leaf.

Nutrient	Percent dry weight (range)
Nitrogen	2.4 - 3.0
Phosphorus	0.25 - 0.24
Potassium	2.7 - 3.5
Calcium	0.4 - 1.0
Magnesium	0.20- 0.36

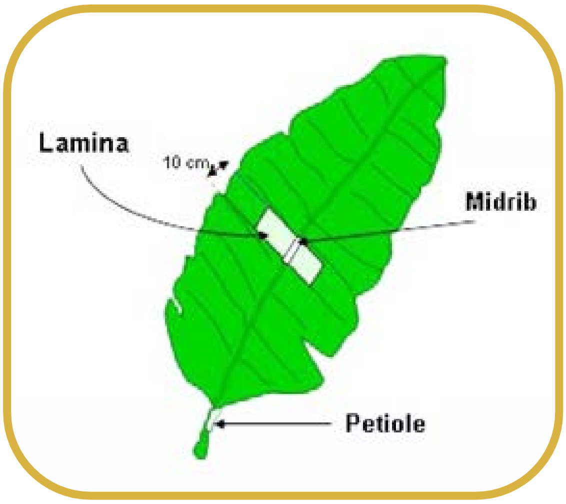
Nutrient	Part per million (range)
Manganese	25 - 150
Zinc	15 - 18
Iron	60 - 80
Copper	5 -9
Boron	11

Samples are taken from the leaf parts at different positions on the plant (Fig 45).

When to sample**:** The samples should be taken either just before flowering or following floral emergence and when all female hands are visible.

Which tissue to sample**:** In most banana-producing countries the laminar structure of leaf 3 is sampled for tissue analysis (IRS method, 1975). However, samples of the central vein of leaf 3 and the petiole of leaf 7 are also used. The laminar structure of leaf 3 is sampled by removing a strip of tissue 10 cm wide, on both sides of the central vein, and discarding everything but the tissue that extends from the central vein to the center of the lamina.

Figure 45: Sampling parts of banana leaves



4.2.3 Interpretation of nutrient status (lamina 3)

Table 26: Standards of N, P and K levels in banana lamina

Nutrient	Normal	Deficient
N	3 - 4 %	2 %
P	0.15% - 0.25%	< 0.15%
K	3 - 4 %	2 %

Table 27: Contents of Macro-nutrients in banana leaves (% in Dry Matter)

Nutrient	Lamina *(leaf 3)*	Midrib *(leaf 3)*	Petiole *(leaf 7)*
N	2.6	0.65	0.4
P	0.2	0.08	0.07
K	3.0	3.0	2.1
Ca	0.5	0.5	0.5
Mg	0.3	0.3	0.3

Table 28: Contents of Micro-nutrients in Banana Leaves (ppm in Dry Matter)

Nutrient	Lamina *(leaf 3)*	Midrib *(leaf 3)*	Petiole *(leaf 7)*
Cu	9	7	5
Zn	18	12	8
Mn	25	80	70
Fe	80	50	30
B	11	10	8
Mo	1.5-3.2		

Table 29: Interpretation of macro and secondary plant nutrient status (lamina 3)*

	Nutrient contents (% DM)					
	N	**P**	**K**	**Mg**	**Ca**	**S**
Deficient	< 2.3	0.12	1.9	< 0.24	0.4	0.21
Low (Critical)	2.3 – 3.3	0.13	< 4.5	0.25 – 0.29		0.21 – 0.25
Optimum	3.3 – 3.7	> 0.14	4.5 – 5.0	0.3 – 0.4	0.8 – 1.3	> 0.25
High	> 3.7		> 5.0	> 0.4	> 1.3	
Excess		0.3	> 5.5			

* - IFA manual – average of literature review

Table 30: Interpretation of micro plant nutrient status *(Martin-Prevel (1999 - IFA-manual)*

	ppm						
	Fe	**Mn**	**Zn***	**Cu**	**B**	**Na**	**Cl %**
Deficient	77	25 – 100	14 – 37				
Low		110 – 150				< 100	
Optimum	> 100	160 – 2500	> 20	9	11	100	(1.0)
High		> 2500				> 100	(2.0)
Excess	300	> 4800				> 300	(3.5)

*May also consider P/Zn ratio (high = Zn deficiency)

Table 31: Interpretation of micro plant nutrient status - Growth stage: Large / fully grown sucker.
(Martin-Prevel (1999 - IFA-manual)

	ppm						
	Fe	**Mn**	**Zn***	**Cu**	**B**	**Na**	**Cl %**
Deficient	-	40-150	6-17	<5?	<10?	-	-
Low	-	-	-	-	-	<60	-
Optimum	80-360	200-1800	20-50	6-30	10-25		0.9-1.8
High	-	2000-3000	-	-	-	>150	>2.0
Excess	-	>3000	-	-	30-100	>3500	3.5

4.3 Nutrients demand

Nutrient management according to nutrient uptake and removal – general recommendation*:

- The nutrient uptake of the whole mats is a base for fertilizer application, only when fertilizing the first crop
- For ratoon crops, crop residues of the previous crops, like leaf trash and cut pseudostems supply additional nutrients – less fertilizer is needed
- Nutrient losses from fertilizers and trash have to be considered for calculating fertilizer rates for plant and ratoon crops
- Split application of fertilizers reduce nutrient losses
- In particular, N and K losses can be high

Irizarry et al. (1988); Twyford & Walmsley (1973/74/76); van der Vorm and van Diest (1982)

Removal of plant nutrients in the harvested banana fruit is one of the major considerations in formulating fertilizer recommendations. The quantities of plant nutrients contained in the whole plant and in the fresh fruit harvested and removed from the field, are the basis for scheduling the fertilization program. The large amounts of K reflect the high K content in the fruit. When the previous crop is being left in the field, the contribution of recycled plant nutrients should be taken into consideration (Tab. 32).

Table 32: Plant nutrient requirements vary according to expected yield and plant growth, considering the contribution of recycled plant parts from the previous crop (expected yield: 30-60 ton/ha).

