2. Cucumber

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ABSTRACT

Cucumber is one of the most important cultivated greenhouse crops. Most varieties are female hybrid cultivars, but monoic cultivars are still in use in some South East European countries. Cucumber cultivation – as for other fast-growing vegetables – is characterized by technologies designed to increase intensive production. Cultural practices aim to provide an appropriate root medium, balanced root/leaf growth, balanced source/sink development, and a good harvesting rate of high-quality fruits. The most important growing practices are microclimate control, fertigation and training. Cucumber is very sensitive to both abiotic and biotic stresses, and serious problems can arise in the case of inappropriate crop management. Integrated pest management provides various approaches for smallholders.

INTRODUCTION

The cultivation area of cucumber in South East Europe (SEE) is almost 2 000 ha and it is the second greenhouse vegetable in the region after tomato. An additional area of > 700 ha is cultivated under tunnels.[1]

INFLUENCE OF ENVIRONMENTAL FACTORS

Cucumber is a typical subtropical plant and grows best under conditions of high temperature, humidity, light intensity and nutrient availability; it is highly sensitive to unfavourable environmental conditions.

Temperature

Air temperature influences vegetative growth, flower initiation, fruit growth and fruit quality. Cucumber growth rate depends on the average 24-hour temperature: the higher the average temperature (≤ 25 °C), the faster the growth. Optimum air temperature depends on the growing period. At germination, the optimum

[1] See Part I, Chapter 2.

temperature is 25–35 °C and, with good moisture, it takes 2–3 days for seeds to germinate. In contrast, at 12 °C, seeds need 12–20 days to germinate and there are many losses. Shoot growth does not occur at air temperatures of < 13–15 °C, while the maximum temperature for vegetative growth is about 38–40 °C.

During the first week after planting, the ideal air temperature is 22–24 °C; thereafter, temperatures should be kept at 20–22 °C until the beginning of harvest. During warm weather, in late spring and early fall and at harvest, it is recommended to lower the air temperature settings by ≤ 2 °C to encourage vegetative growth, especially at night. At higher air temperatures, fruits grow rapidly and compete for assimilates. A longer harvest break may begin, particularly after harvesting cucumbers from the main stem. This can nullify the advantage of an earlier start to the harvest; in addition, plants get older earlier. For good fruit quality, temperatures should be 22–24 °C; at temperatures of < 18 °C, fruits tend to be shorter.

A day/night temperature difference is recommended for winter and early spring cultivation only. Growth performance depends on the 24-hour mean temperature during the long days and short nights of spring/summer. Lowering night temperatures in this period is of no physiological advantage for the plant; it could, however, be done to save energy.

Soil temperature is important, in particular at germination and the young-plant stage. If soil temperature remains < 14–16 °C for a long time, plants wilt and then die. For this reason, cucumber is said to need a "warm foot". Soil heating enables cucumber plants to better endure low air temperature, but this practice is not adopted in SEE countries. Low soil temperatures stimulate soil-borne diseases and reduce the water and nutrient uptake ability of roots, particularly uptake of phosphorus. A minimum root temperature of 19 °C is required, but 22–23 °C is preferable.

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Plate 1
Cold shock of soilless cucumbers as a result of cold-water irrigation

Water temperature in irrigation must also be controlled and adjusted to avoid the appearance of cold shock symptoms (Plate 1). Heat injuries will appear under high transpiration and with inadequate water supply after 1–2 hours (Krug *et al.*, 2002).

Light

Temperature control must be considered in the context of light intensity. Radiation affects total plant leaf area, carbohydrate production and, consequently, productivity. During the winter, the carbohydrate supply is low and productivity is reduced, resulting in many aborted fruits. Light also has a direct influence on fruit quality. For example, fruits grown under low light conditions have less dry matter, are generally light green at harvest and easily turn yellow on the shelf. Young fruits are usually more sensitive to low light intensity than older fruits on the same plant.

Humidity

High humidity used to be generally recommended for greenhouse cucumber. However, high humidity is only appropriate if the water supply is periodically insufficient, because it is important to maintain continuous moisture. High relative humidity increases the risk of water condensation and the development of plant diseases, while low transpiration rate leads to inadequate absorption of nutrients (Krug *et al.*, 2002). 'Beit Alfa' cultivars have good tolerance against powdery mildew. A combination of high daytime and low night-time humidity is recommended for optimal cucumber fruit production and quality.

