Landwirtschaftskammer Nordrhein-Westfalen

Vegetable Production in Modern Greenhouses

Summer school
Hochschule Geisenheim

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Content

- Statistic vegetable production
- Greenhouse construction & interior
- Corps: Tomato, pepper, cucumber
- Crops pests & control
- salad on deep flow technique

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Worldwide production of vegetable by crops and regions

in 1.000 t	World	Asia	China	Europe	Africa	North America	South America	Oceania
Tomatoes	170.751	101.639	52.723	22.734	19.253	19.026	7.161	255
Watermelons	111.009	93.206	75.054	5.295	6.387	2.756	3.112	174
Onion dry	88.475	58.443	22.611	9.889	10.436	4.991	4.276	256
Cucumbers	74.976	65.508	56.904	6.187	1.126	1.856	134	17
Cabbage	71.779	55.121	33.948	11.723	2.825	1.529	251	132
Eggplants	50.193	47.142	29.517	937	1.815	249	20	4
Carrots	38.835	24.274	17.443	8.773	2.018	2.203	1.154	344
Salads and chicory	24.976	16.773	13.659	2.970	349	4.371	323	165
Garlic	24.940	22.882	20.058	836	562	263	368	2
Spinach	24.278	23.100	22.107	590	134	382	44	12
Cauliflower/broccoli	24.175	19.317	9.366	2.389	427	1.789	169	82
Green beans	21.721	19.862	17.032	818	695	219	88	37
Asparagus	7.830	6.919	6.852	286	4	211	400	11
Onions green	4.166	2.609	952	393	676	453	149	224
Artichoke	1.573	146	78	738	423	46	221	0
other	429.769	343.436	220.538	25.770	32.665	16.222	7.643	1.517
Vegetable total	1.169.445	900.377	592.842	100.327	79.793	56.566	25.514	3.232
consumtion per head [kg]	140	177	348	115	68	94	53	101

Source: FAO [2017]

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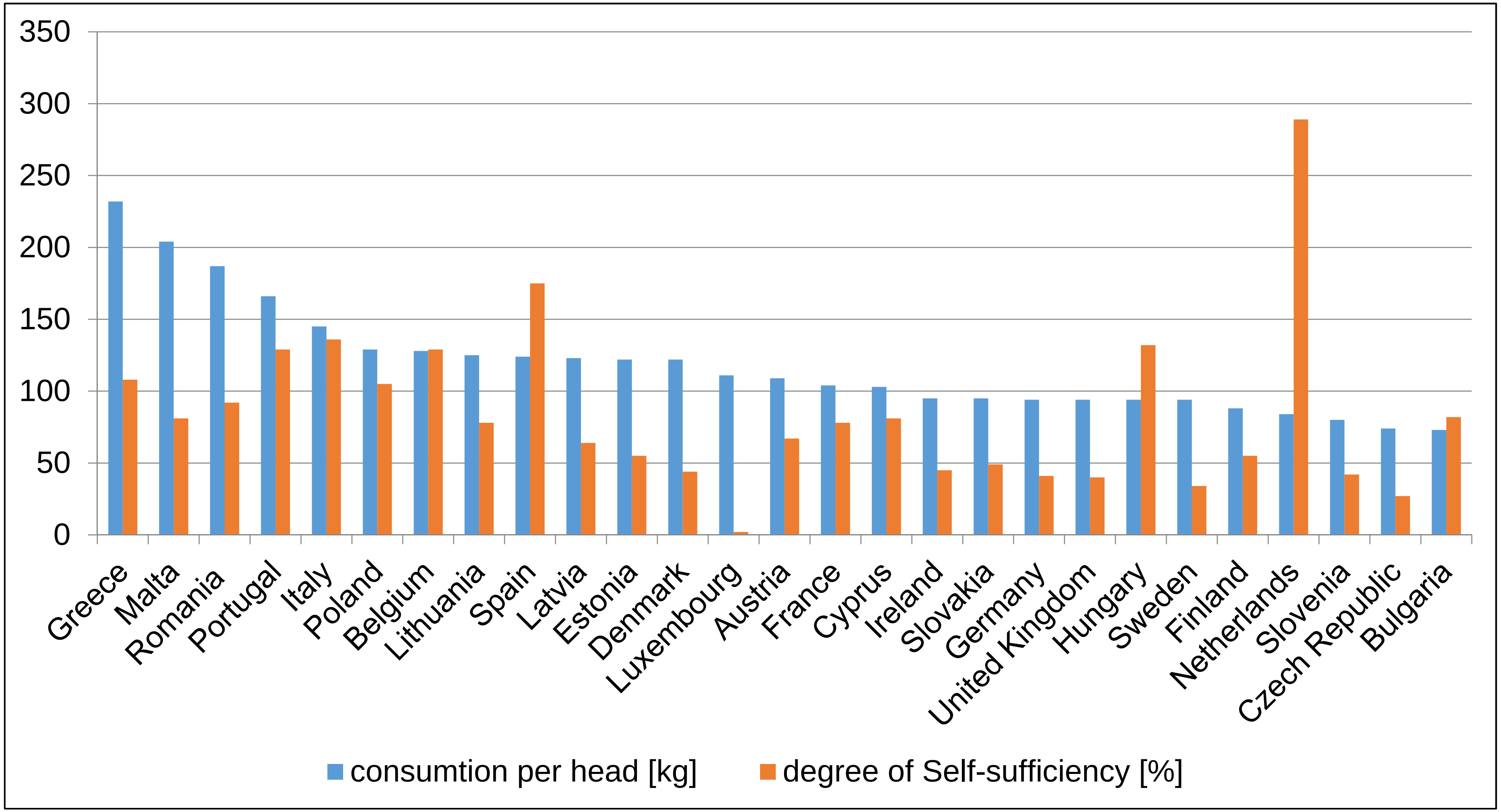
Supply of vegetables in the EU



Source: FAO [2016]

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Cultivation area of the important vegetable types in open field and in greenhouse to federal states in Germany

in ha	2010 open field	2010 Green-house	2013 open field	2013 Green-house	2014 open field	2014 Green-house	2015 open field	2015 Green-house
North Rhine-Westphalia	19.615	199	21.408	193	22.155	191	21.723	190
Rhineland-Palatinate	17.992	64	19.800	49	19.191	51	19.546	51
Lower Saxony	17.119	77	17.510	85	17.376	83	18.279	75
Bavaria	12.160	250	13.797	258	14.835	236	14.653	225
Baden-Württenberg	9.086	452	10.692	445	11.113	441	11.283	411
Hesse	6.570	44	6.681	38	6.885	31	6.877	28
Brandenburg	5.678	44	5.387	41	6.062	42	5.670	41
Schleswig-Holstein	6.129	23	5.528	38	5.904	39	5.720	31
Saxony	4.199	5	4.129	4	4.173	38	3.973	34
Saxony-Anhalt	3.977	43	3.868	38	4.071	19	3.895	18
Mecklenburg-Vorpommern	1.747	13	1.794	14	1.787	17	1.625	14
Thuringia	1.205	46	1.052	36	1.058	37	954	39
Hamburg	462	60	440	48	443	46	451	43
Saarland	133	3	146	4	148	4	154	4
Berlin und Bremen	113	1						
Germany	106.185	1.324	112.232	1.291	115.201	1.275	114.803	1.204

Source: DESTTIS [2016]

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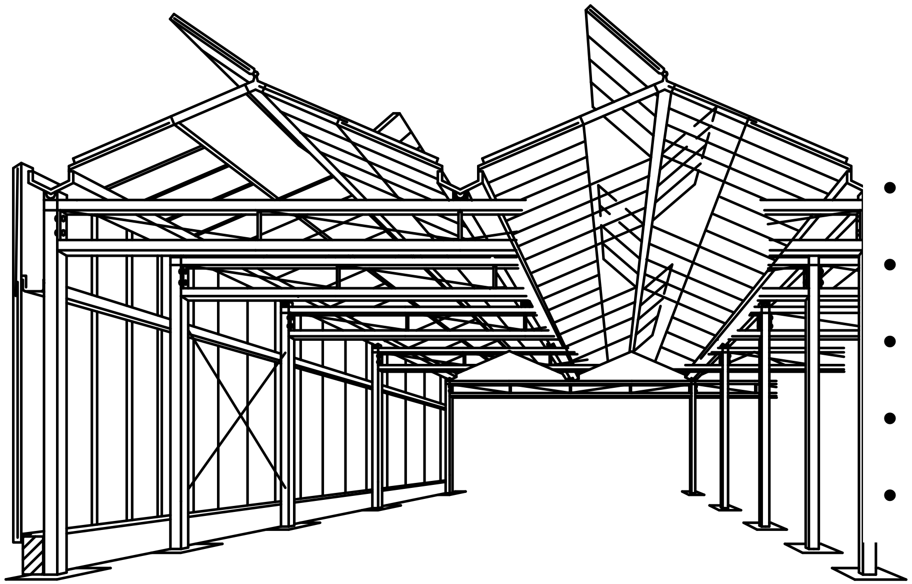
Why greenhouse production?

