PRODUCTION OF HEALTHY PLANTING MATERIAL AND TESTING OF INNOVATIVE GROWING METHODS FOR CROPS, SIGNIFICANT FOR NATIONAL ECONOMY.

LEAD: ”BULDURU TEHNIKUMS”.

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Projekta iesnieguma Nr.22-00-A01612-000011

NACIONĀLAIS ATTĪSTĪBAS PLĀNS 2020

EIROPAS SAVIENĪBA

EIROPA INVESTĒ LAUKU APVIDOS
Eiropas Lauksaimniecības fonds lauku attīstībai

Atbalsta Zemkopības ministrija un Lauku atbalsta dienests

Development of Soilless Cultivation Technologies in Totally Controlled Environment (CEA)

Why We Need CEA?

1. **Climate Independence**
2. **Land & Space Efficiency**
3. **Water Conservation**
4. **Pesticide-Free Production**
5. **Higher Yields & Faster Growth**
6. **Urban & Local Food Supply**
7. **Resilience & Food Security**
8. **Sustainability & Innovation**

- 🌦️ Enables year-round production regardless of weather
- 🏙️ Grows food vertically in urban areas → shortens supply chains
- 📉 Requires up to 90% less land than open-field agriculture
- 💧 Uses up to 95% less water than traditional farming
Closed-loop systems
- ⚡ Optimized light, temperature, CO_2, and nutrients
- 📈 Multiple harvests per year → significantly higher productivity
- 🛡️ Strategic for future pandemics, conflicts, or migration flows
- 🌱 Integrates AI, automation, and renewable energy
- 🧬 Enables global biodiversity in local food systems
- 🌿 Modeling and optimizing nutrient content in yield

Grown in CEA Indoor Systems

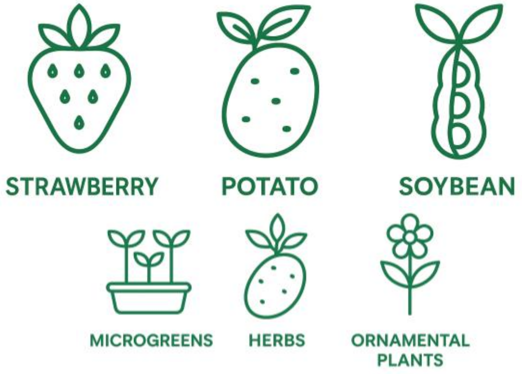
- 🌱 Microgreens
- 🌿 Leafy Greens
- 🌿 Herbs
- 🍓 Fruit and Berry Crops
- 🌾 Legumes and Protein Crops
- 🍄 Fungi
- 🌼 Edible Flowers and Ornamentals
- 🍁 Canabis
- 💧 Medical plants etc

Challenges in Controlled Environment Agriculture (CEA)

- 🔬 **Research Gaps** Limited long-term data on plant physiology under artificial conditions (e.g., for medicinal plants or trees)
- 💡 **High Energy Consumption** Artificial lighting (especially for fruiting crops) and climate control require significant electricity.
- 💰 **High Capital Investment** Building infrastructure (LEDs, HVAC, sensors, automation) is costly and can be a barrier for new entrants.
- 🌡️ **Complex Climate Control** Maintaining optimal light, temperature, humidity, and CO_2 levels across all growth stages is technically demanding.
- 🧪 **Nutrient Management Complexity** Precise formulation and monitoring of nutrient solutions is critical to prevent deficiencies or toxicities.
- 🤖 **Dependence on Technology** Failures in software, sensors, or power systems can lead to crop loss within hours.
- 🧑‍🔧 **Skilled Labor Shortage** Operators must understand horticulture, sensors, automation, and data analytics — a rare skillset.
- 🌐 **Public Awareness & Acceptance** Some consumers remain skeptical about "artificially grown" food or unfamiliar varieties.

Project objectives:

✓Develop growing technologies in CEA:



strawberry youngplants;

pre-basic potato seed material;

soybeans, etc.

✓Evaluate the quality of plant material.

✓Reduce human labor in plant cultivation.

✓ Set up climate chambers.

✓Make flood and drain multi layer growing trolleys.

Strawberry varieties

‘Sonata’
- Short-day variety;
- Cross between;
- High-yielding;
- Uniform, sweet berries;
- Good shelf life.

‘Charlotte’
- Remontant (Everbearing)
- French cultivar
- Aromatic, wild strawberry-like flavor
- Compact growth.

‘Soprano’
- Remontant
- Dutch cultivar
- Continuous production
- Large, flavorful fruits.

‘Albion’
- Remontant cultivar
- From the University of California.
- Large, firm, sweet fruits
- Disease resistance and stable yield.

In Vitro Propagation Protocol for Strawberry

Explant Source

Shoot tips from healthy strawberry plants
Surface sterilized with 99% ethanol under aimit flow

Culture Medium (per 1L)

MS macro- and micronutrients, 30 g/L sucrose, 7,5 g
ph adjusted to 5.7
BAP 1 mg/L, meta-Topolin (mT) 1 mg/L
meta-Topolin riboside (mTR) 1 mg/L

Growth Conditions:

Temperature: 24 ±1°C
Light: 16-hour photopriod, 105-115 µmol/m²/s
Subculture every 4 weeks

Initiation Placed on hormone-suppelmeted MS medium

Multiplication Shoots divided and transferred to fresh med

Rooting & Acclimatization

1. Plantlete transferred to peat
2. Humidity gradually reduced from 90–100 %
3. Full acclimation in 3–4 weeks

Different plant responses to the composition of the light spectrum were observed

LED light intensities μmol·m^{-2}·s^{-1}:
80, 200, 250, 300, 350

OSRAM Phytofy - B9%, G9%, R 94%, FR 5%
RTU - R 60%, G30%, B10%,

The tested light spectra and photon flux densities did not fully meet the physiological requirements of strawberry plants, indicating the need for further spectral optimization.

