Nutritional recommendations for

CUCUMBER

Haifa

Pioneering the Future

Nutritional recommendations for:

CUCUMBER

in open fields, tunnels and greenhouse

Botanical name: *Cucumis sativus L.*
Family: *Cucurbitaceae*
Common names: cucumber, pepino, cetriolo, gherkin, gurke, krastavac, concombre, huanggua, kiukaba, kukama (Tuvalu), khira, kiukamupa, Kukamba, cetriolo

Contents:

1. General information

1.1 The origin of cucumbers

The cucumber most likely originated in India (south foot of the Himalayas), or possibly Burma, where the plant is extremely variable both vegetatively and in fruit characters. It has been in cultivation for at least 3000 years. From India the plant spread quickly to China, and it was reportedly much appreciated by the ancient Greeks and Romans. The Romans used highly artificial methods of growing the cucumber when necessary to have it for the Emperor Tiberius out of season.

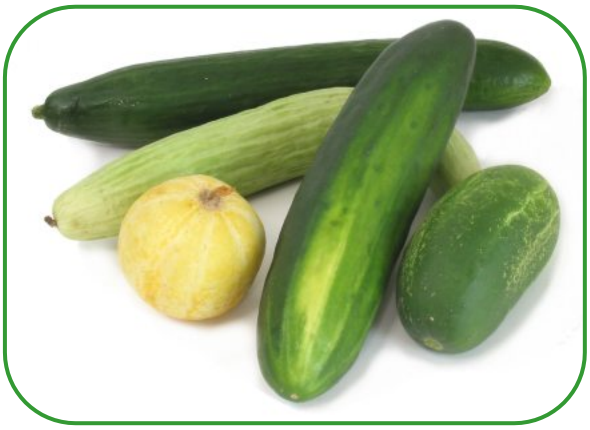


Figure 1.1: Different shapes and colors of several cucumber variety fruits

Columbus brought the cucumber to the New World, along with many other vegetables. He had them planted in Haiti in 1494, and possibly on other islands.

Most of the distinct types of cucumber grown today were known at least 400 years ago. Present forms range from thick, stubby little fruits, three to four inches long, up to the great English greenhouse varieties that often reach a length of nearly two feet.

1.2 Botanical taxonomy

The cucumber (*Cucumis sativus* L.) belongs to the Cucurbitaceae family, one of the more important plant families. The Cucurbitaceae consists of 90 genera and 750 species. The genus *Cucumis* contains nearly 40 species including three important cultivated ones (i.e., *C. anguria* L. [West Indian gherkin], *C. sativus* [cucumber], and *C. melo* L. [cantaloupe]).

Other important crop plants in the Cucurbitaceae family are watermelon (*Citrullus vulgaris* Schrad), muskmelon (*Cucumis melo* L.), squash and pumpkin (*Cucurbita pepo* L., *C. mixta* Pang., *C. moschata* Poir., and *C. maxima* Duch.), and loofah gourd (*Luffa cylindrical* Roem.). Fig-leaf gourd (*Cucurbita ficifolia* Bouche) is also cultivated to some extent, but it is even more important as a disease-resistant rootstock in the grafting of greenhouse cucumbers.

1.3 Nutritional and health values of the cucumber fruit

Table 1.1: The nutritive value of 100 g of edible cucumber

Energy	12 cal	Vitamin A	45 IU
Protein	0.6 g	Vitamin B1	0.03 g
Fat	0.1 g	Vitamin B2	0.02 g
Carbohydrate	2.2 – 3.6 g	Niacin (vitamin B3)	0.3 g
Dietary fiber	0.5 g	**Vitamin C**	**12 mg**
Calcium	**14 mg**		
Magnesium	**15 mg**	Iron	0.3 mg
Potassium	**124 mg**	Sodium	5 mg
Phosphorus	**24 mg**	zinc	0.2 mg

The high water content makes cucumbers a diuretic and it also has a cleansing action within the body by removing accumulated pockets of old waste material and chemical toxins. Cucumbers help eliminate uric acid which is beneficial for those who have arthritis, and its fiber-rich skin and high levels of potassium and magnesium helps regulate blood pressure and help promote nutrient functions. The magnesium content in cucumbers also relaxes nerves and muscles and keeps blood circulating smoothly.

1.4 Plant description

The cucumber plant is a coarse, prostrate annual creeping vine that grows up trellises or any other supporting frames, wrapping around ribbing with thin, spiraling tendrils. The plant has large, prickly, hairy triangular leaves that form a canopy over the fruit, and yellow flowers which are mostly either male or female. The female flowers are recognized by the swollen ovary at the base, which will become the edible fruit.

The fruit

Botanically, the fruit is a false berry or pepo, elongated and round triangular in shape. Its size, shape, and color vary according to the cultivar (Figure 1.1). In the immature fruit, chlorophyll in the cells under the epidermis causes the rind to be green, but, upon maturity, it turns yellow-white. The epidermal layer may have proliferated (warty) areas, each bearing a trichome (spiky hair). The fruit cavity (three locules) contains soft tissue (placenta) in which the seeds are embedded. The regular cucumber bears actual seeds (seeded cucumber), whereas the English cucumber bears either no seeds (seedless cucumber) or barely distinguishable atrophic seeds. Regular cucumbers are short (about 15-25 cm) and uniformly cylindrical. Their thick, deep green skin has light green stripes and a rough surface with strong trichomes. The skin is bitter in taste and not easily digested, so the fruit needs to be peeled before eating. English cucumbers are long (about 25-50 cm) and cylindrical, with a short, narrow neck at the stem end. Their rather smooth surface has slight wrinkles and ridges. The thin skin is uniformly green and not bitter, so the fruit need not be peeled before eating. The cucumber fruit, like that of other Cucurbitaceae, is noted for its high water content, which is around 95% of its fresh weight.

A strong tap root characterizes the root system and may reach 1 m deep. Overall the root system is extensive but rather shallow; many horizontal laterals spread widely and rapidly producing a dense network of rootlets that colonizes the top 30 cm of the soil and usually extends farther than the vine. Some of the lateral roots eventually grow downwards producing a new system of deeper laterals, which replaces in function the tap root as the plant ages. When the base of the plant is hilled and favorable moisture conditions exist, adventitious roots arise easily from the hypocotyl as well as from the nodes along the vines.

The large, simple **leaves** (10-20 cm in the regular cucumber, 20-40 cm in the seedless cucumber) are each borne on long (7-20 cm) petioles. They have five angular lobes of which the central is the largest, and many trichomes cover the surface. At each node above the first 3-5, a simple unbranched **tendril** grows from the base of the petiole. The sensitive tendrils enable the stems, which cannot twist themselves, to climb over other plants or objects. A tendril tip, upon touching a support, coils around it; then the rest of the length of the tendril coils spirally, pulling the whole plant towards the support.

A cross section of the **stem** reveals 10 vascular bundles arranged in two rings. The smaller vascular bundles of the outer ring (first five) are located at the angles of the stem; the larger bundles (remaining five) form the inner ring.

Shoot. The main stem of the cucumber plant begins growing erect but soon after assumes a prostrate trailing habit and grows like a vine over the ground. The branching is of the sympodial type (i.e., a lateral bud at each node grows and displaces the main growing point, the latter assuming a position on the opposite side of the leaf). From the nodes of the main axis originate primary laterals, each of which can have their (secondary) laterals, and so on. All stems are roughly hairy, have an angular cross section, may turn hollow when mature, and bear leaves singly at the nodes.

1.5 Growth stages

1.5.1 Vegetative growth

Vegetative growth consists of 2 Stages:

Stage I – Upright growth is the initial stage that starts when first true leaves emerge and it ends after 5-6 nodes.

Stage II – Vining - starts after 6 nodes. Then, side shoots begin to emerge from leaf axils, while main leader continues to grow. Side shoots are also growing, causing the plant to flop over. Leaves are simple and develop at each node. Each flower/fruit is borne on its own stem attached to the main stem at a node.

Depending on variety and environmental conditions, flowers may begin developing at the first few nodes.

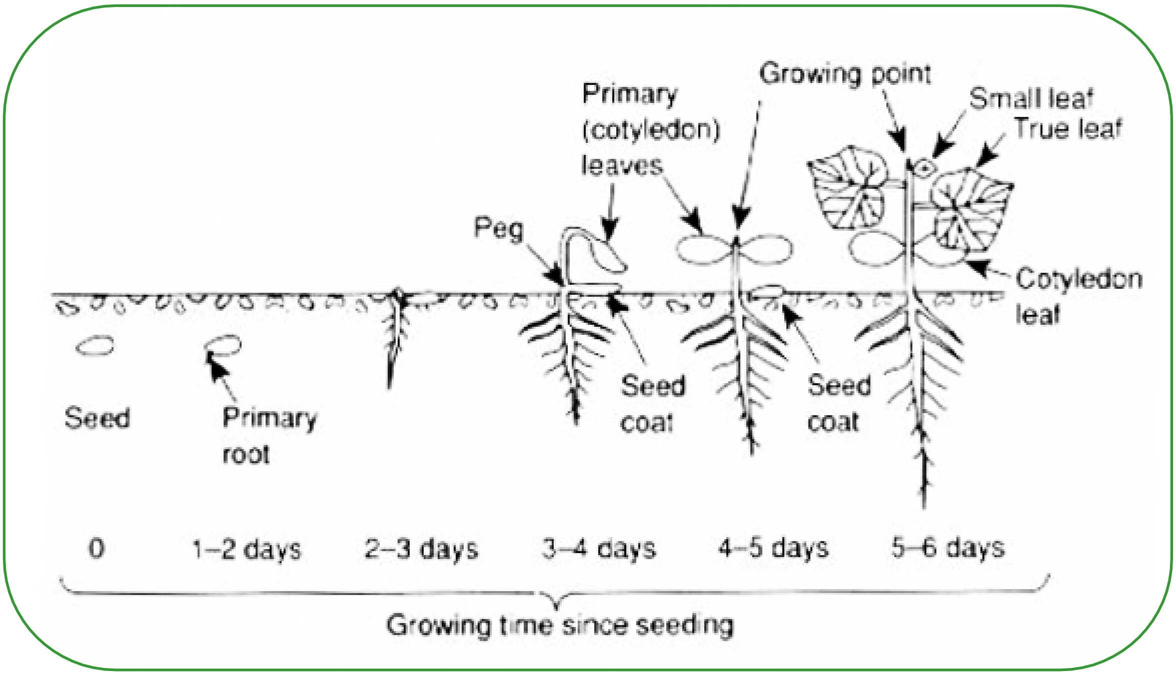


Figure 1.2: Main development processes and organs developments during first 6 days from germination, under optimal conditions.

1.5.2 Flowers and fruits

Flower types

There are different flower types:

- staminate (male).
- pistillate (female). Ovary located at base of the female flower.
- hermaphrodite (both male and female).

Cucumbers are monoecious plants which have separate male and female flowers on the same plant (Figures 1.3 & 1.4). The male flowers appear first and female flowers shortly later. The female flowers have small immature fruit at the base of the flower and male flower do not have any. Pollen is transferred from male to female flower by bees or other insects. When pollinated properly, female flower develops into fruit. There are different types of cucumber hybrids such as gynoecious varieties that produce predominantly female flowers, and seeds of monoecious varieties are mixed with it for pollination. They are very productive when pollenizer is present.

Figure 1.3: Male flower

Figure 1.4: Female flower

Older cultivars, as well as many current cucumber cultivars, have a **monoecious** flowering habit, producing separate staminate and pistillate flowers on the same plant. Although the terminology is not botanically correct, staminate flowers are often referred to as male flowers and pistillate as female.

Monoecious cultivars first produce clusters of five male flowers at the leaf nodes on the main stem. Subsequently, the plant produces both male and female flowers.

Most current hybrids are **gynoecious** (all female flowers). Gynoecious hybrids are widely used because they are generally earlier and more productive. The term "all-female" is somewhat misleading as 5% of the flowers are male under most conditions. These modern F1 hybrids have several advantages. As they bear only female flowers the tiresome job of removing male flowers is unnecessary. They are also much more resistant to disease and rather more prolific. There are two drawbacks – the fruits tend to be shorter than the ordinary varieties and a higher temperature is required. Production of female flowers is naturally promoted by the short days, low temperatures and low light conditions of fall. Flower femaleness can be promoted by applying plant growth substances (PGRs) such as NAA (a type of auxin), and Ethephone (an ethylene promoter). If a purely female variety is grown, need to provide an appropriate pollinator.

In sensitive gynoecious cultivars, production of male flowers is promoted by long days, high temperatures and high light intensity typical to the summer season. Production of male flowers also increases with high fruit load and with stresses exerted on the plant. Maleness can be promoted by applying PGRs such as Gibberelins as well as by silver nitrate and AVG that act as ethylene suppressors.

Parthenocarpic fruit

There are also cucumber hybrids that produce fruits without pollination. These varieties are called parthenocarpic varieties, resulting in fruits that are called 'seedless', although the fruit often contain soft, white seed coats. Such parthenocarpic fruit set also occurs naturally under the low-light, cool-night growing conditions, and short days of fall. Older plants can also produce 'super' ovaries which set fruit parthenocarpically.

Parthenocarpic varieties need to be isolated from standard varieties to prevent cross-pollination and development of fruits that do contain seeds, and may be deformed by greater growth in the pollinated area.

Greenhouse cucumbers are naturally parthenocarpic.

Male/female flowering sequence

On a normal cucumber plant, the first 10 - 20 flowers are male, and for every female flower, which will produce the fruit, 10 - 20 male flowers are produced. Flowering set progressively at the nodes.

Developing fruit at the lower nodes may inhibit or delay fruit at subsequent nodes.

Size and shape of the cucumber fruits are related to number of seeds produced.

1.5.3 Pollination

Since each cucumber flower is open only one day, pollination is a critical aspect of cucumber production. One or more pollen grains are needed per seed, and insufficient seed development may result in fruit abortion, misshapen, curved or short (nubbin) fruit, or poor fruit set. Hence, 10 - 20 bee visits are necessary per flower at the only day the flower is receptive, for proper fruit shape and size. Therefore, it is important to bring hives into the field when about 25% of the plants are beginning to flower. Bringing in the bees earlier is unproductive because they may establish flight patterns to more abundant and attractive food sources such as legumes or wildflowers. Bringing them in later jeopardizes pollination of the first female flowers. It is important to take into consideration that bee activity is greatest during the morning to early afternoon, and that wet, cool conditions reduce bee activity and causes poor fruit set.

Cucumber varieties can cross pollinate with one another but not with squash, pumpkins, muskmelons, or watermelons.

Pollination in gynoecious ("all female flowers") crops is ensured by blending seed of a monoecious cultivar (pollenizer) with seed of the gynoecious hybrid. Typical ratios are 88% gynoecious, to 12% monoecious. Pollenizer seed is often dyed with a different color to distinguish it from that of the gynoecious hybrid. It is difficult to recognize pollenizer seedlings after emergence in the field. Removing 'different looking' seedlings during thinning may leave the field without the pollenizer.

1.5.4 Cucumbers types sorted by final usage, morphology and culture practice

Cucumber cultivars are usually classified according to their intended use as fresh market slicers, pickles, or greenhouse cucumbers. This classification includes several fruit characteristics such as shape, color, spine type (coarse or fine), spine color (white or black), fruit length/diameter ratio, skin thickness, and surface warts.

Each type should be cylindrical with blocky ends, although rounded ends are also acceptable for slicers.

Pickling cucumbers
"Pickling" refers to cucumbers that are primarily used for processing and pickling. Increasingly, more pickling cucumbers are being sold fresh for immediate consumption. Some consumers have a preference for the pickling type because they have thinner skins compared with slicing cucumbers. Pickling fruits are lighter green in color, shorter, thinner-skinned, and characterized by a warty surface. All commercial cultivars have either black or white spines on the fruit surface, a trait related to fruit maturity. White-spined cultivars are generally slower in their rate of development and retain their green color and firmness longer than black-spined fruits. Cultivars with black spines tend to turn yellow prematurely, especially under high temperatures, and produce larger fruits that soften with maturity. Consequently, black-spined cultivars are used for pickling in regions where summer conditions are relatively cool. White-spined hybrids have largely replaced black-spined cultivars in warmer growing regions and in areas where once-over machine harvesting is prevalent.

For processing cucumbers, the grower generally has little choice of cultivar since the processor selects and provides the cultivars to be grown. Gynoecious hybrids are grown for just about all machine harvest. These types have also replaced many of the standard monoecious types that were previously used in hand-harvesting pickling cucumbers.

- Shorter growth cycle of 50-60 days.
- high plant populations 240,000/ha (60,000/acre)
- Concentrated fruit set adapts them for once over machine harvest
- Predominantly female types (PF)
- Some male blossoms are produced as 10-12% male pollinator seeds are mixed in with the gynoecious types or the PF types).
- An average yield is 25 t/ha* (11.4 short ton or 460 bushels/acre).

***All tons terms in this publication are metric, unless otherwise indicated.**

Slicing (fresh consumption) cucumbers
"Slicing" refers to cucumbers that are sold fresh for immediate consumption as a salad item. Characterized by thick, uniform, dark green skins, slicing cucumbers are longer than processing types, and their thicker skins are more resistant to damage during handling and shipping.

Average yield for slicing cucumbers in e.g. North Carolina is 11-14 t/ha (200-250 bushels/acre), but better yields of 33-37 t/ha (600-650 bushels per acre) can be obtained when growing a crop on plastic which is fertigated.

Fruits for fresh market slicing are preferably long, smooth, straight, thick-skinned, with a uniform medium-dark green color. Fresh market cultivars have fewer spines than processing types. For fresh market slicers, both monoecious hybrids and gynoecious hybrids are available. Vigor, uniformity, and higher yields are some advantages of hybrids over previous open-pollinated monoecious cultivars. Regardless of how they are to be used, cultivar differences in earliness and disease resistance are also important considerations for cultivar selection.

Greenhouse cultivars
These should have long, relatively narrow fruits, with rounded ends. Dutch greenhouse cultivars are parthenocarpic with gynoecious expression and high-yield potential, while Japanese greenhouse cucumbers are mostly monoecious. Unlike those for processing and some slicing, greenhouse types are fairly smooth-skinned.

Varieties of cucumber include both the slicing or fresh salad type and the pickling type (which can also be used fresh), and dwarf-vined or bush varieties.

Armenian
The **Armenian** is a long, often much curved type (as noted, actually a melon); owing to its shape, it is sometimes referred to as the "serpent" or "snake" cucumber. It is hard to recommend a particular cultivar, as few catalogues distinguish one "Armenian" type from another.

Oriental

This type is also commonly called **Japanese**, though many Oriental nations commonly grow the type (it is also often called **Asian**). It is another long type, usually thin and straight, with a milder flavor than standard types. The Oriental types have many partisans, who find them tender and better-tasting than common cukes (and less bitter and gas-producing), but otherwise generally similar.