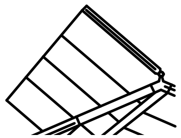
Advantages:
- Protection against climatic factors (frost, wind, rain etc.)
- Timely production through controlled climatic conditions (heating, ventilation, irrigation, artificial lighting)
- Plant protection with beneficial insects (predatory mite, predatory bug, parasitic wasp)
- Pollination with bumblebees

Disadvantage:
- High investment costs (greenhouse, heating system, interior fittings, etc.)
- high expendable material costs (heating material, fertilizer, etc.)
- high effort to protect against diseases, especially against virus diseases
- disinfection of gutters, greenhouse construction and tools needed for cultivation

➢ good product prices are important to generate the costs

Greenhouse construction





- Sidewall: 5 – 6 m
- Roof: 4 m spans
- Roof ventilation: two-way on the ridge
- Covering roof: single glass
- Covering sidewall: double-skin sheet/glass

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Roof ventilation Venlo – greenhouse

Source: Debets Schalke

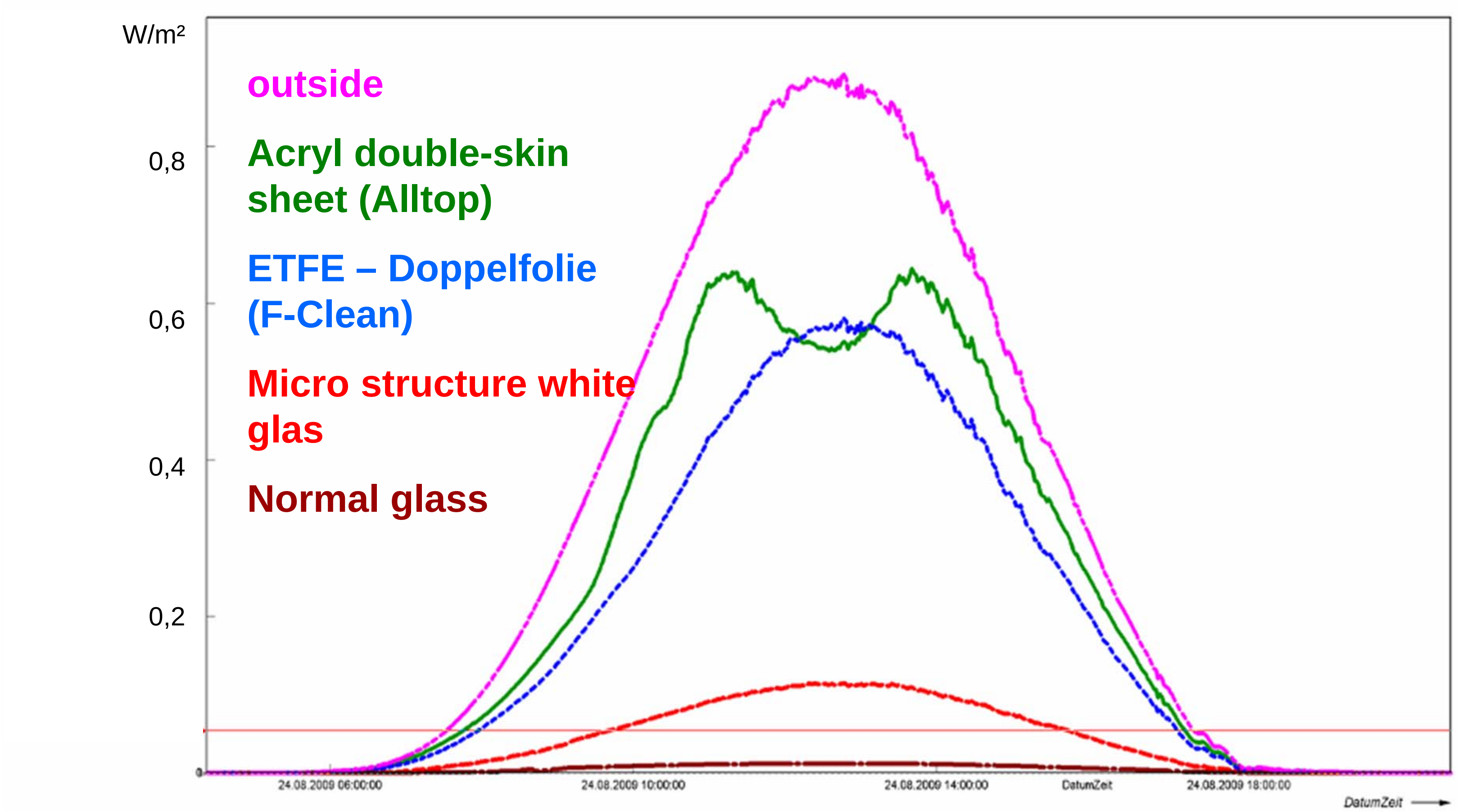
Covering material

Characteristics:

- Light transmission
- Haze: Diffuse/Clear
- Mechanical load capacity
- Stability
- Recyclability

- **The main aim is to bring more light into the greenhouse**
  → 1% more light → 1% more yield

UVB – transmission on a sunny day in august



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Antireflection glass

- Reduce the light reflection of the glass
- more light into the greenhouse
- higher light transmission
- Coating (roughening) on the top of the glass (picture frames, flat screens)

Source: IPM 2006

Diffusivity by cover material

- Diffuse = haze factor
- Non-directional radiation penetrates deeper into plant
- life better exposure of the lower leaves
- higher photosynthesis rate
- higher yield
- Glass with a haze factor 20 – 70 % available
  - Permanent coating (production)
  - Coatings on one side outside "baked"
- temporary coating: "shading colors" e.g. Fa. Mardenkro, Hermadix, Brinkmann etc