CO_2 enrichment

A decrease in CO_2 below the concentration in the outside air should be avoided. The recommended concentration is 600–800 µmol mol^{-1} to increase cucumber yield, although higher concentrations are found in the literature. The concentration of CO_2 applied depends not on the conditions, but on the incurred cost. If there are no industrial CO_2 sources in the vicinity, decomposition of manure or other organic products, such as straw bales, is an effective method. Indeed, the traditional straw bale cultural technique has long been adopted in cucumber cultivation, and it is one of the oldest and simplest methods of CO_2 enrichment in greenhouses.

Soil requirements

Cucumber requires a deep, well-drained, structurally stable, fertile soil with high pore volume. High porosity and stability are important for coping with high and frequent water supply, as well as with stress due to agricultural practices and harvesting. This can be achieved by incorporating large amounts of organic matter and adopting proper tillage measures. Compact, cold soils with a high level of groundwater are not suitable for cucumber. Sandy loam soils with a pH of 5.5–6.5 are more suitable.


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Plate 2
Long-fruit cucumber cultivars


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Plate 3
Short-fruit 'Beit Alfa' cultivars

PRINCIPLES OF CUCUMBER PRODUCTION IN GREENHOUSE

Cultivar choice

Traditional cucumber varieties have both male and female flowers and require pollination to produce healthy fruits with seeds and white spines. When cucumbers do not pollinate properly, the fruits are misshapen and poorly developed, especially at the blossom end (Vandre, 2013).

The most popular cucumber types currently grown in greenhouses are long, seedless hybrid cultivars, often referred to as "European" or "Dutch" cucumbers. These varieties are gynoecious and produce only female flowers. The fruits are parthenocarpic and there is no need for pollination. The fruit has thin, edible, smooth, green skin, sometimes with faint longitudinal ribs. They include the popular 'Beit Alpha' parthenocarpic cultivars, which are are adapted for trellising, have shorter internodes and set multiple fruits in a cluster (Plates 2 and 3).[2]

Soil preparation

Approximately 80% of cucumber roots develop and spread in the top 20-cm layer of soil; they possess poor tolerance to low temperature, drought and flooding. The soil for cucumber planting requires careful preparation and, as for other vegetable crops, it should not be too fine to enable appropriate aeration.

In greenhouse cucumber cultivation, the soil may be flat (Plate 4) or in raised beds. Raised beds are essential for early planting and when the water table is shallow. The bed width should be 60–100 cm, depending on the distance between rows, and the depth 25–30 cm. The topsoil should be finer than the soil layer below. Raised beds are often covered with plastic film or other mulching materials. The application of plastic films before planting brings many benefits: weed

[2] For cultivar choice, refer to the FAO database, Hortivar, available at www.fao.org/hortivar/.

control, increased soil temperature, reduced water consumption and increased profitable early yield. It is, therefore, important to position plastic mulches as early as possible. Plastic films should be laid on moist soil, and a preliminary irrigation is recommended if the moisture level is not adequate. The ideal time to lay out the plastic is midday, so that it can be stretched tight (Egel, 2015).

Cucumber can also be cultivated in growing media. Cultivation in rockwool is common worldwide, but in some SEE countries, local growing media (e.g. perlite and pumice) are frequently adopted. Slabs or bags with a 15- or 30-cm width are used. As for other vegetables, nutrient solution is supplied, based either on the actual electrical conductivity (EC) and the desired pH value, or on average uptake rates. With good irrigation control, 5 litres of substrate per plant is sufficient. Since cucumber is sensitive to salinity, an EC of approximately 2 dS m^{-1} should be maintained during early plant growth and later adjusted to 2.5 dS m^{-1} as plant size increases (Savvas *et al*., 2013).

Cucumber is very sensitive to high salinity (Robinson and Decker-Walters, 1997). Plants grown under saline conditions are subject to serious problems resulting in unsatisfactory yield. High salinity causes retarded plant growth, short internodes and reduced leaf area. Leaves are often dark green and dull (Plate 5). In extreme conditions, necrotic tissues may be present in older leaves. Salinity can be due to a high level of salts in the groundwater, irrigation water, soil or growth medium, or to excessive application of fertilizers.

Planting

Greenhouse cucumbers usually start from transplants. However, direct seeding in beds can sometimes be adopted for late summer or early autumn plantings, when temperatures are sufficiently high for seed germination and the timing of the start of harvest is of less consequence.