Beit Alpha

The **Beit Alpha** (aka mini, hydroponic, snack-size) type (sometimes called Persian) is an Israeli development (developed a lot of useful hot-weather crops, notably melons and lettuces) whose plants are largely or wholly female, and so do not need cross-pollination. They are thought to have an excellent taste and low bitterness. They are well suited for pickling industry due to short length and solid core, as well as their delicate taste.

More recently, short Beit Alpha; parthenocarpic cultivars have taken over the market, as they are adapted for trellising under protected cultivation. Also, short internodes and set multiple fruit in a cluster habit.

European

The **European** (aka Dutch, hothouse, greenhouse, hydroponic), fruit develop the characteristic slender, smooth appearance because they are not pollinated. If the flowers are allowed to be pollinated the resulting cucumber fruit will be shorter, bulbous, and irregular and filled with seeds:

- 30 – 35 cm (12 – 14 in.) long
- 3.5 – 5 cm (1.5 - 2 in.) wide
- Thin skinned
- Seedless
- Parthenocarpic
- Gynoecious

Ball and Round

The "ball" types, small spheres (such as the "lemon cucumber") tend to be especially early. Generally, they are thought to be pleasant but rather low in distinct cucumber flavor, but there are some notable exceptions.

2. Growing cucumbers

2.1 Growing requirements and habits of the plant

The cucumber responds like a semitropical plant. It grows best under conditions of high temperature, humidity, and light intensity and with an uninterrupted supply of water and nutrients. Under favorable and stable environmental and nutritional conditions and when pests are under control, the plants grow rapidly and produce heavily. The main stem, laterals, and tendrils grow fast. They need frequent pruning to a single stem and training along vertical wires to maintain an optimal canopy that intercepts maximum light and allows sufficient air movement. Under optimal conditions, more fruit may initially develop from the axil of 4 each leaf than can later be supported to full size, so fruit may need thinning. Plants allowed to bear too much fruit become exhausted, abort fruit, and fluctuate widely in productivity over time. Excessive plant vigor is indicated by: rapid growth, thick and brittle stems, large leaves, long tendrils, deep green foliage, profusion of fruit, and large, deep yellow flowers. On the other hand, cucumbers are very sensitive to unfavorable conditions, and the slightest stress affects their growth and productivity. Because fruit develops only in newly produced leaf axils, major pruning may be needed to stimulate growth. The removal of entire weakened laterals is more effective than snipping back their tips.

2.2 Important growing parameters

2.2.1 Temperature, general and with special reference to greenhouses

Air temperature is the main environmental component influencing vegetative growth, flower initiation, fruit growth, and fruit quality. Growth rate of the crop depends on the average 24-h temperature the higher the average air temperature the faster the growth. The larger the variation in day night air temperature, the taller the plant and the smaller the leaf size. Although maximum growth occurs at a day and night temperature of about 28°C, maximum fruit production is achieved with a night temperature of 19-20°C and a day temperature of 20-22°C. The recommended temperatures in Table 2.1 are therefore a compromise designed for sustained, high fruit productivity combined with moderate crop growth throughout the growing season. During warm weather (i.e., late spring and early fall), reduce air temperature settings, especially during the night, by up to 2°C to encourage vegetative growth when it is retarded by heavy fruit load. This regime saves energy because a 24-h average can be ensured by the prevailing high temperatures and favorable light conditions.

Table 2.1: Recommended air temperatures for cucumber cropping

	Low light (°C)	High light (°C)	With carbon dioxide (°C)
Night minimum*	19	20	20
Day minimum	20	21	22
Ventilation	26	26	28

*A minimum root temperature of 19°C is required, but 22-23°C is preferable.

The optimum daily average air temperature is 15-24°C (65-75°F). Optimum temperatures for growth are at night, about 18°C, and during the day, about 28°C accompanied by high light intensity.

To ensure satisfactory stand establishment, soil temperatures should be at least 15°C (60°F). The higher the soil temperature, the more rapidly seedlings emerge and the less vulnerable they are to insects and damping-off diseases.

At 15°C (60°F), 9 to 16 days are required for seedlings to emerge. At 21°C (70°F), only 5 to 6 days are required. Even after emergence, cucumbers remain sensitive to cold temperatures. In cold areas, seeds should always be planted late enough to avoid frosts. Exposure to cool conditions will slow growth even if temperatures remain above freezing. Slow-growing seedlings are vulnerable to flea beetles (whose chewing significantly reduces leaf area of young plants). Too high temperatures during flowering decrease pollen viability.

Cool and cloudy growing season may cause bitter fruit.

2.2.2 Light, with special reference to greenhouses

Plant growth depends on light. Plant matter is produced by the process of photosynthesis, which takes place only when light is absorbed by the chlorophyll (green pigment) in the green parts of the plant, mostly the leaves. However, do not underestimate the photosynthetic productivity of the cucumber fruit, which, because of its size and color, is a special case. In the process of photosynthesis, the energy of light fixes atmospheric carbon dioxide and water in the plant to produce such carbohydrates as sugars and starch. Generally, the rate of photosynthesis relates to light intensity, but not proportionally. The importance of light becomes obvious in the winter, when it is in short supply. In the short, dull days of late fall, winter, and early spring, the low daily levels of radiant energy result in low levels of carbohydrate production. Not only do the poor light conditions limit photosynthetic productivity, but also the limited carbohydrates produced during the day are largely expended by the respiring plant during the long night. The low supply of carbohydrates available in the plant during the winter seriously limits productivity, as evidenced by the profusion of aborted fruit. A fully grown crop benefits from any increase in natural light intensity, provided that the plants have sufficient water, nutrients, and carbon dioxide and that air temperature is not too high.

2.2.3 Relative humidity, with special reference to greenhouses

High relative humidity (RH) generally favors growth. However, reasonable growth can be achieved at medium or even low relative humidity. The crop can adjust to and withstand relative humidity from low to very high but reacts very sensitively to drastic and frequent variation in relative humidity. Its sensitivity to such variation is greatest when the crop is developed under conditions of high relative humidity. Other disadvantages of cropping under conditions of high relative humidity include the increased risk of water condensing on the plants and the development of serious diseases. The resultant low transpiration rates are blamed for inadequate absorption and transport of certain nutrients, especially calcium to the leaf margins and fruit. At low relative humidity, irrigation becomes critical, because large quantities of water must be added to the growth medium without constantly flooding the roots and depriving them of oxygen. Furthermore, low relative humidity favors the growth of powdery mildew and spider mites, which alone can justify installing and operating misting devices.

2.2.4 Carbon dioxide in greenhouses

In relatively high temperatures and light intensity, supplemental carbon dioxide applied at a concentration up to 400 ppm has proved economically useful. Regions with a moderate maritime climate, can more likely benefit from carbon dioxide applied in the summer only. But in regions with a continental climate, the need to ventilate the greenhouse actively throughout the hot summer renders the practice less economical. Apply carbon dioxide during the day or any part of the night when artificial light is supplied. It is economically feasible and highly advisable to use liquid carbon dioxide (carbon dioxide gas liquefied under pressure) because of its guaranteed purity and amenity to accurate concentration control. Liquid carbon dioxide is also preferred because burning natural gas or propane to generate carbon dioxide increases the risk of plant injury from gaseous pollutants, e.g. ethylene.

2.2.5 Seed germination

Seeds germinate and emerge in three days under optimum conditions. During this time seed coat remains tight.

Once cotyledons emerge, roots develop quickly. Sunlight delivers photosynthates to true leaves and root system.

During the 1st week cotyledons integrity is very important, and if damaged, plants will set back. Seedlings may recover but they will be weak and susceptible to stresses.

For proper germination, soil temperature must be above 15°C (60°F). If the soil is too cold and wet poor seedling emergence will take place.

Figure 2.1: Cucumber seedling's cotyledons; first true leaves are emerging between the cotyledons.

2.2.6 Planting

Cucumbers growth season is relatively short, lasting 55-60 days for field-grown varieties, and over 70 days for greenhouse varieties.

Planting dates

Cucumbers are almost always direct seeded. Like most cucurbits, they do not transplant well and transplant costs would be hard to recover. Planting depth is 2.5-4 cm (1-1.5 inches). Too deep delays emergence.

Pickling cucumbers have to be very precise on planting dates so that harvest will coincide with processor needs.

For early crop, container-grown transplants are planted when daily mean soil temperatures have reached 15°C (60°F) but most cucumbers are direct seeded. Early plantings should be protected from winds with hot caps or row covers. Growing on plastic mulch can also enhance earliness.

Spacing

Planting spacing depend on the growth method, variety and harvesting method.

Close spacing increases yields, provides more uniform maturity and reduces weed problems. It also results in shorter fruit with a lighter color.
On the other hand, high plant population requires more seeds and slightly higher fertilizer rates.

Table 2.2: Spacing and seeding parameters for open field cultivation

Consumption method	Plant density (plants/ha)	Distance between rows		Distance within row		Seeds mass	
		cm	Feet	cm	Inch	kg/ha	lbs/acre
Hand-harvested							
Fresh (slicers)	40-50,000	90-120	3-4	23-30	9-12	1.7	1.5
Pickles (processing)	60-75,000	90-120	3-4	15-20	6-8	2.0-5.5	2-5
Machine-harvested							
Pickles (processing)	50-75,000	60-70	24-28	5-10	2-4	1.8-5.5	1.8-5

Greenhouse plant spacing should provide: 1-2.5/m^2 or more per plant, depending on pruning and training system. Recommended density is 33,000 - 60,000 plants/ha.

Figure 2.2: Cucumber greenhouse with trellised plants

2.2.7 Soils

Cucumbers prefer light textured soils that are well drained, high in organic matter and have a pH of 6 - 6.8. Adapted to a wide-range of soils, but will produce early in sandy soils. Cucumbers are fairly tolerant to acid soils (down to pH 5.5).

Greenhouse cucumbers generally grow quite well in a wide range of soil pH (5.5-7.5), but a pH of 6.0-6.5 for mineral soils and a pH of 5.0-5.5 for organic soils are generally accepted as optimum. When the pH is too low, add ground calcitic limestone, or an equal amount of dolomitic limestone when the magnesium level in the soil is low, to raise it to a desirable level.

Usually the pH in most greenhouse mineral soils is above the optimum pH range (6.0-6.5). A simple, though temporary, solution to a high pH problem is to add peat, without neutralizing its acidity with limestone. Peat also helps to maintain a good soil structure, but it must be added yearly to make up for loss through decomposition.

Soil preparation before field planting

1. Soil fumigation aids in the control of weeds and soil-borne diseases. Fumigation alone may not provide satisfactory weed control under clear plastic.

2. Black plastic mulching before field planting conserves moisture, increases soil temperature, and increases early and total yield. Plastic should be placed immediately over the fumigated soil. The soil must be moist when laying the plastic. Black plastic can be used without a herbicide
3. Plastic and fumigant should be applied on well-prepared planting beds, 2-4 weeks before field planting.
4. Fertilizer must be applied during bed preparation. At least 50% of the nitrogen (N) should be in the nitrate (NO3) form.
5. Herbicides recommended for use on cucumbers may not provide satisfactory weed control when used under clear plastic mulch on non-fumigated soil..
6. Foil and other reflective mulches can be used to repel aphids that transmit viruses in fall-planted cucumbers.
7. Direct seeding through the mulch is recommended for maximum virus protection. Fumigation will be necessary when there is a history of soilborne diseases in the field. Growers should consider drip irrigation with plastic mulch.

2.2.8 Trellising

Cucumber vines can be trained on trellises to save space and improve yield and fruit quality. But the high cost of trellising makes commercial production by this method uneconomical in most cases. Greenhouse cucumbers must be trellised, because the long fruit bend if they rest on the ground.

Figure 2.3: Different methods of trellising cucumber plants

The major advantages of trellising a cucumber crop include:

- harvesting efficiency
- pest management efficiency
- straighter fruits
- uniform fruit color
- reduction of fruit loss due to soil diseases
- increased yield due to closer rows
- Reduced rate of crooked fruits makes trellising absolutely necessary for Oriental slicing cucumbers.

Disadvantages include:

- extra cost of trellising materials
- labor to erect the system, dismantle it and training the vines

2.2.9 Greenhouse cucumbers

Flowering habit and fruit set
All European greenhouse varieties produce fruit without pollination. They are gynoecious in flowering habit, and fruits develop without the need for pollination.

Cultural practices
Greenhouse cucumbers grow rapidly under optimum environmental conditions, and fruit production begins 60 - 70 days after seeding. For good production, a temperature range of 24 - 27 C° (75 - 80 F°) during the day is desirable. While peak daytime temperatures of 29 - 25 C° (85-90 F°) are tolerable, prolonged periods of high temperatures may adversely affect fruit quality. Night temperatures no lower than 18 C° (65 F°) will allow a rapid growth rate and earliest fruit production.

Planting and plant growing
Plantings of greenhouse cucumbers are ordinarily started from transplants, but direct-seeding in greenhouse beds may also be practical for late summer or early fall plantings, when the time from seeding to fruiting may not be as critical and prevailing temperatures are warm enough for good seed germination without having to heat the greenhouse.

Transplanting makes more efficient use of greenhouse space, because seed germination and early growth of plants can be confined to a smaller nursery area. Disadvantages to transplanting are the costs of containers and the labor costs of transplanting.

Spacing, training and pruning
The decision on the number of plants to be grown in a given area of greenhouse should be based upon expected light conditions during growth of the crop and also upon the method of pruning the plants. With good sunlight, each plant is allotted about 0.5 m^2 (5 $feet^2$) space. Nearly twice that much space may be needed with low light to avoid leaf overlapping and shading by adjacent plants.

Spacing between rows and plants within the row can vary with grower preference. Rows are often spaced 1.2 – 1.5 m (4 - 5 feet) apart, with plants 30 – 45 cm (12 - 18 inches) apart in the row.

Most growers prune their plants by the umbrella system. In this system, all lateral branches are removed as they develop until the plant reaches the overhead support wire. Fruits should not be allowed to develop on the lower 75 cm (30 inches) of the main stem to encourage the plant's rapid vegetative development. Main-stem fruits above that point are allowed to develop at the base of each leaf.

More than one fruit may begin to develop at each node. Some growers thin these to a single vigorous fruit, but it may be more practical to leave all young fruits attached, because it has been observed that more than one may mature

Fruit thinning
Overbearing can sometimes be a problem. To prevent the plants becoming exhausted and to improve fruit size, control the number of the fruit per plant through selective fruit thinning. This technique is powerful, so use it with great caution. The optimum number of fruits per plant varies with the cultivar and, even more, with the growing conditions. Although, limiting the number of fruits per plant invariably results in premium-priced large fruit, growers risk underestimating the crop's potential or failing to forecast good weather. They may decide to remove too many fruits and thus unnecessarily limit production. Fruit thinning is undoubtedly most useful in the hands of experienced growers who can use it to maximize their financial returns. Fruit to be pruned must be removed as soon as it can be handled, before it grows too large.

Irrigation
Maximum yields and fruit quality will be realized only if the plants receive adequate and timely moisture. Cucumber plants have shallow roots and require ample soil moisture at all stages of growth. When fruit begins setting and maturing, adequate moisture becomes especially critical.

The objective of watering is to maintain a fully adequate supply of water to the plant roots without soaking the soil to the extent that air cannot get to the roots. Do not wait until the plants start to wilt. A good practice is to dig into the soil and judge how much water remains before starting the next irrigation. Regular watering on the same day of the week is unwise. The needs of the plants change daily and seasonally. Water young plants planted in the greenhouse in January or February only once every 5-10 days and then only enough to wet 15-20 cm of the soil. Similar plants growing in June may need 5-10 fold as much water. Let the soil texture and structure determine how much water to add at each application. By examining the soil before watering and several hours thereafter, you can assess the effectiveness of the water application. Depending upon soil type and growth conditions, approximately 25–50 mm of water per week is needed to obtain high quality cucumbers. An irregular water supply, particularly during blossoming and fruit development, can detrimentally affect fruit quality and result in increased nubins or hooked fruit.

The pH of the water is also critical and may need to be adjusted. The target pH of the nutrient solution supplied to the plants should be between 5.5 and 6.0. Nitric, sulfuric, or phosphoric acid are recommended for reducing the pH if it is above 7. If the source water is alkaline due to high bicarbonate concentrations, the pH should be adjusted before the fertilizer salts are added to prevent precipitation. If it is necessary to raise the pH, potassium hydroxide is usually used.

Important: Irrigation timing should not interfere with pollination and should allow surfaces to dry before nightfall.

The drip irrigation system is better than most other conventional soil irrigation systems, because it can be used to control crop growth by regulating the supply of water and nutrients. The drip system also allows reduced relative humidity (RH) in the greenhouse, because not all the soil is irrigated and because the system is compatible with the use of white polyethylene film as a light-reflecting mulch. In countries suffering from lack of good irrigation water the drip irrigation method has an important feature expressed by high water efficiency leading to very remarkable water savings. Resources, including irrigation water and energy, are thus used more efficiently with this system.

In most cases, use common in-line drippers with a standard flow of 2L/h and one dripper per plant. However, because of the shallowness and extensiveness of the cucumber root system, consider a 4-L/h dripper, which usually results in more lateral movement of the irrigation water. Even better, provide two drippers (2 L/h each) per plant.

Micro-sprinklers, or misters, have also been tried at ground level along the row of plants, with favorable results on root growth, plant vigor, and productivity. However, such irrigation systems, if not properly managed, can easily lead to overwatering and then to disease outbreaks caused by excessive humidity and plant stem wetness. Another alternative is to use lay-flat polyethylene tubes (about 5 cm ID), with small holes spaced 10 cm apart. This system usually applies water to a much larger area than the drip system but does not raise the RH as much as a micro-sprinkler or micro-mister system. Although fairly inexpensive, the lay-flat tube irrigation system has a short lifespan, which requires its frequent replacement. It is not a good choice for large greenhouses, because the water delivery rates vary significantly along the length of the line (i.e., not pressure compensating). Irrigate the crop up to four times a day, and use the irrigation system to apply fertilizer to the crop.

Fertilization

Greenhouse cucumbers grow quickly and should never be allowed to suffer from lack of water or nutrients. Advanced cucumber cultivation must supply the crop with optimal rates of nutrients throughout the growth cycle in the most efficient manner possible, and without degrading soil and water resources. The nutrient uptake rate by greenhouse cucumbers is very high. One study indicates that cucumbers may require in the range of 28 kg/ha (25 lbs/acre) of nitrogen, 5 kg/ha (5 lbs/acre) of phosphorus, and 40 kg/ha (35 lbs/acre) of potassium per week during peak fruit production. Fertilizer management practices need to assure that plant requirements are satisfied to achieve good yields of high-quality fruit. An important method that can assure that plant requirements are really satisfied is leaf analysis.