Cultivar	Runner Production (M0)	Yield Increase (M1)	Disease Resistance (Year 1)
Sensation	70–80 runners/plant (vs 25–30)	+20% Year 1, +35% Year 2	No disease or pest symptoms
Malling Centenary	50–60 runners/plant	+40% Year 2	Year 1: clean; Year 2: powdery mildew, mites
Albion (CEA)	50–60 runners/plant	+20% Year 1, larger berries	Good mildew resistance, some spider mites
Soprano (CEA)	70–80 runners/plant (M0 only)	2.6 kg/plant in Year 1	High sensitivity to blossom rot, mildew
Charlotte (CEA)	78–80 runners/plant	+10% Year 1	Year 2: mildew, mites; Year 1: healthy

Cultivar Comparison (Meristem M0/M1 vs Control Plants)

Observations open field, greenhouse

- Meristem-derived plants produced **significantly more runners and higher yield** than controls.
- **CEA-grown remontant cultivars (e.g. Charlotte, Soprano, Albion)** require mildew control in 2nd year.
- **Soprano** is initially weak but stabilizes; **Charlotte** gives high Brix but is disease-prone.
- **Sensation** is robust, consistent, and **disease-free over 2 years** – suitable for propagation.

Strawberry Runner Production Protocol

Acclimatization Phase (Weeks 1–4)

- In vitro plantlets transferred to trays with peat:perlite (1:1) mixture.
- Grown under high humidity (~95%) at 25 °C.
- Acclimatization period: **4-6 weeks**.
- Gradual adaptation to LED light (16h/day), lowered humidity.

Mother Plant Establishment (Weeks 5–16)

- After acclimatization, plantlets are transplanted into **2 L pots**.
- Substrate: peat + vermiculite or commercial mix.
- Runner production peaks after ~12 weeks.

Runner Collection and Rooting (Weeks 17–20)

- Runners are **severed** and embedded in peat:vermiculite mix (1:1).
- Tray density: 60 plantlets per tray.
- Initial rooting under **25 °C and 90% RH** for 1 week.
- Humidity gradually reduced; fertigation begins with ½ strength, then full.

Youngplants

- Youngplants are ready for berry production **6–10 weeks** after rooting.
- Plants begin **flower bud formation** in pots.

Nutrient Solution Management

For motherplants (EC 2.1 mS/cm):

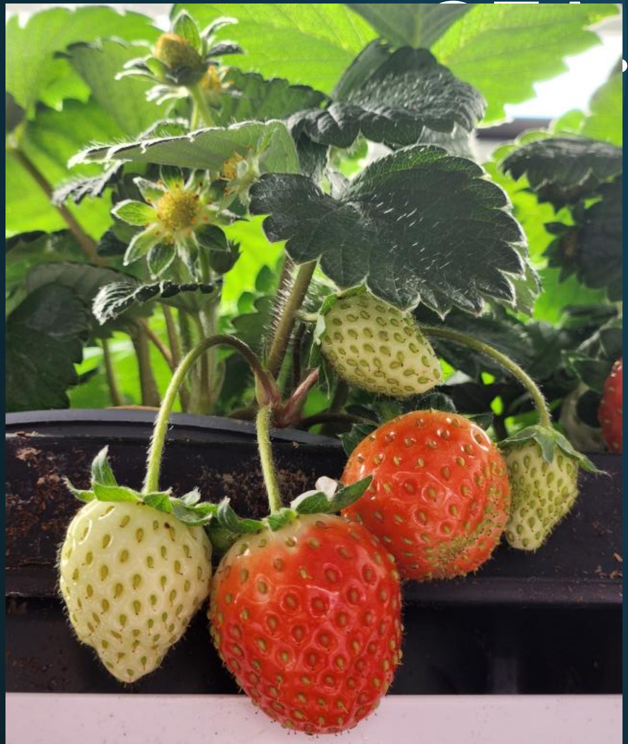
- $N\text{-}NO_3$: 9.7 | SO_4: 1.5 | P: 1 | $N\text{-}NH_4$: 1 | K: 4.75 | Ca: 3.16 | Mg: 0.93 (mmol/L)

For rosettes (first 3 weeks, EC 1.3 mS/cm):

- $N\text{-}NO_3$: 5 | SO_4: 0.89 | P: 0.7 | $N\text{-}NH_4$: 0.3 | K: 3 | Ca: 1.8 | Mg: 0.5 (mmol/L)