Nutrients requirements (kg/ha)				
N	**P_2O_5**	**K_2O**	**CaO**	**MgO**
Uptake by whole plants				
198 - 339	68 - 114	734 - 1268	165 - 273	92 - 155
Removal by yield				
57 - 114	15 - 30	240 - 480	24 - 48	21 - 42
Available nutrients from recycled previous crop				
48	12	280	16	16
Recommended application rates				
190 - 359	91 - 146	454 - 988	67 - 121	76 -139

Table 33: Nutrient Uptake by Cavendish Banana (per Mt of whole bunch banana)*

Variety	Plant Nutrient (kg/mt					
	N	P_2O_5	K_2O	MgO	CaO	S
Cavendish group	4 - 7	0.9 - 1.6	18 - 30	1.2 - 3.6	3 - 7.5	0.4 - 0.8
Other	Up to 10	Up to 3.5	Up to 60	1.2 - 3.6	Up to 12	0.4 - 0.8

** - IFA World Fertilizer Manual, 1991*

Summary: Nutrient uptake - N, P, K

- **Nitrogen**
  - constant need for N throughout the growth period
- **Phosphorous**
  - constant need for small P amounts throughout the growth period
- **Potassium**
  - constant need for K throughout the growth period
  - 80% of K application should be done before peak flowering
  - Smaller K rates at early stages, increased K rates in month before and after flowering (from "large" to "shot")
- **Magnesium**
  - constant need for small Mg amounts throughout the growth period.
- **Calcium**
  - Main Ca uptake until shooting/shot
  - No net Ca uptake into bunch after shooting
  - Main Ca application for fruit production should focus on periods before shooting
- **Sulfur**
  - The most rapid S uptake occurs from sucker to shooting stage.
  - After shooting the uptake rate is reduced.

4.3.1 Nitrogen

The form of nitrogen (N) either ammonium (NH_4^+) or nitrate (NO_3^-), plays an important role when choosing the right fertilizer for Nutrigation™ of banana plants.
Nitrate-nitrogen (NO_3^-) is a preferable source of nitrogen as it suppresses the uptake of chloride (Cl^-) and at the same time promotes the uptake of cations, such as: potassium (K^+), magnesium (Mg^+) and Calcium (Ca^{++}). Also, the nitrate form of nitrogen, increases the pH of soil solution near the root system, which is an especially important feature in tropical acidic soils.
The nitrogen in Multi-K® potassium nitrate is entirely in nitrate (NO_3^-) form, which makes it a suitable fertilizer for fertigation.
A better solution is to use Multicote®, Multicote® Agri and CoteN™, controlled-release fertilizers (for product details, see page 71), which would release gradually all plant nutrients according to plant's needs, while preventing leaching losses.

4.4 Suggested fertilizer rates and their plant nutrients content

Common standards for applying N, P and K*

N

- Split N application
- Every 1-3 month in relatively dry climates
- In humid tropics, at high rainfall, or irrigation; apply every 2-4 weeks, while with MulticoTech™ (4M), apply every 10 weeks.

P

- P application once/year broadcast to ratoon crops or incorporated into soil before planting
- On P fixing soils; rates may be 4 times higher than plant need
- In healthy plantation P dressings may biennially

K

- 80% of K should be applied by flowering
- Apply K more frequently under leaching conditions
- Rates of K according to soil analysis, e.g. if exchangeable K is < 0.4 meq/100 g soil

** - Lahav & Turner (1989 - IPI-Bulletin No 7), Martin-Prevel (1999 – IFA manual)*

4.4.1 Haifa NutriNet™ web software for Nutrigation™ programs

Haifa fertilization recommendations are available in the online Knowledge Center on our website, www.haifa-group.com. Use the NutriNet™ web software, accessible through our website or directly at www.haifa-nutrinet.com, to generate recommended fertilizer rates according to the expected yield under your growing conditions.

Soil-applied fertilization schedule and fertigation rates may vary according to cultivar, climatic conditions, growth stages and expected yield. By using the **Haifa NutriNet™** program on-line, you may obtain Haifa's recommendations most suitable to your growing conditions by selecting the expected yield, growing method and growth stages.
The following is an example of recommendations for two expected yield levels (30 and 60 T/ha) of banana, as determined by NutriNet™:

Table 34: Amount of fertilizers (kg/ha/year) and their applied plant nutrients, for expected yield of 30 T/ha, respectively.

Suggested Nutrigation™	**All nutrients in kg/ha**					
	Fertilizer	**N**	**P_2O_5**	**K_2O**	**CaO**	**MgO**
	(kg)	190	91	454	67	76
Suggested fertilizers						
Ammonium nitrate (34%)	0					
Haifa MAP (12-61-0)*	149	17.9	91			
Multi-K® (13-0-46)*	987	128.3		454		
Haifa Cal Calcium nitrate (26% CaO)*	258	38.7			67	
Magnesium sulfate (16% MgO)	475					76
TOTAL	1869	237	91	454	67	76

* Fertilizers produced by Haifa. For details, see Appendix X.

Table 35: Amount of fertilizers (kg/ha/year) and their applied plant nutrients, for expected yield of 60 MT/ha, respectively

Suggested Nutrigation™	**All nutrients in kg/ha**					
	Fertilizer (kg)	**N** 359	**P_2O_5** 146	**K_2O** 988	**CaO** 121	**MgO** 139
Suggested fertilizers						
Ammonium nitrate (34%)	0					
Haifa MAP (12-61-0)*	239	28.7	146			
Multi-K® (13-0-46)*	2148	279.2		988		
Haifa Cal Calcium nitrate (26% CaO)*	465	69.8			121	
Magnesium sulfate (16% MgO)	869					139
TOTAL	3721	473	146	988	121	139

* Fertilizers produced by Haifa. For details, see Appendix I.

4.4.2 Soil-applied fertilizers

In soils with low fertility, such as sandy and calcareous soils, bananas should be fertilized frequently (minimum 6 to 8 times a year) for maximum production. 35% of N, P, and K application should be applied during vegetative growth after planting and before flower differentiation, 40% before flower emergence, and the remaining 25% after flower emergence. The potash requirement is high and **Multi-K®** with a high K_2O content (13-0-46) is recommended as a source of K. The N-P_2O_5-K_2O ratio of 3-1-6 is recommended. A suggestion to prepare such ratio of water-soluble fertilizers, is presented in Tab. 36.

