Nutritional recommendations for

PEPPER

Haifa

Pioneering the Future

Nutritional recommendations for

PEPPER

in open-field, tunnels and greenhouse

Botanical name: *Capsicum annuum L.*
Synonyms: Capsicum, bell-pepper, paprika, piment, pimiento, pepperoni, gemusepaprika.

Contents:

1. General growing conditions

1.1 Growing method

Open-field, greenhouse or tunnels

1.2 Soil type

Better results will be obtained by growing in light soil such as sandy loam or loams, well drained, rich in organic matter. The preferable pH of the soil should be between 6.5 and 7.5.

1.3 Specific sensitivities

Sensitivity to soil-borne diseases

Peppers are prone to soil-borne diseases caused by fungi, viruses or bacteria. Therefore it is recommended to avoid growing peppers on plots that used for other sensitive crops (tomatoes, eggplants, Irish potatoes, sweet potatoes, cotton, soybeans and others) on recent years. A regime of 3-year rotation between small grains and pepper is recommended.

Sensitivity to salinity

Under saline conditions, sodium cations compete with the potassium cations for the uptake sites in the roots, and chloride competes for the uptake of nitrate-nitrogen and will reduce yield. This will result in a potassium deficiency in the pepper plants, leading to a low fruit number per plant. Corrective measures under such conditions must include the following steps:

- Abundant application of potassium, as this specific cation can successfully compete with the sodium, and considerably reduce its uptake and negative effects.
- Abundant application of nitrate, as this specific anion can successfully compete with chloride, and markedly reduce its uptake and adverse effects.
- Also, calcium may help to suppress the uptake of sodium. When sufficient calcium is available, the roots prefer uptake of potassium to sodium, and sodium uptake will be suppressed.

Zinc nutrition in plants seems to play a major role in the resistance to salt in pepper and other crops. Adequate zinc (Zn) nutritional status improves salt stress tolerance, possibly, by affecting the structural integrity and controlling the permeability of root cell membranes. Adequate Zn nutrition reduces excessive uptake of sodium (Na^+) by roots in saline conditions.
The methods of implementing these measures are discussed in chapter 2.

Sensitivity to calcium deficiency

Peppers are highly sensitive to calcium deficiency, which is manifested in the Blossom-end rot (BER) symptom on the fruits. Salinity conditions severely enhance BER intensity. But manganese (Mn) was recently found to serve as antioxidant in pepper fruit hence the addition of manganese to peppers grown under salinity may alleviate BER symptoms in the fruits. Special care must be taken to avoid growing conditions, which enhance BER phenomenon. Please read more about it in chapter 2.

1.4 Desirable temperatures

Table 1. Optimal temperatures for pepper plants by growth stage.

Growth stage	Temperature (°C)		
	Minimum	Maximum	Optimal
Germination	13	40	20-25
Vegetative growth	15	32	20-25 (day) 16-18 (night)
Flowering and fruiting	18	35	26-28 (day) 18-20 (night)

1.5 Irrigation

Greenhouse grown peppers enjoy a longer growing season. They consume, therefore, a larger amount of water than open-field grown peppers during their respective growing season.
Water stress affects pepper growth by reducing the number of leaves and the leaf area, resulting in less transpiration and photosynthesis. Root density is reduced by ~20 % under water stress conditions, compared to sufficiently irrigated plants.
Excessive irrigation will cause water-logging, root death due to anaerobic soil conditions, delayed flowering and fruit disorders.
The root system consists of a deep taproot with laterally spread branches about 50 cm long, and adventitious roots. Therefore a drip system equipped with a Nutrigation™ (fertigation) device is advisable.

1.6 Crop uses

Pepper is used as a fresh vegetable, pickled vegetable, fresh chili spice and dried paprika powder.

1.7 Growth stages

Growth stages of plants consist of four general periods, having unique nutritional needs of the plant, consequently requiring different fertilization regimes:

- Vegetative growth from planting or seeding to first flowering.
- From flowering to fruit set
- Fruit ripening to first harvest
- From first to last harvest

The duration of each stage may vary according to growing method, variety characteristics and climatic conditions.

Table 2: An example of various growth stages durations:
Location: Central Israel
Variety: *Maor*
Growing method: Greenhouse
Number of days to flowering: 35-40
Number of days to 1st harvest: 70

Growth stage	Stage duration (days)	Plant age (days)
Planting	1	1
Vegetative	24	25
Flowering	10	35
Fruit set	10	45
1st Harvest	25	70
Harvest to Last Harvest	170	240