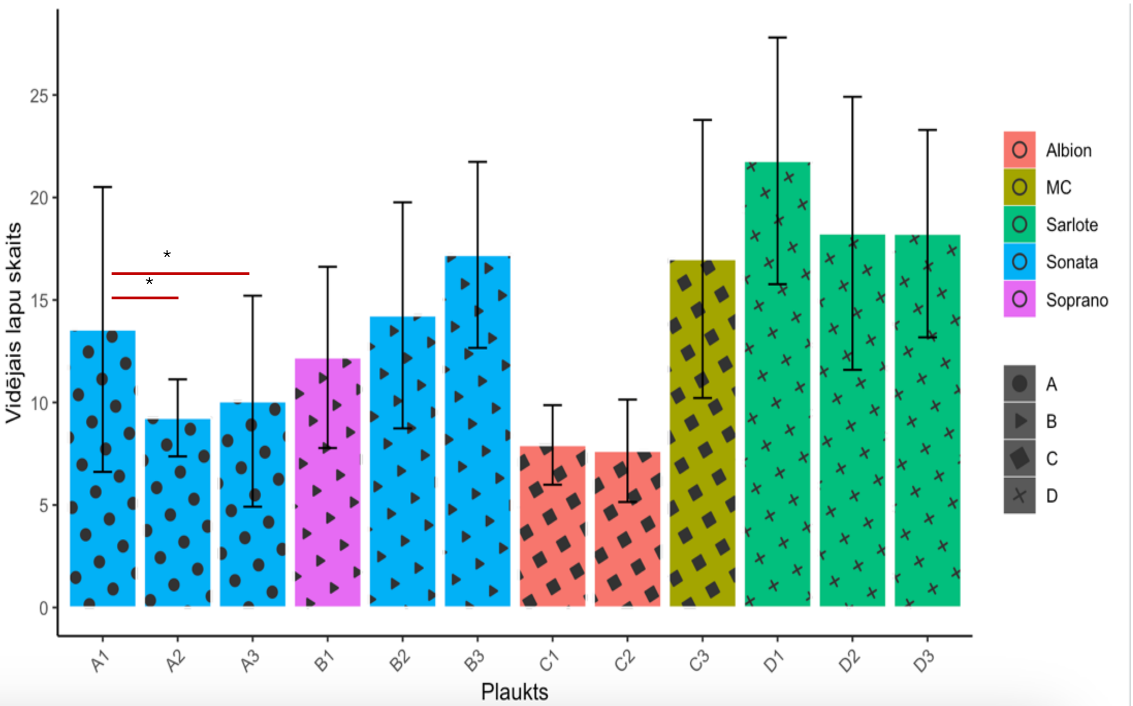
Watered as needed based on plant stage and uptake 1-2x per week

The yield potential of the grown youngplants is assessed in the plastic tunnel and



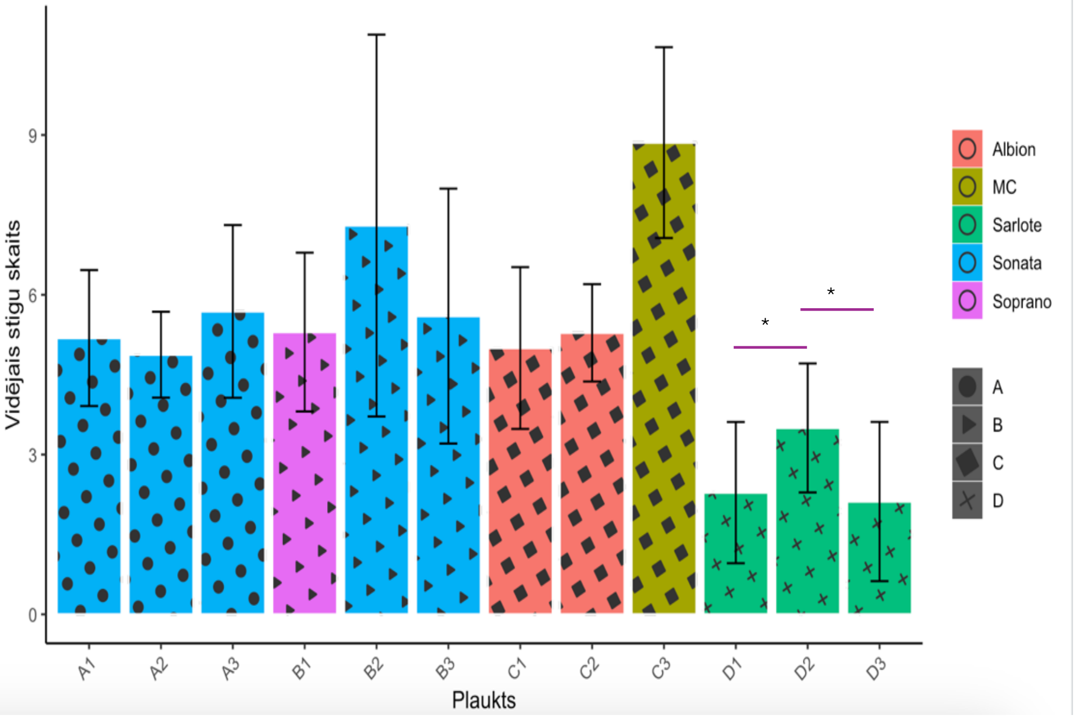
During cultivation, parameters were recorded for the mother plants :

- Average number of leaves.
- Average length of leaf stalk.
- Width and length of leaf blade.
- Average number of rosettes per plant.



Each strawberry cultivar demonstrated distinct patterns of runner formation and rooting success.

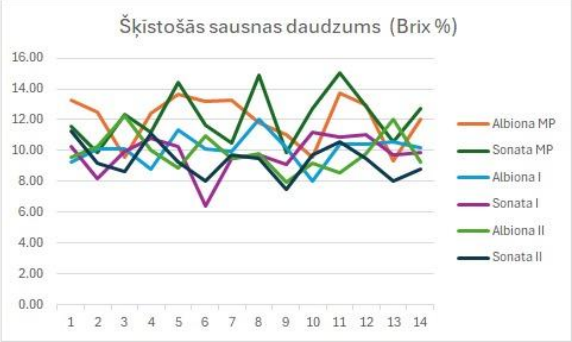
These differences highlight the importance of cultivar-specific approaches in runner-based propagation systems.

