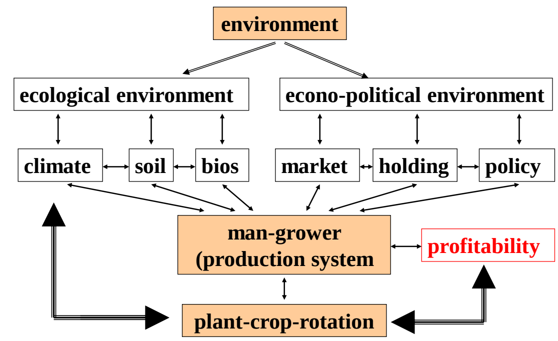
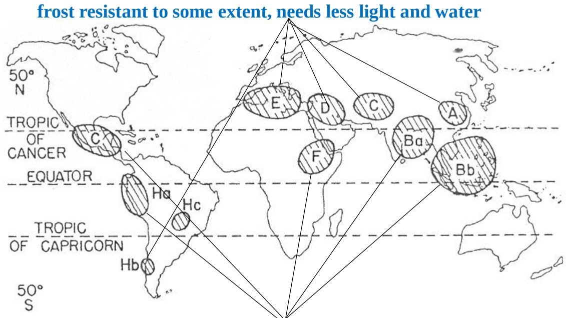
Environmental factors influencing the growth of vegetables and their control in the field

The environment – man –plant system (Krug, 1997)



Temperate zone originated vegetables: cold season plants, frost resistant to some extent, needs less light and water

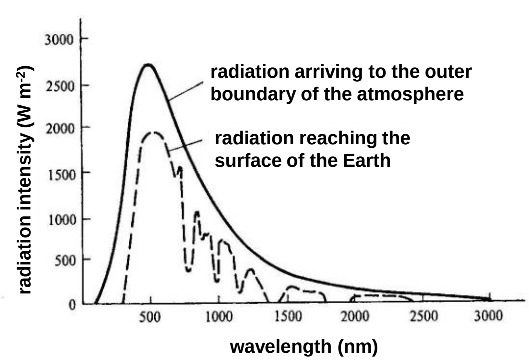


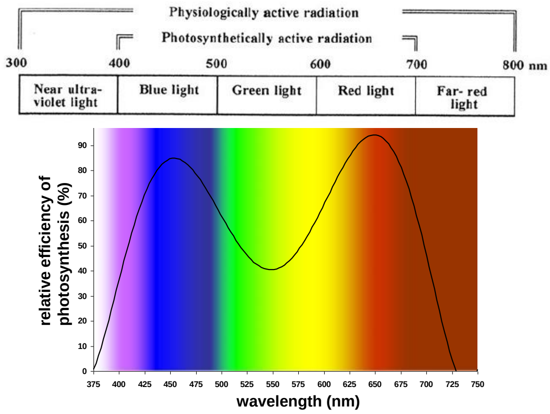
Tropical zone originated vegetables: warm season plants, frost sensitive, needs more light and water

Light

Characteristics of light

- **quality** – Photosynthetically Active Radiation (PAR)
- **intensity** – amount of irradiance (W m^{-2}, lux)
- **duration** – photoperiod (daylength)
  – duration of sunshine
- **effectivity** – extent of leaf area (LAI)
  – chlorophyll concentration



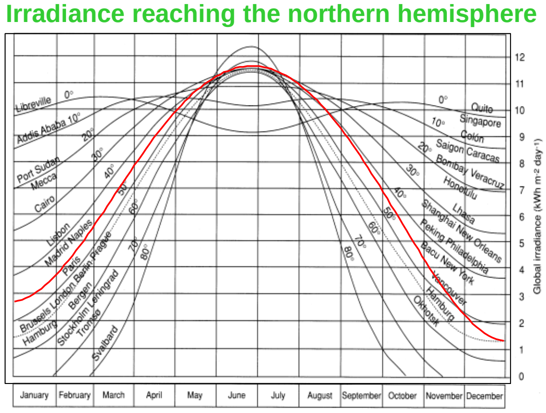


Units of light intensity and their conversion

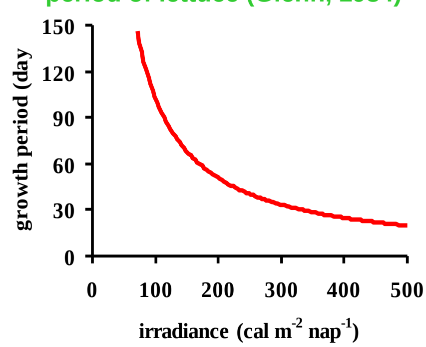
Irradiance intensity: W m^{-2}
Light intensity: lux
Photon flux density: mmol m^{-2} s^{-1}