2. Nutritional requirements

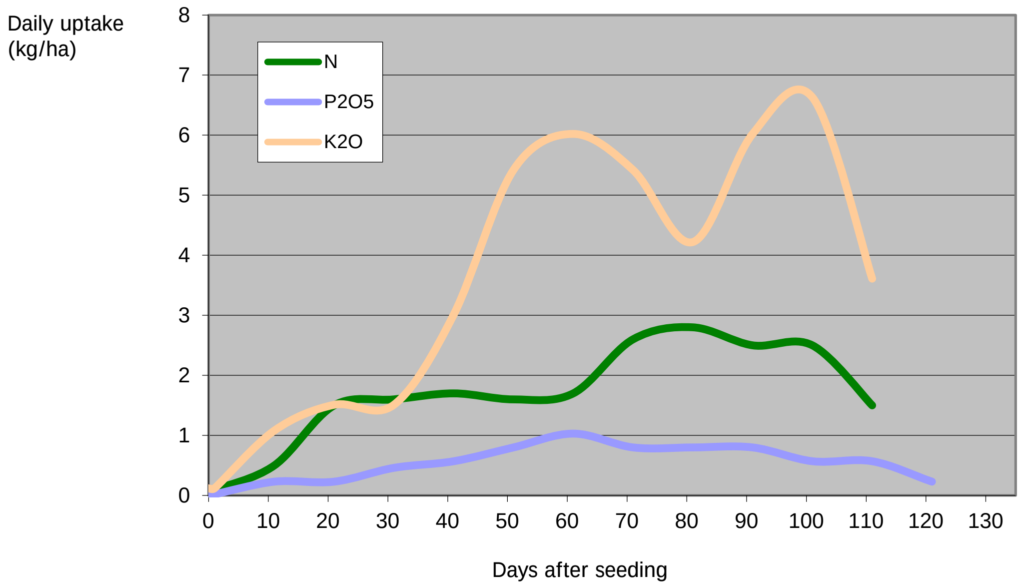
2.1 Main functions of plant nutrients

Table 3: 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 and a-biotic stresses, counteracts salinity
Calcium (Ca)	A major building block in cell walls, and reduces susceptibility to diseases.
Sulphur (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 Nutrient uptake curves

Figure 1: Nutrient requirements curves (kg/ha/day) in pepper cv *Maor*.
Seeding: July 14th ; Soil type: Sand ; Plant Density: 100,000 plants/ha
Expected yield: 75 T/ha



As can be seen in figure 1, the greatest absorption of nutrients occurs in the first 60 days of growth, and another peak takes place after the first fruit removal. Therefore, the plant requires high nitrogen application early in the growing season with supplemental applications after the fruit initiation stage. Improved nitrogen use efficiency and greater yields are achieved when the nitrogen is applied under polyethylene mulches and with 12 weekly N applications in a drip irrigation system (Nutrigation™).
At least 50-90% of the total nitrogen should be applied in nitrate (NO_3^-) form.

2.3 N-P-K functions in pepper

Nitrogen (N) contributes to the vegetative growth of the pepper plant. It is important that the plant, when reaching the flowering stage, will be well developed vegetatively; or it will have a low yielding potential. Pepper plants were found to positively respond (by increasing number of flowers and fruits) to higher nitrogen concentrations than the usual norms for other crops.

Phosphorus (P) is essential for the normal development of the roots and reproductive organs (flowers, fruit, seeds). Highly available phosphorous is needed for the establishment of the transplant. Phosphorus shortage in the soil will result in development of too small and short branches, many undeveloped buds and less fruit in general. Adequate phosphorus enhances early fruit ripening.

Potassium (K) - adequate levels enhance the accumulation of carbohydrates and the resistance to low temperatures and diseases. See figure 2.
Potassium deficiency slows down the growth rate of pepper plants. Potassium deficiency symptoms are: brown spots at the edges of the leaves and fruits, and sometimes there is curling and drying of the leaves. Severe potassium deficiency will retard the transportation of sugars within the plant, leading to starch accumulation in the lower leaves.

Figure 2: Effects of potassium (K) on pepper yield, under constant N rate of 224 kg/ha