GRUDA

Plate 4
Greenhouse cucumber plants cultivated directly in soil using drip irrigation system

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Plate 5
Growth retardation of cucumber plants as a result of high soil salinity


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Plate 6
Grafted cucumber transplants

Cucumber transplants may be grown on their own rootstock or grafted (Plate 6). Successful cucumber establishment from transplants requires special care and attention. The root system of very young seedlings is easily damaged and is slow to resume growth under low soil temperature. On the other hand, overgrown transplants develop thick tap layers over the roots, resulting in poor stand establishment.[3]

Seedlings should be placed deep in the ground and irrigated immediately with sufficient water to guarantee quick stand establishment. It is imperative to maintain optimum temperatures and avoid major fluctuations between day and night temperatures in the days immediately after transplanting.

Plant density

The plant density in greenhouses depends on the expected light conditions during growth and the pruning method. To avoid overlapping leaves and shading by adjacent plants, a plant typically requires about 0.5 m^2 with good sunlight, but nearly twice as much space may be needed in northern countries where light intensity is low.

In general, under good light conditions in southern Europe, a plant density of 2.2–2.5 m^{-2} is adequate. In northern locations 1.3–1.5 plants m^{-2} are recommended to ensure good air circulation and sufficient light for fruit production. Spacing between rows and between plants within the row varies according to grower preference. Rows are often 1.2–1.5 m apart, with plants 0.40–0.45 m apart in the row. In general, planting density is higher for short-fruit cultivars of the 'Beit Alpha' group.

Trellising and pruning

Cucumbers are trellised using a string or wire system. Growers, according to their experience and preference, adopt various methods. The main objective is to achieve uniform sunlight throughout the greenhouse.

For optimal cucumber production, it is important to achieve a balance between vegetative growth and fruit load throughout the plant growth cycle. Continuous pruning of shoots, foliage, fruits and flowers is necessary. If there are too many fruits, a large proportion may be aborted, malformed or poorly coloured, because

[3] See Part II, Chapter 6.

the plant may not have sufficient assimilates (Plate 7). The situation deteriorates further under poor light conditions.

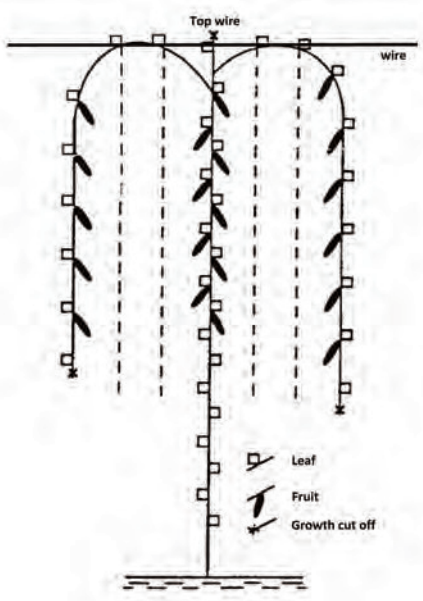

GRUDA

Plate 7
Heavy, not balanced cucumber fruit load with aborted and malformed fruits

Generally for long-fruit cultivars, only one fruit per leaf axial should be allowed to develop, although with vigorous cultivars more than one fruit may sometimes mature at a node. Short, midi types can support several fruits per node and give good yields, with a minimum of three to four fruits harvested at each node.

Most growers in SEE countries prune their plants using an umbrella system (Figure 1). Plants need to establish a strong root system and vegetative stem prior to fruit-set. It is, therefore, important to remove all lateral branches, flowers and tendrils for 8–10 leaf nodes. The first fruit may be allowed to develop earlier at 5–6 leaf nodes in the case of short-fruit cultivars, or under favourable growing conditions (e.g. optimum temperature and high light intensity). The main stem fruits above that point are allowed to develop at the base of each leaf. All lateral branches are removed, and plants are trained to a single stem. The bottom leaves should also be gradually removed as new leaves form on the upper part of the stem.

FIGURE 1
Umbrella pruning system



Vandre, 2013.

Once the plant reaches the support wire, it is allowed to grow about 20 cm along the support wire, or two leaf nodes above the height of the wire. A lateral shoot is then allowed to grow at each of the two top leaf nodes hanging down from the wire.

Irrigation

Proper irrigation is key to both yield and product quality. Cucumber has relatively high water requirements; irrigation frequency is therefore generally high. It is important to maintain a proper water–air ratio in the root zone to ensure an adequate supply of oxygen to the roots.

Daily water consumption depends on climatic conditions, such as light intensity, temperature and relative humidity, as well

as plant density and phenological stage. The soil type does not affect the total amount of water needed, but it does influence the frequency of water application. In light sandy soils, the water drains off quickly, and high frequency with less water per application is required. When mulching is applied, significantly less water is needed through irrigation because of reduced evaporation.