Table 36: Preparation of 1 ton 3:1:6 ratio N: P_2O_5: K_2O water soluble fertilizer.

Fertilizer	Fertilizer analysis			Amount of fertilizers (kg)	Plant nutrients (kg)		
	N	P_2O_5	K_2O		N	P_2O_5	K_2O
Urea	46	0	0	140	64	0	0
Haifa MAP	12	61	0	96	12	59	0
Multi-K®	13	0	46	764	99	0	351
Total kg				1000	175	59	351
N: P_2O_5: K_2O Ratio					3	1	6

The dry form of **Multi-K®** is also suitable for broadcasting in the banana plantation, either manually or with fertilizer spreaders. Two forms of **Multi-K®** enable perfect matching with the grower's means, i.e. soluble, made of crystalline particles, and prills (2-3 mm granules). Both forms are fully water soluble, however, the prills form may be most suitable for hand and mechanized spreading. The prills is the form of choice also for blending with other granulated fertilizers.

Figure. 46: A common technique of side dressing in a concentrated band near the plant (Central - and South-America)

The amount of fertilizer depends on size and age of the stalk and on the number of stalks per mat (Tab. 37). Fertilization of young plants should be started with N-P_2O_5-K_2O ratio of 3-1-6 (when higher analysis formula is used, amount of fertilizer per mat should be reduced, proportionally), with 2-3% magnesium, applied every 2 months, and increasing gradually to 2.5 kg to 3.0 kg at flowering and fruiting time, 10 to 18 months later.

Table 37: Fertilizer program for banana plants 1.

Months from planting a sucker or piece of rhizome	Amount of 3-1-6 fertilizer/mat/application (kg)[2]	Nutritional sprays (times/year)[3]	Iron applications (times per year)[4]
1 - 6	0.25 – 0.5	1-2	1-2
6 -12	0.5 – 1.0	1-2	1-2
12 -18	1.5 – 2.0	1-2	1-2
18 +	2.5 – 3.0	1-2	1-2

[1] - *A fertilizer containing nitrogen, phosphate, potash, should be applied every 2 months throughout the year.*

[2] – *In case of a fertilizer with higher analysis, the amount should be reduced proportionally.*

[3] - *Foliar applications of micronutrients may be applied 1-2 times per year.*

[4] - *Iron applications, especially in calcareous soils, should be made 1-2 times per year.*

If manganese (Mn) and zinc (Zn) are needed, at least one nutritional spray containing manganese and zinc is recommended annually. Copper should be included in the spray if no copper-containing fungicide is used. Banana plants growing in acidic sandy soils may be fertilized with 0.25 to 0.5 kg dry iron sulfate 1-2 times during the warmer part of the year. Banana plants growing in high pH, calcareous soils may be fertilized with 30 to 60 g of chelated iron material (EDDHA) during the warmer part of the year.

4.4.3 Examples of soil-applied fertilization practices

The following is considered a common practice in several banana growing countries:
Please note that application values may differ among locations, yields, application methods, etc., but generally the application rate of potassium is 1.5-2 fold higher than that of nitrogen.

a. Colombia, Santa Marta , a common practice is:

Table 38: Common fertilization practice in Colombia

Balanced application (kg/ha)		
N	P_2O_5	K_2O
600 - 900	300 - 450	900 - 1800

b. Tropical regions

Plant density: 1200-1800 mat/ha
Expected yield: 45-80 T/ha

Table 39: Fertilization practice in tropical regions

Nutrient requirements (kg/ha)			Recommended fertilizers (kg/ha)			
N	P_2O_5	K_2O	AN	Haifa MAP	SOP*	Multi-K® **
400 - 600	70 - 100	600 - 800	1000 - 1540	120 - 160	840 - 1020	390 - 520

* In regions with neither water salinity - nor soil salinity problems, SOP can be replaced by KCl **during the wet season only**.
** 30% of the annual potassium requirement should be applied at the time of bunch initiation.

The annual quantity of the recommended fertilizers should be divided to as many and as frequent applications as possible. In plantations without irrigation facilities, the applications should be done during the rainy season only.

c. Soil salinity area:
In an area that suffers from soil salinity, with plant density: 1200-1800 mat/ha and expected yield: 45-60 MT/ha, the fertilization practice is:

Table 40: Fertilization recommendation in saline areas.

Nutrient requirements (kg/ha)			Recommended fertilizers (kg/ha)*		
N	P_2O_5	K_2O	AN	Haifa MAP	Multi-K®
250 - 450	70 - 100	400 - 600	610 - 1130	120 - 160	850 - 1300

(Source: Suescun and Eduardo 1993.)
* The annual amount of the recommended fertilizers is divided to 6-8 applications. In growing areas without irrigation facilities, the applications are done during the rainy season.

AN =Ammonium nitrate, 33,5-0-0
Haifa MAP = Mono ammonium phosphate, 12-61-0
Multi-K® = Potassium nitrate 13-0-46

d. West Bengal

Table 41: Fertilizer recommendations for banana (Giant Governor)

Nutrient requirements (g/tree/year)*		
N	P_2O_5	K_2O
250	125	500

* Applied in split applications throughout the growing cycle. Fertilization is done on the 3rd, 6th and 9th months after planting.

e. Subtropical regions

Table 42: Fertilizer recommendations

Season	Nutrient requirements (kg/ha)			Recommended fertilizers (kg/ha)			
	N	P_2O_5	K_2O	AN	Haifa MAP	SOP*	Multi-K® **
Spring	130 - 200	100 - 150	300 - 350	330 - 510	160 - 250	650- 760	-
Summer	150 - 230	0	300 - 400	450 - 670	-	650 - 870	-
Autumn	120 - 170	100 - 150	250 - 350	90 - 125	160 - 250	-	550 - 570

* in regions with neither water salinity - nor soil salinity problems, SOP can be replaced by KCl **during the wet season only.**