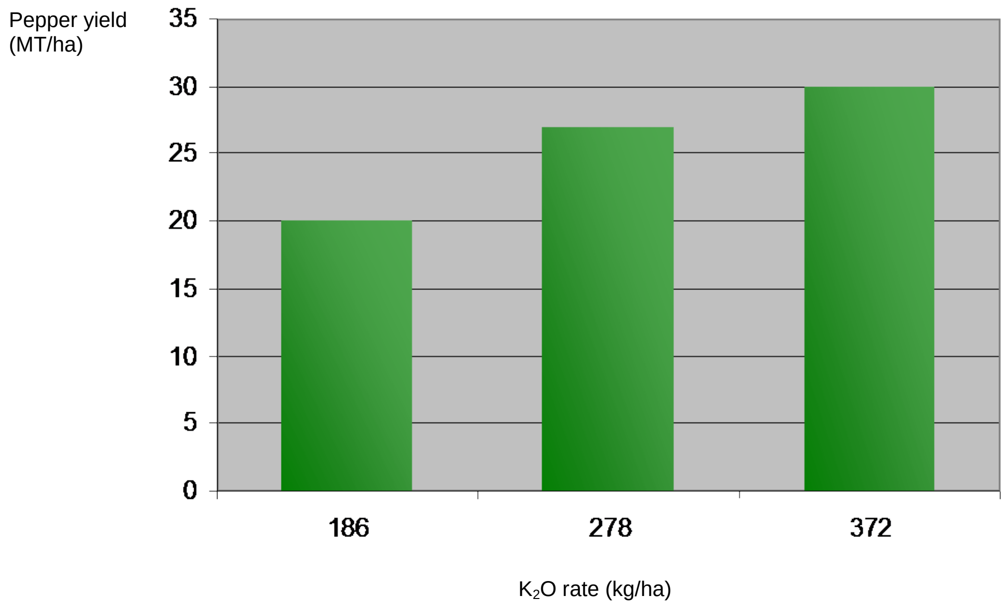


Table 4: Example of optional growing methods and the required rates of macro- and secondary plant nutrients

	Greenhouse	Open Field
Expected yield (T/ha)	75 - 200	11 - 140
Plant density (plants/ha)	50,000 - 100,000	30,000 - 50,000
Nutrients Uptake (kg/ha)		
N	390 - 920	116 - 705
P_2O_5	200 - 330	132 - 276
K_2O	640 - 1530	174 - 1155
CaO	100 - 210	38 - 174
MgO	60 - 150	22 - 115
S	40 - 50	35 - 40

2.4 Nutritional disorders in pepper

Table 5: Visual symptoms exhibited by pepper plants under nutritional disorders

Nutrient	Deficiency symptoms	Excess / Toxicity symptoms
Nitrogen	Plant development gradually slows down. Gradual drying, beginning at leaf margins, of the area between the lower leaf veins. The petioles bend and hang downwards, parallel to the stem. The plant develops few flowers and fruit setting is poor. The fruit receptacle is thin, and the ovary is small. Sometimes there is no fruit development on the plant at all, and on those plants that bear fruits, the fruit is deformed. See figure 3.	Plants are usually dark green in color, have abundant foliage, but usually with a restricted root system. Flowering and seed production can be retarded.
Phosphorus	The plants display limited growth. The leaves are hard and brittle to the touch. Flower formation is defective. Few flowers develop, and in those that do develop, only one in every four or five develops a fruit. The fruit is underdeveloped, with a thin receptacle, and very few seeds. The root system is undeveloped. See figure 4.	No typical primary symptoms. Copper and zinc deficiencies may occur due to excessive phosphorus.
Potassium	Yellow chlorosis spots appear between leaf veins, firstly in the lower leaves. The veins and the areas adjacent to these spots do not change their color. Later, the chlorotic spots become lighter. (This can be seen mainly in the upper parts of the plant). There is little fruit setting, and not much fruit, which is smaller than usual. See figure 5.	Usually not excessively absorbed by plants. Excessive potassium may lead to magnesium, manganese, zinc or iron deficiencies.
Sulfur	Causes leaves to become yellowish.	Reduction in growth and leaf size. Leaf symptoms often absent or poorly defined. Sometimes interveinal yellowing or leaf burning.

Nutrient	Deficiency symptoms	Excess / Toxicity symptoms
Magnesium	Is common on pepper plants. Yellowing of the leaves is apparent in the interveinal areas and veins remain green. The oldest leaves are affected first. Sometimes magnesium deficiency occurs when excessive applications of potassium have been made. It may also show up under extremely hot dry weather. See figure 6.	Very little information available.
Calcium	The most common reason for Blossom End Rot of the fruit (see figure 7). This may be corrected by foliar spray of calcium chloride or calcium nitrate. Further information following on page 10.	No consistent visible symptoms. Usually associated with excessive soil carbonate.
Iron	Symptoms show at the later stages of growth. The young leaves fade and then become yellow in the areas between the veins. The veins remain green.	Rarely evident in natural conditions. Has been observed after foliar iron sprays manifested as necrotic spots.
Chloride	Wilted leaves, which then become chlorotic bronze, and necrotic. Roots become stunted and thickened near tips.	Burning or firing of leaf tips or margins. Bronzing, yellowing and leaf abscission and sometimes chlorosis. Reduced leaf size and lower growth rate.
Manganese	Chlorotic spots between the upper leaf veins.	Sometimes chlorosis, uneven chlorophyll distribution. Reduction in growth. Lesions and leaf shedding may develop later.
Boron	The deficiency manifests itself very quickly. The lower leaves curl upwards. Growth is stunted. The plant develops a thick, short stem. The apex withers and the leaves become yellow from bottom to top of the plant. See figure 8. There is a reduced production of flowers, and fruit setting is poor.	Yellowing of leaf tip followed by progressive necrosis of the leaf beginning at tip or margins and proceeding toward midrib. See figure 9.
Zinc	The leaves become narrow and small in chili.	Excessive zinc commonly produces iron chlorosis in plants.
Copper	Appear late in the vegetative stage. The leaf margins curl and dry up. The leaves and the fruit become narrow and rectangular.	Reduced growth followed by symptoms of iron chlorosis, stunting, reduced branching, thickening and abnormal darkening of rootlets.
Molybdenum	The foliage turns yellow-green and growth is somewhat restricted. The deficiency occurs most commonly on acidic substrates.	Rarely observed. Sometimes leaves turn golden yellow.