Leaf analysis

Visual diagnosis of disorders can be confused by symptoms induced by non-nutritional factors such as disease, pests and chemicals. Leaf analysis can be used to confirm a visual diagnosis. This involves chemical testing of leaves to establish whether specific nutrients are present in plant tissue at normal concentrations. This technique can be used to check the suitability of a fertilizer program and to anticipate the need for nutrient supplements. A disadvantage of leaf analysis is that it is slow, as most laboratories will take at least a week to process samples and report the results back to the grower. In many cases, laboratories do not interpret results or recommend how to remedy the situation.

Nutrigation™ (fertigation) (the application of fertilizer through the irrigation system) is a popular and efficient **method** of fertilizing field and greenhouse vegetables. Fertilizers are either dissolved in a large holding tank and the solution pumped to the crop, or they are mixed in concentrated stock solutions, which are then incorporated, using fertilizer injectors, into the irrigation water. Several makes and models of fertilizer injectors are available at varying costs and offer varying degrees of fertigation control. A sophisticated fertilizer injection system capable of meeting the nutrient requirements of a series of crops automatically from the same set of stock solutions was developed may use an IBM-compatible computer to activate a series of dosimetric pumps at varying frequencies for the preprogrammed application of a desired concentration of individual nutrients. It also automatically adjusts the supply of water and nutrients to the crops in accordance with crop and environmental conditions. Introducing drip irrigation and fertigation has made it necessary to consider the fertilizer needs of a crop in terms of the concentration of fertilizer (and therefore the concentration of nutrients) in the irrigation water rather than on the basis of the cropped area. Furthermore, the recommendations regarding the nutrient content of the fertigation solutions of drip irrigated crops are based mainly on the physiological responses and commercial productivity of the crops. Most earlier recommendations for fertilizer application to traditionally grown crops in soil were based on estimates of nutrient removal by the crop.

Base fertilizers are not normally applied when drip irrigation is used, but peat and lime, may be still needed pre-planting to improve soil structure and adjust soil pH.

Two general examples of fertigation regimes are given, based on leaf analyses done during growth season, but this issue is further elaborated in chapter 3 (dealing with the entire aspect of cucumber mineral nutrition.

Table 2.3: Nutrigation™ schedule and rates for cucumber with N:K ratio = 1:2 *

Days after planting	Daily nitrogen	Daily potash	Cumulative			
			nitrogen	potash	nitrogen	potash
			kg/ha		lbs/acre	
(preplant)			28	50	25.0	45.0
0 - 14	0.9	1.8	42	84	37.6	75.2
15 - 63	1.5	3.0	124	220	110.3	196.6
64 - 77	0.7	1.4	135	243	120.1	216.6

Table 2.4: Nutrigation™ schedule and rates for cucumber with N:K ratio = 1:1 *

Days after planting	Daily nitrogen	Daily potash	Cumulative			
			nitrogen	potash	nitrogen	potash
			kg/ha		lbs/acre	
(preplant)			27	27	24.0	24.0
0 - 7	1.0	1.0	35	35	31.0	31.0
8 - 21	1.5	1.5	58	58	52.0	52.0
22 - 63	2.0	2.0	152	152	136.0	136.0
64 - 70	1.5	1.5	168	168	150.0	150.0

* Based on leaf analysis.

Figure 2.4: Nutrigation™ is a well-established method to increase cucumbers productivity.

Crop rotation

It is recommended not to rotate to crops in the same family during a 3-year cycle for most diseases, but 5 years must be maintained after Fusarium wilt incidence.

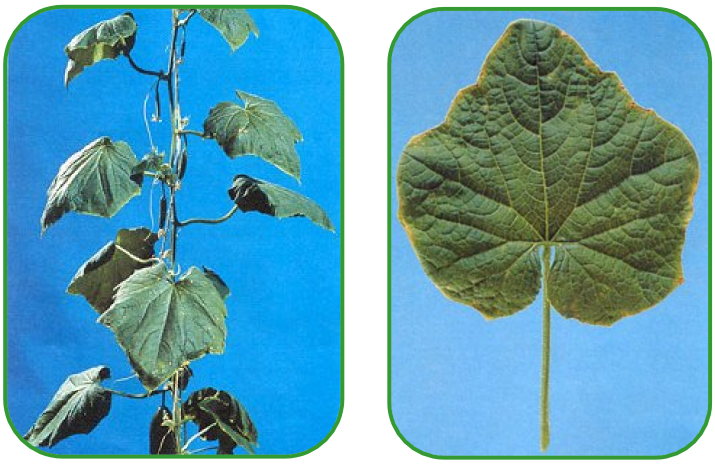
Cucumbers Phytophthora blight is the same as buckeye rot on tomatoes. All curucbits get it, although there are differences in susceptibility. Therefore, cucumbers should be rotated with crops other than peppers, eggplants, tomatoes, and other cucurbits.

2.2.10 Specific sensitivities

Cucumbers and other cucurbits have a number of specific sensitivities that may jeopardize yields and fruit quality. Among these sensitivities we can mention general salinity (high E.C. values), sensitivity to specific ions such as calcium, magnesium, sodium, chloride and perchlorate.

Salinity

Salinity damages may be caused by high E.C. ground water, irrigation water, soil or growth medium, and by excessive application of fertilizers.



Figures 2.5 & 2.6: High salt or E.C.: Leaves appear dull and leathery. A narrow yellow border develops around the leaf margin.

Plants grown under saline conditions are stunted and produce dark green, dull, leathery leaves that are prone to wilting (Figure 2.5). A narrow band of yellow necrotic tissue is often present on leaf edges (Figure 2.6). This can affect leaf expansion, causing a slight downward cupping of the leaf. After a serious water stress, the oldest leaves may develop a uniform pale green chlorosis and small necrotic areas within the leaf. If water supply is maintained, leaves may only develop a band of pale green tissue around their edges. Plants are likely to wilt in warm weather.

Numerous studies have showed a linear decrease in the yields of cucumbers as the salt concentration of the irrigation water increased. The yield reduction was about 17% for a 1 mmho/cm increase in the E.C. (See Figures 2.7.& 2.8.)

Figure 2.7 clearly shows also that cucumber plants are sensitive to saline conditions. Salinity hinders the vegetative growth of the plants. Moreover, salinity severely reduces crop productivity as shown in Figure 2.8.

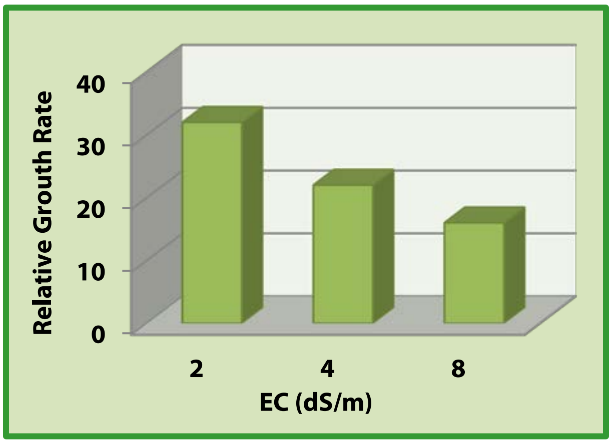


Figure 2.7: The effect of E.C. on relative growth rate of cucumber (cv. *Dina*) seedlings (*Al-Harbi,* 1995*)*

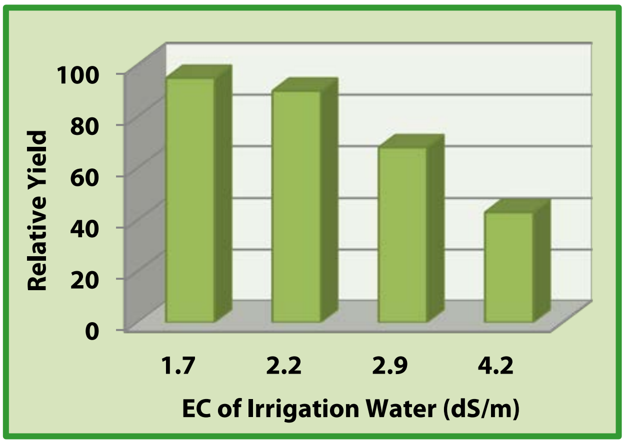


Figure 2.8: The effect of salinity on cucumber yield *(Ayers, 1977*)

Cultural treatments to counteract salinity effects are:

- Leach the soil or growing medium with fresh water until the excess fertilizer is removed.
- Adjust the fertilizer program to ensure that rates do not exceed crop needs.
- Use cultivars that are more salinity resistant.
- Apply abundant amounts of potassium fertilizer, other than potassium chloride, as potassium markedly enhances plants ability to cope with salinity stresses.

Chloride (Cl^-) toxicity

Normal cucumber growth requires only small quantities of chloride similar to iron, but if the supply is plentiful more is taken up. Chloride toxicity can develop into a serious problem. Particular attention is required in recirculated hydroponic growth systems. Crop analysis showed that when sodium and chloride were added to the irrigation water, chloride was taken up in much greater quantities by the cucumber roots than sodium. The chloride anion markedly reduces plant vigor and tends to accumulate in the leaves margins, producing a band of pale green tissue around the leaf margin with some leaf-edge scorching and necrosis (tissue death), that stems from

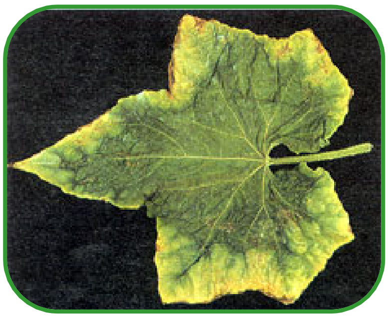


Figure 2.9: Chloride toxicity symptoms on cucumber leaf

concentration rise up to 3% (!!!) (See Figure 2.9.) Such leaves are prone to premature leaf abscission, and reduced photosynthesis activity.

Due to the specific chloride sensitivity of cucumbers, it is highly recommended to avoid fertilizers containing chloride, such as potassium chloride (muriate of potash (KCl), or calcium chloride ($CaCl_2$) in field grown cucumbers. Moreover, chloride-free fertilizers are an absolute prerequisite in hydroponic systems for best cucumber yields.

Perchlorate toxicity

Perchlorate anion $(ClO4)^-$ is present in mineral deposits of natural nitrates. Therefore, it is sometimes present in fertilizers produced from those deposits, like potassium nitrate produced in Chile. Perchlorate is a strong acid which decreases the activity of the enzyme RuDP (Ribulose Diphosphate Carboxylase). When used for the cultivation of greenhouse vegetables it was proved that perchlorate at minute concentrations of 0.3% of the nutrient solution resulted in the "***Bolblad***" syndrome manifested by the following symptoms:

- Leaf curl and malformation developing into partial necrosis.
- Partial opening of the female flowers.
- Marked reduction in yields due to reduced fruit-set.
- Malformed cucumbers.

Glyphosate toxicity

Glyphosate is a very popular wide-range herbicide. When used near cucumber plants, minute amounts absorbed by the cucumber plant are enough to produce damages that include upward-curling, pale green to yellow younger leaves and severe stunting. (See Figure 2.10.)

Figure 2.10: Glyphosate toxicity symptoms on cucumber leaves

2.2.11 Yields

Yields of cucumbers greatly vary according to varieties and growth conditions. The world average is 15 t/ha, while yields of 350 t/ha or more are obtained in modern greenhouses in Europe.
Beit Alpha varieties can yield: 250-450 t/ha and Dutch varieties yield 400 t/ha.
Where yields are 30-60 t/ha under poor cultivation conditions, they can reach 100-300 t/ha under optimal temperature, humidity, light intensity and pollination, achieved under glass).

2.2.12 Harvesting

Cucumber crop matures within 40 - 50 days and harvesting starts 45 - 55 days after planting. Harvest during summer to early fall depending on planting time, and variety.

Unless an once-over mechanical harvester is being used, mainly for the pickling industry, fresh consumption cucumbers should be harvested at 2-4 day intervals, when the fruits have reached desired size, to avoid losses from oversized and over-mature fruit.

Important: Over mature cucumbers left on the vine inhibit new fruit set.

Pickling types are harvested when fruits are 5-7.5 cm (2-4 inches) long, and slicing types (for fresh market) - when fruits are dark green, firm, 15-20 cm (6-8 inches) long with a diameter of 4-5 cm (1½ - 2 inches).

Fresh-market cucumbers are ready for harvesting when they are about 6 to 10 inches long and 1.5 to 2.5 inches in diameter. The cucumber should be dark to medium green, without any signs of yellowing. On average, 58 to 65 days are required from seeding to maturity, depending on the cultivar and the growing conditions. Fresh-market cucumbers are harvested by hand. Because the individual fruits do not develop and mature consistently, the timing of maturity is not uniform within a field. As a result, fresh-market cucumbers typically are picked between 6 to 8 times over a 3-week period. In some situations, fresh-market cucumbers can be picked up to 12 to 15 times in a season. The number of pickings depends on when the seeds are planted and the supply and demand situation in the market. Price is an important factor in picking. Once prices for cucumbers fall below a certain level, it become uneconomical for growers to continue harvesting.

Pickling cucumbers are ready for harvesting when the ratio of length-to diameter ranges from 2.9 to 3.1. The cucumbers should be medium green, slightly lighter than fresh cucumbers, without any signs of yellowing. On average, it takes 55 to 65 days from seeding to maturity, depending on the cultivar and growing conditions.

Pickling cucumbers are either hand or machine harvested. Hand harvesting is common in areas where migrant labor is readily available. When harvested by hand, the field is typically picked 5 to 6 times. Pickling cucumbers must be harvested at 3- or 4-day intervals to prevent oversizing. If a machine is used for harvesting, however, the field is only picked once.

3. Plant nutrients functions, optimal- and off-levels

3.1 Leaf analysis

Visual diagnosis of disorders can be confused by symptoms induced by non-nutritional factors such as disease, pests and chemicals. Leaf analysis can be used to confirm a visual diagnosis. This involves chemical testing of leaves to establish whether specific nutrients are present in plant tissue at normal concentrations. This technique can be used to check the suitability of a fertilizer program and to anticipate the need for nutrient supplements. A disadvantage of leaf analysis is that it is slow: most laboratories will take at least a week to process samples and report the results back to the grower. In many cases, laboratories do not interpret results or recommend how to remedy the situation.

Leaf analysis in cucumbers is based on a sample of the youngest fully mature leaf (with petiole) at the early flowering stage. Table 3.1 lists the standards used to interpret the leaf analysis report.

Table 3.1: Leaf analysis standards for **field-grown** cucumbers (in dry matter of youngest fully mature leaf with petiole taken at early flowering stage). Source: *Ankerman & Large*, 1992.

Nutrient	Unit	Deficient	Low	Normal	High	Excessive
Nitrogen	%	<1.8	1.8–2.5	3.5–5.5	5.5–7	>7
Phosphorus	%	<0.20	0.20–0.3	0.3–0.7	0.7–1.0	>1.0
Potassium	%	<2.0	2.0–3.0	3.0–4.0	4.0–5.0	>5.0
Calcium	%	<1.0	1.0–2.0	2.0–3.0		
Magnesium	%	<0.15	0.15–0.6	0.6–1.5	1.5–2.5	>2.5
Sulfur	%		<0.3	0.3–1.0		
Sodium	%			0–0.35	>0.35	
Chloride	%			0–1.5	1.5–2.0	>2.0
Copper *	mg/kg	<3	3–10	10–20	20–30	>30
Zinc *	mg/kg	<15	15–30	30–70	100–300	>300
Manganese *	mg/kg	<15	15–50	50–200	200–500	>500
Iron	mg/kg	‡	<50	50–200		
Boron	mg/kg	<20	20–30	30–70	70–100	>100
Molybdenum	mg/kg	<0.2	0.2–0.5	0.5–2.0		

*Values for copper, zinc and manganese in leaves sprayed with fungicides or nutrient sprays containing trace elements cannot give a reliable guide to nutritional status.

‡ Leaf analysis is not a reliable guide to iron deficiency because of surface contamination with soil, immobility of iron within the plant, or the presence of physiologically inactive iron within tissues.

Table 3.2: Leaf analysis standards for **greenhouse** cucumbers (in dry matter of 3rd-5th leaves from the top, Source: *C. de Kreif, et al.*, 1992.

Nutrient	Unit	Deficient	Normal	Excessive
Nitrogen	%	<1.8	4.2-5.6	
Phosphorus	%	<0.47	0.6–0.9	
Potassium	%	<2.35	3.2–4.5	
Calcium	%	<1.2	2.2–2.4	
Magnesium	%	<0.37	0.4–0.7	
Sulfur	%		0.3–0.6	
Copper	mg/kg	<5	5–17	
Zinc	mg/kg	<26	50–140	>300
Manganese	mg/kg	<15	55–300	>550
Iron	mg/kg		85–300	
Boron	mg/kg	<43	50–76	>108
Molybdenum	mg/kg	<0.29	1.0–2.0	

3.2 Nitrogen (N)

Most plants need nitrogen in large amounts. It is generally considered to drive plant growth. Nitrogen plays an essential role in the composition in all proteins in all plants. Since it is a major structural and functional factor for every plant, crop yields are highly dependent on N availability to the plant. Nitrogen is required in the production of chlorophyll (the green pigment in leaves), which is responsible for converting sunlight to usable plant energy. Therefore, shortage of nitrogen reduces the plant's capacity to trap energy through photosynthesis. It is important that when reaching the flowering stage the plant will be well developed vegetatively; or it will have a low yielding potential.

3.2.1 Nitrogen application form: nitrate, ammonium, urea and ammonia

The form in which N is supplied is of major importance due to the crop's sensitivity to the status of related nutrients, as demonstrated in many studies, four of which are cited hereby:

- In hydroponics culture, NO_3^- nutrition results in greater plant growth than with either ammonium-nitrate or urea nutrition.
- Uptake of K is greatly inhibited in cucumber seedlings (cv. *Saticoy*) fed by nutrient solution containing NH_4^+ + NO_3^- (2:1 ratio), compared to NO_3^- only (Figure 3.1). Moreover, this study also established that the ammonium ion doubles the chloride influx into roots, and this inhibits growth of the seedlings. As shown in paragraph 2.2.10 (page 25), the Cl^- anion is specifically toxic to cucumber seedlings.
- The ratio NO_3^- / NH_4^+ influences the concentration of K in the sap of cucumber seedlings. The higher the ratio, the higher is the concentration of K in the xylem sap (Figure 3.2). Another study showed that chloride content in the plant sap was markedly increased with increased ammonium.
- When nitrogen is supplied as ammonia (NH_3) both shoot and root biomasses, yield and K content decrease, possibly because ammonia causes morphological changes in the roots

that interfere with their ability to absorb nutrients. Moreover, ammonia also inhibits roots respiration, resulting in net efflux of K.

Table 3.3: Leaf analysis nitrogen standards for **field-grown** cucumbers (in dry matter of youngest fully mature leaf with petiole taken at early flowering stage).