** 30% of the annual potassium requirement should be applied at the time of bunch initiation.

Table 43: Nutrient recommendations in banana growing areas*

Region	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	comments
Cameroon	140 - 400	0	0 (-800)	No K on volcanic soils
South Africa	140-500	0-100	750-1600	+ Organic manure
Canary Islands-drip	500-600	200-300	700-1000	+ Organic/ plastic mulch
Can. Isl – surf. Irrig.	600-800	300-450	900-1500	plastic mulch
Israel, coast	400	200	1440	
India	300-600	320-345	340-720	+ manure
Taiwan	400	115	900	
Australia				
- N. Territ.	110	230	760	
- Queensland	280-370	160-460	480-1560	+ dolomite
- N.S. Wales	180	90-230	360-720	
Brazil, Sao Paulo	250-500	125-240	500-950	
Costa Rica	300-450	0-160	600-750	50-200 MgO, 500-600 CaO
Honduras	290	0	0	Sufficient K in most soils
Carribeans	160-300	80-120	600	

** - Martin-Prevel (1999 – IFA manual)*

4.5 Controlled release fertilizers

Haifa's **Multicote® Agri** products contain polymer-coated fertilizer granules, that slowly release plant nutrients into the soil solution at a pre-determined rate. Moisture in the soil is absorbed by the encapsulated fertilizer granules - dissolving the nutrients inside and releasing them into the root zone.

Why to use Multicote® Agri?

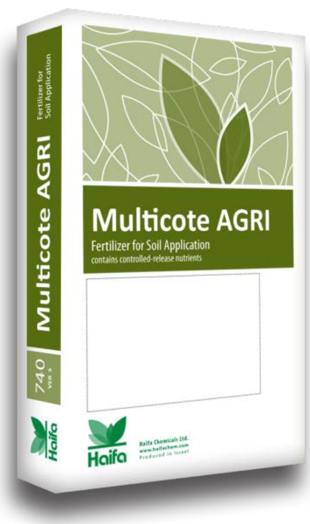
- **Multicote® Agri** can be used in **any kind of soil**. The release rate is determined exclusively by the soil temperature, which is also a major factor affecting plant growth rate. Soil type, humidity, pH, and microbial activity do not affect the release rate
- In tropical regions, where **heavy rains may leach out plant nutrients** from the root zone and where **many fertilizer applications are required** to offset loses, **Multicote® Agri** will be the ultimate solution. It is not affected by soil moisture or heavy rainfall, as it releases gradually plant nutrients.
- Since banana crop requires heavy and continuous feeding**, many fertilizer applications are required**. Consequently, **Multicote® Agri** saves on number of applications, thereby it considerably saves labor.
- Many experiments and field trials proved the efficiency of this product, resulting in **higher yields**.
- The efficiency of **Multicote® Agri**, due to a continuous nutrients release into the soil solution is much higher than conservative fertilizers. Consequently, lower rate of **Multicote® Agri** may be applied; saving on fertilizer expenditure as well as on freight cost.
- Wherever environmental concern over fertilizer ground-water contamination is an issue, **Multicote® Agri** will be the product of choice.

Multicote® Agri application concepts:

In many banana-growing countries **Multicote® Agri** proved to produce the highest yield at a competitive cost as compared to regular fertilization. There are two main application concepts:

1) In tropical regions with heavy rains, the use of **Multicote® Agri** will result in considerably less losses of plant nutrients as compared to conventional fertilizer applications. Also, less applications per year will be required.

2) In irrigated banana plantations where fertigation is practiced, **Multicote® Agri** can be applied during the rainy season where irrigation is not being practiced. This combination of both application methods, will save labor and ensure continuous plant nutrients supply during the rainy period.



4.5.1 Application recommendations

In tropical regions and where heavy rains may leach plant nutrients from the root zone of banana plant, **Multicote® Agri** is recommended.
Based on field trials and growers experience, **Multicote® Agri** 17-7-25+2MgO can be applied every 2 months at a rate of 260 g/mat /year.

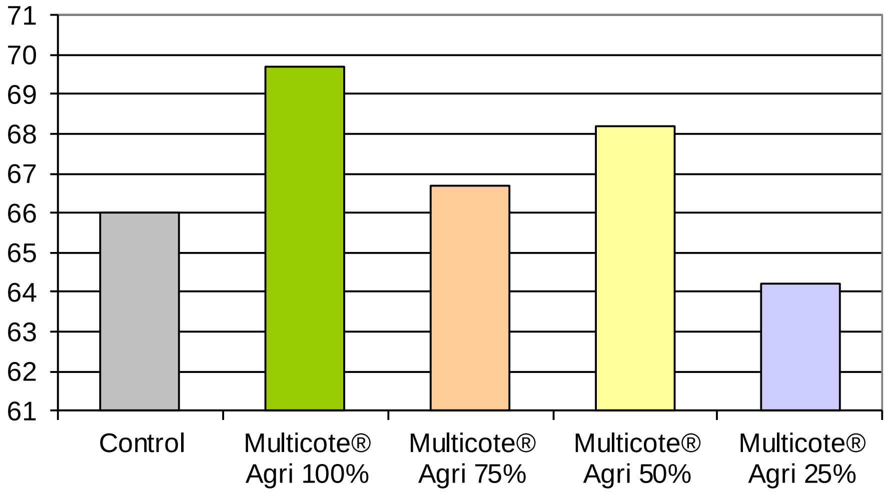
In irrigated fields, where only part of the growing period (about 4 months) is a rainy season, two applications of **Multicote® Agri** at a rate of 145 g / application /mat are recommended.
The rest of the time, about 8 months, water-soluble fertilizers should be fertigated. A water-soluble N-P-K fertilizer of a 3:1:4 ratio may be applied, such as 14-5-18 or 17-6-22. Eight monthly applications, of 150 g / application / banana plant, are recommended.