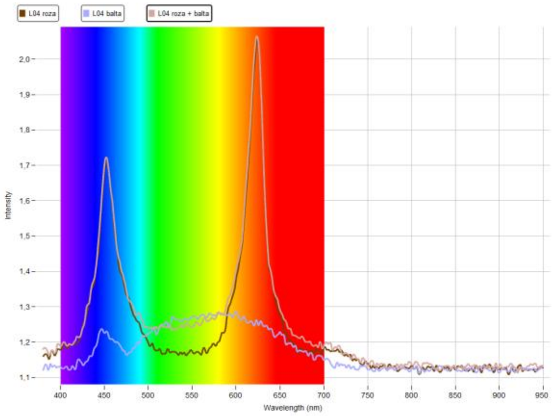


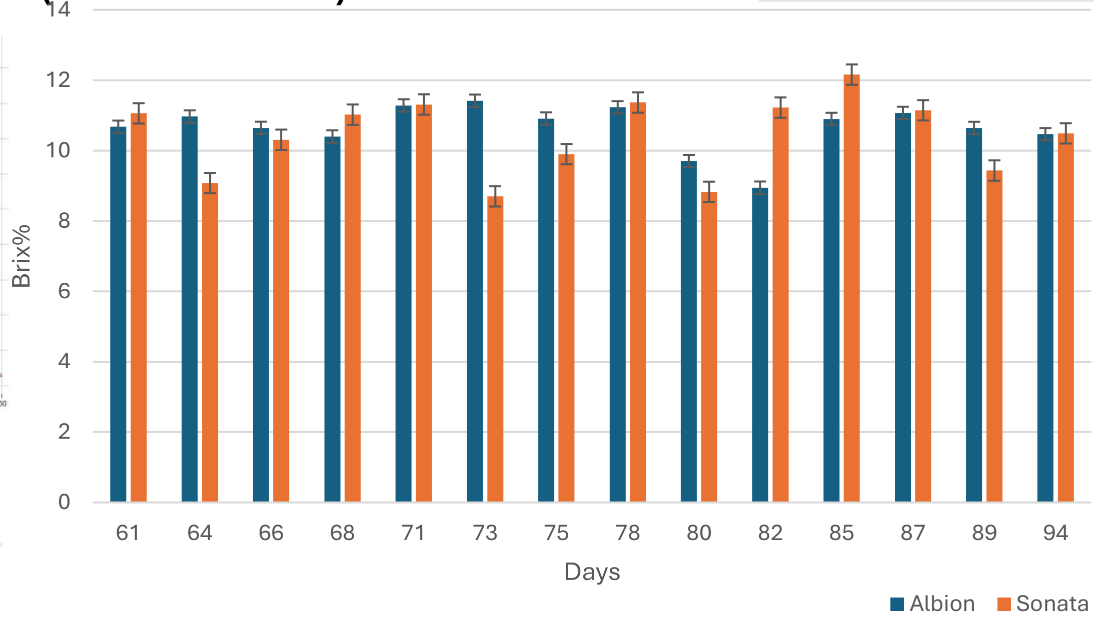
The **F-value** for runner number was calculated at **F(2, N)=27.61**, indicating statistically significant variability among cultivars.

Manual irrigation resulted in uneven water distribution, which contributed to significant fluctuations in soluble solids content (Brix%) among individual fruits.
Semi-automated irrigation in the next rotation improved uniformity of taste and Brix.

‘Albion’ 9.5% to 12.3% Brix (SD ≈ 0.9%), and **‘Sonata’** from **9.0% to 12.6%** (SD ≈ 1.1%)







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Conclusions and Perspectives

- 'Sonata' is the most effective cultivar for indoor farming, demonstrating high yield and berry production.
- Despite 'Charlote's' high BRIX percentage indicating a higher sugar content, its moderate growth and yield make it less suitable for consistent indoor cultivation compared to 'Sonata' and ‘Albion’.
- 'Albion' presents a balanced option with good berry quantity, weight, and moderate sugar content, although its performance is slightly overshadowed by 'Sonata'.
- Further research is needed to refine cultivation techniques and understand cultivar-specific responses to controlled environments.

Acknowledgements

EIP-AGRI project "Production of healthy planting material and testing of innovative growing methods for crops, significant for the national economy", contract number 22-00-A01612-000011.

Potato Minituber Cultivation Protocol CEA

'Frieslander'
Origin: The Netherlands
Maturity: Early cultivar (~70–85 days)
Yellow skin, light yellow flesh

'Agrie dzeltenie'
Origin: AREI Latvia
Very early cultivar (~65–75 days)
Yellow skin, yellow flesh

In Vitro Propagation Protocol for Potato

Rooting & Acclimatization

1. Rooted shoots transferred to perlite
2. Humidity gradually reduced during 2-week period
3. Cuttings ready for transfer to aeroponic systems

- **Explant Source**
  - Virus-free plantlets derived from meristem culture
  - Rooted in vitro and pre-acclimatized in perlite trays

  Culture Medium (per 1L)
  - MS macro- and micronutrients – 4.3 g
  - FeNaEDTA – 0.086 g
  - Thiamine HCl – 2.5 mg
  - Sucrose – 20 g
  - Agar – 6.0 g
  - pH adjusted to 5.7, autoclaved at 121°C for 20 minutes