Figure 3: Nitrogen (N) deficiency

Figure 4: Phosphorus (P) deficiency

Figure 5: Potassium (K) deficiency

Figure 6: Magnesium (Mg) deficiency.

Figure 7: Calcium (Ca) deficiency as blossom-end rot (BER) of the fruit

Blossom end rot (BER)

BER occurs mainly during hot weather conditions. Fruits are affected in their early stages of development (10-15 days after fruit set); the cause is related to the rate of calcium supply to the fruit, which is lower than the rate of the fruit growth. This results in the collapse of certain tissues in the fruit, demonstrated as BER. Factors that favor BER are directly related to limited calcium uptake and transport to the fruit, like high salinity, high temperatures and high growing intensity and water shortage.

Pepper spots

Black spot or *stip* is shown in the fruit as grey/black spots, which develop under the skin in the fruit wall about the time the fruit attains a diameter of 8 centimeters or more. As the fruits ripen, the spots slightly enlarge and turn green or yellow. Stip is a calcium disorder, caused by excessive N-NH_4 and K rates. Susceptibility greatly varies by variety.

Figure 8: Boron deficiency; the growing points die and decay, and the leaves are misshapen

Figure 9: Boron excess

2.5 Leaf analysis standards

Table 6: Macro and secondary plant nutrients contents in pepper plant leaves

	Deficient	Normal	High
	% of dry matter		
N	2-2.5	3-4	4-5
P	0.25	0.3-0.4	0.4-0.6
K	2	3.5-4.5	4.5-5.5
Ca	1	1.5-2	5-6
Mg	0.25	0.25-0.4	0.4-0.6
Na		0.1	

Table 7: Micro plant nutrients contents in pepper plant leaves:

	Deficient	Normal	High
	ppm of dry matter		
Fe	50-100	200-300	300-500
Mn	25	80-120	140-200
Zn	25-40	40-50	60-200
Cu		15-20	24-40
B		40-60	60-100
Mo		0.4	0.6

2.6 Plant Nutrient Requirements

Table 8: Nutritional requirements of pepper in greenhouse

Expected yield (Ton/ha)	Removal by yield (kg/ha(					Uptake by whole plant (kg/ha)				
	N	P_2O_5	K_2O	CaO	MgO	N	P_2O_5	K_2O	CaO	MgO
25	50	15	87	12	7	140	35	201	107	32
50	100	30	175	25	15	221	57	330	153	49
75	150	45	262	37	22	303	79	457	198	64
100	200	60	350	50	30	384	101	585	244	81
125	250	75	437	62	37	466	123	712	290	97
150	300	90	525	75	45	547	145	841	336	114
175	350	105	612	87	52	629	167	968	381	129
200	400	120	700	100	60	710	189	1096	427	146

Table 9: Nutritional requirements of pepper in open field

Expected yield (Ton/ha)	Removal by yield (kg/ha(					Uptake by whole plant (kg/ha)				
	N	P_2O_5	K_2O	CaO	MgO	N	P_2O_5	K_2O	CaO	MgO
20	40	12	70	10	6	121	30	173	95	28
40	80	24	140	20	12	191	49	282	137	43
60	120	36	210	30	18	261	67	390	179	57
80	160	48	280	40	24	331	86	499	221	72
100	200	60	350	50	30	402	105	608	263	86
120	240	72	420	60	36	472	124	716	305	100
140	280	84	490	70	42	542	142	825	347	115

3. Fertilization recommendations

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, and the grower's experience. For detailed recommendations, consult a local Haifa representative.

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3.1 Soil-grown pepper

3.1.1 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 customized Nutrigation™ programs, considering specific growth conditions.

The following is an example of recommendations, determined by NutriNet™, with the assumption to split the scheduled fertilization into:

a) Base-dressing (pre-plant) fertilizers, followed by:

b) Nutrigation™ (fertigation) at different growth stages, on sandy-loam soil, when the expected yield is 65 ton/ha:

a) Base-dressing (kg/ha):

Base dressing - pepper

All nutrients in kg/ha

	N	P_2O_5	K_2O	CaO	MgO
Suggested base dressing	92	115	234	76	48
Actual base dressing					
% Surface covered	100%				
Ammonium nitrate (34%)	279				
Superphosphate (25%)	460				
Potassium sulfate (50%)	468				
Dolomite (26%)	292				
Magnesium sulfate (16%)	300				

Suggestion accepted | Free choice

b) Nutrigation™

Total amount of fertigation-applied fertilizers (kg/ha)