4.5.2 Multicote® Agri proven performances

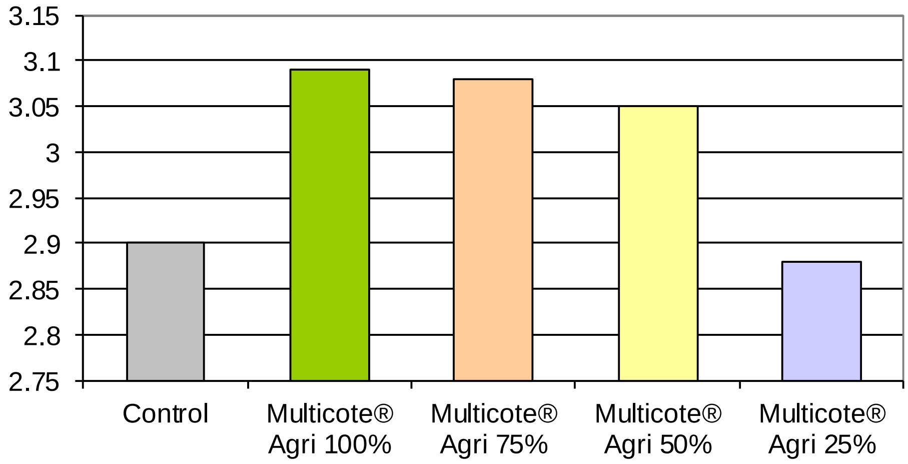
In Colombia, in cooperation with Chiquita, **Multicote® Agri** was compared to the regular commercial treatments (control). The N-P-K quantity was the same in all treatments while four combinations of **Multicote® Agri** content in each treatment varied from 100%, to 75%, 50% and 25%. The growth of the plant was measured: circumference, height of mother and daughter plants, % bunches emerging per week and number of weeks per plant.
Multicote® Agri performed better than the control on the 50-100% nutrient applications was practiced. (Figs. 47 a-d)

Figure 47 a-d: The effect of Multicote® Agri on growth of banana (cv. Williams)

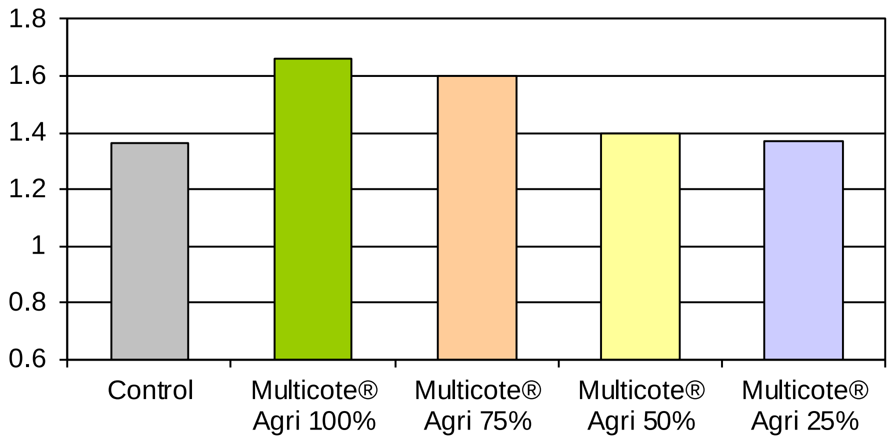
a. Perimeter of mother plant (cm)



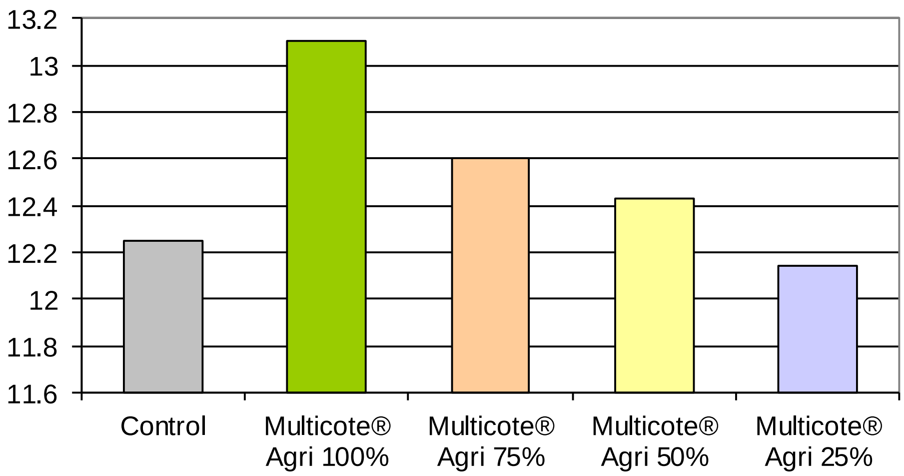
b. Height of mother plant (cm)



c. Height of daughter plant (cm)



d. Number of leaves on mother plant



In the Philippines, a large-scale experiment was carried out by Mt. Kitanglad Agriventure, Inc. (*MKAVI*) in Lantapan, Bukidnon, comparing **Multicote® Agri** 12-0-44 to the regular fertilization program (control) (Tab. 45). The objective was to determine the effect of improving common intensive nutrition scheme by applying the N & K as **Multicote® Agri** treatments:

Treatments:

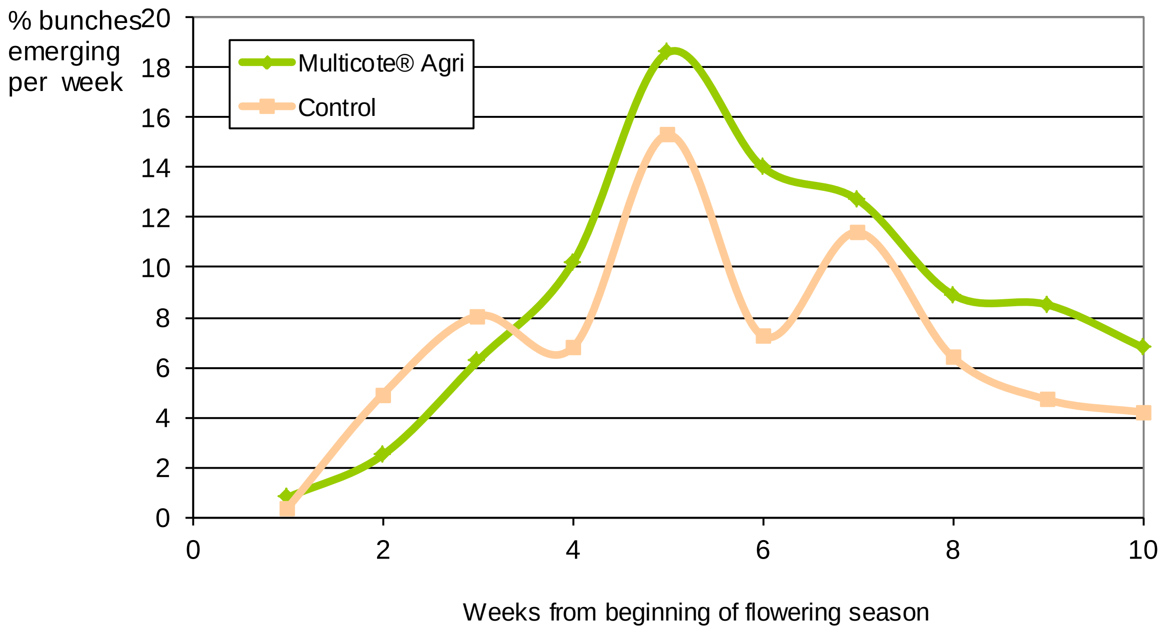
- Control

	Rate	Source
N	400 kg/ha	Uea, ammonium sulphate
P_2O_5	50 kg/ha	DAP
K_2O	1330 kg/ha	KCl
+ Fe + Zn		
+ Calcigline		