Drip irrigation is the most common and convenient irrigation method for cucumbers. Furrow irrigation can cause plant lodging due to an overdose of water. Sprinkler irrigation can encourage fungal diseases. The EC of the water must be taken into account when choosing the water source: water with EC < 1 dS m^{-1} and a slightly acidic pH is recommended. The pH can be lowered by using inorganic acids. On the other hand, when soil is saline, the irrigation amounts should be increased to allow salt leaching.

Fertilization

Nutrient demand of cucumber is highest at fruit-set. It remains high throughout production and decreases at the senescence stage. While cucumber has a high nutrient requirement, it is very sensitive to excesses or sudden variations in the nutrient supply, as well as to significant fluctuations in nutrient concentrations in the soil. In order to prevent over- or underfertilization, it is vital to carry out frequent analysis of the nutrient content of the soil and water used. The fertilization programme should be based on the analysis results.

Nitrogen (N) is crucial for cucumber growth. Plant growth and fruit harvesting rates largely depend on N availability. The N requirement is lower at the beginning of the growth cycle. The N absorption rate increases rapidly from day 36 after emergence. This corresponds to the start of fruit harvesting and continues throughout the harvesting period. Other nutrients follow a similar pattern. Therefore, while the daily rates of N and K application gradually increase with time, the rate of P fertilizer application remains almost unchanged during the growing period (Table 1).

As with other fruit vegetables, the most absorbed nutrient is **potassium (K)**. Approximately 90% of K is absorbed during the last 36 days of the crop cycle (SQM, 2015). Although it does not have a major effect on the total harvested yield, K enhances plant resistance to several abiotic stresses and plays an important role in improving fruit quality.

Fertigation, or the application of fertilizers through the irrigation system, is the most popular and efficient method of fertilizing greenhouse vegetables. Recommendations regarding the nutrient content of fertigation solutions are based mainly on the physiological responses of the specific crop to each element. There are two methods:

- **Quantitative:** Fertilizers are dissolved in a large holding tank and the solution is pumped straight to the crop (Table 1).
- **Proportional:** Fertilizers are mixed in concentrated stock solutions and incorporated into the irrigation water through fertilizer injectors (Table 2). The total amount of nutrients delivered to the plant depends on the amount of irrigation water (Haifa, 2011).

Side-dressing fertilizers should not be applied when drip irrigation is used, as it is assumed that fertigation can easily satisfy the precise daily demands of the crop. However, organic fertilizers and lime may be needed before planting, in order to improve soil structure and adjust soil pH.[4]

TABLE 1
Recommended nutrient amounts as active ingredients for quantitative fertilization method of soil-grown, greenhouse cucumbers

Growth stage	Nutrient demand (kg ha^{-1})			
	N	P_2O_5	K_2O	MgO
Establishment	40	10	60	10
Vegetative growth	70	20	140	40
Flowering – fruit-set	80	20	200	30
Harvesting	50	20	100	20
Total	240	70	500	100

Haifa, 2011.

TABLE 2
Recommended nutrient amounts as active ingredients for proportional fertilization method of soil-grown, greenhouse cucumbers

Growth stage	Assumption		Nutrient demand (kg m^{-3})			
	No. days per stage	Irrigation rate (m^3 ha^{-1} day^{-1})	N[a]	P_2O_5	K_2O	MgO
Establishment	25	25	0.06	0.02	0.10	0.02
Vegetative growth	30	40	0.06	0.02	0.12	0.03
Flowering – fruit-set	30	55	0.05	0.01	0.12	0.02
Harvesting	25	60	0.03	0.01	0.07	0.02

[a] 80–90% as NO_3^-, 10–20% as NH_4^+.
Haifa, 2011.

[4] See Part II, Chapter 2.

Main disorders, pests and diseases

Cucumber grows fast and develops an abundant leaf area. The leaves are soft, tender and highly susceptible to pests and diseases. The most frequent and devastating pests and diseases are listed in Table 3.[5]

Harvesting and post-harvest handling

Cucumber harvest in a protected environment starts approximately 30–45 days after transplanting with variations according to cultivar, climatic conditions and technology used. Cucumbers are harvested as immature fruit when full length has been reached. Over-mature cucumbers left on the vine inhibit new fruit-set, and production decreases if fruits are left on the plant for a long time. Harvest should take place at the coolest time of day, in order to avoid excess heating of the product. To minimize damage and disease spread, it is important to use a sharp clean tool to cut the fruit from the plant.