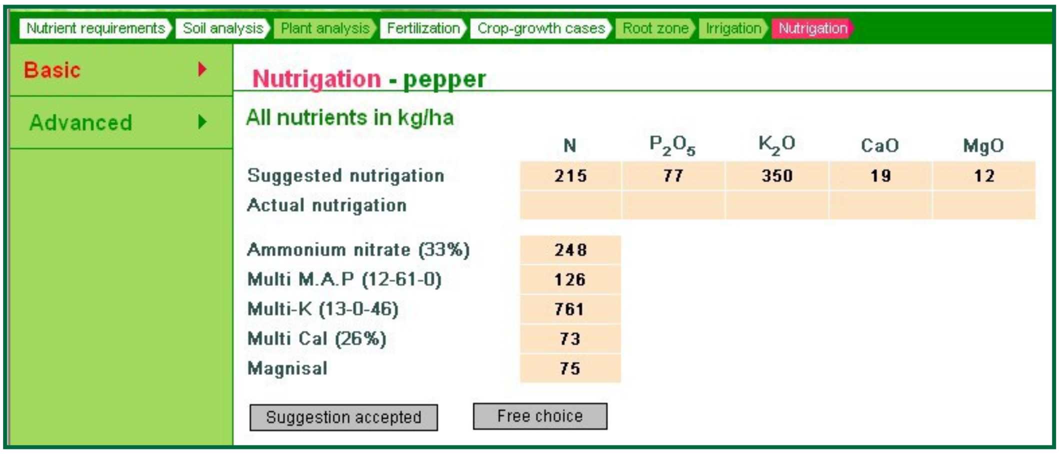


Table 10: The total contribution of plant nutrients from each fertilizer as calculated by NutriNet™:

Fertilizer	kg/ha	N	P_2O_5	K_2O	CaO	MgO
Ammonium nitrate 34-0-0	247.7	81.7				
Haifa MAP 12-61-0	126.2	15.5	77			
Multi-K® 13-0-46	760.9	98.9		350		
Calcium nitrate (26% CaO)	73.1	11			19	
Magnesium sulfate (16% MgO)	75					12
Total	1283	215	77	350	19	12

Table 11: Recommended nutrient rates per ha per day and per growth stage as calculated by NutriNet™:

Phase	Days from sowing / planting	kg/ha/day					kg/ha/phase				
		N	P_2O_5	K_2O	CaO	MgO	N	P_2O_5	K_2O	CaO	MgO
Planting	1	1	0	1	0	0	1	0	1	0	0
1st phase	2-30	0.66	0.24	1.07	0.07	0.03	119	7	31	2	1
Main season	31-70	2.65	0.95	43	0.23	0.15	106	38	172	9	6
End season	71-130	1.98	0.72	3.23	0.18	0.12	119	43	194	11	7
						Total	2455	88	398	22	14

Table 12: Recommended fertilizers rates per growth stage

Phase	Days from sowing / planting	kg/ha/phase				
		Ammonium nitrate 34-0-0	Haifa MAP* 12-61-0	Multi-K® * 13-0-46	Haifa Cal* (26% CaO)	Magnesium sulfate (16% MgO)
Planting	1	2	0	2	0	0
1st phase	2-30	23	11	67	8	6
Main season	31-70	132	62	374	35	38
End season	71-130	145	70	422	42	44
	Total	**302**	**143**	**965**	**85**	**88**

*
Multi-K® = Potassium nitrate
Haifa MAP = Mono-ammonium phosphate
Haifa Cal = Calcium nitrate

Example: Growing practice of peppers in Israel

Duration of the growth season:

- In the southern part of the country (dry and hot climate) growth season of pepper in net houses starts on August and ends by the end of April. The season is rather long because of the scarcity of precipitates (ca 70 mm per year).
- The summer growth term starts on April and lasts till the end of December.
- In greenhouses and plastic tunnels the growth season is between August and April.
- In open field the season starts on April and ends on June.

Table 13: NK ratio

The N:K ratio is 1-1.5 to 1-2

	Kg / ha /Ton pepper yield
N	20-30
P_2O_5*	27.5
K_2O*	48-60

* Conversion factors: P = P_2O_5 x 0.44 ; K = K_2O x 0.83

Standard pepper plant density in Israel is 30,000 – 35,000 plants/ ha.
Average yield of open-field grown pepper in Israel is 55 – 70 T/ha.
Average yield of net house grown pepper in Israel is 90 – 110 T/ha.