In the range of PAR:
W m^{-2} = 4.6 mmol m^{-2} s^{-1}
klux = 18 mmol m^{-2} s^{-1}
klux = 4.0 W m^{-2}

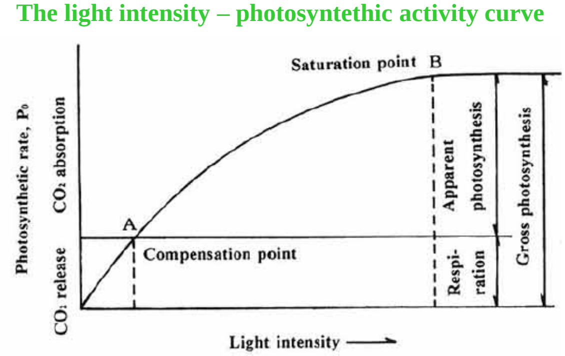
Irradiance reaching the northern hemisphere



Effect of irradiance on the length of growth period of lettuce (Glenn, 1984)



The light intensity – photosyntethic activity curve



Tazawa, 1999

Key points of the light intensity – photosyntethic activity curve

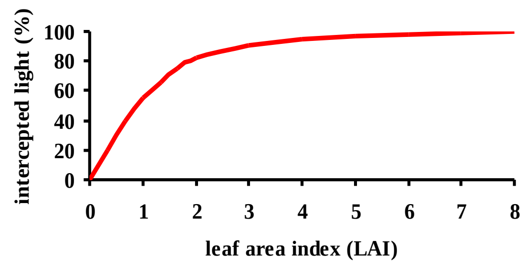
- **Threshold for photosynthesis – about 4 lux**
- **Compensation point - where the rate of photosynthesis equals to the rate of respiration; for most of the plants it is around 1-2.000 lux**
- **Light saturation point – the level of irradiance above which the rate of photosynthesis doesn't increase; its valaue is quite species specific, depends on the place of origin of the species; renges between 25 and 80 thousand lux for the most important vegetables**

Light saturation value for some vegetables (klux)

- **Watermelon** **80**
- **Tomato** **70**
- **Cucmber** **55**
- **Melon** **55**
- **Celery** **45**
- **Eggplant** **40**
- **Cabbage** **40**
- **Green peas** **40**
- **Potato** **30**
- **Lettuce** **25**

Tazawa, 1999

Effect of leaf area index on the ratio of intercepted light (Filius, 1994)



maximum LAI ≠ optimum LAI

Methods for light regulation on the field

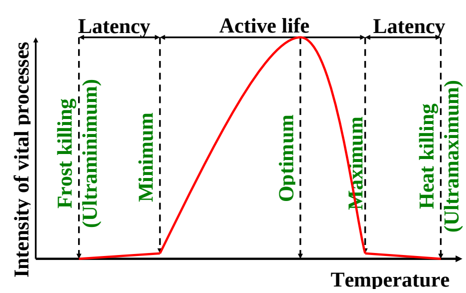
- use of reflective mulches
- use of coloured mulches
- shading
- blanching
- etiolating plants by soil covering

Temperature

Temperature defines (I):

- possibility of growing a given plant; dates of sowing and planting
  - cardinal temperatures: **minimum, optimum, maximum; low and high temperature injuries: freezing injury – below 0°C, chilling injury – above 0°C and below 10°C, high temperature injury – above 45-50°C (in the cells)**
  - length of growing season: **number of frost-free days – average period between the last (spring) and the first (autumn) killing frosts**
  - heat units: **Σ(daily maximum + daily minimum)/2 – threshold temperature for growing from sowing to harvest; its unit is degree-days**

Effect of temperature ont he intensity of vital processes and the cardinal temperatures



Temperature defines (II):

- speed of vital processes
  - Van't Hoff's law ($Q_{10} = 2$): in the range of 5 and 35°C for every 10°C rise in temperature, the rate of dry matter production doubles
  - diurnal change (thermoperiodicity): a large diurnal range is favourable for net photosynthesis; very high night temperatures are not beneficial; too big diurnal change can cause quality problems

Temperature defines (III):

- occurrence of some phenological stages
  - vernalization: the exposure of certain plants to low temperatures induces or accelerates flowering (bolting). The required length of low temperature varies with species.
  - fruit set: occurs above a threshold value

Thermoclassification of vegetables based on their climatic ranges (MacGillivray, 1953)