Nutrient	Unit	Deficient	Low	Normal	High	Excessive
Nitrogen	%	<1.8	1.8–2.5	2.5–4.5	4.5–6	>6

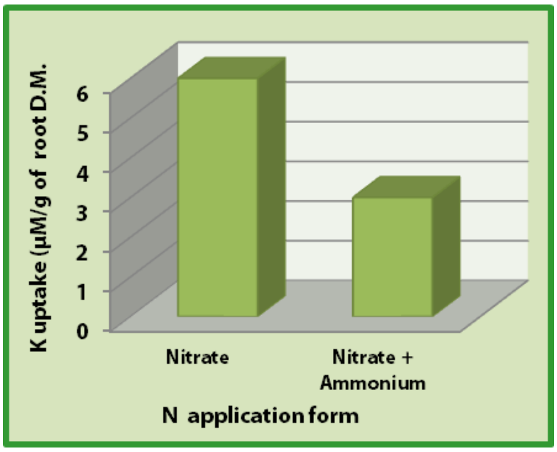


Figure 3.1: The effect of nitrogen form on K uptake (*Martinez and Cerda*, 1989).

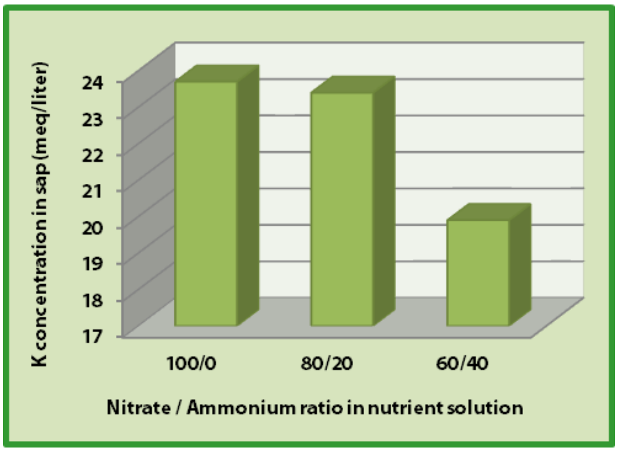


Figure 3.2: The effect of NO_3^-/NH_4^+ ratio in the soilless nutrient solution on the concentration of K in the sap of cucumber (cv. *Hyclos*) seedlings (*Zornoza and Carpena*, 1992).

3.2.2 Nitrogen deficiency

Failure to supply ample available nitrogen causes bleaching of the older leaves, (Figure 3.3), impaired plant development, delayed growth, thin stems (Figure 3.4) and distorted and discolored fruit (Figure 3.5). In severe cases, the whole plant collapses. Nitrogen deficiency may render the cucumber plant very sensitive to salinity.

Healthy Deficient

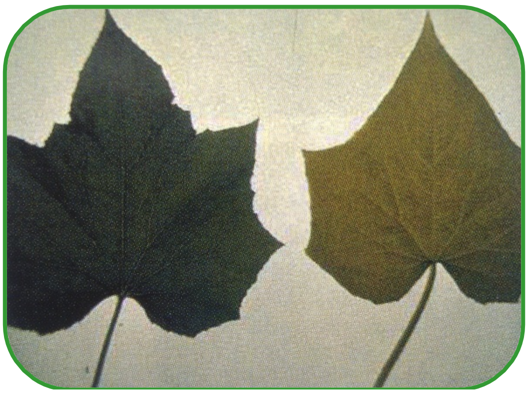


Figure 3.3: Typical nitrogen deficiency symptoms in cucumber leaves.

Figure 3.4: Left: Completely stunted and pale plant that has not received any N after germination

Center: A healthy plant.

Right: A plant that received less N than the center one. Older leaves turn pale green to yellow; this discoloration spreads to younger leaves up the plant.

Figure 3.5: Nitrogen deficient cucumber fruit is misshapen and chlorotic.

Both vegetative growth and fruit production are severely restricted when nitrogen supply is inadequate. Plants appear pale and spindly. New leaves are small but remain green, whereas the oldest leaves turn yellow and die. If the problem is not corrected, the yellowing spreads up the shoot to younger leaves. Yield is reduced and fruit are pale, short and thick.

Treatment

In soil-grown crops: side-dress with 20–50 kg/ha of N, or apply fortnightly foliar sprays of 2% urea at high volume. To prevent possible salt burn to leaves when applying any foliar spray, spray late in the afternoon or during cloudy weather.

For crops grown in soilless media, use a nutrient solution containing 150–200 ppm N.

3.2.3 Excessive nitrogen

Plants given slightly too much nitrogen show excessive growth and a softer plant; leaves will be darker green and sometimes thickened and brittle.

Plants given highly too much nitrogen are generally stunted and have strong, thick stems, short internodes, a mass of tendrils, short side shoots, fewer flowers, and small fruit. The middle and older leaves cup downwards and wilt easily in warm conditions. Leaf

Figure 3.6: Symptoms of excessive nitrogen include wilting and downward cupping of the older leaves, followed by yellow and brown burnt areas on lower leaves.

scorching is common. Transparent spots occur between the veins or at the leaf edges, which eventually turn yellow and then brown.

Treatment
Leach the soil or growing medium with fresh water to remove the excess fertilizer.

Adjust the fertilizer program to ensure that rates do not exceed crop needs.

3.3 Phosphorus (P)

Phosphorous is essential for the normal development of the roots and reproductive organs (flowers, fruit, seeds). Phosphorus promotes strong early plant growth and development of a strong root system. Highly available phosphorous is needed for the establishment of the seeded or transplanted cucumbers. Phosphorus is required for cellular division and formation of molecules taking part in energy transformation (ADP & ATP).

Plants require phosphorus at all stages of growth, but demand is greatest during crop establishment and early plant growth. If phosphorus becomes limiting, it is translocated from older to younger tissues, such as the leaves, roots and growing points. In a crop such as cucumbers, which has a continuous production of new vegetative and fruiting tissues, a regular supply of phosphorus (and other elements) is needed to ensure that the plant can sustain quality fruit production over a prolonged period.

For soil-grown crops, P availability is usually optimal when the soil pH is between 6.0 and 6.5.

In acid soils (pH < 6.0), the P is associated ("tied up" or "fixed") with iron and aluminum compounds that are slowly available to most plants.

In soil where pH is greater than 6.5, the P is primarily associated with calcium and magnesium. The higher the pH calcium- and magnesium- phosphate compounds are less available to plants.

Table 3.4: Leaf analysis phosphorus standards for field-grown cucumbers (in dry matter of youngest fully mature leaf with petiole taken at early flowering stage).

Nutrient	Unit	Deficient	Low	Normal	High	Excessive
Phosphorus	%	<0.20	0.20–0.3	0.3–0.7	0.7–1.0	>1.0

3.3.1 Phosphorus deficiency

When soils are low in phosphorus, they must be regularly supplemented with fertilizer. To ensure uninterrupted phosphorus supply, a P- fertilizer must be applied to the soil before planting. A soil test is therefore essential to establish the soil's phosphorus status and to estimate how much (if any) phosphorus fertilizer is required.

Phosphorus-deficient plants have weak roots, are stunted, and produce small, dark, dull, gray-green leaves (Figure 3.7). The oldest leaf, at the base of the shoot, turns bright yellow (Figure 3.8). However, unlike nitrogen deficiency, the leaf directly above this leaf remains dark green (Figure 3.9). Brown patches appear between the veins on mature leaves. These become scorched and spread until the leaf dies prematurely. Fruit set is reduced, so production is impaired until the deficiency is corrected.

Figure 3.7: Left: A phosphorous deficient plant is stunted and has small, dark green, dull leaves.

Right: A healthy plant.

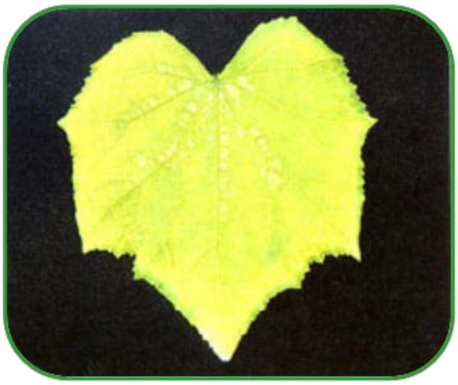


Figure 3.8: An older leaf of a P-deficient plant shows brown, scorched spots between the veins.

Figure 3.9: A P-deficient plant. The oldest leaf of this stunted plant is bright yellow, but the leaf above it remains dark green.

Treatment

A soluble phosphorus source such as mono potassium phosphate (e.g. Haifa MKP) can be supplied through fertigation (Nutrigation™) or by foliar spray, to revive established crops with deficiency symptoms. These treatments should be repeated for the rest of the crop life. Soil-grown crops will not respond immediately to these treatments.

For crops grown in soilless media, use a nutrient solution containing 25–50 ppm P.

3.3.2 Phosphorus toxicity

Phosphorus toxicity is uncommon in soil-grown crops but can occur in hydroponic crops.

Figure 3.10: Various P-toxicity symptoms on a cucumber plant.

3.4 Potassium (K)

3.4.1 The role of potassium in cucumber nutrition

Potassium is a major nutrient that plays a key role in many physiological processes in all plants among which are:

- Activation at least 60 different enzymes involved in plant growth and metabolism.
- Regulation of the water balance of the plant through the roots osmotic gradient and the functioning of stomata guard cells.
- Involvement of the activation of several enzymes and control of ATP formation as a part of photosynthesis.
- Enhancing the translocation of nutrients through the xylem system and of organic compounds, mainly carbohydrates, in the phloem system from source to sink.
- Involvement in any major step of protein synthesis.
- Reduction of plant susceptibility to plant disease, and a-biotic stresses.
- Counteracts salinity.

Adequate potassium levels enhance the production and floem transportation of carbohydrates within the plant. Potassium also play an important role in enhancing plant resistance to low temperatures, salinity, drought and diseases.

Ample amounts of potassium should therefore be supplied to the crop to ensure abundant K levels in all major organs.

Severe potassium deficiency will retard the transportation of sugars within the plant, leading to starch accumulation in the lower leaves.

Cucumbers are unique among most crops in their high potassium requirements. In fact, the cucumber plant is one of the only crops requiring more potassium than nitrogen (Figure 3.11). Moreover, increase in cultivation intensity requires a higher K/N ratio (Table 3.5).

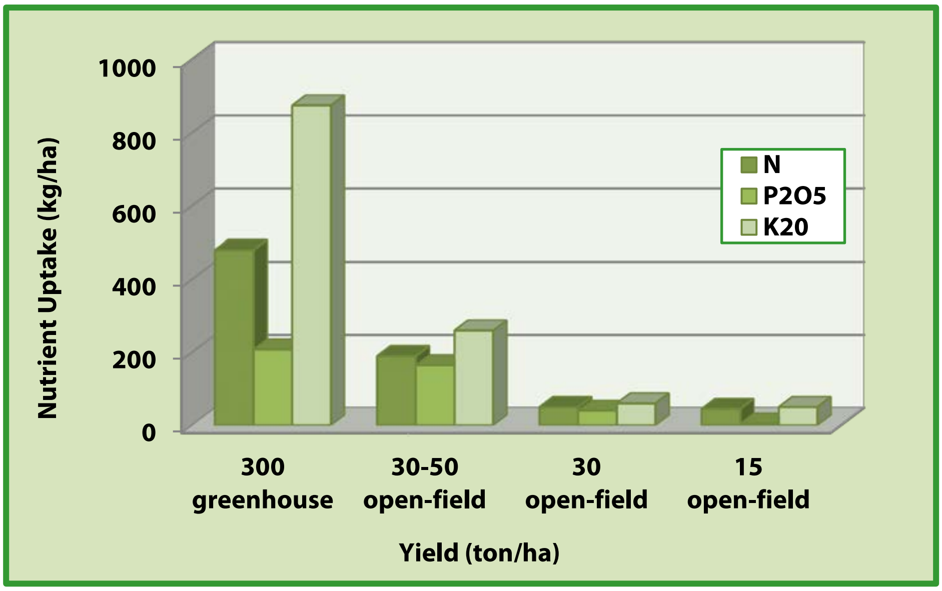


Figure 3.11: N-P-K uptake rates by cucumber crops at various growing conditions and yields.

Table 3.5: Indicative N-P-K ratios at various growing conditions (*La Malfa*, 1992)

	Open Field	Greenhouse
Expected yield (Ton/ha)	15 – 30	120 - 300
Typical N:P:K ratio	1:0.5:1.5	1:0.5:2

High concentrations of K are found in various plant parts, and serve as a method to assess crop nutritional status. On a whole organ basis, potassium is generally equally distributed between roots and shoots.

Table 3.6: Leaf analysis potassium standards for field-grown cucumbers (in dry matter of youngest fully mature leaf with petiole taken at early flowering stage).

Nutrient	Unit	Deficient	Low	Normal	High	Excessive
Potassium (K)	%	<2.0	2.0–3.0	3.0–4.0	4.0–5.0	>5.0

Normal levels in petiole sap are 3,500 – 5,000 ppm K.

The accumulation of K in stems, petioles and leaves correlates with the growth curve of these organs; this suggests a mechanism that balances K uptake and release. K accumulates rapidly in each leaf during its early developmental stage (Figure 3.12). The overall demand of the plant leaves creates therefore a sigmoid ascending curve.

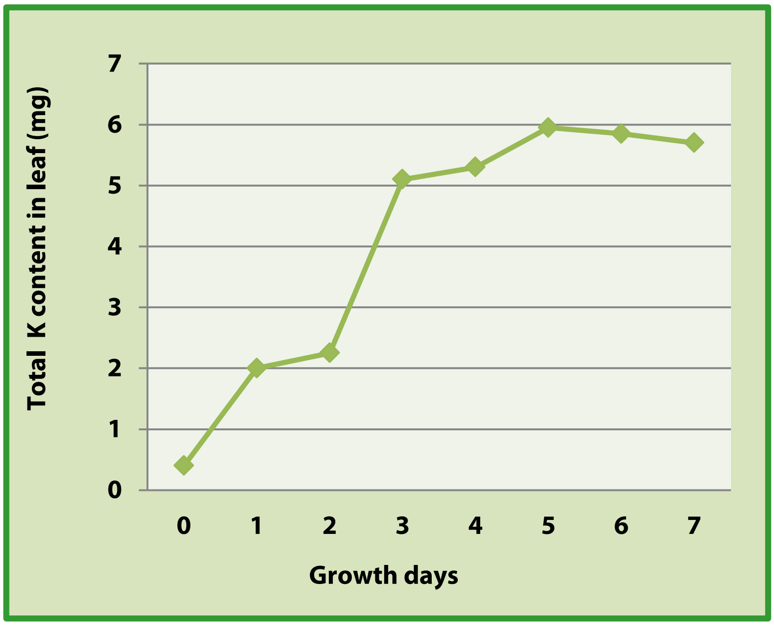


Figure 3.12: The accumulation dynamics of K in a cucumber leaf (cv. *Kasairaku*) as related to its age (*Iwahashi et al.*, 1982).

3.4.2 Potassium enhances cucumber yield

a) Soilless on peat bags, potassium applied by fertigation

It has been shown clearly the positive effect of potassium fertilization on cucumber yields. When grown on peat bags, a potassium level of 50 mg/l in liquid feed by fertigation produces a mean yield of 9.98 kg/plant of cucumbers.

Yield was increased by 91% to 19.1 kg/plant when the potassium level was raised from 50 to 250 mg/l (Figure 3.13).

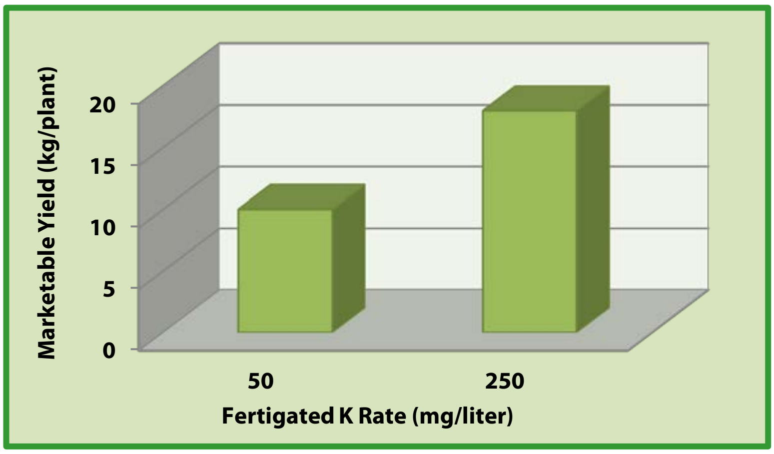


Figure 3.13: Effect of fertigated K on the yield of soilless cucumber (cv. *Femdam*), (*Adams et al.*, 1992).

Another study has shown a clear positive response of cucumber productivity to potassic nutrition of the plants. Total number of fruit units was increased by 15% as a result of a slight increase of additional 100 ppm in potassic fertilization.

b) Open field, potassium applied by side dressing

A very similar response was also obtained in open field conditions. The research was conducted during two consecutive years and showed remarkable positive reaction of cucumber yield to intensive potassic fertilization (Figure 3.14).

Figure 3.14: Effect of side-dressed K on the yield of field-grown cucumbers (cv. *Poinsett*), (*Forbes and White*, 1986).

3.4.3 Potassium enhances cucumber disease resistance

Potassium has a well-known effect of both enhancing plant resistance to pathogens and of reducing the impact of the infection. The following results have been reported for cucumbers in this context:

- Potassium lessens the effect of Angular Leaf Spot caused by Pseudomonas lachrymans.
- Fruit gray mold caused by Botrytis cinerea is reduced by 27% - 33% by the application of supplemental K to parthenocarpic cucumbers grown in tunnels.
- Foliar sprays of potassium salts solutions have been shown to control Powdery Mildew caused by Sphaerotheca fuliigiena (Figure 3.15). The researchers postulated that the foliar spray produces systemically induced resistance.

Figure 3.15: Left: A cucumber leaf heavily infected by Powdery Mildew.
Right: Leaves from adjacent plant treated with Multi-K®.

The results shown in Figure 3.16 demonstrate the remarkable results of reducing the damage to cucumbers from this fungus by spraying potassium nitrate (e.g. Multi-K®).