Source: Mardenkro

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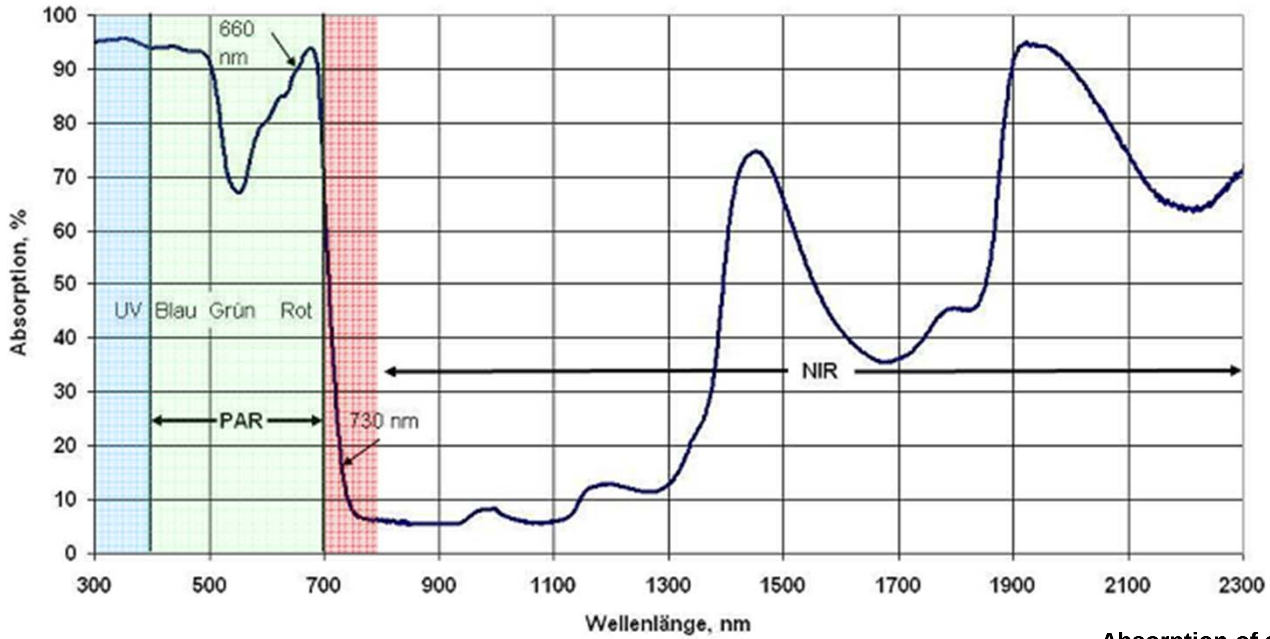
Systems for applying and removing the shading colors by a roof cleaner

Redusol – Shading color → Reduclean – Cleaning agent

Source: greentech, Amsterdam

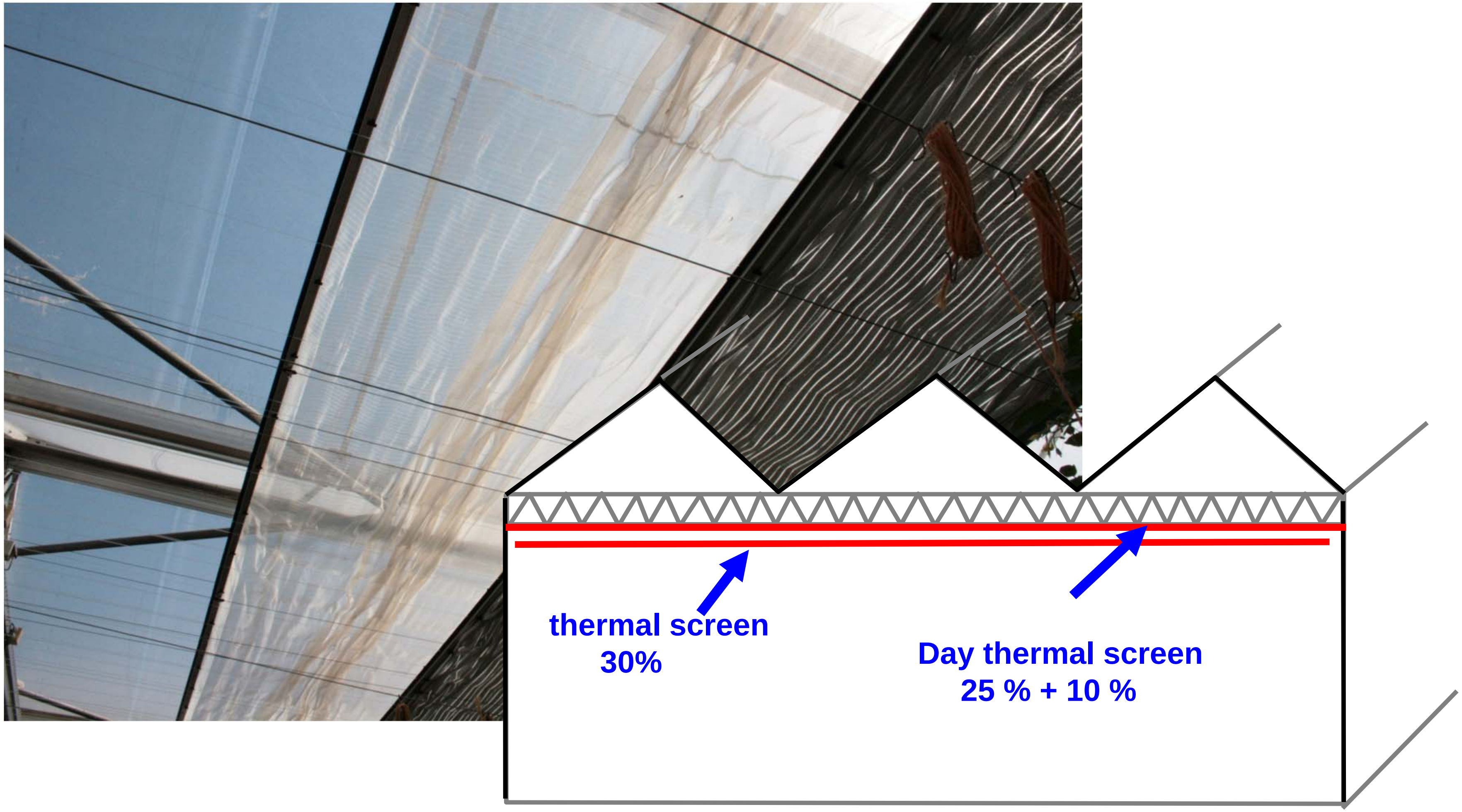
Near infrared Blockade (NIR)



Absorption of a tomato leaf
Source: B. von Elsner, GKL 2007, Heidelberg

- Plants need radiation (light) Spectral range 300 - 800 nm
- Longer wavelengths > 800 – 3000 nm = near infrared NIR
- hardly influence on photosynthesis
- heat plants and interior unnecessarily (energy storage?)
- Optimal: reflection outside on glass surface / do not let through (absorb)

Thermal screens → energy saving and shading the plants



Thermal screens → energy saving and shading the plants

Source: Ludvig Sevnsson

- Check thermal screens → Tightness, Cracks, mechanical strength
- Installation → tightness, mechanical reliability, Rack drive trouble-free

→ important for energy saving and protect the plants for sunburn

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Heating system → control the temperature and the humidity

Conventional production

Organic production

- Conventional production with Buisrail – system and Forcas – pipes between the culture
- Organic production with Alcoa – pipes between the culture

Buisrail system → transport system

Greenhouse scissorslift for crop work

Source: metazet formflex

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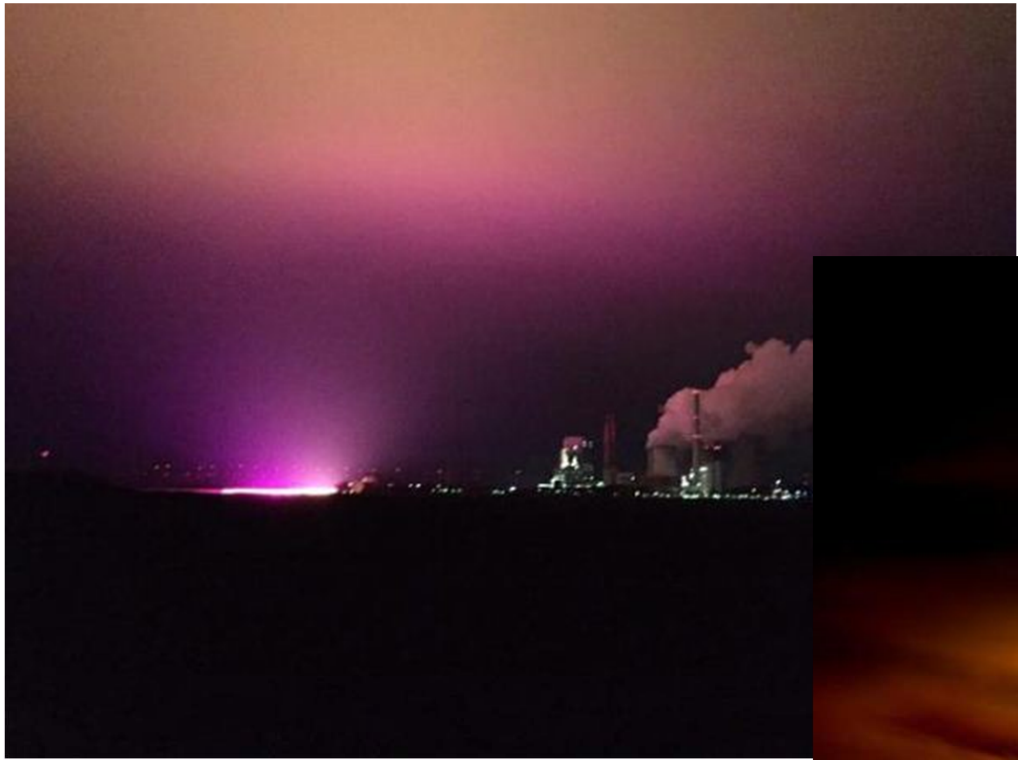
Buisrail system → transport system