Table 14: Open field Pepper fertilization program (Planting on the 1-15 of April):

A. Plant nutrients

Growth phase	Stage duration (days)	kg/ha/day			kg/ha/phase		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
First 2 weeks	14	1-1.5	1-1.5	1-1.5	14-21	14-21	14-21
Vegetative Growth	14	2-2.5	1	3.0-4.0	28-35	14	42-56
Flowering - fruit set	40	3.0-4.0	1	4.5-5	120-160	40	180-200
Fruit set - harvest	75	2 - 2.5	1	3.0-4.0	150-185	75	225-300
Total	145				300-400	140-150	460-580

B. Actual fertilizers

Growth phase	Stage duration (days)	kg/ha/day			kg/ha/phase		
		A.N.*	Multi-K®*	Haifa MAP*	A.N.*	Multi-K®*	Haifa MAP*
First 2 weeks	14	0.5-1	2.5-4	3.5-5.5	7-14	35-55	50-75
Vegetative growth	14	0.5-1.5	8-14.5	3.5	7-21	110-200	19
Flowering - fruit set	40	3-5.5	12-13	3.5	120-220	480-520	140
Fruit set - harvest	75	0.5-1.5	8-14.5	3.5	37-110	600-1100	263
Total	145				170-365	1225-1875	470-495

* A.N. = ammonium nitrate

Multi-K® = Potassium nitrate

Haifa MAP = Mono-ammonium phosphate

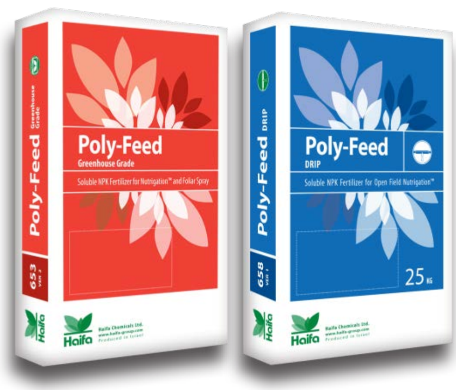
3.1.2 Poly-Feed® water-soluble NPK fertilizers

Table 15: fertilization recommendations for bell pepper in tunnels. Expected yield: 50 ton/ha

Growth stage	Days	Poly-Feed® formula	kg/ha/day	Total kg/ha
Initial establishment	7	15-30-15	8	56
Vegetative to fruit set	20	19-19-19	13	260
Fruit set to 1st harvest	20	18-9-27	13	260
Harvest	100	18-9-27	13	1300

Table 16: fertilization recommendations for bell pepper in greenhouse. Expected yield: 120 ton/ha

Growth stage	Days	Poly-Feed® formula	kg/ha/day	Total kg/ha
Initial establishment	10	15-30-15	8	80
Vegetative to fruit set	25	19-19-19	13	325
Fruit set to 1st harvest	20	18-9-27	15	600
Harvest	170	18-9-27	13	2210



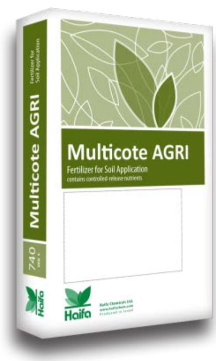
3.1.3 Multicote® Agri Controlled Release Fertilizers

An $N:P_2O:K_2O$ ratio of 2:1:3 is recommended, as pre-plant application. This application will take care of the nutritional requirement of the plot for the entire growth season.
Multicote® Agri granules should be incorporated into the soil, 10cm deep and 10cm away from the planting row.

Consult a local Haifa representative for detailed explanations and instructions.

Table 17: Multicote® Agri application recommendations bell pepper in greenhouse

kg/ha	Analysis	Longevity
2,500 - 3,500	17-9-27	8 months



3.1.4 Foliar nutrition

To correct plant nutrient deficiency at the critical stage, spray with the suitable Haifa water-soluble fertilizer at a safe concentration. The safe spray concentration may vary, depending on climatic conditions. In order to determine the safe spray concentration, one should spray it on a few plants and check for any phytotoxicity symptoms after 3-5 days.

Table 18: Haifa water-soluble fertilizers for foliar application:

Fertilizer	Curing Treatment	Recommended concentration
Haifa Bonus	Potassium deficiency	1 % - 2 %
Haifa MAP	Phosphorous deficiency	0.5 % - 1 %
Haifa MKP	Phosphate and potassium deficiency	0.5 % - 1 %
Magnisal®	Magnesium deficiency	0.5 % - 0.75 %
Poly-Feed®	N-P-K and micronutrients deficiency	0.75 % - 1.5 %

Table 19: Example of foliar feeding program (complement to Nutrigation™), Mexico

Growth stage	Product	Spray conc. (%)	Application rate (kg/ha)
Transplanting	Poly-Feed® 12-43-12+ME	0.5-1	1-2
Vegetative	Poly-Feed® 19-19-19+ME	1-2	3-4
	Magnisal®	0.5	1-2
	Haifa Micro Comb	0.1	0.5
Fruit setting	Poly-Feed® 10-10-43+ME	1-2	3-4

Time intervals between sprayings: 15 days

3.2 Soilless-grown pepper

3.2.1 straight fertilizers

There are different growth media with different physical and chemical characteristics. The following are general fertilization recommendations for all soilless growth media.

Fertilizer stock solution: Once dissolved, not all fertilizers are inter-compatible with each other. Therefore, they have to be split into two fertilizer tanks: A and B, according to their compatibility. Fertilizers containing phosphorus (P) or sulfur (S) should be dissolved in Tank A only, while fertilizers containing calcium (Ca) or magnesium (Mg) should be dissolved in Tank B.