- Multicote® Agri 12-0-44, 800 kg/ha

Multicote Agri® treatment produced higher and earlier yields, compared to the control plot.

<u>Figure 48</u>: Multicote Agri® treatment resulted in earlier emergence of bunches in Banana (cv. Williams)



<u>Conclusion</u>:

Multicote® Agri increases the profits of banana growers by reducing number of applications and fertilization rates, and by producing higher yields.

4.6 Nutrigation™ (fertigation)

As explained in the beginning of this brochure, the banana is a tropical herbaceous evergreen plant with no natural dormant phase. Therefore, it has a high water demand throughout the year, especially at high temperatures.
In this respect, the important properties of the banana plant are:

- High transpiration potential due to the large broad leaves and high leaf area index
- Shallow root system as compared with most fruit tree crops
- Poor ability to withdraw water from soil beneath field capacity
- Rapid physiological response to soil water deficiency

These properties make banana plants extremely sensitive to slight variations in soil water content, and emphasize the importance of correct irrigation scheduling.
Nutrigation™ (fertigation) is a technique that combines irrigation with fertilization. During the several decades since this technique has been developed, it became well established as a potent method in modern agriculture, resulting in higher yields and improved quality of the crops.

The main advantage of all micro-irrigation systems is that they are spread across the field and a large area can be irrigated from a single control point. Labor requirement is therefore minimal, uniformity of application is high, a specific root zone area can be continuously wetted and any desired irrigation regime can be applied. In addition, water loss by evaporation is minimal especially when drip irrigation is practiced. Soluble fertilizers can be applied easily and efficiently through the system directly to the root zone.

- When fertigation is carried out via drip system or micro-sprinklers, it allows expanding the growing areas to marginal lands with a limited water-holding capacity. Such instances may be sandy or rocky soils, where accurate control of water and nutrients in the immediate vicinity of the root system is critical.
- In Hawaii, shifting to drip irrigation combined with Nutrigation™ in bananas has doubled the yield obtained from a well-managed, conventional sprinkler-irrigated plantation.

Table 44 provides an illustration for the responsiveness of the banana to Nutrigation™ with **Multi-K**® potassium nitrate.

Table 44: Effect of different potassium sources on bunch weight and total yield of bananas supplied with 600 kg/ha/Yr of K_2O in the form of either K_2SO_4, or **Multi-K**® or a combination of both (1:1)*.

Treatment	Bunch weight (kg)	Yield (boxes/ha)	B/C *
Control K_2SO_4	42.43	2975	--
K_2SO_4 + Multi-K®	44.91	3143	10.3
Multi-K®	47.06	3294	10.5

** - Guerrero and Gadban, 1996 "Laoespensa" Cienaga Magdalena. Colombia*
* Benefit/cost ratio expresses the ratio between the additional benefit/income and the additional cost associated with the treatment.

The results of this trial show that **Multi-K**® is markedly superior to K_2SO_4, agronomically and economically.

Tropical regions
Plant density: 1200-1800 mat/ha;
Expected yield: 45-60 MT/ha

Table 45: Nutrigation™ program in tropical regions

Nutrient requirements (kg/ha)			Recommended fertilizers (kg/ha)			
N	P_2O_5	K_2O	AN	Haifa MAP	SOP*	Multi-K® **
300 - 400	70 - 100	500 - 700	750 - 1100	120 - 160	700 - 980	330 - 460

* In regions with neither water salinity - nor soil salinity problems, SOP can be replaced by KCl during the wet season only.
** 30% of the annual potassium requirement should be applied at the time of bunch initiation.

- The annual quantity of the recommended fertilizers should be divided to weekly applications.
- During the rainy season fertilizers should be applied by means of short (technical) irrigation cycles, designed for this purpose only.

Subtropical regions

Table 46: Nutrigation™ program in subtropical regions

Season	Nutrient requirements (kg/ha)			Recommended fertilizers (kg/ha)			
	N	P_2O_5	K_2O	AN	Haifa MAP	SOP*	Multi-K® **
Spring	90 - 130	70 - 75	175 - 210	270 - 390	115 - 120	350 - 420	0
Summer	120 - 160	0	175 - 210	360 - 485	0	350 - 420	0
Autumn	90 - 110	70 - 75	150 - 180	100 - 150	115 - 120		330 - 390

* In regions with neither water salinity - nor soil salinity problems, SOP can be replaced by KCl during the wet season only.
** 30% of the annual potassium requirement should be applied at the time of bunch initiation.

- The annual quantity of the recommended fertilizers should be divided to weekly applications. The common practice is to divide the entire amount of fertilizers by the number of the irrigation weeks. The fertilizers are supplied in weekly amounts.
- Alternatively, the fertilizers can be applied continuously with the irrigation water, at a constant rate - proportional fertigation.