Artificial lightning



Artificial lightning

LED interlight

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Artificial lightning

High pressure sodium lamp

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Artificial lightning

- 13.000 – 14.000 Lux/m² installed light power for fruit vegetable (winter months)

- Amount of light (kluxh) is the sum by light hours over a defined period of time

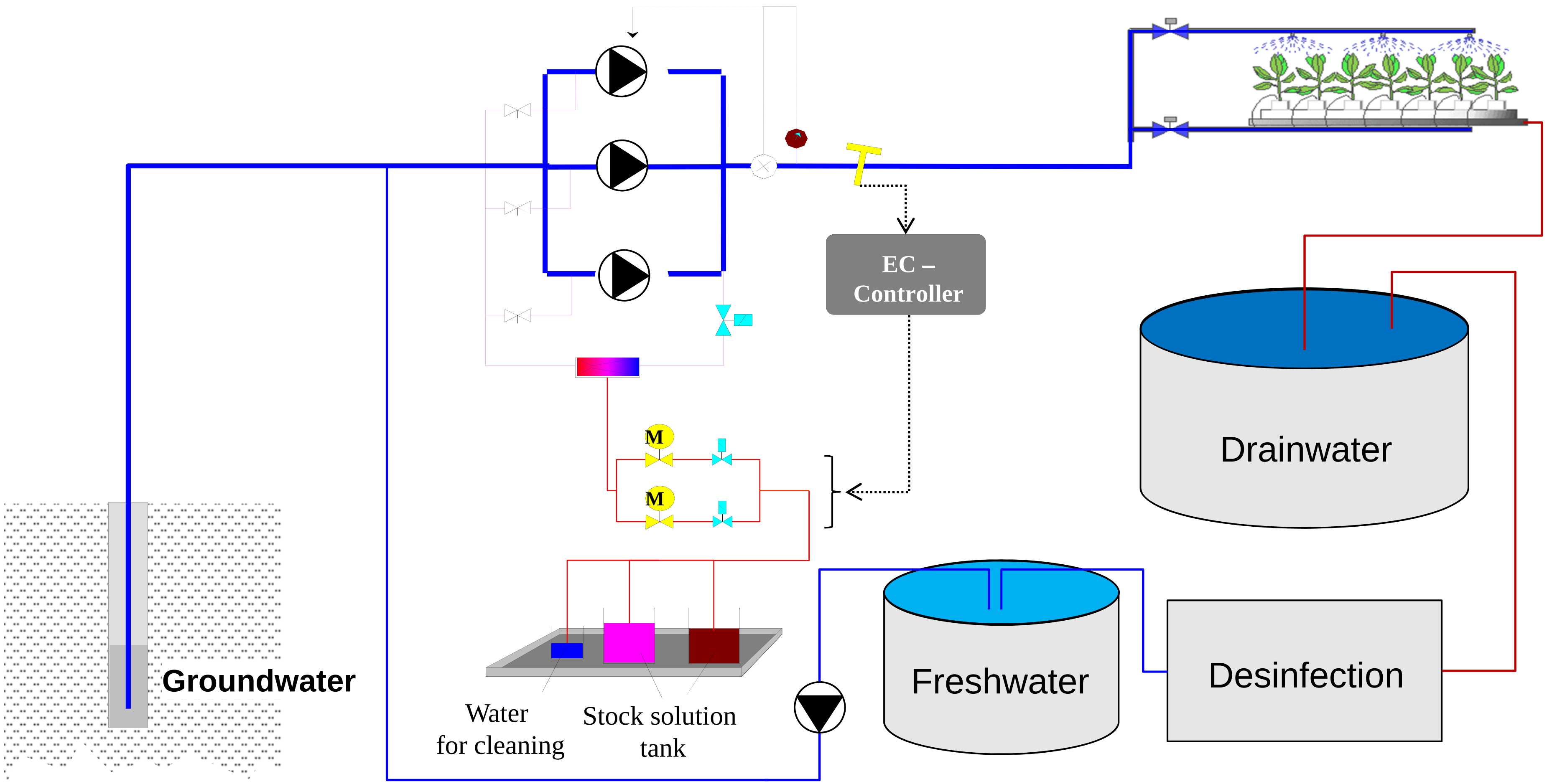
- Amount of light per day at z. Eg tomato
  - Plant without flower 50 kluxh
  - Plant with 1. bloom 75 kluxh
  - Plant with 2. flower 100 kluxh
  - Plant with 3. flower 125 kluxh
  - etc.
  - in full yield 150 – 200 kluxh

Why additional CO_2?

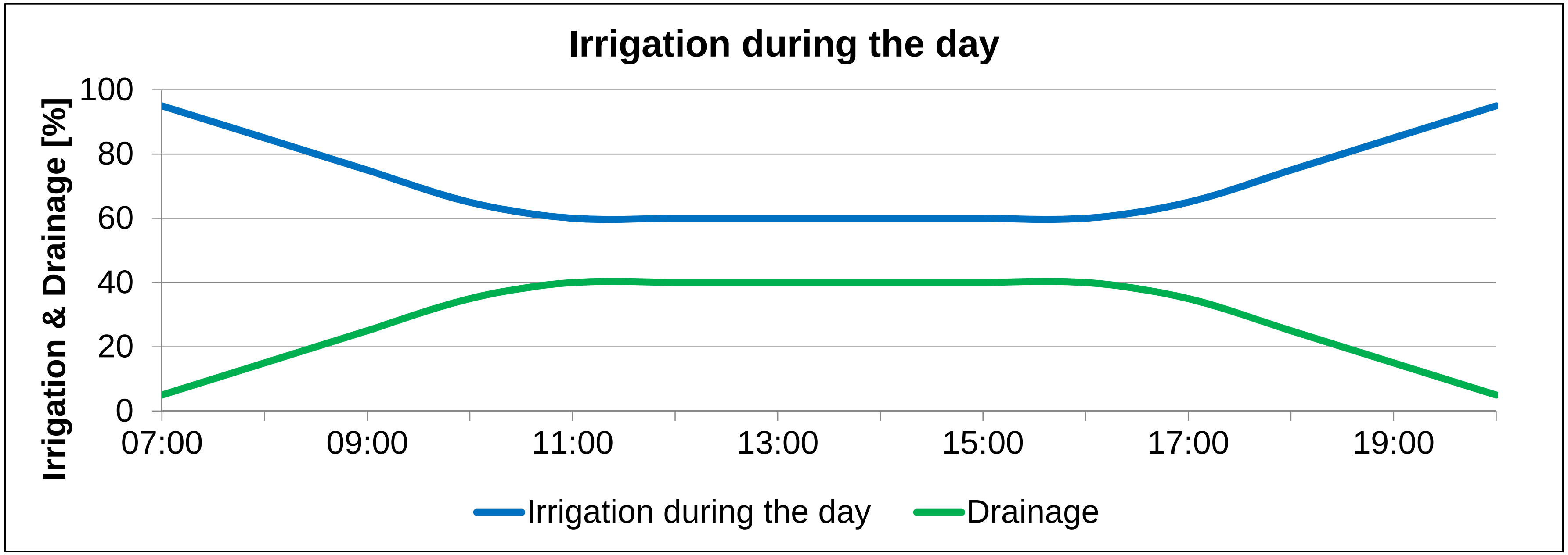
- Cultivation in well insulated greenhouses reduces the CO_2 concentration by photosynthesis very quickly during the day, which can not sufficiently prevent effective by ventilation!
- Depending on the season, concentrations between 0.06 and 0.12 Vol.% are considered ideal. CO_2 fertilization gives higher yields to preenhouse production
- Vegetable growing: 150 - 200 kg CO_2 /ha × h
- Technical CO_2 is very pure. Therefore, it is safe for use in horticulture.
- CO2 Generator