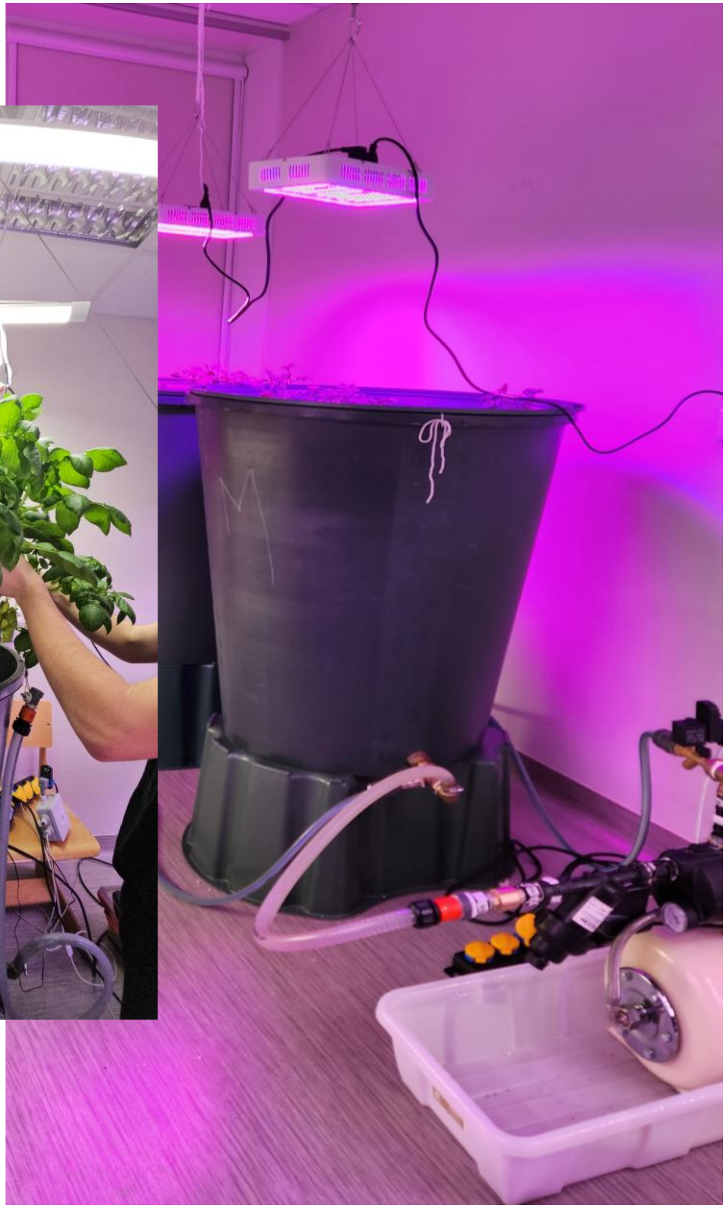
  Growth Conditions
  - Temperature: 16°C
  - Light: 16-hour photoperiod, ~150 μmol/m^2/s
  - CO_2: 500–600 ppm, RH ~60%
  - Subculture interval: Every 3 weeks

  Initiation
  - Cultured on standard MS medium with sugar and vitamins

  Multiplication
  - Shoots are subcultured every 3 weeks to fresh medium

Growing Systems

•**Aeroponic systems:**
•200–210 L tanks with perforated covers. Plants fixed using polyurethane plugs.
•Misting frequency: 10 seconds every 45 minutes, later gradually extended to every 3 hours.
•UV sterilization lamp or nutrient solution changed every 2 weeks.
•**Substrates:**
•Peat, vermiculite, perlite in 11 L containers in climate chambers.
•Greenhouse peat substrate enriched with topsoil, dolomite flour, clay, gravel, vermiculite, Osmocote, and *Trichoderma*.



Environmental Conditions

- **Temperature:** Day 22 °C, Night 19 °C
- **Photoperiod:**
  - First 30 days: 16 h day / 8 h night
  - Continuously short day (10 h) to stimulate tuberization
- **Humidity:** 60%
- **Root sprinkler**: 10 sec ON, 45 min OFF, 4-5 BAR water pressure.
- **CO_2 concentration:** 500–600 ppm
- **Lighting:** White LEDs ~150 μmol/m^2/s +R&B LEDS