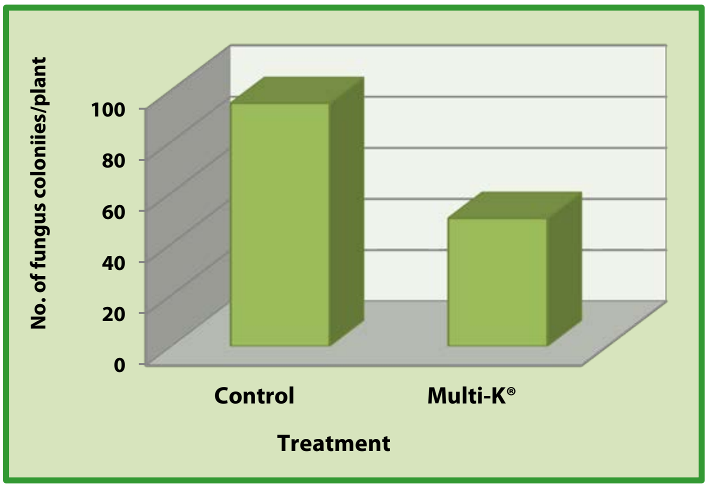


Figure 3.16: The effect of foliar sprays of Multi-K® on powdery mildew in cucumbers (cv. *Delila*), (*Reuveni et al.*, 1996)

A remarkably increased resistance of cucumber plants (cv. Corona) to infection by Pythium ultimum was brought about by enhanced potassic nutrition. Shoots dry weight was increased by 20%, roots dry weight – by 28%, and number of class 1 fruits – by 71%.

3.4.4 Potassium deficiency symptoms

Potassium deficiency will take place when the concentration of K falls to below 3,000 ppm in the petiole sap or below 3.5% in the dry weight of the leaf laminae. Such deficiency may develop when cucumbers are grown in soil and sufficient K is not available to the plant during the growth period, as required by the plant.

Deficiencies will develop very quickly in soilless culture if adequate rate of potassium is not regularly maintained in the irrigation solution.

- Symptoms of potassium deficiency first appear on older leaves. Typically, chlorosis first appears at the leaf margins, then, the interveinal area is affected. The symptoms progress from the base towards the apex of the plant. Yellowing and scorching of the older leaves begins at the edges and eventually spreads between the main veins towards the center of the leaf (Figure 3.17).
- Leaf symptoms are accompanied by abnormal fruit development, often with a brown or spotted appearance.
- The plant is stunted with short internodes and small leaves.

Figure 3.17: The potassium deficient plant has yellow scorched older leaves, which turn dry and papery.

Figure 3.18: Typical potassium deficiency symptoms as shown on the leaves.

Potassium deficiency influences plant water regulation by affecting cell turgor and the opening and closing of stomata, hence, deficient crops are prone to wilting.

As potassium is mobile in the plant, it moves to the younger leaves when supplies are short.

Although the growth of deficient plants may not be seriously impaired, the yield and quality of fruit are often greatly reduced. Fruit may not expand fully at the stem-end, although they will swell at the tip-end, a symptom that is also caused by water stress (Figure 3.19).

Figure 3.19: Fruit fails to expand at the stem end.

Treatment

- In medium or heavy soils, where potassium movement is rather slow, potassium nitrate (e.g. prilled Multi-K®) should be incorporated in the soil before planting. An early soil test can be used to determine the rate needed.
- In sandy soils, where quick response to potassium fertilizer is expected, an application of side-dressed soluble Multi-K®, may result in fast correction of the deficiency.
- Nutrigation™ (fertigation) feeding with soluble Multi-K® can also be used to treat a deficient crop.
- Foliar sprays with soluble Multi-K® or Poly-Feed® is effective and can cure the K deficiency within a short period of time (see pages 90-91).
- For crops grown in soilless media, use a nutrient solution containing 150–200 ppm K.

Do not over apply potassium fertilizer, especially in light soil or in soilless systems, as excessive K causes N deficiency in the plants and may affect the uptake of other cations such as Mg and Ca.

3.4.5 Interrelationships between potassium and other nutrients

- An over-optimal level of either potassium or nitrogen may induce or accentuate a phosphorous deficiency.
- An over-optimal potassium level may induce Mg deficiency and decrease yields in cucumber grown in peat.
- A K/Ca ratio of 1.33 was found optimal for nutrient solution, in greenhouse- grown cucumbers is sand culture. Under such conditions highest yields and highest Ca uptake were obtained.
- Potassium deficiency can induce or accelerate iron deficiency, and enhance nitrogen accumulation.

3.5 Calcium (Ca)

Calcium takes a key role in the structure and functioning of cell membranes and the strength of cell walls. Calcium also reduces plant susceptibility to diseases. Most calcium-related disorders of crops are caused by unfavorable growing conditions and not by inadequate supply of calcium to the roots. Rapidly growing crops in hot windy conditions are most at risk. Deficiencies can also develop when cucumbers grow quickly under continuously humid conditions, as in a greenhouse. Other contributing factors are waterlogging, soil salinity, high potassium or ammonium supply, and root diseases.

Calcium moves in the plant's transpiration stream and is deposited mainly in the older leaves. Deficiencies are found in the youngest leaves and growing points, which have low rates of transpiration. Emerging leaves appear scorched and distorted and may cup downwards because the leaf margins have failed to expand fully (Figure 3.20). Mature and older leaves are generally unaffected. With a severe deficiency, flowers can abort, and the growing point may die. Fruits from calcium-deficient plants are smaller and tasteless, and may fail to develop normally at the blossom end.

Figure 3.20: Youngest leaves of calcium deficient plants cup downwards and their edges become scorched.

Figure 3.21: Calcium-deficient cucumber leaves.

Table 3.7: Leaf analysis calcium standards for field-grown cucumbers (in dry matter of youngest fully mature leaf with petiole taken at early flowering stage).

Nutrient	Unit	Deficient	Low	Normal	High	Excessive
Calcium	%	<1.0	1.0–2.5	2.5–5.0		

Treatment of calcium deficiency

Applying lime to acidic soils and reducing the use of ammonium-based fertilizers is recommended to avoid insufficient calcium availability in the soil.

Existing injury from calcium deficiency can be reduced by regular foliar sprays of fully soluble calcium nitrate, (15.5-0-0+26.5 CaO), e.g. Haifa Cal, at 800g / 100L).

For crops grown in soilless media, use a nutrient solution containing fully soluble calcium nitrate, (15.5-0-0+26.5 CaO), e.g.Haifa Cal at a rate of 150–200 ppm Ca. Keep the conductivity of water in the growing medium below 2 dS/m as the incidence of deficiency increases with increasing conductivity.

Excessive Ca may be problematic when growing cucumbers on calcareous soils. High Ca in the soil usually causes high pH which then precipitates many of the micronutrient so they become unavailable to the plant, it may also interfere with Mg absorption.

3.6 Magnesium (Mg)

Magnesium is a center constituent of the chlorophyll molecule, so its key role in the photosynthesis process is crystal-clear. Magnesium deficient soils may be found in coarse-textured soils in humid regions, and especially on light, sandy, acidic soils in higher-rainfall areas. Magnesium deficiency can be also induced by heavy rates of potassium, ammonium or calcium (heavy liming) fertilizers. Symptoms are more likely to show during cold weather or on heavy wet soils, when roots are less active.

Magnesium deficiency causes yellowing of older leaves. (See Figures 3.22 & 3.23.) The symptom begins between the major veins, which retain a narrow green border. A light tan burn will develop in the yellow regions if the deficiency is severe. Fruit yields are reduced.

Figure 3.22: Yellowing between the major veins of older leaves (left) turns to a light tan papery burn (right). Younger leaves (top) are less affected.

Figure 3.23: Yellowing and light tan burn on older leaves of magnesium deficient plant.

Table 3.8: Leaf analysis magnesium standards for field-grown cucumbers (in dry matter of youngest fully mature leaf with petiole taken at early flowering stage).

Nutrient	Unit	Deficient	Low	Normal	High	Excessive
Magnesium	%	<0.15	0.15–0.3	0.3–1.5	1.5–2.5	>2.5

Treatment

- Incorporate into deficient soils before planting any of the following magnesium-rich minerals:
  - Magnesite ($MgCO_3$ - 28.8 % Mg, or 47.8 % MgO), at 300 kg/ha.
  - Dolomite ($CaMg(CO_3)_2$ 21.7 % Ca, or 30.4% CaO, and 3.2 % Mg, or 21.96% MgO), at 800 kg/ha.
- A deficiency in a current crop can be corrected by fortnightly foliar sprays of fully soluble magnesium nitrate (11-0-0+16 MgO), e.g. Magnisal® at 2 kg / 100 L) at volume of 500–1,000 L/ha.
- For crops grown in soilless media, use Magnisal® in a nutrient solution containing 30 ppm Mg.

3.7 Sulfur (S)

The main function of sulfur in the plant is as a core constituent of the essential amino acids cystin, cystein and methionine, as well as taking part in the composition and functioning of many co-enzymes. The vitamins Thiamine and Biotin use sulfur, so this element plays a key role in plant metabolism. Hence, sulfur deficiency will result in deficient proteins, in a way that resembles nitrogen deficiency. But, as sulfur has low mobility in the plant its deficiency symptoms will show firstly on the newly formed, young leaves, as negated to nitrogen deficiency.

Sulfur is generally present at adequate amounts in soil-grown cucumbers that receive sulfate salts of potassium or magnesium.

When it occurs sulfur deficiency shows as a general yellowing of the entire foliage, especially- on the new growth. This can be differentiated from similar symptoms produced by iron and manganese deficiency, as with sulfur deficiency the veins of the leaves do not remain green, but the leaf blade takes on a dull uniform yellow coloration.

Sulfur levels in hydroponic solutions may be in the range of 20-200 ppm, because plant requirements of this element are pretty flexible between quite a wide range.

Table 3.9: Leaf analysis sulfur standards for **field-grown** cucumbers (in dry matter of youngest fully mature leaf with petiole taken at early flowering stage).

Nutrient	Unit	Deficient	Low	Normal	High	Excessive
Sulfur	%		<0.3	0.3–2.0	2.0-4.0	

Excessive sulfur in the soil (seldom) may cause premature dropping of leaves.

3.8 Manganese (Mn)

The function of manganese in the plant is closely associated with the function of iron, copper and zinc as enzyme catalysts. Manganese is needed for photosynthesis, respiration, nitrate assimilation and the production of the plant hormone auxin. Without manganese, hydrogen peroxide accumulates in the cells and damages them. Like iron, manganese is immobile within the plant, accumulating mostly in the lower leaves.

Deficiencies are more likely in calcareous or alkaline soils, or over-limed soils; availability is high in acidic soils.

The veins of middle to upper leaves of manganese-deficient plants remain green while the rest of the leaf becomes a uniform pale green to yellow. (See Figure 3.24.)

Figure 3.24: Typical color contrast between the veins and the rest of the leaf blade of middle to upper sulfur deficient cucumber leaves

Table 3.10: Leaf analysis manganese standards for field-grown cucumbers (in dry matter of youngest fully mature leaf with petiole taken at early flowering stage).

Nutrient	Unit	Deficient	Low	Normal	High	Excessive
Manganese *	mg/kg	<15	15–60	60–400	400–500	>500

*Values for manganese in leaves sprayed with fungicides or nutrient sprays containing trace elements cannot give a reliable guide to nutritional status.

Treatment

- Spray the foliage with manganese sulfate (100 g/100 L).
- For crops grown in soilless media, use a nutrient solution containing 0.3 ppm Mn.

Manganese toxicity

- Found under strongly acid conditions.
- Numerous small reddish-brown spots appear between the veins of the oldest leaves and on leaf petioles of plants with excess manganese (Figure 3.25). With time, the tissue around each spot becomes chlorotic, and the older leaves turn pale and age prematurely.
- Manganese toxicity may show by reduction in growth.
- Cucumbers are not particularly sensitive to excess manganese, and tissue concentrations may be relatively high before toxicity symptoms show.
- Manganese toxicity can induce iron deficiency.

Figure 3.25: Small reddish-brown spots appear between the veins of the oldest leaves of Mn-excessive cucumber leaves.

Treatment

Manganese toxicity in soil-grown crops is associated with acidic conditions and waterlogging. Correction therefore involves liming and improving drainage and irrigation scheduling.

3.9 Iron (Fe)

Iron is needed to produce chlorophyll and to activate several enzymes, especially those involved in photosynthesis and respiration. Iron is immobile in the plant.

Deficiencies of iron are more likely in alkaline or calcareous soils, and can be induced by over-liming, poor drainage, or high concentrations of metallic ions in the soil or nutrient solution. Iron availability decreases at pH above 7. Manganese toxicity can induce an iron deficiency.

Iron deficiency causes a uniform pale green chlorosis of the newest cucumber leaves; all other leaves remain dark green. Initially, the veins remain green, which gives a net-like pattern. If the deficiency is severe, the minor veins also fade, and the leaves may eventually burn, especially if exposed to strong sunlight.

Figure 3.26: Youngest leaves (left and center) are pale green to yellow with green veins. In severe cases (center) of iron deficiency, the minor veins also fade, and affected leaves appear light yellow to white. On the right, a healthy leaf.

Figure 3.27: Pale green symptoms first appear on young leaves.

Treatment

The best long-term action is to correct soil chemical and physical problems. Good drainage and soil aeration favor iron availability.

Foliar sprays of iron sulfate (150 g/100 L) can be used to treat symptoms, but symptoms will return if the sprays are discontinued.

For crops grown in soilless media, use a nutrient solution containing 2–3 ppm Fe. Iron chelates are generally less likely to precipitate under alkaline conditions and are normally preferred in hydroponic solutions.

Table 3.11: Leaf iron analysis standards for field-grown cucumbers (in dry matter of youngest fully mature leaf with petiole taken at early flowering stage).

Nutrient	Unit	Deficient	Low	Normal	High	Excessive
Iron	mg/kg		<50	50–300		

Leaf analysis is not a reliable guide to iron deficiency because of surface contamination with soil, immobility of iron within the plant, or the presence of physiologically inactive iron within tissues.

Iron toxicity will be revealed by bronzing of leaves with tiny brown spots.

3.10 Boron (B)

Boron is important in the regulation of developing cells and in pollination. Seed set and fruit development are affected by deficiency. Plants are rather exacting in their requirements for boron, and the margin between deficiency and excess is particularly narrow. For example, in mini cucumbers, a leaf boron concentration of 30–70 µg/g is desirable, but deficiency occurs at less than 20 µg/g and toxicity- at more than 100 µg/g.

Figure 3.28: Boron-deficient cucumber leaves.

Boron is not readily moved from old to new tissues; hence continuous uptake by roots is needed for normal plant growth.

Boron deficiency causes both leaf and fruit symptoms. The main leaf symptoms are a distortion of newer leaves (in severe cases the growing point dies) and the appearance of a broad yellow border at the margins of the oldest leaves.

Young fruit will die or abort at high rates (Figure 3.29).

Figure 3.29: Aborted fruit (top); twisting and scarring (center and bottom).

The symptoms of boron deficiency on mature fruit are distinctive and include stunted development and mottled yellow longitudinal streaks, which develop into corky markings (scurfing) along the skin.

These symptoms are often most severe near the blossom end of the fruit. Similar symptoms can occur on fruit grown in greenhouses with inadequate winter heating. Developing and mature fruit can taper and curve at the blossom end. The proportion of pith to seed is often higher in boron-deficient fruit.

Not to be confused with symptoms of fruit scurfing and severe twisting with damage by western flower thrips.

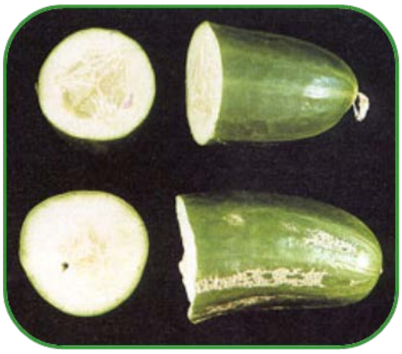


Figure 3.30: Deficient fruit (bottom) have a high proportion of pith to seed and corky markings on the skin.

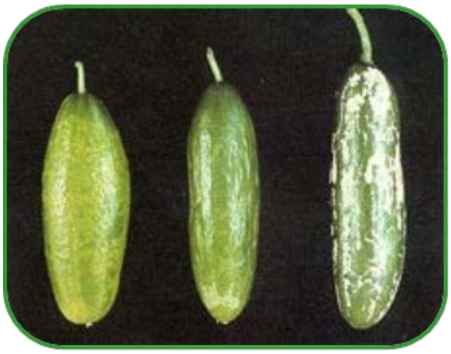


Figure 3.31: Longitudinal, mottled yellow streaks (left and center) develop into corky markings on the skin (right).

Treatment
One needs to be very careful when treating a boron-deficient crop, as excessive boron can be toxic, and boron is highly toxic to most plants at quite low rates. Trial foliar sprays are advisable. Take care with soil treatments to ensure an even spread, and be aware that

An application of 10 kg borax per hectare to deficient soil before planting will prevent boron deficiency. Foliar sprays of borax (100 g/100 L) may also be used.

For crops grown in soilless media, use a nutrient solution containing 0.3 ppm B.

Table 3.12: Leaf boron analysis standards for **field-grown** cucumbers (in dry matter of youngest fully mature leaf with petiole taken at early flowering stage).

Nutrient	Unit	Deficient	Low	Normal	High	Excessive
Boron	mg/kg	<20	20–30	30–70	70–100	>100

Boron toxicity
Cucumber plants are very sensitive to high boron levels.

Boron toxicity is indicated by yellowing between the veins of older leaves. This is followed quickly by the development of small, brown necrotic spots, which eventually join to form large areas of dead tissue. At the same time, the newer leaves become chlorotic and are distorted because of damage in the bud. Few female flowers may develop.

Treatment
Boron toxicities are harder to correct than deficiencies. Problems in crops are usually caused by careless application of boron. When this happens, the soil can be flushed with fresh water to remove the excess.

Figure 3.32: Boron toxicity in older leaves, including yellowing between the veins (left) followed by small brown necrotic spots (center) and large areas of dead tissue (right).

3.11 Zinc (Zn)

Zinc contributes to the formation of chlorophyll and the production of the auxins plant hormones. It is an integral part of several plant enzymes. Zinc deficiency appears as a distortion and interveinal chlorosis (yellowing) of older plant leaves, and retards plant development as a consequence of low auxin levels in the tissue.

In soils zinc becomes less available as the soil pH rises and in the presence of calcium carbonate. A heavy application of phosphorus can induce zinc deficiency due to the precipitation of the zinc in the form of zinc-phosphates. Uptake of zinc is hindered by over-optimal copper, iron, manganese, magnesium, and calcium. The normal zinc content of soils usually falls in the range of 10-300 ppm Zn.

Hydroponically grown cucumbers develop zinc deficiency when plants have too low zinc in the nutrient solution. Normal zinc levels in hydroponic solutions runs at 0.1-0.5 ppm.

The symptoms of deficiency are not well defined, but usually a slight interveinal mottle develops on the lower leaves, this symptoms spreads up the plant. The upper internodes remain short. Small leaf size most characterizes zinc deficiency; in severe cases, short internodes cause the top of the plant to grow bushy. Overall growth is restricted and the leaves become yellow-green to yellow except for the veins, which remain dark green and well defined.

Symptoms of deficiency appear when the concentration drops below 15-20 ppm Zn.

Treatment
Spraying with zinc sulfate (5 g/L) easily corrects a zinc deficiency.

Table 3.13: Leaf zinc analysis standards for field-grown cucumbers (in dry matter of youngest fully mature leaf with petiole taken at early flowering stage).