Irrigation system → drip system

Construction of a closed irrigation system



Control of irrigation



- Irrigation depending on the substrate, between 70 and 200 ccm
- Starts between 50 and 150 joules or 15 and 25 klxh
- Fixed irrigation starts to protect the substrate moisture
- 20 and 40% drainage water
- Night start only, when substrate moisture is below 15%
- Irrigation starts about 2 hours after sunrise and end 3 to 1 hours before sunset

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Fertigation system for drip systems

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Fertilizing scheme

Stock solution A 1.000 liter tank		Stock solution B 1.000 liter tank	
Fertilizer	**mass [kg]**	**Fertilizer**	**mass [kg]**
Calcium nitrate	44,400	mono potassium phosphate	22,000
Potassium nitrate	62,700	Magnesium sulphate	52,000
Ammonium nitrate	5,000	Iron chelate (13% Fe)	1,000
		Manganese sulphate (25% Mn)	0,250
		Boric acid (14% B)	0,090
		Copper sulphate (25% Cu)	0,030
		Zinc sulphate (23% Zn)	0,035
		Ammonium molybdate (57% Mo)	0,008

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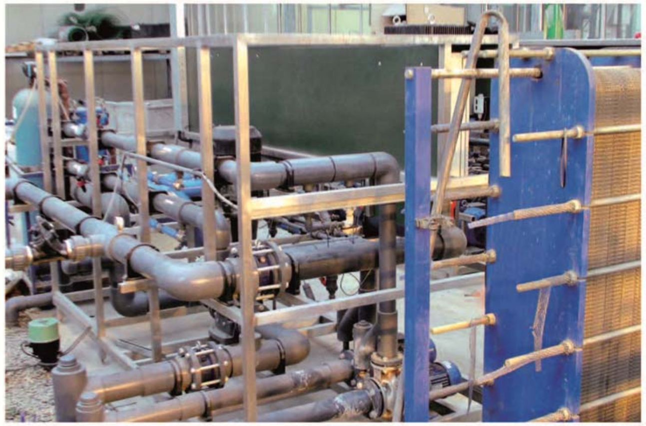
Drainwater disinfection

- Thermal water sterilization
  - Hot water treatment
- Chemical water sterilization
  - Ozone
  - Chlorine
- Radiation
  - UV radiation
- Filtration
  - Slow filtration

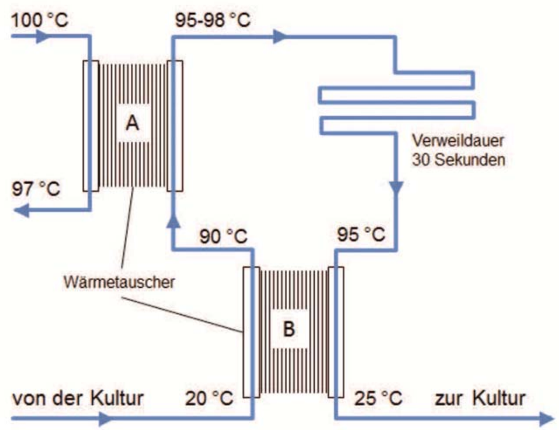
Thermal water sterilization

KTBL Datenblatt 738, Wohanka und Domke, 2015

- Pre-filtering the used nutrient solution
- Heating for approx. 30 sec. at 95 - 98 ° C
- Heating unit with special boilers (natural gas)
- very good effects against bacteria, nematodes, fungus and viruses
- high energy consumption (approx. 9.6 kWh / m³)
- Flow rate approx. 2 - 3 m³/ha
- Investment costs approx. 30.000 €/ha and high operating costs



Source: KTBL Datenblatt 738, Wohanka und Domke, 2015



Chemical water sterilization → Ozone

- Pre-filtering of the used nutrient solution
- high-voltage electric field (O_2 to O_3)
- 10g O_3/m³ water and hour
- broad effect due the oxidation of organic substances
- high investment costs approx. 60.000 €/ha and operating costs

Source: Wohanka und Domke, 2015

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Chemical water sterilization → Chlorine (electrochemically activated water)

- Pre-filtering of the used nutrient solution
- Electrochemically activated water
- Membrane - electrolysis process
- Use of common salt (NaCl) or potassium chloride (KCl)
- main active ingredient → hypochlorous acid (HClO)
- Reaction products → hydrogen peroxide, chlorine dioxide, ozone
- pH 5.5 - 7.0
- Trichloromethane → carcinogenic substance
- wide effect against fungus, nematodes and bacteria, no effect against virus
- Investment costs approx. 30.000 €/ha and operating costs 0.1 €/m³ treated water

Source: KTBL Datenblatt 738, Wohanka und Domke, 2015

Chemical water sterilization → Chlorine dioxide

- not to be confused with classic chlorination
- Pre-filtering of the used nutrient solution
- Chloride acid procedure
- Use of dilute saline (NaCl) and hydrochloric acid (HCl)
- main active ingredient → chlorine dioxide (ClO_2)
- pH independent
- no formation of trichloromethane
- wide effect against fungus, nematodes and bacteria, no effect against virus
- Investment costs approx. 20.000 €/ha and operating costs 0.1 €/m³ treated water

Source: KTBL Datenblatt 738, Wohanka und Domke, 2015

UV – Radiation

- Pre-filtering of the used nutrient solution
- UVC radiation (~ 190 - 209 nm) has a germicidal effect
- Optimum effect by 254 nm
- UV dose (J/m²) = irradiance (W/m²) × irradiation time (sec.)
- Practical application: 1000 - 2500 J/m²
- Damage to the DNA
- Transmission <50% → Intersection with rainwater
- Fertilizer (Fe chelates) → absorption (> 50%) → iron deficiency
- Investment costs approx. 35.000 €/ha and high operating costs

Source: KTBL Datenblatt 738, Wohanka und Domke, 2015

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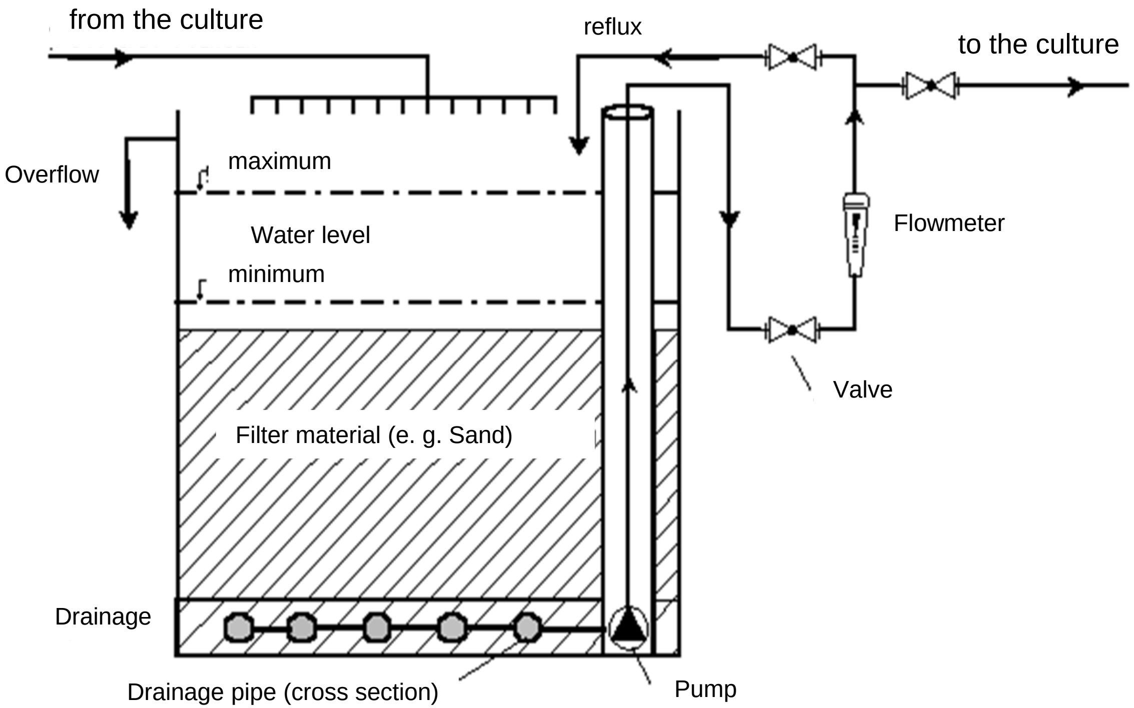
Slow filtration