- Cool season crops
  - optimum 16-18°C, intolerant to monthly mean above 24°C, some tolerance to freezing: spinach, beet, parsnip, turnip, cabbage, radish, broccoli
  - the same, but damaged by freezing: cauliflower, pea, Swiss chard, celery, carrot, lettuce
  - optimum 18-30°C, tolerant of frost: onion, asparagus
- Warm season crops
  - optimum 18-30°C, intolerant of frost: sweet corn, bean, tomato, pepper, cucumber, melon, squash
  - long season, will not thrive below 21°C: watermelon, eggplant, okra

Thermoclassification of vegetables based on their optimal temperature value (Markov-Haev, 1953)

- Cool season crops; cold tolerant crops
  - 13°C: cole crops, radish, horse radish
  - 16°C: potato, pea, carrot, parsley, lettuce, chicory, sorrel, spinach, rhubarb
  - 19°C: garden beet, celery, onion, garlic, leek, asparagus
- Warm season crops; warm liking crops
  - 22°C: tomato, pepper, eggplant, pumpkin, bean, sweet corn
  - 25°C: watermelon, melon, cucumber, squash

Optimum temperature values by phenological stages in Markov-Haev's system

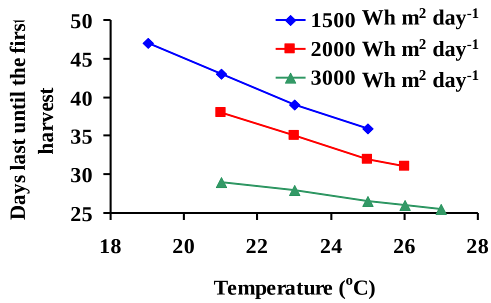
- Germination: T + 7 °C
- Cotyledon stage: T - 7 °C
- Seedling stage: T
- Vegetation period: T ± 7 °C

- Thresholds for growth: T ± 10 - 14 °C

Methods for temperature regulation on the field

- temporary covering of plants
- formation of beds and ridges
- use of mulches
  - plastic mulches – warming or cooling effect depending on the colour
  - organic mulches – cooling effect
- irrigation
  - cooling effect
  - frost protection
- frost protection by smoking

Effect of temperature and irradiance on the time of first fruit harvest of cucumber (Liebig 1980)



Correlation between light intensity and the optimum temperature in sweet pepper forcing (Túri, 1993)

Light intensity	Optimum T
5 - 10 thousand lux	20 °C
10 - 20 thousand lux	23 °C
20 - 30 thousand lux	25 °C
above 30 thousand lux	27 °C

Wind

- wind effects
  - humidity → rate of transpiration
  - CO_2 concentration → rate of photosynthesis
- wind can aid
  - reproductiv processes
- wind can cause
  - mechanical damage

Water (Moisture)

Classification of regions according to amount of precipitation

- Arid < 250 mm/year
- Semiarid 250-500 mm/year
- Subhumid 500-1000 mm/year
- Humid 1000-1500 mm/year
- Wet > 1500 mm/year

Freshwater withdrawal by sector

	Agriculture	Industry	Domestic use
Africa	87	4	9
Near-East	86	6	8
Asia	81	12	7
Central-America	76	6	18
Australia, Oceania	72	10	18
South-America	69	12	19
North-America	38	48	14
Europe	33	52	15
WORLD	70	20	10

World Resource Institute

Fundamental indicators

Evaporation (E) – mm/day
Transpiration (T) – mm/day
Evapotranspiration (ET) – mm/day
Potential evapotranspiration (PET) – mm/day
Water use efficiency (WUE) – kg/m^3

Evapotranspiration - ET_0 mm/day - Estimated values different -agro - climatic regions

Regions	10 C ^{0} below	20 C ^{0}	30 C ^{0} above
Tropical			
humid	3 – 4	4 – 5	5 - 6
sub humid	3 – 5	5 – 6	7 - 8
semi - arid	4 – 5	6 – 7	8 - 9
arid	4 – 5	7 – 8	9 - 10
Subtropical			
Summer rainfall			
humid	3 – 4	4 – 5	5 - 6
sub humid	3 – 5	5 – 6	6 - 7
semi – arid	4 – 5	6 – 7	7 - 8
arid	4 – 5	7 – 8	10 - 11
Winter rainfall			
humid, sub humid	2 – 3	4 – 5	5 - 6
sem i – arid	3 – 4	5 – 6	7 - 8
arid	3 – 4	6 – 7	10 - 11
Temperate			
humid, sub humid	2 – 3	3 – 4	5 - 7
semi -arid, arid	3 – 4	5 – 6	8 - 9