Nutrient	Unit	Deficient	Low	Normal	High	Excessive
Zinc *	mg/kg	<15	15–20	20–100	100–300	>300

*Values for zinc in leaves sprayed with fungicides or nutrient sprays containing trace elements cannot give a reliable guide to nutritional status.

Zinc toxicity
Zinc toxicity can be caused by contamination of the water used in soilless culture. Contact of corrosive nutrient solutions with galvanized pipes or fittings has been known to lead to zinc toxicity in sensitive seedlings. Galvanized greenhouse frames and wires are other possible sources of excess zinc.

Toxicity occurs in soils contaminated by their proximity to zinc smelters and mines.

Toxicity can be expected when the zinc concentration exceeds 150-180 ppm (old leaves) or 900 ppm (tops of plants).

In the case of zinc toxicity, the entire veinal network, initially dark green, becomes somewhat blackened. The blackish appearance of the main veins helps distinguish zinc toxicity from manganese deficiency in which the veins remain green. In severe cases of zinc toxicity the and the symptoms resemble those of iron deficiency.

Zinc toxicity causes a pale green chlorosis of newer leaves. If toxicity is severe, pinhead-sized light-brown spots may appear between the veins. Older leaves may wilt and appear dull. All leaves are a lighter green than is normal.

Other zinc toxicity symptoms include sever stunting, reddening; poor germination; older leaves wilt; entire leaf is affected by chlorosis, edges and main vein often retain more color.

Figure 3.33: Zinc toxicity in cucumber leaves, pale-green chlorosis. Young leaves become yellow.

Treatment
Remove eroding galvanized metal parts. Apply lime or phosphate.

3.12 Molybdenum (Mo)

Molybdenum is involved in many enzymes and is closely linked with nitrogen metabolism as it is an important component of nitrate-reductase and nitrogenase enzymes.

Molybdenum is present in soil as an anion, in contrast to most other micronutrients, which are present as cations. The availability of molybdenum increases as the pH rises and therefore a deficiency of this element is more likely to occur in acid (and sandy) soils, in which case liming might be helpful.

Plants need tiny amounts of molybdenum, an average 0.2 ppm Mo available in soils is adequate.

Molybdenum deficiencies are rare, but have been observed in plants growing in peat.

Initially, the green of the leaves fades, particularly between the veins. Later, leaves can turn yellow and die. In some cases, parts of mature leaves remain green at first, giving rise to a blotchy appearance. Symptoms start first in lower leaves and spread upwards, the younger ones remaining green. Growth might appear normal but flowers stay small. Severe deficiency cases in peat can significantly reduce yield (up to 84%), but raising the pH (up to 6.7) through liming restores yield to near normal.

Treatment
As a preventative measure on peat, apply sodium molybdate at 5 g/m^3. Treat a deficiency either by applying sodium molybdate to the soil at 150
mg/m^2 or by spraying with a solution of sodium molybdate in water at 1 g/L.

Toxicity
Plants can take up high levels of molybdenum without harmful effects on growth, Intense yellow or purple color in leaves may be rarely observed.

There might be concern for human health with high molybdenum
levels in the produce.

Table 3.14: Leaf analysis molybdenum standards for field-grown cucumbers (in dry matter of youngest fully mature leaf with petiole taken at early flowering stage).

Nutrient	Unit	Deficient	Low	Normal	High	Excessive
Molybdenum	mg/kg	<0.2	0.2–0.5	0.5–2.0		

3.13 Copper (Cu)

Several enzymes with diverse properties and functions depend on copper, including those involved in photosynthesis and respiration. Although copper is mobile in plants well supplied with the element, it is much less mobile in deficient plants. Therefore copper concentration in young developing tissue is likely related to plant status. **However, soil analysis is a more useful guide to copper deficiency than tissue analysis.**

Copper deficiency is unusual, partly because the widespread use of copper in plumbing and in fungicides ensures an adequate supply in most cases. Occasionally it becomes a problem with crops in peat media or in all plastic hydroponic systems when no copper is added to the nutrient solution. High soil pH reduces available copper, but this effect is much smaller than for manganese, iron, and boron.

Copper deficiency symptoms

Restricted growth, short internodes and small leaves. Initially, interveinal chlorotic blotches appear on mature leaves, but later symptoms spread upwards on the plant. The leaves eventually turn dull green or bronze, their edges turn down, and the plant remains dwarfed.

Furthermore, bud and flower development at the top of the plant decreases.

Copper deficiency can dramatically reduce yield (by 20-90%). The few fruits that are produced develop poorly with small, sunken brown areas scattered over their yellow-green skin.

Treatment

To prevent copper deficiency in peat media, where it is most common, add copper sulfate at 10 g/m^3, as a precaution. Generally, nutrient solutions should contain 0.03 ppm Cu. For quick results, spray plants with a solution of copper sulfate using up to 1 g/L, plus calcium hydroxide (approx. 0.5%) for pH adjustment.

Table 3.15: Leaf analysis copper standards for field-grown cucumbers (in dry matter of youngest fully mature leaf with petiole taken at early flowering stage).

Nutrient	Unit	Deficient	Low	Normal	High	Excessive
Copper	mg/kg	<3	3–7	8–20	20–30	>30

Values for copper in leaves sprayed with fungicides or nutrient sprays containing trace elements cannot give a reliable guide to nutritional status.

Toxicity

Copper toxicity, although rare, can appear as an induced iron chlorosis, where the soil is contaminated with copper either from industrial sources or after repeated spays of copper-containing fungicides. Toxic effects persist, and the only partial solution is heavy liming. In hydroponic systems, extensive use of copper plumbing can produce copper contamination.

4. 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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4.1 Nutrients demand/uptake/removal

One ton of cucumber fruits removes from the soil:

	N	P_2O_5	K_2O
Grams	800 – 1,350	270 - 900	1,350 – 2,250
Lbs	1.8 - 3	0.6 - 2.0 l	3 – 5

Table 4.1: Recommended plant nutrients under different growing conditions and expected yields.

Growing method	Expected yield (t/ha)	N	P_2O_5	K_2O	MgO	CaO
		Kg / ha				
Under glass	300	450-500	200-250	800-1,000	130	300
Outdoor crop	High-yielding	170	130	270		
Outdoor crop	30-40	100	100	200		
Outdoor crop	30	50	40	80		
Outdoor crop	15	47	13	65		

4.2 Generic fertilizers recommendations

Table 4.2: A general fool-proof recommendation for N-P-K fertilization regime and timing allocation before and during the growth season, based on soil tests.

Fertilizer timing	Nitrogen kg/ha	Soil phosphorus level (kg/ha P_2O_5)				Soil potassium level (kg/ha K_2O)			
		Low	Med	High	Very high	Low	Med	High	Very high
Total recommended	120-140	170	120	60	30	230	170	120	60
Pre-plant: broadcast & incorporate	60	120	60	0	0	170	120	60	0
Band-place*	30	60	60	60	30	60	60	60	60
Side-dress when vines begin to run, or fertigate	30	0	0	0	0	0	0	0	0

*15 cm to side of seed row and 10 cm deep

4.2.1 General fertilizing principles for cucumbers

Pre-plant treatments

Amending soil pH
Cucumbers prefer light textured soils that are well drained, high in organic matter and have a pH of 6 - 6.8. Adapted to a wide-range of soils, but will produce early in sandy soils. Cucumbers are fairly tolerant to acid soils (down to pH 5.5).

Greenhouse cucumbers generally grow quite well in a wide range of soil pH (5.5-7.5), but a pH of 6.0-6.5 for mineral soils and a pH of 5.0-5.5 for organic soils are generally accepted as optimum. When the pH is too low, add ground calcitic limestone, or an equal amount of dolomitic limestone when the magnesium level in the soil is low, to raise it to a desirable level. Use the rates given in Table 4.3 as a guide; the actual lime requirement is best assessed by an appropriate laboratory test.

Table 4.3: Lime requirements for correcting soil pH to 6.5

Soil pH	Sandy Loam	Loam, silty loam	Clay loam, organic
	Lime mass (t/ha)		
6.0	3.0	4.5	6.0
5.5	6.0	9.0	12.0
5.0	9.0	12.0	18.0
4.5	12.0	15.0	24.0
4.0	15.0	18.0	30.0

Note: The rates of lime suggested are for the top 15 cm of soil. If acidity has to be corrected to a greater soil depth, increase the rates accordingly.

Usually the pH in most greenhouse mineral soils is above the optimum pH range (6.0-6.5). A simple, though temporary, solution to a high pH problem is to add peat, without neutralizing its acidity with limestone. Peat also helps to maintain a good soil structure, but it must be added yearly to make up for loss through decomposition.

Pre-plant fertilizers for growth in soil beds
Apply pre-plant fertilizers after soil steaming and leaching, and incorporate them into the greenhouse soil. Add these fertilizers to the limestone that may be needed for adjusting the pH level of the soil (Table 4.3). Add as much of the required calcium and phosphorus as possible as a base dressing, because these nutrients store effectively in the soil and their absence from liquid feeds prevents most clogging problems of the irrigation system. Provide the calcium in the form of limestone and the phosphorus in the form of superphosphate, both finely ground. Furthermore, these nutrients, by nature of their source and their ability to bind to soil particles, are released slowly into the soil solution and therefore do not raise the total amount of salts dramatically, nor do they upset the nutrient balance of the soils to which they are added as a base dressing. Also, supply a good portion of potassium along with magnesium, as base fertilizer; the ratio of potassium to magnesium in the soil should be 2:1. Avoid applying nitrogen. Make the final decision on base fertilization after receiving the soil test results and consulting with your horticultural crop adviser. Treat the recommended rates of base fertilizers (Table 4.4) as a general guide only.

Table 4.4: Recommendations for base fertilizer

Fertilizer	**Amount**	
	kg/ha	**lbs/ac**
Superphosphate (0-20-0, fine grade)	250	225
Potassium sulfate	500	445
Magnesium sulfate	250	225
Add the following in combination, if needed:		
Calcitic limestone	800	715
Peat	800 bales/ha	

Incorporate the relevant fertilizers into the soil to avoid micronutrient deficiencies, indicated by soil analysis.

During crop growth, the most important element needed is nitrogen. It should be supplied in the irrigation water (fertigation) at each irrigation, from soluble fertilizer materials, such as potassium nitrate (13-0-46), e.g. **Multi-K**®; calcium nitrate (15.5-0-0+26.5 CaO), e.g. **Haifa Cal;** or ammonium nitrate (33-0-0). During the first few weeks after transplanting, fertigate with 6-11 kg/ha (5-10 lbs/ac) of N per week, during fruit production.

In soilless systems, plants are grown with a complete nutrient solution, composed of potassium nitrate (13-0-46), e.g. **Multi-K**® + mono-ammonium phosphate (12-61-0) e.g. **Haifa MAP** or mono-potassium phosphate, e.g. **Haifa MKP** + calcium nitrate (15.5-0-0+26.5 CaO), e.g. **Haifa Cal,** magnesium nitrate (11-0-0+16MgO), e.g. **Magnisal®,** or with a complete N-P-K controlled-release fertilizer (CRF), e.g. **Multicote**®, at rates of 0.6-1.2 kg/m^3 (1-2 lb/yd^3) of nitrogen, or with a combination of the soluble- and the CRF materials. When used in combination, rates for each material should be reduced by 30-40%. Nutrient solution should be applied every irrigation by fertigation. Frequency of application will depend upon plant size and greenhouse temperature, but will vary from once or twice daily, immediately after transplanting, to several times per day on warm days during harvest.

Always apply some pre-plant N-P-K to assure good development of the seedlings and first vegetative stage of the plants.

Adjust rates to soil type, and soil test results.

	Kg / ha	Lbs / acre
Nitrogen	50-70	45-63
Phosphorus (P_2O_5)	10-120	9-108
Potassium (K_2O)	10-170	9-153

See Table 4.2 for more specific rates, based on soil tests.

If drip irrigation is used, apply the 60 kg/ha (55 lbs/acre) N preplant.

Then, during growth season apply 0.6-1.1 kg/ha (0.5 to 1 lbs/acre) N daily, or 3.5-7 kg/ha (3-6 lbs./acre) N on a weekly basis, through the drip system.

If plastic mulching is practiced, the N rate can be reduced because N losses from leaching are greatly reduced. For this culture system, it is recommended to apply 60 kg/ha (50 lbs/acre) N broadcast preplant over the row, just prior to laying the plastic.

At vining, when the plant roots have reached the edge of the plastic, sidedress 35 kg/ha (30 lbs/acre) N on either side of the plastic.

Soil pH: Optimum soil pH range is 5.8-7.0. If the soil pH is below 5.8 and the available soil calcium is less than 2,200 kg/ha (2,000 lbs/acre), apply 2,200 kg/ha (2,000 lbs/acre) of agricultural lime 8 to 12 weeks before planting.

Lime and dolomitic limestone: If soil test indicates less than 70 ppm magnesium, pre-plant application of Magnesite or Dolomite is recommended, at rates indicated in paragraph 2.5, or to apply magnesium sulfate (9.8% Mg), or its equivalent at 170-220 kg/ha (150 - 200 lbs/acre), by pre-plant broadcasting and incorporating.

Lime and phosphates: If both lime and phosphates are required, both should be incorporated together 8 - 12 weeks before planting.

Phosphate: On soils very low in available phosphate, apply 1,700 kg/ha (1,500 lbs/acre) of triple super-phosphate (0-47-0) or its equivalent. If grower chooses to apply the phosphorus just before planting, mono-ammonium phosphate fertilizer grade (11-52-0) at 1,700 kg/ha (1,500 lbs/acre) should be incorporated in the planting row 25-30 cm (10 - 12 inches) deep.

Organic manures are useful even for outdoor crops, especially in low CEC soils.

Side dressing treatments

The N application should be split into as many applications as possible. If fertigation (Nutrigation™) equipment is available N should be applied in every irrigation pulse. Otherwise, fortnightly dressings should be done along the harvesting period.

Side-dressing N: It is recommended to apply 50 kg/ha (45 lb. per acre) N in a band to either side of the row when plants are rapidly vining. **At least half of the nitrogen should be in the nitrate (NO_3) form**.

For fresh market cucumbers, an additional 35 kg/ha (30 lbs/acre) N is usually added when the plants have 2-4 leaves and vines are just starting to fall over into the rows, but no more than 45 kg/ha (40 lbs./ac) of N or K_2O should be applied at any one time. Pickling cucumbers are not responding to any additional N applications due to their short harvest period.

Additional application(s) should be made every two weeks with the onset of harvest as side dress and covered with surface soil. The following options are recommended:

- A 3:1 mixture of ammonium sulfate (21-0-0): **Multi-K®** (13-0-46), at the rate of 220 kg/ha (200 lbs/ acre)
- A 1:1 mixture of urea (46-0-0): **Multi-K®** (13-0-46), at the rate of 220 kg/ha (200 lbs/ acre)
- An N-P-K complex water soluble fertilizers, such as **Polyfeed®** at the equivalent N:K ratios may be fertigated = Nutrigated™ (injected through the irrigation system).

Deficiencies of Mg and of B, Fe and Mn, may occur and demand direct application of these nutrients, by the methods and rates mentioned in Chapter 2, paragraphs: 2.5, 2.7-2.9.

Table 4.5: Recommendations for the application rates and weeks allocation of soluble fertilizers to be evenly broadcasted on the soil in a soil cucumber greenhouse, irrigated by flooding, as determined for greenhouses in Canada. Source: *Papadopoulos.*

Do not apply this program as is, to a drip-irrigated plot as it will produce very high salt concentrations near the root system.

Week from planting	Potassium nitrate	Calcium nitrate	Ammonium nitrate	10-52-10	20-5-30	Magnesium sulfate
	Kg/ha					
1				150		
2	50	50			100	100
3	50				100	
4	50	100			100	100
5	50				100	
6	100	100			100	100
7	100				100	
8	100	100	50		100	
9	100				100	100
10	100	100	50		100	
11	100				100	
12	100	100	50		100	100
13	100				100	

Week from planting	Potassium nitrate	Calcium nitrate	Ammonium nitrate	10-52-10	20-5-30	Magnesium sulfate
	Kg/ha					
14	100	100	50		100	
15	100				100	100
16	100	100	50		100	
17	100				100	
18	100	100	50		100	100
19	100				100	
20	100	100	50		100	
21	100				100	
22					100	
23					100	

*Caution: If fertilizers are first mixed in concentrated stock solutions before they are applied to the crop, group them as indicated by the colors grouping. Do not mix in the same concentrated solution a fertilizer containing calcium and one containing sulfate or phosphate, because such a mixture forms a thick suspension that can plug watering equipment.

Note: Choose soluble fertilizer formulations that are as free as possible of chlorides, sulfates, and carbonates.

Table 4.6: Recommendations for the application rates and allocation by weeks of generic soluble fertilizers in a soil cucumber greenhouse, fertigated by drip irrigation. As determined for greenhouses in Canada, source: *Papadopoulos.*

Week from planting	Fertilizers in stock solution A* (kg/1,000 L)			Fertilizers in stock solution B* (kg/1,000 L)			Irrigation	
	CN	PN	Amm. nitrate	MKP	$MgSO_4$	MgN	Volume (L/plant/day)	EC (mS/cm)
	Spring Crop							
1	50	0	0	100	25		0.4	1.94
2	50	35	0	15	25		0.6	2.09
3	35	50	10	15	25		0.8	2.24
4	35	50	15	15	25		1.0	2.46
5	35	55	15	15	25		1.2	2.54
6	35	60	15	15	25		1.6	2.61
7	35	65	15	15	25		2.0	2.69
8	35	70	15	15	25		2.2	2.69
9	35	70	15	15	25		2.4	2.69
10	35	70	15	15	25		2.6	2.69
11	35	70	15	15	25		2.8	2.69
12-17	35	60	15	15		35	4.0	2.46
18-22	35	55	15	15		35	5.0	2.46
23-end	35	50	15	15		35	4.0	2.31

Week from planting	Fertilizers in stock solution A* (kg/1,000 L)			Fertilizers in stock solution B* (kg/1,000 L)			Irrigation	
	CN	PN	Amm. nitrate	MKP	$MgSO_4$	MgN	Volume (L/plant/day)	EC (mS/cm)
	Fall crop							
1	50			100	25		0.4	1.94
2	50	35		15	25		0.8	2.09
3	35	50	10	15	25		1.0	2.24
4	35	50	15	15	25		1.2	2.46
5-12	35	50	15	15		35	3.0	2.46
13-end	35	50	15	15		35	2.0	2.31

CN = Calcium nitrate (15.5-0-0-26CaO) e.g. **Haifa Cal**

PN = Potassium nitrate (13-0-46), e.g. **Multi-K®**

Amm. nitrate = Ammonium nitrate (33.5-0-0)

MKP = mono-potassium phosphate (0-52-34), e.g. **Haifa MKP**

MgN = magnesium nitrate (11-0-0+16MgO), e.g. **Magnisal®**

*Caution: If fertilizers are first mixed in thick stock solutions before they are applied to the crop, group them as indicated. Do not mix in the same concentrated solution a fertilizer containing calcium and one containing sulfate or phosphate, as such a mixture results in a thick suspension that can plug watering equipment.