The concentration of the fertilizers stock solution depends on:
1. The ambient temperature (higher ambient temperature enables higher concentration)
2. The injection rate - how many liters of the fertilizer solution will be injected into each cubic meter (1000 liters) of the irrigated water

Dividing the injection capacity by one cubic meter should be the concentration of the fertilizer solution. If, for example, the injector will deliver 5 L into each cubic meter of the irrigated water (1000 L / 5 L = 200), the amount of fertilizer dissolved in the tank should be multiplied by 200.

Example I - Holland

The following example was prepared to fit *Dutch* conditions (low transpiration and low water EC). Considerable and proportional reduction in the concentration of the macronutrients should be practiced at lower water quality prevailing in other conditions.

Table 20: Nutrition database for sweet pepper in Holland, grown on rockwool

Parameter	Nutrient solution (ppm)
EC (mS/cm)	2.2
N- NH_4	17.3
N- NO_3	216.9
P	39
H_2PO_4	121.3
K	254.2
Ca	190.5
Mg	36.5
S, total	55.5
SO_4	168.2

Table 21: Recommended water-soluble fertilizers and their rates, to prepare the above recommended solution:

Fertilizers	g/m³	Plant nutrients – g/m³ solution						
		NO_3	NH_4	P*	K*	Ca*	Mg*	S*
Multi-K®	500	65			190			
Haifa SOP	150				63			22.5
Haifa Cal	1000	155				190		
Magnisal®	120	13.2					10.8	
$MgSO_4$	260						26	33.8
Haifa MAP	140		16.8	37.8				
Total		233.2	16.8	37.8	253	190	36.8	56.3

Example II – Florida, USA

Table 22: Hydroponic fertilizer solution concentration for growing peppers in a shade house on a composted pine bark medium

Nutrient	Nutrient Concentration (ppm = mg/L)	
	Transplant to first flower	After first flower
N	100	130
P	50	50
K	120	200
Ca	100	150
Mg	40	50
S	50	60

Table 23: Recommended water-soluble fertilizers and their rates to prepare a fertilizer solution from transplant to first flower and a fertilizer solution after first flower.

A. From transplant to first flower

Fertilizers	g/m³	Plant nutrients – g/m³ solution						
		NO_3	NH_4	P*	K*	Ca*	Mg*	S*
Multi-K®	150	19.5			57			
Haifa Cal	530	82.15				100.7		
$MgSO_4$	400						40	52
Haifa MKP	220			49.94	61.6			
Total		101.65	0	49.94	118.6	100.7	40	52

* conversion factors: P x 2.29 = P_2O_5 ; K x 1.20 = K_2O ; Ca x 1.40 = CaO ; Mg x 1.66 = MgO ;
S x 3.00 = SO_4

B. After first flower

Fertilizers	g/m³	Plant nutrients – g/m³ solution						
		NO_3	NH_4	P*	K*	Ca*	Mg*	S*
Multi-K®	360	46.8			136.8			
Haifa Cal	680	105.4				129.2		
$MgSO_4$	470						47	61.1
Haifa MKP	220			49.94	61.6			
Total		152.2	0	49.94	198.4	129.2	47	61.1

Example III – general USDA recommendations:

<u>Table 24:</u> Total nutritional requirements

Nutrient	Nutrient Concentration (ppm = mg/L)	
	Transplant to first flower	After first flower
N	70	160
P	50	50
K	119	200
Ca	110	190
Mg	40	48
S	55	65

<u>Table 25:</u> Recommended water-soluble fertilizers and their rates to prepare a fertilizer solution

A. From transplant to first flower

Fertilizers	g/m³	Plant nutrients – g/m³ solution						
		NO_3	NH_4	P*	K*	Ca*	Mg*	S*
Multi-K®	80	10.4			30.4			
Haifa SOP	60				25.2			9
Haifa Cal	580	89.9				110.2		
$MgSO_4$	400						40	52
Haifa MKP	220			49.94	61.6			
Total		100.3	0	49.94	117.2	110.2	40	61

B. After first flower

Fertilizers	g/m³	Plant nutrients – g/m³ solution						
		NO_3	NH_4	P*	K*	Ca*	Mg*	S*
Multi-K®	140	18.2			53.2			
Haifa SOP	200				84			30
Haifa Cal	1000	155				190		
$MgSO_4$	480						48	62.4
Haifa MKP	220			49.94	61.6			
Total		173.2	0	49.94	198.8	190	48	92.4

* conversion factors: P x 2.29 = P_2O_5 ; K x 1.20 = K_2O ; Ca x 1.40 = CaO ; Mg x 1.66 = MgO ; S x 3.00 = SO_4

Example IV – Israel

Recommendations are for macro nutrients (N, P & K) by growth stages.

<u>Table 26:</u> Recommendations for nutrient concentrations in irrigation (drip) water for soilless grown peppers in Israel.