Micronutrient solution

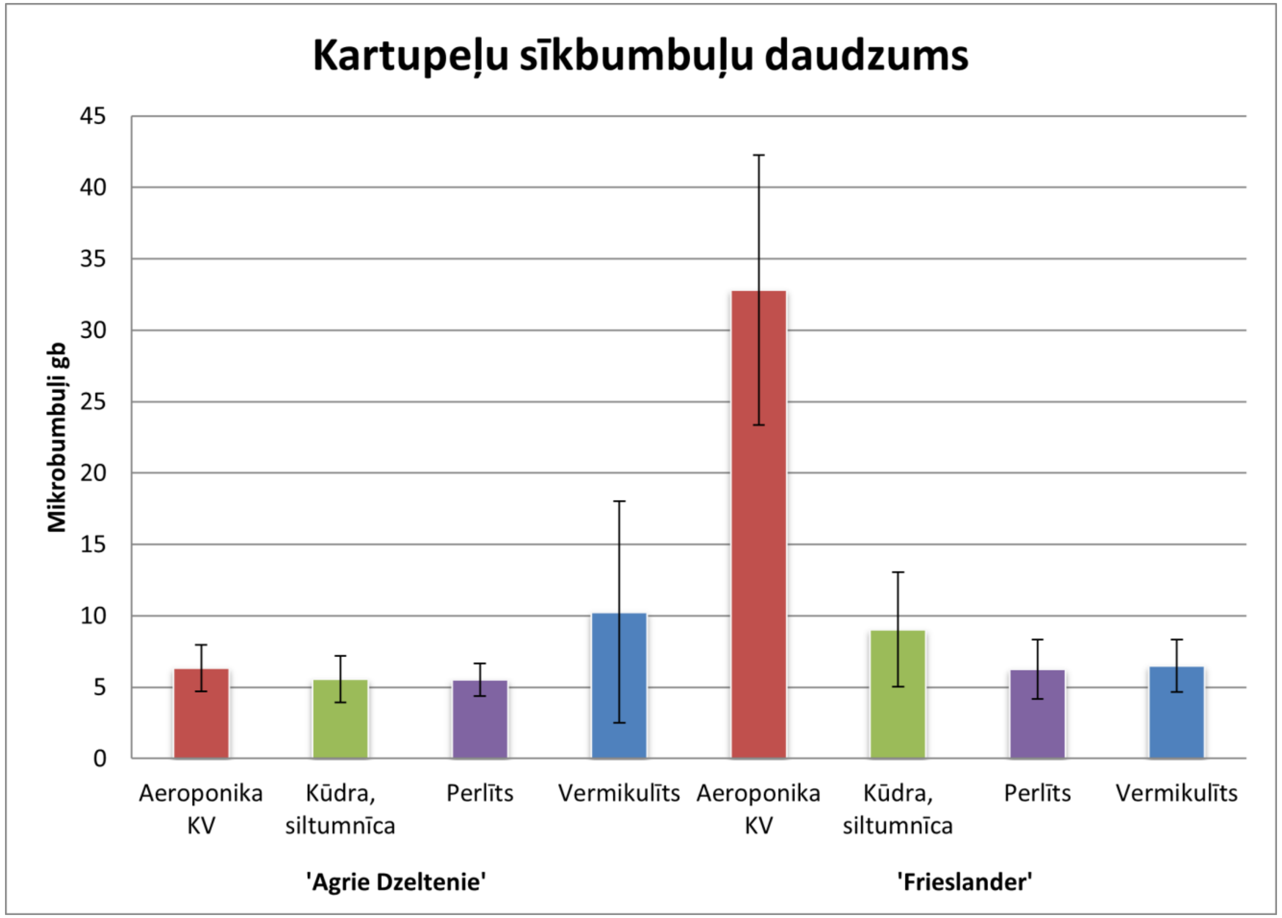
- Basic solution composition (macro-elements):

KH_2PO_4 – 120 mg/LK_2SO_4 – 400 mg/L$Ca(NO_3)_2$ – 1200 mg/L$MgSO_4$ – 650 mg/L

- Micronutrient solution:

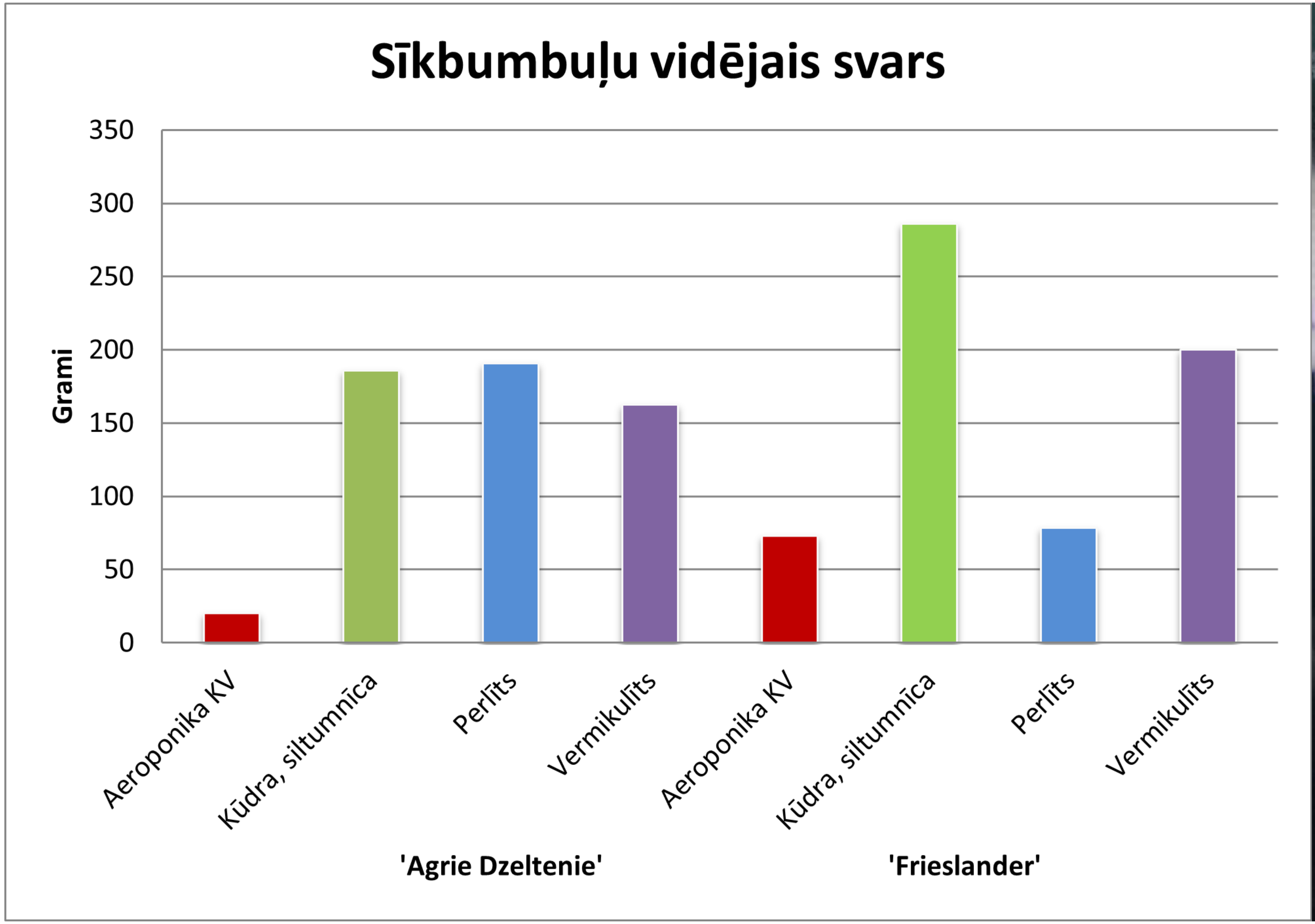
$ZnSO_4$ – 63 mg/LFe-DTPA – 630 mg/L$MnSO_4$ – 150 mg/LEDTA mix – 700 mg/L$NaMoO_4$ – 20 mg/L$CuSO_4$ – 8 mg/LH_3BO_3 – 300 mg/L