Notes:

- Trace elements must also be added to all the above fertilizer feeds; a typical trace element mix (e.g., **Haifa Micro Comb** chelated micronutrient mix) contains 7.1% Fe, 3.48% Mn, 1.02% Zn, 0.76% Cu, All as EDTA chelates. 0.485% Mo as ammonium molybdate; when added to the stock solution at the rate of 1 kg/1000 L it contributes to the final solution 0.7 ppm Fe, 0.2 ppm Mn, 0.04 ppm Zn, 0.01 ppm Cu, 0.13 ppm B, & 0.006 ppm Mo, with a 1:100 dilution ratio.
- Dissolve the given amount of each fertilizer, including trace elements, in 1000 L of water and add to the irrigation water in equal doses, ideally with a multihead fertilizer injector. Start injection at a very low rate and increase the rate of injection progressively, and uniformly on all heads, until the desired EC is achieved. Adjust the pH of the fertigation solution to 5.5 by injecting a dilute solution of phosphoric, nitric, or sulfuric acid. Alternatively, dissolve the prescribed fertilizers, including the micronutrient mix, into 100 000 L of water, adjust the pH, and apply directly to the crop.
- The recommended strength of the stock solutions is within the working range of a fertilizer injector with a 1:100 mixing ratio. If a fertilizer injector with a 1:200 mixing ratio is used, double the amount of each fertilizer. Make similar adjustments for fertilizer injectors with other mixing ratios. If the solubility limit of a fertilizer (e.g., potassium nitrate) is exceeded, prepare more than one stock solution of the same fertilizer and divide the amount of the fertilizer equally between the stocks.

Table 4.7: Nutrient concentration in the final nutrient solution when one part of each of stock solutions A and B, prepared as prescribed in Table 4.6, are mixed with 98 parts of water (i.e. 1:100 dilution ratio). Source: *Papadopoulos.*

Week	N-NO3	N-NH4	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B	MO	Expected EC * (mS/cm)
	Spring Crop												
1	72	3	235	300	95	25	0.7	0.2	0.04	0.01	0.13	0.006	1.94
2	117	15	35	175	95	25	0.7	0.2	0.04	0.01	0.13	0.006	2.09
3	140	25	35	133	67	25	0.7	0.2	0.04	0.01	0.13	0.006	2.24
4	145	25	35	133	67	25	0.7	0.2	0.04	0.01	0.13	0.006	2.46
5	151	25	35	251	67	25	0.7	0.2	0.04	0.01	0.13	0.006	2.54
6	158	25	35	270	67	25	0.7	0.2	0.04	0.01	0.13	0.006	2.61
7	164	25	35	289	67	25	0.7	0.2	0.04	0.01	0.13	0.006	2.69
8-11	170	25	35	308	67	25	0.7	0.2	0.04	0.01	0.13	0.006	2.76
12-17	196	25	35	270	67	32	0.7	0.2	0.04	0.01	0.13	0.006	2.46
18-22	189	25	35	251	67	32	0.7	0.2	0.04	0.01	0.13	0.006	2.39
23-end	183	25	35	233	67	32	0.7	0.2	0.04	0.01	0.13	0.006	2.31
	Fall crop												
1	72	3	235	300	95	25	0.7	0.2	0.04	0.01	0.13	0.006	1.94
2	122	12	35	175	67	25	0.7	0.2	0.04	0.01	0.13	0.006	2.09
3	140	15	35	133	67	25	0.7	0.2	0.04	0.01	0.13	0.006	2.24
4	145	25	35	133	67	25	0.7	0.2	0.04	0.01	0.13	0.006	2.46
5-12	186	25	35	270	67	32	0.7	0.2	0.04	0.01	0.13	0.006	2.46
13-end	189	25	35	251	67	32	0.7	0.2	0.04	0.01	0.13	0.006	2.39

*The EC of the water has been assumed at 0.045 S/cm and is included.

Table 4.8: Recommended nutrient levels for cucumbers in NFT solution in normal water.
Note: The NFT system is not recommended for long-term cucumber crops because of frequent, and unresolved, crop losses from widespread root death.

Stock solution A (1,000 Liter tank)		**Stock solution B** (1,000 Liter tank)	
Fertilizer	**Mass**	**Fertilizer**	**Mass**
Calcium nitrate	44.4 kg	Mono potassium phosphate (MKP)	22.0 kg
Potassium nitrate	62.7 kg	Magnesium sulfate	50.0 kg
Ammonium nitrate	5.0 kg	Iron chelate (13% Fe)*	1.0 kg
		Manganese sulfate (25% Mn)*	250 g
		Boric acid (14% B)*	90 g
		Copper sulfate (25% Cu)*	30 g
		Zinc sulfate (23% zinc)*	35 g
		Ammonium molybdate (57% Mo)*	8 g

*Alternatively, include 2.0 kg of **Haifa Micro Soilless combination** chelated micronutrient mix; which provides the following micronutrient concentrations: 1.4 ppm Fe, 0.4 ppm Mn, 0.08 ppm Zn, 0.26 ppm B, 0.02 ppm Cu, and 0.012 ppm Mo.

Notes:

- Prepare the final solution by adding equal volumes of both stock solutions in water until a recommended final solution EC of 3.28 mS/cm is achieved; adjust the pH to 6.2 by adding phosphoric (low-light conditions) or nitric (high-light conditions) acid. Ideally, stock solutions are mixed and pH is adjusted automatically by electrical conductivity and pH controllers.
- When starting a new crop, begin with an EC of 2.24 mS/cm and gradually increase to 3.28 mS/cm over 1 week.
- A background EC of 0.045-0.091 mS/cm from the water supply is assumed.

Assuming a dilution ratio of 1:100 for stock solutions A and B, the theoretical nutrient concentrations in the circulating diluted NFT solution are as follows:

Nutrient	ppm
Nitrate (NO_3-N)	156
Ammonium (NH_4-N)	12
Phosphorus	50
Potassium	302
Calcium	84
Magnesium	50
Iron	1.3
Manganese	0.62
Boron	0.12
Copper	0.07
Zinc	0.08
Molybdenum	0.03

Table 4.9: Recommended nutrient levels for cucumbers in NFT solution in **hard** water.

Stock solution A (1,000 Liter tank)		Stock solution B (1,000 Liter tank)		Stock solution C (1,000 Liter tank)	
Fertilizer	**Mass**	**Fertilizer**	**Mass**	**Fertilizer**	**Volume**
Calcium nitrate	50.0 kg	Potassium nitrate	80.0 kg	Nitric acid (67%)	54 L
		Potassium sulfate	40.0 kg	Phosphoric acid (85%)	24 L
		Magnesium sulfate	60.0 kg		
		Ammonium nitrate	0.6 kg		
		Iron chelate (13% Fe)	3.0 kg		
		Manganese sulfate (25% Mn)	400 g		
		Boric acid (14% B)	240g		
		Copper sulfate (25% Cu)	80 g		
		Zinc sulfate (23% zinc)	40 g		
		Ammonium molybdate (57% Mo)	10 g		

No phosphatic fertilizer has been included other than the phosphoric acid in stock solution C. Where the water is not particularly hard and the acid requirement is correspondingly low, include

1.5 kg of mono-potassium phosphate, e.g. **Haifa MKP**, in stock solution B, while decreasing the amount of potassium sulfate from 40 to 30 kg.

Note: Assuming a dilution ratio of 1:100 for stock solutions A and B, the theoretical nutrient concentrations in the circulating diluted NFT solution are as follows:

Nutrient	ppm	Remarks
Nitrate (NO_3-N)	192	The nitric acid of stock solution C supplies additional nitrogen
Ammonium (NH_4-N)	12	
Phosphorus	0	The phosphoric acid of stock solution C supplies the phosphorus
Potassium	490	
Calcium	85	The calcium content of the water supply has not been taken into account.
Magnesium	59	
Iron	4.5	
Manganese	1.0	
Boron	0.34	
Copper	0.2	
Zinc	0.09	
Molybdenum	0.05	

5. Haifa's fertilization recommendations

5.1 Fertilizers recommendations for a variety of growth conditions

5.1.1 Open-field using granular N-P-K fertilizers

Plant density: 30,000 – 40,000 / ha
Expected yield: 25 – 35 ton / ha

Pre-plant application

Nutrient Demand (kg/ha)*				Suggested Fertilizers (kg/ha)*			
N	P_2O_5	K_2O	MgO	AN	SSP	SOP	$MgSO_4$
85	150	270	50	256	750	540	300

AN = Ammonium Nitrate (33.5-0-0)
SSP = Single Super Phosphate (0-20-0)
SOP = Sulfate of Potash (0-0-50)
***CaO** = may be required if soil and water are low in calcium

Side dressing

Table 5.1: Nutrients demand and recommended fertilizers for side-dressing of open-field cucumbers

Growth stage	Nutrient Demand (kg/ha/stage)				Recommended Granular N-P-K-Mg Fertilizers (kg/ha/stage)		
	N	P_2O_5	K_2O	MgO	18-18-18	20-3-20	12-0-42+4MgO
Vegetative development	50	50	50	5	280	-	-
Flowering – fruit-set	50	10	50	0	-	250	-
Production	70	0	230	20	-	-	2 x 275*
Total	170	60	330	25	280	250	550

*2 applications of 275 kg/ha each, at 10 days interval.

5.1.2 Open-field using fully water soluble N-P-K fertilizers and fertigation setup

Plant density: 30,000 – 40,000 / ha
Expected yield: 40 – 50 ton / ha

When fields are equipped with fertigation setup, Nutrigation™ (fertigation) is recommended (for details see the relevant paragraph on page 21). When fertilizers are properly soil applied and Nutrigated, the expected yield may be increased by app. 80% as compared to the application of granular fertilizers, to around 40 – 50 t/ha.

Pre-plant application

Nutrient Demand (kg/ha)			Suggested Fertilizers (kg/ha)		
N	**P_2O_5**	**K_2O**	**AN**	**SSP**	**SOP**
60	160	200	180	800	400

AN = Ammonium Nitrate (33.5-0-0), **SSP** = Single Super Phosphate (0-20-0),
SOP = Sulfate of Potash (0-0-50),
CaO = may be required if soil and water are low in calcium.

Nutrigation™ (fertigation)*

Table 5.2 : Nutrients demand and recommended fertilizers for Nutrigation™ of open-field cucumbers

Growth stage	Nutrient Demand (kg/ha/stage)				Recommended Fertilizers (kg/ha/stage)			
	N	**P_2O_5**	**K_2O**	**MgO**	**Multi-K®**	**Haifa MAP**	**AN**	**Magnisal®**
Vegetative development	40	10	60	10	130	16	42	60
Flowering – Fruit-set	70	20	140	40	300	33	-	250
Production	80	20	200	30	430	33	-	190
Total	190	50	400	80	860	82	42	500

*The fertilizers should be applied every 1 – 2 irrigation cycles.

Multi-K® = Potassium nitrate (13-0-46),
Haifa MAP = Mono-ammonium Phosphate, technical grade (12-61-0),
AN = Ammonium Nitrate (33.5-0-0),
Magnisal® = Magnesium nitrate (11-0-0-16MgO)
CaO = may be required if soil and water are low in calcium.

5.1.3 Greenhouse and tunnels

<u>A – Soil grown</u>
Plant density: 18,000 – 24,000 / ha
Expected yield: 120 – 150 ton / ha

Total nutrients application (kg/ha)			
N	**P_2O_5**	**K_2O**	**MgO**
300	240	700	100

CaO = may be required if soil and water are low in calcium

Pre-plant application

Nutrient demand (kg/ha)			Suggested fertilizers (kg/ha)		
N	P_2O_5	K_2O	AN	SSP	SOP
60	160	200	180	800	400

AN = Ammonium Nitrate (33.5-0-0), **SSP** = Single Super Phosphate (0-20-0),
SOP = Sulfate of Potash (0-0-50),
CaO = may be required if soil and water are low in calcium.

i. Nutrigation™ (fertigation) – by QUANTITIVE* delivery

Table 5.3: Nutrients demand and recommended fertilizers for quantitative Nutrigation™ of soil-grown, greenhouse cucumbers

Growth stage	Nutrient Demand (kg/ha/stage)				Recommended Fertilizers (kg/ha/stage)			
	N	P_2O_5	K_2O	MgO	Multi-K®	Haifa MAP	AN	Magnisal®
Establishment	40	10	60	10	130	16	42	60
Vegetative development	70	20	140	40	300	33	-	250
Flowering – fruit-set	80	200	200	30	430	33	-	190
Production	50	20	100	20	215	33	-	190
Total	240	70	500	100	1075	115	42	690

*The application rate is based and a quantity per area regardless of the concentration in the irrigated water. The fertilizers should be applied every 1-2 irrigation cycles.

Multi-K® = Potassium nitrate (13-0-46),
Haifa MAP = Mono-ammonium Phosphate (12-61-0),
AN = Ammonium Nitrate (33.5-0-0),
Magnisal® = Magnesium nitrate (11-0-0-16MgO)

Calcium

In case of soils low in calcium this plant nutrient should be applied from fruit-set until the end of harvest. Rates should be adjusted according to the concentration in the soil and irrigation water. Total requirement rate = 2–4 kg/ha/day CaO, which can be applied as 11.5 kg/ha/day of **Haifa Cal** 15.5-0-0-26CaO.

ii. Nutrigation™ (fertigation) – by PROPORTIONAL* delivery

Table 5.4: Nutrients demand and recommended fertilizers for proportional Nutrigation™ of soil-grown, greenhouse cucumbers

Growth stage	Assumptions		Nutrient Demand (kg/m³)				Recommended Fertilizers (kg/m³)			
	No. of days/ stage	Irrigation rate (m³/ha/day)	N	P_2O_5	K_2O	MgO	Multi-K®	Haifa MAP	AN	Magnisal®
Establishment	25	25	0.06	0.02	0.10	0.02	0.21	0.03	0.07	0.1
Vegetative development	30	40	0.06	0.02	0.12	0.03	0.25	0.03	0	0.21
Flowering – fruit-set	30	55	0.05	0.01	0.12	0.02	0.26	0.02	0	0.12
Production	25	60	0.03	0.01	0.07	0.01	0.14	0.02	0	0.13

*The concentration of applied plant nutrients is unchanged and is constant during the entire irrigation cycle.
The fertilizers should be applied every 1 – 2 irrigation cycles

Multi-K® = Potassium nitrate (13-0-46),
Haifa MAP = Mono-ammonium Phosphate (12-61-0),
AN = Ammonium Nitrate (33.5-0-0),
Magnisal® = Magnesium nitrate (11-0-0-16MgO)
CaO may be required if soil and water are low in calcium.

B - Soilless grown

Cucumber can be grown in greenhouses on soilless media, such as perlite, Rockwool, peat, etc. When growing cucumbers on soilless media, **special care** must be taken in monitoring the nutrients that the crop receives, as there is no soil to compensate for the spent nutrients.

The following factors should be taken in account:

- **pH:** The pH in the nutrient solution should be maintained at 5.5 – 6.5. The pH can be lowered by the use of acids. Adjustment of pH levels can be accomplished by slight changes in nitrate/ammonium ratio in the nutrient solution.
- **Electrical Conductivity (EC):** The EC of the nutrient solution and the root zone should not exceed 2.2 and 3.0 dS/m, respectively. The difference between the EC of the nutrient solution and the drain water should not exceed 1.5 – 2.0 dS/m (depending on the properties of the water supply).
- **Nitrate (NO_3):** The level of nitrate in the drain water should be 200 – 300 ppm depending on the nitrate level, which changes according the growth stage.
- **Nitrate/Ammonium ratio** should not be lower than 5:1.
- **Nitrite (NO_2):** The level of nitrite should be **zero,** because its presence in the growth medium impairs root functioning.
- **Ammonia (NH_3) and ammonium (NH_4):** high level of either ammonia or ammonium interferes with the ability of the roots to absorb K.

Figure 5.1: Crop Load on Beit Alpha Cucumber (cv. *Sarig*), in greenhouse cucumbers.

Table 5.5: Nutrition database for greenhouse-grown cucumbers under Dutch growing conditions:

Parameter	Concentration						
	Rockwool		Rockwool (reuse drainage)		Plant – dry matter (7-8%)		
	Nutrient Solution	Root Environ.	Nutrient Solution	Root Environ.	Guiding Range	Deficient	Excessive
EC (mS/cm)	2.2	3.0	1.7	3.0			
	Concentration (mg/l)				(%)		
NH_4	22.5	< 9.0	18.0	< 9.0			
K in sap					0.59 –0.63	< 0.18	
K	312.8	312.8	254.2	312.8	3.13 – 3.91	< 2.35	
Ca	160.4	260.7	110.3	260.7	2.41 – 3.21	< 1.20	
Mg	33.4	72.9	24.3	72.9	0.36 – 0.73	< 0.37	
N, total					4.20 – 5.60		
NO_3	992.0	1116.0	728.5	1116.0	1.86		
S, total					0.32		
SO_4	132.1	336.4	96.1	336.4			
P					0.62 – 0.93	< 0.47	
H_2PO_4	121.3	87.3	121.3	87.3			
Si	21.1	16.9	21.1	16.9			
Na					0.06 – 0.07		
	Concentration mg/L or ppm)				mg/Kg (ppm)		
Fe	0.838	0.838	0.838	1.396	83.8 – 111.7		
Mn	0.549	0.385	0.549	0.385	54.9 – 164.8		> 549.3*
Zn	0.327	0.458	0.327	0.458	49.0 – 143.8	< 26.1	
B	0.270	0.054	0.270	0.540	54.0 – 75.6	< 43.2	> 108.0
Cu	0.048	0.095	0.048	0.095	10.2	< 8.9**	
Mo	0.048	-	0.048	-	0.96 – 9.59	< 0.29	

* in old leaves

**in young leaves; in old leaves deficient at Cu < 5.08 mg/kg DM

Important note: The above-mentioned database was prepared to fit Dutch conditions. Minor modifications may be required to correspond to your local conditions.