FAO data

Water requirements of some vegetables

Shallow rooted

cabbage	300 mm
lettuce	450 mm
spinach	250 mm
onion	400-600 mm
sweet corn	450 mm

Medium rooted

bean	300-450 mm
beet	450 mm
carrot	400 mm
cucumber	450 mm
pea	450 mm
pepper	450 mm

Deep rooted

asparagus	500 mm
tomato	600 mm
watermelon	450-600 mm
artichoke	300 mm
winter squash	450 mm

Possible methods for reducing drought

- Choice of appropriate cultivation method
- Water conserving tillage methods
- Minimalisation of the extent of weed
- Cultivation of drought-resistant plant species
- Development of irrigation and melioration
- Horticultural crops (vegetables, fruits) grown in irrigated fields

Soil and nutrients

Soil requirements of vegetable crops

- it is relatively uniform
- Soil type
  - chernozem soils
  - brown forest soils
  - meadow and flood plain soils
  - sand soils
- Soil composition
  - loamy soils
  - early production – sandy soils
  - for storage and processing – clay loam, silty clay soils
  - the case of root vegetables – the consumed part is developing in the soil

- Soil structure
  - good water penetration and water holding capacity
  - good aeration
  - quick warming up
- Depth of soil
  - depth of rooting
- pH
  - optimal between 5,8 and 7,5 (6,5-7,0)
  - more acid soils are suitable too – solanaceous crops
  - more alkaline soils are suitable too – cole crops, asparagus, celery, table beet

- Lime content
  - opt. 1-2%, above 5% ionantagonism occurs
  - under 1% liming is necessary
- Organic matter content
  - close correlation with structure and nutrient supplying capacity
  - opt. 3-5%, under 1% is poor quality
  - too high value is not favourable for storage and processing purposes
- Level of available nutrients
  - is in correlation with structure and organic matter
- Salt content
  - it is optimal under 0,05%, above 0,3% inadequate
  - has to be evaluated in connection with organic matter content

Nutrition of higher plants

- They are autotroph organisms,
- taking up nutrients from soil, water and air,
- through their roots (in ionic and chelate forms) or leaves (in ionic, chelate and gaseous forms).
- According to their concentrations nutrients are:
- macroelements - C, H, O
  - N, P, K,
  - Ca, Mg, S (mesoelements)
- microelements - Fe, Cu, Mn, Zn, B, Mo
  - Ni, Co, Na, Cl
- trace elements - eg. Si, Se, Ti, V, I, Li, Cs, F

Nitrogen

- nitrate (NO_3^-), ammonium (NH_4^+), [urea (NH_2-CO-NH_2), nitrogen gas (N_2)]
- growth of vegetative parts, crop size, yield
- suboptimal N supply ⇒ retarded growth, lower yield
- N/K (N/P) ratio balance between vegetative and generative parts
- too much N ⇒ decreased quality; lower nutritive value, worse storability; bigger disease sensitivity; salt injury

Phosphorus

- generative processes (flowering, fruit setting, seed formation), root formation
- its deficiency causes bad unsatisfactory fruit setting, and insufficient root formation
- relatively difficult uptake ⇒ relative deficiency is common

Potassium

- enhances generative processes
- adequate quality (nutritive value, colouring materials), storability (dry matter content), disease and cold tolerance
- its deficiency causes quality decrease
- its too big amount can cause problems in the uptake of other cations, or even salt injury

Calcium

- can not be retranslocated
- cell growth, growing point, firmness of cell wall, pectin content, storability
- its deficiency causes decrease in quality (eg. blossom-end-rot) die back of the growing point
- most difficult uptake among the macronutrients ⇒ its deficiency is usually relative
- too big amount - problems in the uptake of other cations (ionantagonism, pH)

Magnesium (Mg)

- constituent of chlorophyll ⇒ photosynthesis
- its deficiency is quite common, especially on sandy and on acid soils
- K:Mg and Ca:Mg ratios have key roles in its uptake process

Sulphur (S)

- constituent of proteins and vitamins; constituent of redox systems
- other nutrients do not influence its uptake

Microelements

- key roles in enzymatic processes
- difficult to uptake them
- usually they can not be retranslocated

Salt injury

- Every vegetable crop is relatively salt sensitive, but there are some differences among them.
- Distinctly salt sensitive ones: lettuce, cucumber, peppers with yellow wax fruits, parsley, carrot
- A little bit salt tolerant ones: cole crops, tomato, asparagus, watermelon

Soil characteristics effecting plant nutrition

- **Soil composition ⇔ leaching**
- **Organic matter content**
- **Nutrient content**
- **pH ⇔ nutrient availability**