- physical, chemical and especially biological effects
- Filter medium: mostly quartz sand (grain size 0.2 – 2 mm) or rock wool
- Flow rate: 10 – 30 cm/h, equivalent to 100 - 300 l/m² × h
- approx. 15 m² sand filter → 1.5 – 4.5 m³/h filtration capacity
- metal tanks with foil lining are often used in greenhouses



- high efficiency against small spore fungus (e.g. *Fusarium*) and bacteria
- efficiency against nematodes and viruses is not sufficient
- low investment costs 1 m³/h → approx. 10.000 €/ha and operating costs

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Tomato production

- Sowing at the end of September in the greenhouse
- 75 days of cultivation/grafting on the stock
- Planting Dec. or Jan.
- Culture duration 43 to 46 weeks, until the end of October
- Yields Vine – tomato up to 50 kg/sqm
- Yields Cocktail - tomato up to 20 kg/sqm
- Sales must be above 50 €/sqm!

Typical tomato types

Rote Cocktailtomate

- Sehr süß
- Knackig

Rote Eier-Cocktailtomate

- Süß
- Knackig
- Außergewöhnliche Form

Rote Paprika-Cocktailtomate

- Süß, sehr geschmacksintensiv
- Knackig
- Schnittfest

Rote Honig-Paprika-Cocktailtomate

- Edeltomate an der Rispe
- Sehr süß
- Knackig
- Außergewöhnliche Form

Typical tomato types

Rote Flaschen-Cocktailtomate

- Weniger süß
- Schnittfest
- Längliche Form

Rote Honig-Cocktailtomate

- Edeltomate an der Rispe
- Sehr süß
- Knackig
- Farbintensiv

Schwarze Schoko-Cocktailtomate

- Knackig
- Süß, mild im Geschmack

Gelbe Eier-Cocktailtomate

- Süßer Geschmack
- Farbintensiv

Typical tomato types

Rote Strauchtomate

- Weniger süß
- Eignet sich sehr gut für Tomate Mozzarella und Bruschetta

Rote Aromatomate

- Weniger süß
- Aromatisch

Rote Ochsenherztomate

- Viel Fruchtfleisch, wenig Säure
- Zarte Schale
- Eignet sich sehr gut zum Kochen von Suppen und Soßen
- Außergewöhnliche Form

Schwarze Schokotomate

- Zarte Schale
- Süß im Geschmack

Vegetable crop pest

- **Powdery mildew** (*Oidium neolycopersici*)
- Powdery mildew fungus develop on surface of the leaves and petioles.
- For an infection are temperatures of up to 16 to 22 ° C and a humidity of 70 – 80%.
- Yellow varieties are more susceptible!

Tomato Early Blight Disease (*Alternaria solani*)

- On the lower leaves arise roundish, grey to brown spots
- The disease also spreads to the upper leaves over time. Heavily infected leaves die off and curl up.
- The fruits usually begin to rot in the calyx area.

Source: backgarden.org

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Vegetable crop pest

Bacterial wilt (*Clavibacter michiganense*)

- After planting, individual leafs begin to wilt.
- One half of the plant can still be completely healthy, while the other half shows wilting or already dies.
- The fruit shows small spots.

Clavibacter michiganensis ssp. michiganensis symptoms on tomato

Blossom end rot

- The Blossom end rot is not a disease, it is a calcium deficiency.
- Also a nutrient deficiency. To work against a targeted fertilization and sufficient water is needed.

Vegetable crop pest → Virus diseases

- Pepino mosaic virus (PepMV)
- Jordanvirus = Tomato brown rugose fruit virus (ToBRFV)
- Tobacco Mosaic Virus (TMV)
- Tomato Spotted Wilt Virus (TSWV)

Pepino mosaic virus

Tomato brown rugose fruit virus

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Energy and water consumption for tomato culture

- inside temperature: 16 - 22 ° C
- Humidity: 70 – 85 %
- Tomato as year – round culture → 40 to 46 KW
- 300 – 250 kWh/sqm × a → heating energy necessary
- 50.000 kWh/ha electricity consumption
- Water consumption → max. 7 L water/day/sqm = 1500 L/sqm/a (approx. 30 l/kg tomatoes)

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Remove the tomato plant

Remove the tomato plant

Steenks Service

Bio Chopper
Compact Chipper

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Pointed pepper and bell pepper

Climate conditions for Bell peppers

- inside temperature: 18 - 25 ° C
- Humidity: 70 – 85 %
- Buds and flowers drop down by temperatures under 14 °C and over 24 °C
- Optimal temperature for flower development are 16 – 21 °C
- Increase the humidity an warm days
- Permanent shading reduces the flower development sustainably

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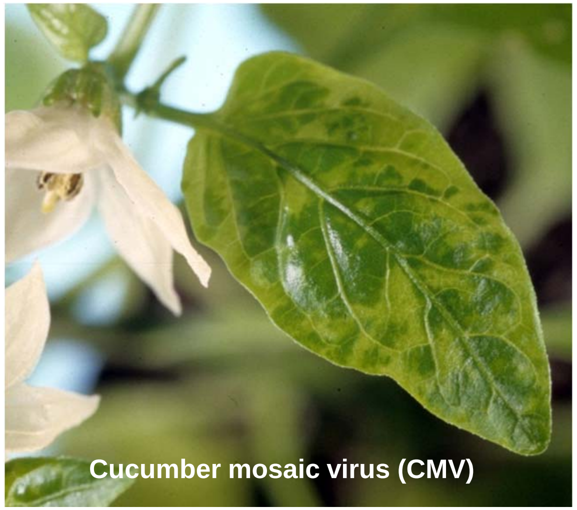
Bell peppers harvester

Vegetable crop pest → Virus diseases

- Cucumber mosaic virus (CMV)
- Tobacco mosaic virus (TMV)
- *Pepper mottle virus* (PeMV)
- *Tomato spotted wilt virus* (TSWV)
- *Alfalfa mosaic virus* (AMV)
- *Tomato spotted wilt virus* (TSWV)
- etc.



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Cucumber

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Cucumber→ Virus diseases

• Cucumber mosaic virus	Non-persistent by aphids, mechanical, grafting, seeds
• Zucchini yellow mosaic virus • Papaya ringspot virus • Watermelon mosaic virus • Moroccan watermelon mosaic virus • Potato virus Y	Non-persistent by aphids, mechanical, grafting; Seed transmission depends on the virus – typ
• Squash mosaic virus	Non-persistent by aphids, mechanical, grafting, semen; not by pollen
• Cucumber green mottle virus	Mechanical, beetle (Raphidopalpa fevicolis), seeds, grafting, soil, plant remains, irrigation systems

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Cucumber→ different fungus diseases

- Downey mildew (*Pseudoperonospora cubensis*)
- Powdery mildew (*Sphaerotheca fuliginea*)
- Fusarium wilt (*Fusarium oxysporum*)

Vegetable crop pest → Aphids

- Aphids are an important insect pest in sweet pepper, tomato, cucumber and many other greenhouse crops
- Aphids have a world-wide distribution
- Aphids are the most important vectors of viral diseases. They can transmit over 100 different viruses and is thus rightfully feared by many growers
- Nymphs and adults extract nutrients from the plant and disturb the balance of growth hormones. As a result, the plant's growth is retarded giving rise to deformed leaves
- Aphids retirement sugar in form of honeydew and making the crop and its fruit sticky. Black fungal moulds (*Cladosporium* spp.) grow on this honeydew, contaminating fruit and rendering them unsuitable for market.
- Pesticides are effective against aphids. Natural predator such as parasitic wasps (*Aphidius colemani* and *Aphidius matricariae*) also effective.