Sources:

- *N. Straver*. Nutrient solutions for vegetables and flowers grown in water or substrates. 10th Ed. 1994.
- *C. de Kreij, Sonneveld C., Warmenhoven M.G. and Straver N.A.* Guide values for nutrient element contents of vegetables and flowers under glass. 3rd Ed. 1992

Table 5.6: Fertigation of soilless grown cucumbers during establishment to flowering stage

Growth stage Establishment – Flowering	Nutrients concentration in the irrigation water (g/m³=ppm)					Recommended fertilizers (g/m³)				
	N*	P	K	Ca	Mg	Multi-K®	Haifa MKP	AN	CN	Magnisal®
Requirement	150	45	220	100	40					
Contents in water**	-	-	-	100	20					
Addition by fertilizers	150	45	220	-	20	420	200	220	-	210

* 80-90% as NO_3^-, 10-20% as NH_4^+

**Based on content in irrigation water 100 ppm Ca and 20 ppm Mg.

Table 5.7: Soilless fertigation of cucumbers during fruit-set to production stage

Growth stage Fruit-set – Production	Nutrients concentration in the irrigation water (g/m³=ppm)					Recommended fertilizers (g/m³)				
	N*	P	K	Ca	Mg	Multi-K®	Haifa MKP	AN	CN	Magnisal®
Requirement	200	50	330	140	70					
Content in water**	-	-	-	100	20					
Addition by fertilizers	200	50	300	40	50	690	220	100	210	400

* 80-90% as NO3-, 10-20% as NH4+

** Based on content in irrigation water 100 ppm Ca and 20 ppm Mg.

Multi-K® = Potassium nitrate (13-0-46),
Haifa MKP = Mono Potassium Phosphate (0-52-34),
AN = Ammonium Nitrate (33.5-0-0),
Haifa Cal = Calcium Nitrate (15.5-0-0-26CaO)
Magnisal® = Magnesium nitrate (11-0-0-16MgO)
Micronutrients should be maintained at the following levels (ppm) throughout the growth period:

Fe	Mn	Zn	Cu	B	Mo
(ppm = g / m³)					
0.9	0.55	0.32	0.05	0.25	0.05

5.2 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 assist you in working out the recommended fertilizer rates at different growth stages according to the expected yield under your growing conditions.

The following are examples of recommendations for cucumbers grown in different soils and growing methods, as determined by NutriNet™:

A – Open-field grown cucumbers on loam (medium) texture soil
The expected yield is 40 t/ha. Irrigated by **drip** and the fertilizer application method is: **base-dressing followed by side-dressing**.

At the first stage, NutriNet™ presents the removed plant nutrients by the crop and the recommended application rates based on the expected yield and the selected growing method (Table 5.8):

- Growth method: Open field
- Soil type: loam
- Expected yield: 40 t/ha

Table 5.8: Nutrient requirements and recommended plant nutrient rates of cucumbers grown in loam soil with expected yield of 40 t/ha

	Plant Nutrient Requirements (kg/ha)				
	N	P_2O_5	K_2O	CaO	MgO
Removal by yield	44	20	80	10	8
Uptake by the whole plant	144	62	257	194	46
Recommended rates	173	180	334	97	46
Adjusted rates to loam soil	158	180	360	97	46

The next step allows selecting the methods of irrigation and fertilization. In the following example, the irrigation is by drip system and the fertilization by applying **base-dressing followed by side-dressing** (Tables 5.9, 5.10 and 5.11).

Table 5.9: Recommended base-dressing + side-dressing plant nutrient rates on irrigated crop by **drip**

	N	P_2O_5	K_2O	CaO	MgO
Adjusted rates to loam soil	158	180	360	97	46
Base dressing (kg/ha)	47	108	144	78	37
Side dressing (kg/ha)	133	86	259	23	11
Total (kg/ha)*	180	194	403	101	48

*The values in this field take into account the inefficiency factors involved in base- and side-dressings.

Table 5.10: Suggested base-dressing fertilizers* rates to supply the recommended plant nutrients at expected yield of 40 t/ha cucumbers. The N-P-K-Ca-Mg are applied at 30-60-40-80-80%, respectively.

Suggested base-dressing fertilizers	Fertilizers (kg/ha)	Plant nutrients (kg/ha)				
		N	P_2O_5	K_2O	CaO	MgO
		47	**108**	**144**	**78**	**37**
Ammonium nitrate (34%)	142	47				
Superphosphate (25%)	432		108			
Potassium sulfate (50%)	288			144		
Dolomite (26%)	300				78	
Magnesium sulfate (16%)	231					37

*Other fertilizers of choice may be introduced to supply the recommended plant nutrients.

Table 5.11: Suggested side-dressing fertilizers* rates to supply the recommended plant nutrients at expected yield of 40 t/ha cucumbers. The N-P-K-Ca-Mg are applied at 70-40-60-20-20%, respectively.

Suggested side-dressing fertilizers	Fertilizers (kg/ha)	Plant nutrients (kg/ha)				
		N	P_2O_5	K_2O	CaO	MgO
		133	**86**	**259**	**23**	**11**
Ammonium nitrate (34%)	141	133				
Superphosphate (45%)	191		86			
Multi-K® (46%)	563			259		
Calcium nitrate (26%)	88				23	
Magnesium sulfate (16%)	69					11

*Other fertilizers of choice may be exchanged to supply the recommended plant nutrients.

B – Open-field grown cucumbers, for processing, on clay (heavy) texture soil

The expected yield is 80 t/ha. Irrigated by **drip** and the fertilizer application method is: **base-dressing followed by Nutrigation™ (fertigation).**

- Growth method: Open field
- Soil type: clay
- Expected yield: 80 t/ha

Table 5.12: Nutrient requirements and recommended plant nutrient rates of cucumbers, grown on clay soil with expected yield of 80 t/ha

	Nutrient requirements (kg/ha)				
	N	P_2O_5	K_2O	CaO	MgO
Removed by yield	88	40	160	20	16
Uptake by the whole plant	239	104	427	299	74
Recommended rates	287	231	555	150	74
Adjusted rates to clay soil *	263	231	598	150	74

The next step allows selecting the type of irrigation and fertilization method. In the following example, the irrigation is by **drip system followed by Nutrigation™ (fertigation)** (Tables 5.13, 5.14, 5.15, 5.16 and 5.17).

Table 5.13: Recommended base-dressing and side-dressing plant nutrient rates on cucumbers crop irrigated by **drip**

	N	P_2O_5	K_2O	CaO	MgO
NPK required (kg/ha)	263	231	598	150	74
Base dressing (kg/ha) *	79	139	239	120	59
Nutrigation™ (fertigation) (kg/ha) **	184	92	359	30	15
Total (kg/ha) ***	263	231	598	150	74

* The N-P-K-Ca-Mg are applied at 30-60-40-80-80%, respectively.

** The N-P-K-Ca-Mg are applied at 70-40-60-20-20%, respectively.

***The values in this field take into account the efficiency involved in base dressings + Nutrigation™ .

Table 5.14: Suggested base-dressing fertilizers* rates to supply the recommended plant nutrients at expected yield of 80 t/ha

Suggested base-dressing fertilizers	Fertilizers (kg/ha)	Plant nutrients (kg/ha)				
		N	P_2O_5	K_2O	CaO	MgO
		79	**139**	**239**	**120**	**59**
Ammonium nitrate (34%)	239	79				
Superphosphate (25%)	556		139			
Potassium sulfate (50%)	478			239		
Dolomite (26%)	462				120	
Magnesium sulfate (16%)	369					59

*Other fertilizers of choice may be introduced to supply the recommended plant nutrients.

Table 5.15: Suggested Nutrigation™ fertilizers* rates supplying the recommended plant nutrients at expected yield of 80 t/ha

Suggested Nutrigation™ (fertigation) fertilizers	Fertilizers (kg/ha)	Plant nutrients (kg/ha)				
		N	P_2O_5	K_2O	CaO	MgO
		184	92	359	30	15
Ammonium nitrate (33%)	112	36.8				
Haifa MAP (12-61-0)	151	18.1	92			
Multi-K® (13-0-46)	780	101.5		359		
Haifa Cal (26%)	115	17.3			30	
Magnesium sulfate (16% MgO)	94					15
TOTAL	1,252	184	92	359	30	15

*Other fertilizers of choice may be introduced to supply the recommended plant nutrients.

Table 5.16: Plant nutrients distribution at the various growing stages by fertigation

Growth stage	Nutrigation™ (kg/phase/ha)				
	N	P_2O_5	K_2O	CaO	MgO
Planting	1	0	1	0	0
1st growth	12	6	24	2	1
Main season	104	53	202	17	8
End season	97	50	190	16	8
TOTAL	214	109	417	35	17
Kg suggested *	178	91	348	29	14

*The values in this fields take into account the efficiency involved in Nutrigation™ .

Table 5.17: Suggested fertigation fertilizer rates at various growing stages of processing cucumbers

Growth stage	Fertilizer 1	kg	Fertilizer 2	kg	Fertilizer 3	kg	Fertilizer 4	kg	Fertilizer 5	kg
Planting	A.N.	2	no fert.	0	Multi-K®	2	no fert.	0	no fert.	0
1st growth	A.N.	11	MAP	10	Multi-K®	54	C.N.	8	$Mg(SO_4)_2$	6
Main season	A.N.	81	MAP	89	Multi-K®	454	C.N.	65	$Mg(SO_4)_2$	56
End season	A.N.	75	MAP	82	Multi-K®	426	C.N.	62	$Mg(SO_4)_2$	50

A.N. = Ammonium nitrate (34%)
MAP = MAP (12-61-0)
Multi-K® = Potassium nitrate (13-0-46)
C.N. = Calcium nitrate (26% CaO)
$Mg(SO_4)_2$ = Magnesium sulfate (16% MgO)

C – Tunnel grown cucumbers on loam (medium) texture soil

The expected yield is 120 t/ha. Irrigated by **drip** and the fertilizer application method is by based dressing followed by Nutrigation™ (fertigation).

- Growth method: Tunnel
- Soil type: loam
- Expected yield: 120 t/ha

Table 5.18: Nutrient requirements and recommended plant nutrient rates of cucumbers grown in clay soil with expected yield of 120 t/ha

	Nutrient Requirements (kg/ha)				
	N	P_2O_5	K_2O	CaO	MgO
Removed by yield	132	60	240	30	24
Uptake by the whole plant	323	141	578	382	97
Recommended rates	388	275	751	191	97
Adjusted rates to loam soil	355	275	809	191	97

The next step allows selecting the type of irrigation and fertilization method. In the following example, the irrigation is by drip system also used for Nutrigation™ (fertigation) (Tables 5.19, 5.20, 5.21, 5.22 and 5.23).

Table 5.19: Recommended base-dressing and side-dressing plant nutrient rates on cucumber crop irrigated by **drip**

	N	P_2O_5	K_2O	CaO	MgO
NPK required (kg/ha)	355	275	809	191	97
Base dressing (kg/ha) *	107	165	324	153	78
Nutrigation™ (fertigation) (kg/ha) **	248	110	485	38	19
Total (kg/ha) ***	355	275	809	191	97

* The N-P-K-Ca-Mg are applied at 30-60-40-80-80%, respectively.

** The N-P-K-Ca-Mg are applied at 70-40-60-20-20%, respectively.

***The values in this field take into account the efficiency involved in base dressings + Nutrigation™ .

Table 5.20: Suggested base-dressing fertilizer* rates to supply the recommended plant nutrients at expected yield of 120 t/ha

Suggested base dressing fertilizers	Fertilizers kg/ha	Plant nutrients (kg/ha)				
		N	P_2O_5	K_2O	CaO	MgO
		107	**165**	**324**	**153**	**78**
Ammonium nitrate (34%)	324	107				
Superphosphate (25%)	660		165			
Potassium sulfate (50%)	648			324		
Dolomite (26%)	588				153	
Magnesium sulfate (16%)	488					78

*Other fertilizers of choice may be introduced to supply the recommended plant nutrients.

Table 5.21: Suggested Nutrigation™ fertilizer* rates supplying the recommended plant nutrients at expected yield of 120 t/ha

Suggested Nutrigation™ (fertigation) fertilizers	Fertilizers kg/ha	Plant nutrients (kg/ha)				
		N	P_2O_5	K_2O	CaO	MgO
		248	110	485	38	19
Ammonium nitrate (33%)	165	54.3				
Haifa MAP (12-61-0)	180	21.6				
Multi-K® (13-0-46)	1,054	137.1		485		
Haifa Cal (26%)	146	21.9			38	
Magnesium sulfate (16% MgO)	119					19
TOTAL	1,664	248	110	485	38	19

*Other fertilizers of choice may be introduced to supply the recommended plant nutrients.

Table 5.22: Fertigation rates of plant nutrients at the various growing stages

Growth stage	N	P_2O_5	K_2O	CaO	MgO
Planting	1	0	2	0	0
1st growth	17	8	34	3	1
Main season	144	64	282	22	11
End season	135	60	265	21	10
TOTAL	297	132	583	46	22
Kg suggested	248	110	485	38	19

Table 5.23: Suggested fertigation fertilizers rates at various growing stages of tunnel grown cucumbers

Growth stage	Fertilizer 1	kg	Fertilizer 2	kg	Fertilizer 3	kg	Fertilizer 4	kg	Fertilizer 5	kg
Planting	A.N.	1	no fert.	0	Multi-K®	4	no fert.	0	no fert.	0
1st growth	A.N.	12	Haifa MAP	13	Multi-K®	74	C.N.	12	$Mg(SO_4)_2$	6
Main season	A.N.	115	Haifa MAP	105	Multi-K®	613	C.N.	85	$Mg(SO_4)_2$	69
End season	A.N.	106	Haifa MAP	98	Multi-K®	576	C.N.	81	$Mg(SO_4)_2$	63

A.N. = Ammonium nitrate (34%)
MAP = MAP (12-61-0)
Multi-K® = Potassium nitrate (13-0-46)
C.N. = Calcium nitrate (26% CaO)
$Mg(SO_4)_2$ = Magnesium sulfate (16% MgO)

D – Greenhouse grown cucumbers on sandy (light) texture soil

The expected yield is 300 t/ha. Irrigated by **drippers** that serve also for fertilizer application by Nutrigation™ (fertigation).

- Growth method: Greenhouse
- Soil type: sandy
- Expected yield: 300 t/ha

Table 5.24: Nutrient requirements and recommended plant nutrient rates of cucumbers grown in sandy soil with expected yield of 300 t/ha

	Nutrient requirements (kg/ha)				
	N	P_2O_5	K_2O	CaO	MgO
Removal by yield	330	150	600	75	60
Uptake by the whole plant	667	293	1,197	698	190
Recommended rates	800	458	1,556	349	190
Adjusted rates to soil type (sand)	800	458	1,556	349	190

The next step allows selecting the irrigation and fertilization methods. In the following example, the irrigation is by **drip system that is also used for Nutrigation™ (fertigation)** (Tables 5.25, 5.26, 5.27 and 5.28).

Table 5.25: Recommended nutrients rates applied by Nutrigation™

	N	P_2O_5	K_2O	CaO	MgO
NPK required (kg/ha)	800	458	1,556	349	190
Nutrigation™ (fertigation) (kg/ha)	800	458	1,556	349	190
Total (kg/ha)	800	458	1,556	349	190

Table 5.26: Suggested fertilizer* rates supplying the recommended plant nutrients at expected yield of 300 t/ha

Suggested Nutrigation™ (fertigation) fertilizers	**Fertilizers (kg/ha)**	**Plant nutrients (kg/ha)**				
		N	**P_2O_5**	**K_2O**	**CaO**	**MgO**
		800	**458**	**1,556**	**349**	**190**
Ammonium nitrate (33%)	0	0				
Haifa MAP (12-61-0)	751	90	58			
Multi-K® (13-0-46)	3,383	439.7		1,556		
Haifa Cal (26%)	1,342	201.3			349	
Magnesium sulfate (16% MgO)	1,188					190

*Other fertilizers of choice may be introduced to supply the recommended plant nutrients.

Table 5.27: Plant nutrient fertigation rates at the various growth stages

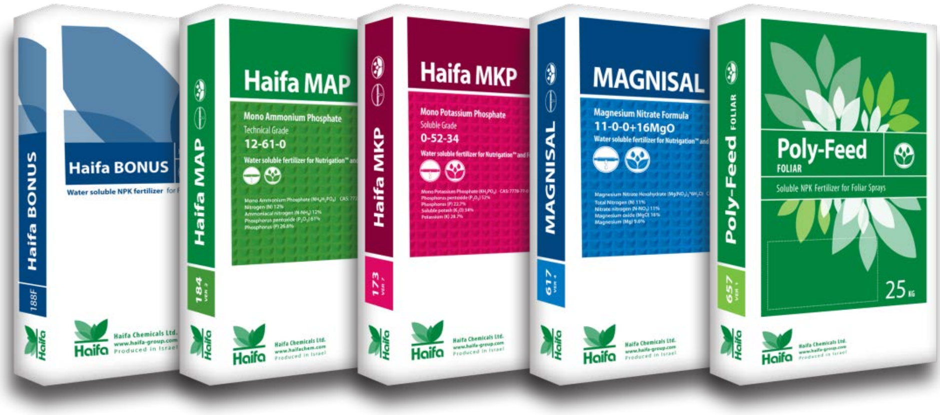
Growth stage	**N**	**P_2O_5**	**K_2O**	**CaO**	**MgO**
Planting	3	2	6	1	1
1st growth	60	32	108	24	13
Main season	502	266	905	203	111
End season	470	250	849	190	104
TOTAL	1,035	550	1,868	418	229
Kg suggested	800	458	1,556	349	190

Table 5.28: Suggested fertigation fertilizers rates at the various growth stages of greenhouse-grown cucumbers

Growth stage	**Fertilizer 1**	**kg**	**Fertilizer 2**	**kg**	**Fertilizer 3**	**kg**	**Fertilizer 4**	**kg**	**Fertilizer 5**	**kg**
Planting	A.N.	1	Haifa MAP	3	Multi-K®	13	C.N.	4	$Mg(SO_4)_2$	6
1st growth	A.N.	27	Haifa MAP	52	Multi-K®	235	C.N.	92	$Mg(SO_4)_2$	81
Main season	A.N.	226	Haifa MAP	436	Multi-K®	1967	C.N.	781	$Mg(SO_4)_2$	694
End season	A.N.	0	Haifa MAP	410	Multi-K®	1846	C.N.	731	$Mg(SO_4)_2$	665 0

A.N. = Ammonium nitrate (34%)
MAP = MAP (12-61-0)
Multi-K® = Potassium nitrate (13-0-46)
C.N. = Calcium nitrate (26% CaO)
$Mg(SO_4)_2$ = Magnesium sulfate (16% MgO)

Fertilization and fertigation rates may vary according to cultivar, growing method, climatic conditions, growth stages and expected yield. By using Haifa NutriNet™ (www.haifa-nutrinet.com) 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.



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

Cucumbers		
1 bushel cucumbers (US)	48	lbs
	21.77	kg
	0.0217	MT

From	To	Multiply by	From	To	Multiply by
Acre	Hectare	0.40469	Hectare	Acre	2.471
Kilogram	Lbs	2.2046	Lbs	Kilogram	0.4532
MT	Lbs	2204.6			
MT	cwt (hundred weight)	22.046			
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
lbs/acre	kg/ha	1.121	kg/ha	lbs/acre	0.89
mS/cm	mg/L (or ppm)	670	mg/L (or ppm)	mS/cm	0.0015

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	1.01
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

1 m.eq	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	-