For cucumber and other vegetables, European marketing and quality standards are adopted. Explanatory brochures are published by the United Nations Economic Commission for Europe (UNECE)[6] and the Organization for Economic Co-operation and Development (OECD).[7]

Cucumbers lose moisture rapidly and tend to soften during storage. Harvested fruit should, therefore, be placed in clean harvesting containers, kept in the shade and taken to the packing house as soon as possible after harvest. Careful handling is vital to avoid damage to the thin skin. The optimum storage temperature for cucumbers is 10–12.5 °C at a relative humidity of 95%. Storage or transit temperatures below this range may result in chilling injury after 2–3 days.

[5] See Part II, Chapter 5.
[6] Available at http://www.unece.org/trade/agr/standard/fresh/FFV-StandardsE.html.
[7] Available at http://www.oecd.org/tad/code/oecdfruitandvegetablesstandardsbrochures.htm.

TABLE 3
Identification and control of the most common cucumber disorders, pests and diseases

Symptoms	Reasons	Prevention and control measures
Pale green to yellow leaves, especially in older leaves New leaves green but small	N deficiency	Apply adequate fertilization
Chlorosis at leaf margins in interveinal area, especially in older leaves	K deficiency High root pressure	Apply adequate fertilization and irrigation
Youngest leaves cup downwards, edges scorched Death of growing points	Ca deficiency High salinity	Control climate and growing conditions Apply adequate Ca fertilization Avoid overfertilization Use good water quality
Flower and fruit abortion Malformed fruits	Fruit overload, delayed harvesting Low light intensity Temperature and humidity variation Thrips	Control climate conditions Harvest frequently Control thrips
Pale green to yellow chlorosis with green veins of newest leaves	Fe deficiency	Lower pH of soil or nutrient solution Use Fe formulation available in higher pH (e.g. iron chelates) Improve soil drainage and aeration
Trails and tunnels in leaves	Leafminer	Adopt hygiene measures Destroy infected leaves Spray with insecticide
Yellow leaves, sticky or covered with sooty mould	Whitefly	Use whitefly parasitoids (e.g. *Encarsia formosa*)
Stippled, distorted and light-coloured leaves	Mite	Apply *Phytoseiulus persimilis* Use insecticides
Stunted plant growth	Nematodes (*Meloidogyne* spp.)	Adopt crop rotation Adopt integrated approach for plant growth Apply soil solarization Adopt grafting and use resistant cultivars Use soilless culture
Wilting of plants	*Fusarium oxysporum* f. sp. *radicis-cucumerinum*	Adopt crop rotation Adopt grafting and use resistant cultivars Use soilless culture Remove and destroy infected plants
Yellow spots on the upper leaf side, undersides with fluffy purplish mildew, especially in older leaves	Downy mildew caused by *Pseudoperonospora cubensis* Humid conditions at night Temperatures of 15–20 °C	Adopt drip (not overhead) irrigation Improve air circulation Reduce air humidity Use resistant cultivars
White superficial spots on leaves (and stem)	Powdery mildew caused by *Sphaerotheca fuliginea* or *Erysiphe cichoracearum*	Use resistant cultivars Avoid high plant densities Apply fungicides
Mosaic colouring of leaves	Cucumber mosaic virus spread by aphids	Use healthy, certified seed Use insect-proof nets and mulch Monitor and control aphid vectors Control weed Use yellow sticky traps

GAP recommendations – Cucumber production

- Pay maximum attention to soil and irrigation water temperature and soil management, in order to obtain high yields and high-quality greenhouse cucumbers:
  - Maintain a "warm foot" for optimal growth.
  - Control the temperature of the irrigation water to avoid shock caused by cold water at the beginning of cultivation. If cold water from wells is used, keep it for a while in a small reservoir to allow it to reach the ambient temperature.
  - Analyse soil, water and nutrients, in order to apply adequate and balanced nutrients or fertigation at appropriate times and in appropriate doses.
  - Avoid using saline water and do not overfertilize.
  - Irrigate frequently and in small doses.
  - Apply tillage and mulching to prevent upwards movement of saline water from deeper layers.
  - Control soil-borne pathogens, avoiding chemical treatments for soil disinfection.

- Use the correct plant density:
  - Increase plant space under low radiation.
  - Consider the cultivar used – short-fruit plants can generally be planted at a higher density than long-fruit plants.

- Do not allow plants to become overburdened with fruits.
- Carry out timely pruning of plants to balance leaf/fruit development.
- Apply mulch to control weeds, increase soil temperature, reduce water consumption and increase profitable early yield.
- Handle harvested fruit carefully without damaging the thin skin.
- Keep harvested fruit in the shade and take to the packing house as soon as possible after harvest.
- Maintain appropriate storage temperatures (not too low) to avoid chilling injuries.

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