pH: 5.5–6.0H_2O_2: 20 ml added with each solution change 1x a week.



Aeroponics provides a higher yield of 25-40 tubers per plant, compared to the variety ‘Agrie Dzeltenie’, for which the change in cultivation technology did not significantly affect the yield, maintaining 5-10 tubers per plant.

The average number of produced minitubers varies significantly depending on the substrate used. $F(1, 213) = 36.898611$, $p < 0.00001$



For the variety ‘Frieslander’, the average weight of minitubers was higher when grown in peat and vermiculite compared to those grown in air or perlite, while for the variety ‘Agrie Dzeltenie’, the lowest tuber weight was observed under aeroponic conditions

Conclusions

- For the potato variety ‘Frieslander’, cultivation in aeroponics is a promising method for obtaining healthy planting material.
- For the variety ‘Agrie Dzeltenie’, changing the substrate does not affect yield.
- Aeroponic cultivation allows for a higher number of tubers due to repeated harvesting during the growth cycle.
- Substrate cultivation results in fewer but larger minitubers.

Soya ‘Erica’

Soybeans showed poor growth performance in aeroponic systems, while plants developed well in a peat and perlite mixture (3:1).

Unlike in field conditions, the soybeans exhibited vigorous vine-like growth, reaching up to 1.2 meters in height under white LED lighting at 150 μmol/m^2/s.

Yield 170 gr from 20 plants

Observations

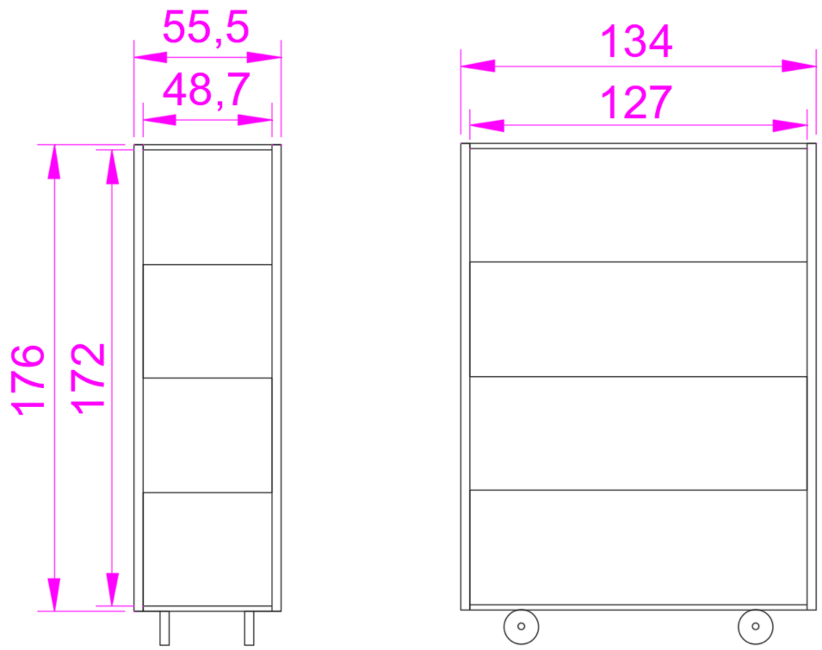
- Experimental yield: 3.4 tonnes per hectare
- Comparable to leading global soybean producers (USA, Brazil, etc.)
- Growing cycle: ~3 months → up to 4 harvests per year
- Even without optimization, CEA can offer 3× higher yield vs field conditions
- Further improvements possible: lighting spectrum, substrate composition, growth regulators, etc.

Yield 170 gr from 20 plants
Average number of pods per plant: 22
Average number of beans per plant: 47

Microgreens, sweet potatoes, rice, wheat, begonias, verbena etc

Climate chambers.