Table 47:

Season	Daily irrigation rate (mm)	Nutrient requirements (kg/ha)			Recommended fertilizers (kg/ha)			
		N	P_2O_5	K_2O	AN	Haifa MAP	SOP*	Multi-K® **
Spring	3-4	40-30	30-20	120-90	115-85	50-35	240 - 180	0
Summer	5-8	40-30	-	120-90	120-90	-	240 - 180	0
Autumn	4-6	40-30**	30-20	120-90	-	50 -35	-	260-195

* 30% of the annual potassium requirement is applied at time of bunch initiation.
** All the nitrogen amount is supplied during autumn by ***Multi-K®*** and ***Haifa MAP***

4.7 Foliar feeding

The plant roots readily absorb most mineral nutrients. However, many other plant organs are able to absorb nutrients in their ionic form from solutions. The extensive area of plant leaves makes them a natural candidate as a complementary feeding channel. Indeed, this method is now widespread in feeding management of many crops. The unique advantages that this method offers for banana growers are as follows:

- When the banana crop require plant nutrients, which are fixed and immobile in the soil.
- When deficiencies are detected at advanced stages of plant growth, and a quick correction is necessary.
- When root activity is hampered by external stresses such as low soil temperature, poor aeration, nematodes, rodents, or damage by machinery.
- When the effectiveness of direct soil application is limited due to weed infestation. As foliar application bypasses weed competition, this method ensures high availability to the target organs.
- When the roots are unable to provide the plant with certain nutrients at adequate rates, during specific critical stages of growth. This syndrome may take place even in fertile soils.

4.7.1 Foliar feeding practices

In Martinique, Philippines, Colombia and elsewhere it has become a prevailing practice to apply **Haifa Bonus** at a rate of 70-100 g/mat (25-30% of the yearly potassium requirement) at the time of bunch initiation. The high availability of **Haifa Bonus** to the plant makes it the best fertilizer in meeting the plant's increasing demand for nutrients at this critical stage of plant development that determines yield.

In Colombia, Mexico and elsewhere, foliar sprays during the vegetative growth and bunch development were found to be remarkably beneficial in increasing bunch weight, number of hands per bunch and number of fingers per hand (Tabs. 50, 51).

Table 48: Effect of foliar application of **Haifa Bonus** on banana plants at two locations, in Colombia*

	Bunch weight (kg)	Hands/bunch	Fingers/hand (2nd basal)
Control	29.8	8.09	20.0
Haifa Bonus **	34.0	9.11	21.3

* *Guerrero and Gadban, 1992, **"La Ceiba"** Santa Maria, Colombia*

** Six spray applications at 2% concentration, at 30-days intervals,.

Table 49: Effect of foliar application of **Haifa Bonus** on banana plants*

	Bunch weight (kg)	Hands/bunch	Fingers/hand (2nd basal)	*B/C* ***
Control	35.9	9.4	23.10	
Haifa Bonus **	37.9	10.5	23.25	13.5

**Guerrero and Gadban, 1993, San Rafael Cienaga Magdalena, Colombia*

** Four spray applications at 30-days intervals at 2% concentration.

*** Ratio between additional benefits and the additional cost associated with the treatment.

It is a Costa-Rican banana growers' practice to make **44** foliar-spray applications per year to control **Black Sigatoka** disease. Researchers from CORBANA (Corporacion Bananera Nacional) have found positive effects on vegetative growth and bunch development, when 22 of these applications were combined with **Haifa Bonus** at 600 g/ha (Tab. 52).

Table 50: Advantageous effects of combining **Haifa Bonus** in pesticide spraying*

	Number of leaves at flowering	Pseudostem diameter (cm)	Hands/bunch (%)	Bunch weight (%)
Control	13.75	13.6	100	100
Urea	13.91	14.4	102	108
Haifa Bonus **	14.25	14.4	106	113

**Sancho and Guzman, 1996)*

It is a Mexican banana growers' practice to make **36-44 foliar spray** applications per year to control **Black Sigatoka** disease. They use to combine **Haifa Bonus** with the pesticides ***Bravo 720*** and ***Tilt*** as follows:
Ground spraying:
2-4% **Haifa Bonus** in 300-400 liter/ha spray solution.
Air spray application: 7-8% **Haifa Bonus** in 20 liter/ha spray solution.

4.7.2 Foliar application recommendations

When application is done by ground spraying, the rate should be 2-4% **Haifa Bonus** dissolved in 300- 400 liter/ha spray solution. Total rate: 6-12 kg/ha.
When application is done by aerial spraying, the rate should be 8-10% **Haifa Bonus** dissolved in 20 liter/ha spray solution.

Time and number of applications:

In subtropical regions
Three to five spraying treatments at 3-4 week intervals.
Recommended concentration for ground application is 2-4%
Recommended concentration for aerial application is 8-10%

In tropical regions
Applications can be done throughout the year, up to 22 applications, that can be tank-mixed with pesticide sprays.

Compatibility:
Haifa Bonus is highly compatible with most pesticides used in banana cultivation. It is also compatible with other plant nutrients used for correcting common deficiencies such as magnesium, zinc and boron. It is advisable to confirm compatibility of your intended mix by preparing a sample of the spray materials at their recommended concentrations in order to rule out the possibility of a detrimental cross reaction. This mixture should be sprayed onto small area prior to commercial treatment, in order to assess whether an adverse effect occurs.

Susceptibility:
High temperature and low humidity may increase the susceptibility of banana plants to possible spray injury. The preferred time for spraying is early morning or late evening.
Plants under stress conditions should not be sprayed!

Appendix I: Haifa Specialty Fertilizers

Pioneering Solutions

Haifa develops and produces **Potassium Nitrate** products, **Soluble Fertilizers** for Nutrigation™ and foliar sprays, and **Controlled-Release Fertilizers**. Haifa's Agriculture Solutions maximize yields from given inputs of land, water and plant nutrients for diverse farming practices. With innovative plant nutrition schemes and highly efficient application methods, Haifa's solutions provide balanced plant nutrition at precise dosing, composition and placing. This ultimately delivers maximum efficiency, optimal plant development and minimized losses to the environment.

Potassium Nitrate

Haifa's Potassium Nitrate products represent a unique source of potassium due to their nutritional value and contribution to plant's health and yields. Potassium Nitrate has distinctive chemical and physical properties that are beneficial to the environment. Haifa offers a wide range of potassium nitrate products for Nutrigation™, foliar sprays, side-dressing and controlled-release fertilization. Haifa's potassium nitrate products are marketed under the Multi-K® brand.