Source: Koppert

Vegetable crop pest → Whitefly

Greenhouse whitefly (*Trialeurodes vapariorum*)
Sweetpotato whitefly(*Bemesia tabaci*)

- Adult is whiteflies and very small; it looks like a miniature moth.
- They typically feed on the undersides of leaves, flying up in clouds when disturbed.
- Immature stages are flat, oval, white to greenish, and semi – transparent.
- Eggs are white and laid singly on white, chalky-looking spots on the lower leaf surface.
- Whiteflies feed by sucking sap from the plants.
- Damaged leaves wilt, turn yellow or brown, and may drop, all of which reduces photosynthetic area.
- Whiteflies also produce honeydew, which may attract ants or become covered with a growth of sooty mold.
- Pesticides are ineffective, because the white flies are resistant against them. Natural predator such as parasitic wasps (*Encarsia fromosa*) and predatory bugs (*Macrolophus pygmaeus*) are more effective.

Source: Koppert

Vegetable crop pest → spider mite

Twospotted spider mite (Tetranychus urticae)

- Adult mites are about 0,15 mm long, have four pairs of legs, are greenish to pink or cream color, and have various-size black spots on the body.
- Under warm conditions, spider mites move rapidly within the colony area.
- Damaged leaves become somewhat stippled on the upper surface and may turn brown or bronze with heavy damage.
- The undersurface of leaves may have a grayish cast due to webbing. Wilting, leaf deformity, tissue death, and abscission all may take place.
- Pesticides are effective against spider mite. Natural predator such as predatory mite (*Phytoseiulus persimilis*) also effective.

Source: Koppert

Vegetable crop pest → Thrips

Onion thrips (*Thrips tabaci*)
Sweetpotato whitefly(*Frankinella occidentalis*)

- Thrips are is distributed throughout the world. It is found outdoors on many plants and in greenhouses on cucurbits, tomato, sweet pepper, eggplant and many others.
- Thrips cause damage to plants by piercing the cells of the surface tissues and sucking out their contents, causing the surrounding tissue to die.
- The resulting silver-grey patches on leaves and the black dots of their excreta indicate their presence in the crop. The vigour of the plant is reduced by loss of chlorophyll.
- Fruit damage, for instance in cucumber, only occurs if the crop is heavily infested.
- In some countries thrips in as an important vector of tomato spotted wilt virus.
- Pesticides are ineffective, because the thrips are resistant against them. Natural predator such as predatory mites (*Amblyseius swirskii* and *Neoseiulus cucumeris*) are more effective.

Amblyseius swirskii

Neoseiulus cucumeris

Source: Koppert

Vegetable crop pest → Tomato leafminer

Tomato leafminer (*Tuta absoluta*)

- The leaves, flowers and young fruits of tomatoes are damaged.
- The moth also affects the herb of the potato (*Solanum tuberosum*), the eggplant (*Solanum melongena*), Pepino (*Solanum muricatum*) and related ornamental plants such as the petunia.
- Pesticides are effective against tomato leaf miner. Natural predator such as predatory bugs (*Macrolophus pygmaeus*) and Bt – based insecticide (*Bacillus thuringiensis*) are also effective.

Source: Wikipedia

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Deep flow technique (DFT)

- The system is not disinfected, it is only filled with fresh nutrient solution
- The water depth is 30 cm deep and the water temperature varies during the day minimal (22.5 ° C)
- In horticultural practice, the system can be provided with a pH and EC control sensor
- In our experiment, the nutrient solution is permanently kept in motion with a pump and the water is so aerated

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Deep flow technique (DFT)