Multilayer Ebb&Flow



Automation Objectives and Concepts

Root Irrigation System Monitoring (Aeroponics)

Water level monitoring with capacitive sensors

Voltage detection to alert in case of power outages

Monitoring of irrigation using:

- **Fog sensors** – experimentally validated and functional
- **Humidity sensors** – tested but found unreliable due to condensation

Flood Table Automation fertigation (Strawberries)

Microcontroller-operated **inlet and drain valves**

Use of **float sensors** to detect water level and **leak sensors** on the floor

Option to control the system via **SMS or physical buttons**

Root Irrigation System Monitoring (Aeroponics)

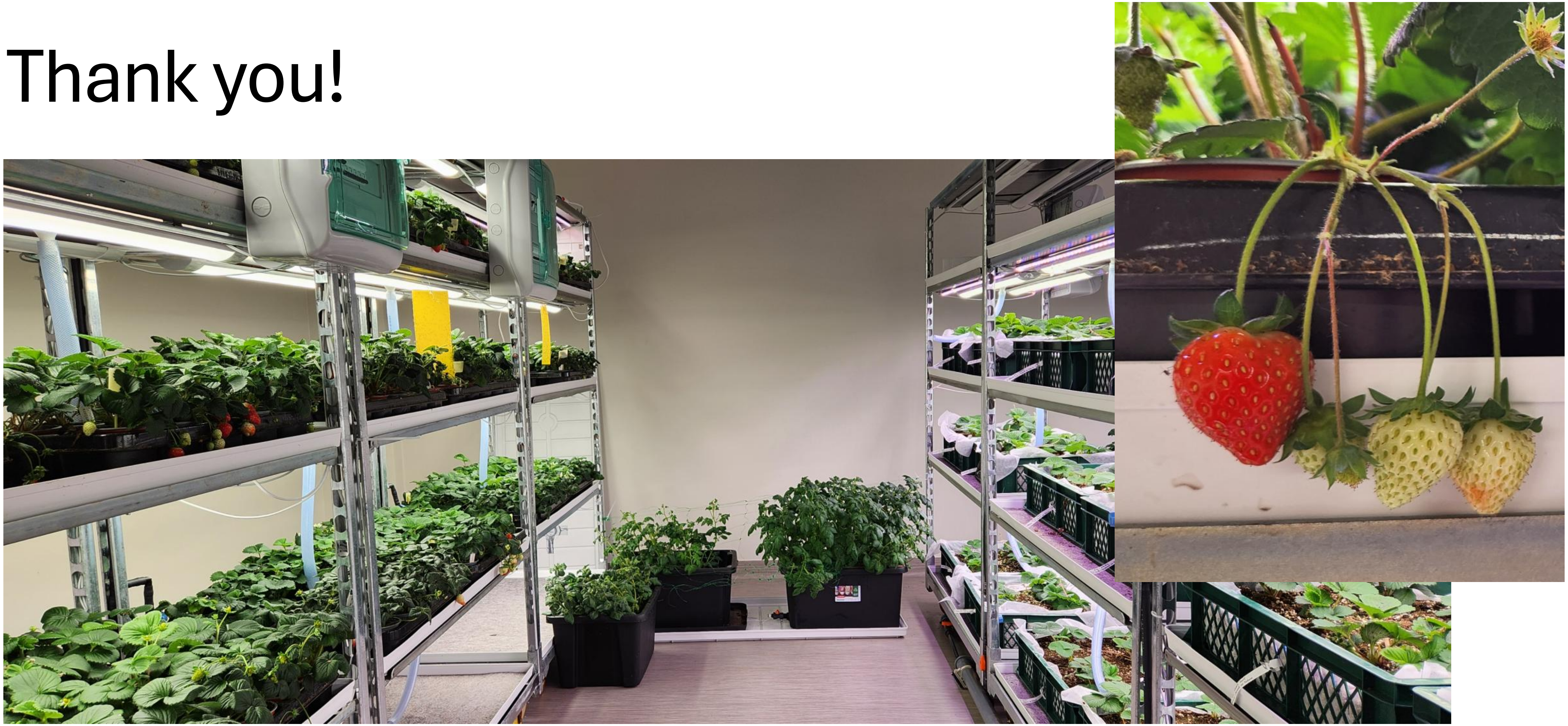
Planned Objectives	Achieved Results
Develop CEA technologies for strawberries, potatoes, soybeans	✓ Strawberry hydroponic protocol developed and validated for multiple cultivars
Establish disease-free in vitro propagation for high-value crops	✓ In vitro propagation + successful acclimatization for strawberries and potatoes
Test aeroponic cultivation of minituber potatoes	✓ Aeroponics increased tuber count to 25–40 per plant for 'Frieslander'
Trial hydroponic soybean cultivation	✓ Soybeans grew poorly in aeroponics but performed well in peat/perlite (3:1) → yield ~3.4 t/ha
Optimize light, substrate, irrigation parameters for CEA systems	✓ Identified suboptimal LED spectra → need for spectral optimization; semi-automation improved Brix
Automate and reduce human labor in plant cultivation	✓ Semi-automated irrigation reduced variability; multi-layer ebb & flow trays installed
Install 3 climate chambers and at least 1 double-deck ebb&flow system	✓ Climate chambers and 2-level irrigation systems implemented and tested
Evaluate quality of CEA-grown material	✓ Brix%, rooting rates, leaf and runner metrics measured and statistically analyzed (e.g., ANOVA: $p<0.001$)
Extend findings to other crops (e.g., herbs, microgreens, ornamentals)	✓ Begonias, verbena, sweet potato, rice, and wheat tested under CEA conditions

Conclusion: All core goals were met or exceeded.

🚀 Further Improvements & Future Focus

- **LED spectrum refinement:** match spectral needs for each crop stage
- **Automated nutrient control systems:** reduce risk of over-/under-supply
- **AI-driven climate management** to balance energy use & crop performance
- **Screening of new cultivars** specifically bred or selected for indoor systems, fast breeding
- **Increased mechanization** of transplanting and harvesting processes
- **Modular multi-crop vertical systems** for commercial rollout

Thank you!



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