Multi-K® Products

Pure Multi-K®

Multi-K® Classic	Crystalline potassium nitrate (13-0-46)
Multi-K® Prills	Potassium nitrate prills (13-0-46)

Special Grades

Multi-K® GG	Greenhouse-grade potassium nitrate (13.5-0-46.2)
Multi-K® pHast	Low-pH potassium nitrate (13.5-0-46.2)
Multi-K® Top	Hydroponics-grade potassium nitrate (13.8-0-46.5)

Enriched Products

Multi-npK®	Enriched with phosphate; crystalline or prills
Multi-K® Mg	Enriched with magnesium; crystalline or prills
Multi-K® Zn	Enriched with zinc; crystalline
Multi-K® S	Enriched with sulfate; crystalline
Multi-K® B	Enriched with boron; crystalline or prills
Multi-K® ME	Enriched with magnesium and micronutrients; crystalline

Nutrigation™

Nutrigation™ (Fertigation) delivers pure plant nutrients through the irrigation system, supplying essential nutrients precisely to the area of most intensive root activity. Haifa's well-balanced Nutrigation™ program provides the plant with their exact needs accordingly with seasonal changes. Decades of experience in production and application of specialty fertilizers for Nutrigation™ have made Haifa a leading company in this field. Haifa keeps constantly up to date with contemporary scientific and agricultural research, in order to continuously broaden its product line to better meet the requirements of crops and cropping environments.

HAIFA offers a wide range of water-soluble fertilizers for Nutrigation™. All products contain only pure plant nutrients and are free of sodium and chloride

Multi-K®	Comprehensive range of plain and enriched potassium nitrate products
Poly-Feed®	Soluble NPK fertilizers enriched with secondary and micro-nutrients
Haifa MAP	Mono-ammonium phosphate
Haifa MKP	Mono-potassium phosphate
Haifa Cal	Calcium nitrate
Magnisal®	Our original magnesium nitrate fertilizer
Haifa Micro	Chelated micronutrients
Haifa VitaPhos-K™	Precipitation-proof poly-phosphate for soilless Nutrigation™
Haifa ProteK	Systemic PK fertilizer

Foliar Feeding

Foliar Feeding provides fast, on-the-spot supplementary nutrition to ensure high, top quality yields and is an ideal feeding method under certain growth conditions in which absorption of nutrients from the soil is inefficient, or for use on short–term crops. Precision-timed foliar sprays are also a fast-acting and effective method for treating nutrient deficiencies. Foliar application of the correct nutrients in relatively low concentrations at critical stages in crop development contributes significantly to higher yields and improved quality. Haifa offers a selection of premium fertilizers for foliar application. Haifa offers a selection of fertilizers for foliar application:

Haifa Bonus High-K foliar formulas enriched with special adjuvants for better absorption and prolonged action

Poly-Feed® Foliar NPK formulas enriched with micronutrients specially designed to enhance the crop performance during specific growth stages

Magnisal®, **Haifa MAP**, **Haifa MKP**, **Haifa Cal** and **Haifa Micro** are also suitable for foliar application.

Controlled Release Nutrition

Multicote®, Haifa's range of Controlled Release Fertilizers includes products for agriculture, horticulture, ornamentals and turf. Multicote® products provide plants with balanced nutrition according to their growth needs throughout the growth cycle. Multicote® products enhance plant growth, improve nutrients use efficiency, save on labor and minimize environmental impact.

Single, pre-plant application controlled-release fertilizer can take care of the crop's nutritional requirements throughout the growth season. Controlled release fertilizers are designed to feed plants continuously, with maximal efficiency of nutrients uptake. Controlled release fertilizers save labor and application costs. Their application is independent of the irrigation system, and does not require sophisticated equipment.

Taking advantage of MulticoTech™ polymer coating technology, Haifa produces Multicote® line of controlled release fertilizers.

Multicote® Products

Multicote® for nurseries and ornamentals; NPK formulae with release longevities of 4, 6, 8, 12 and 16 months
Multicote® Agri / Multigro® for agriculture and horticulture
CoteN™ controlled-release urea for arable crops
Multicote® Turf / Multigreen® for golf courses, sports fields, municipals and domestic lawns

Appendix II: Conversion tables

From	To	Multiply by	From	To	Multiply by
P	P_2O_5	2.29	P_2O_5	P	0.44
P	PO_4	3.06	PO_4	P	0.32
H_3PO_4	H_2PO_4	0.9898	H_2PO_4	H_3PO_4	1.38
K	K_2O	1.20	K_2O	K	0.83
Ca	CaO	1.40	CaO	Ca	0.71
Mg	MgO	1.66	MgO	Mg	0.60
S	SO_3	2.50	SO_3	S	0.40
S	SO_4	3.00	SO_4	S	0.33
N	NH_4	1.28	NH_4	N	0.82
N	NO_3	4.43	NO_3	N	0.22

From	To	Multiply by	From	To	Multiply by
Acre	Hectare	0.405	Hectare	Acre	2.471
Kilogram	Lbs	2.205	Lbs	Kilogram	0.453
Gram	Ounces	0.035	Ounces	Gram	28.35
Short Ton	MT	0.907	MT	Short Ton	1.1
Gallon (US)	Liters	3.785	Liters	Gallon (US)	0.26
Kg/Ha	Lbs/acre	0.892	Lbs/acre	Kg/Ha	1.12
MT/Ha	Lbs/acre	892	Lbs/acre	MT/Ha	0.001

1 meq	Correspondent element (mg)	1 mmol	Correspondent element (mg)	Weight of ion
NH_4^+	14 mg N	NH_4^+	14 mg N	18 mg NH_4^+
NO_3^-	14 mg N	NO_3^-	14 mg N	62 mg NO_3^-
$H_2PO_4^-$	31 mg P	$H_2PO_4^-$	31 mg P	71 mg P_2O_5
HPO_4^{2-}	31 mg P	HPO_4^{2-}	31 mg P	35,5 mg P_2O_5
HPO_4^{2-}	15.5 mg P	K^+	39 mg K	47 mg K_2O
K^+	39 mg K	Ca^{2+}	40 mg Ca	28 mg CaO
Ca^{2+}	20 mg Ca	Mg^{2+}	24 mg Mg	20 mg MgO
Mg^{2+}	12 mg Mg	SO_4^{2-}	32 mg S	48 mg SO_4
SO_4^{2-}	16 mg S	Na^+	23 mg Na	-
Na^+	23 mg Na	Cl^-	35.5 mg Cl	-