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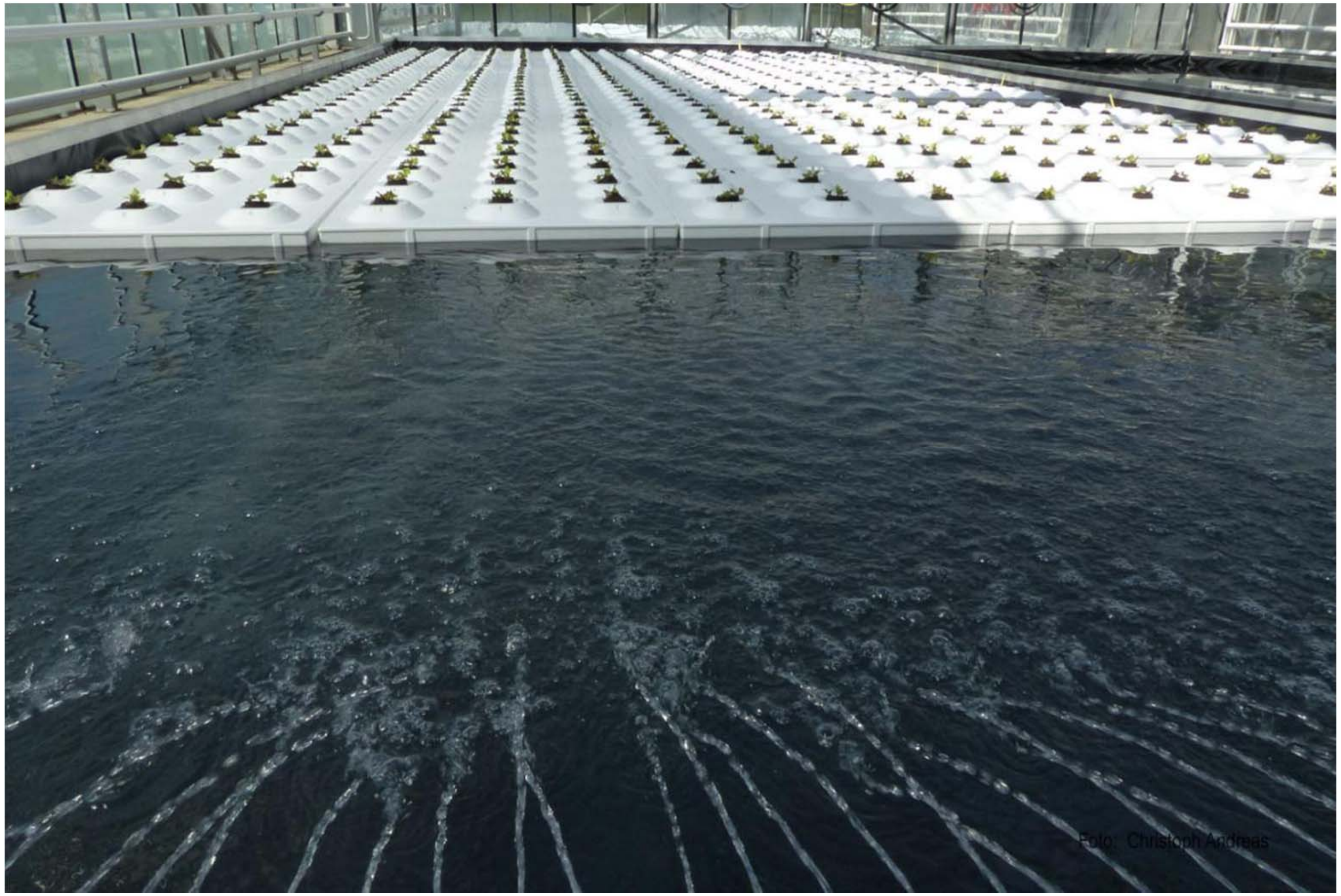
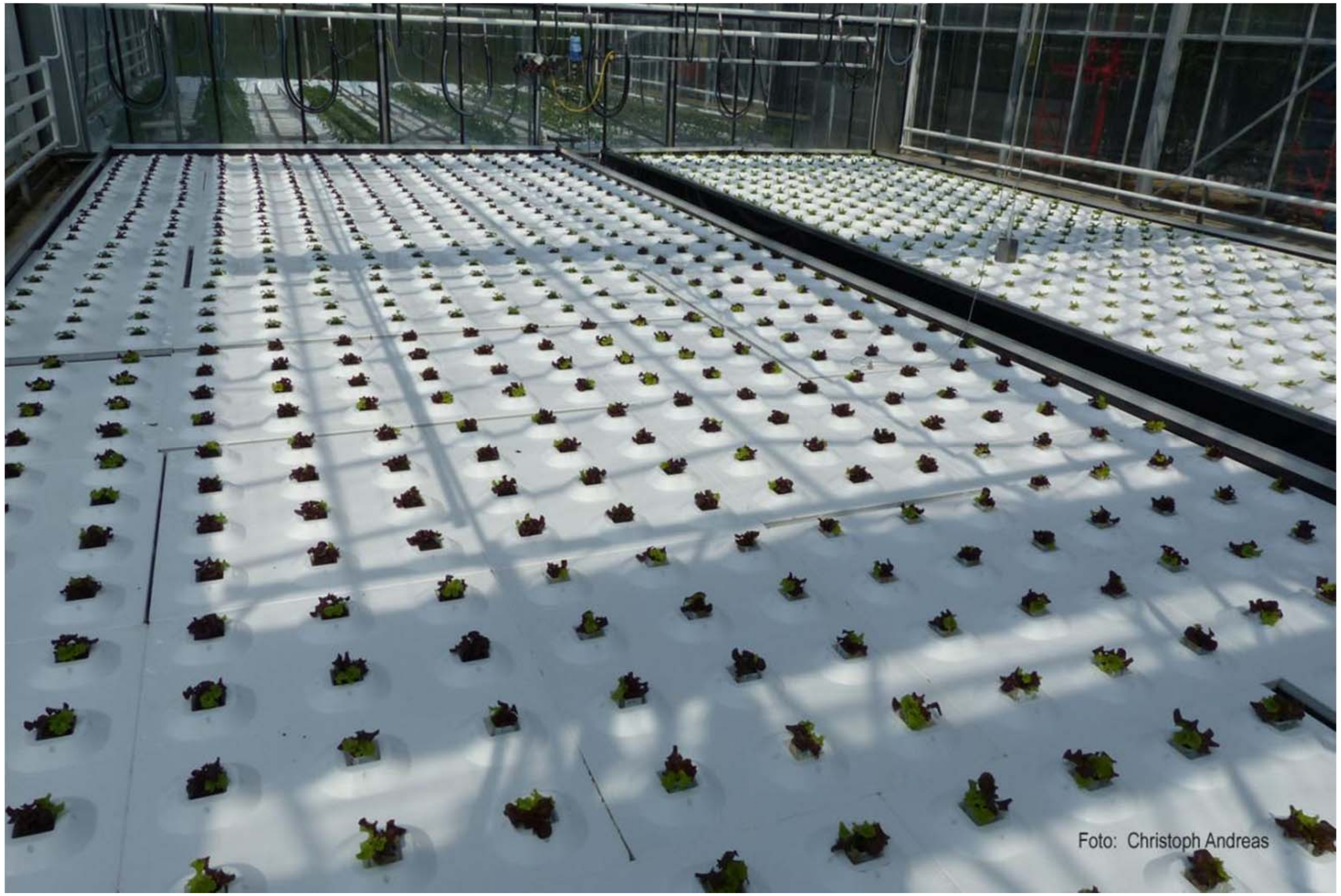
Deep flow technique (DFT)



Deep flow technique (DFT)



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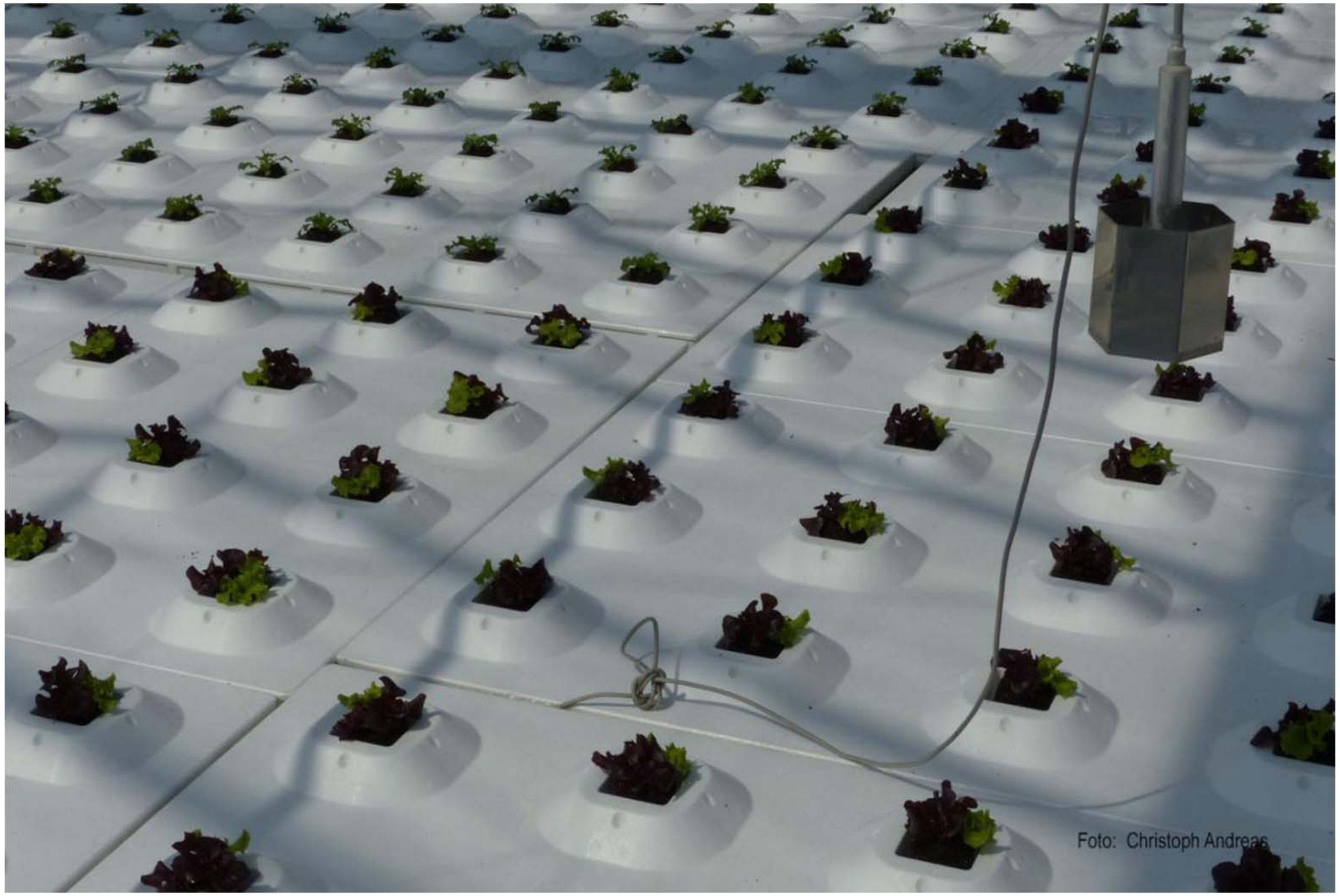
Deep flow technique (DFT)



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Deep flow technique (DFT)

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Thank you very much for attention

Landwirtschaftskammer Nordrhein – Westfalen
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