Growth Stage	Period	(g/m³)		
		N	P*	K*
Establishment –3rd flower	Early Fall	50 - 60	15 - 20	75 - 80
Fruit development and growth	Fall	80 - 100	25 - 30	100 - 120
Harvesting	Winter	150 - 180	30 - 35	200 - 230
Harvesting	Early Spring	140 - 150	30 - 35	160 - 190
Harvesting	Spring-Summer	120 - 130	25 - 30	150 - 160

Important: EC of irrigation water should be lower than 2.0 mS/cm

Table 27: Required amount of fertilizers to supply the above-recommended nutrients, by growth stages

A. Establishment to 3rd flower

Fertilizers	g/m³	Plant nutrients – g/m³ solution			
		NO_3	NH_4	P*	K*
Ammonium nitrate	50 - 70	8.5 - 11.9	8.5 - 11.9		
Multi-K®	200 - 210	26 - 27.3			76 - 79.8
Haifa MAP	60 - 80		7.2 - 9.6	16.2-21.6	
Sub-total N		50 - 70	8.5 - 11.9		
Total		50.2 - 60.7		16.2 - 21.6	76 - 79.8

* conversion factors: P x 2.29 = P_2O_5 ; K x 1.20 = K_2O ; Ca x 1.40 = CaO ; Mg x 1.66 = MgO ; S x 3.00 = SO_4

B. Fruit development & growth

Fertilizers	g/m^3	Plant nutrients – g/m^3 solution			
		NO_3	NH_4	P*	K*
Ammonium nitrate	10 - 130	17 – 22.1	17 – 22.1		
Multi-K®	260 - 320	33.8 – 41.6			98.8 – 121.6
Haifa MAP	90 - 110		10.8 – 13.2	24.3 – 29.7	
Sub-total N		50 - 70	8.5 - 11.9		
Total		78.6 - 99		24.3	98.8 – 121.6

C. Harvesting - winter

Fertilizers	g/m^3	Plant nutrients – g/m^3 solution			
		NO_3	NH_4	P*	K*
Ammonium nitrate	200 - 250	34 - 42.5	34 - 42.5		
Multi-K®	530 - 610	68.9 - 79.3			201.4 - 231.8
Haifa MAP	110 - 130		13.2 - 15.6	29.7-35.1	
Sub-total N		102.9-121.8	47.2 - 58.1		
Total		150.1 - 179.9		29.7 - 35.1	201.4 - 231.8

D. Harvesting – early spring

Fertilizers	g/m^3	Plant nutrients – g/m^3 solution			
		NO_3	NH_4	P*	K*
Ammonium nitrate	210 - 200	35.7 - 34	35.7 - 34		
Multi-K®	42 - 500	54.6 - 65			159.6 - 190
Haifa MAP	110 - 130		13.2 – 15.6	29.7 – 35.1	
Sub-total N		90.3 - 99	48.9 – 49.6		
Total		139.2 – 148.6		29.7	159.6

E. Harvesting - spring - summer

Fertilizers	g/m^3	Plant nutrients – g/m^3 solution			
		NO_3	NH_4	P*	K*
Ammonium nitrate	160 - 210	27.2 – 35.7	27.2 – 35.7		
Multi-K®	400 - 420	52 – 54.6			152 – 159.6
Haifa MAP	100 - 110		12 – 13.2	27 – 29.7	
Sub-total N		79.2 – 90.3	39.2 – 48.9		
Total		118.4 – 139.2		27 – 29.7	152 – 159.6

* conversion factors: P x 2.29 = P_2O_5 ; K x 1.20 = K_2O ; Ca x 1.40 = CaO ; Mg x 1.66 = MgO ;
S x 3.00 = SO_4

3.2.2 Poly-Feed® water soluble NPK fertilizers

Table 28: Recommended composition of nutritional solution for soilless-grown peppers

A. In moderate or cold climate with low sun radiation and soft water (North and North-East Europe, North France, UK, Japan, Korea)

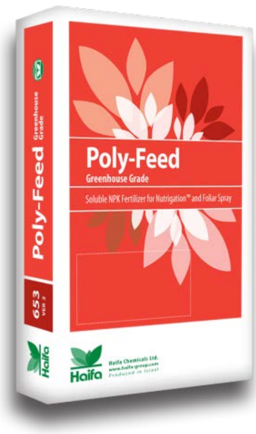
Concentration in irrigation water (ppm)					Recommended Poly-Feed® formula	Conc. (kg/m³)
N	P	K	Ca	Mg		
190	45	285	130	40	14-10-34+ME	1.0

Some acid and Haifa Cal calcium nitrate should be added to adjust the pH and to complete calcium requirements.

B. In hot climate with high sun radiation and hard water (Middle East, Mediterranean countries)

Concentration in irrigation water (ppm)					Recommended Poly-Feed® formula	Conc. (kg/m³)
N	P	K	Ca	Mg		
170	40	215	100	35	11-12-33	0.8

Some acid and Haifa Cal calcium nitrate should be added to adjust the pH and to complete calcium requirements.



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	-