Agriculture et Agroalimentaire Canada
Agriculture and Agri-Food Canada

Organic greenhouse soil-less growing systems for vegetables : a sustainable approach that respect organic principles

BioGreenhouse

COST
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

COST is supported by the EU Framework Programme Horizon 2020

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Agriculture and Agri-Food Canada
Agassiz Research & Development Centre

Organic farming - principles

Production systems that sustain the health of soils, ecosystems, and people

No GMO
No pesticides
No synthetic fertilizers
No growth hormones or antibiotics
No sewage sludge

Minimize system inputs
&
Environmental burdens

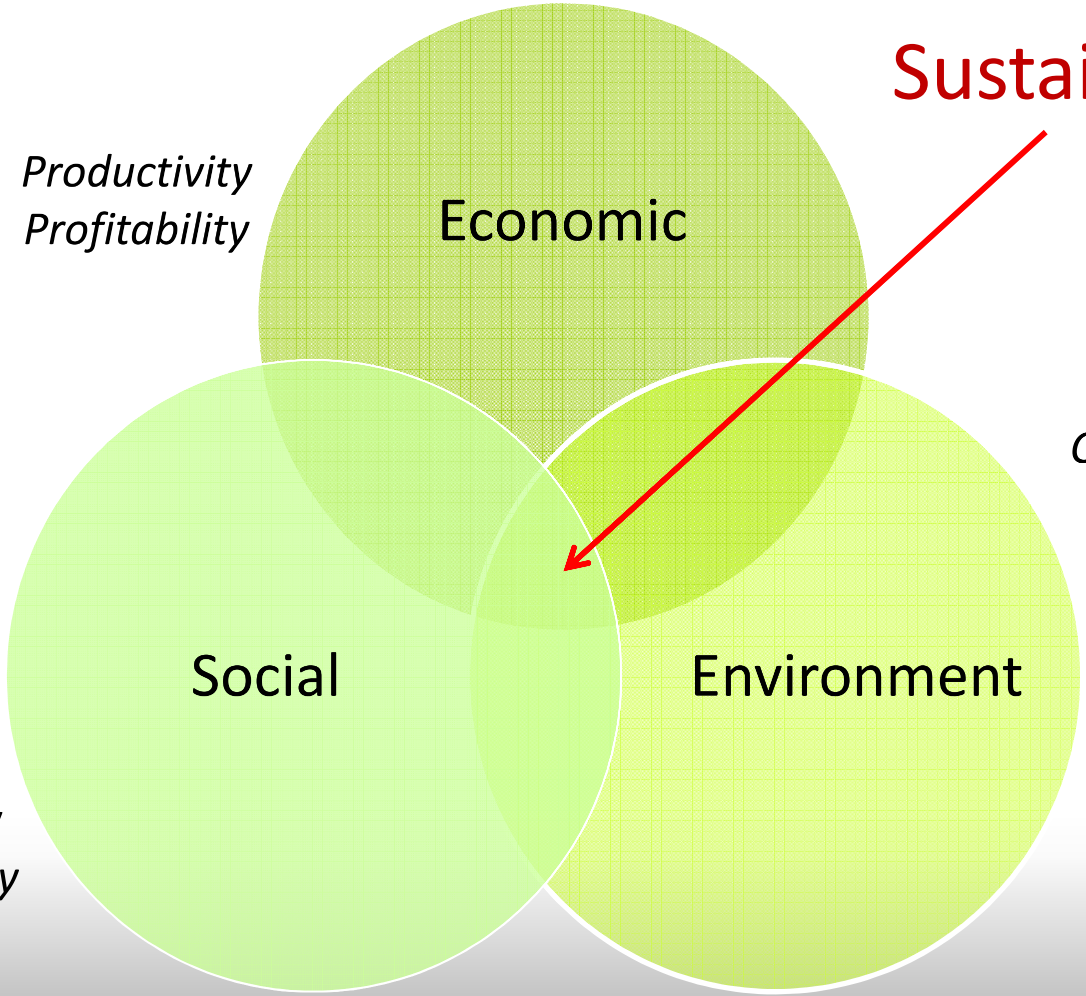
- Sustainable waste management
- Balanced nutrient approaches
- Soil and water conservation practices
- Mechanical and biological control of pests

✓ 87 countries have adopted organic standards
✓ 283 organic certification bodies worldwide
✓ 172 countries

To regulate the use of the term "organic," protect consumers, and facilitate trading between countries

Sustainable production system

Productivity
Profitability

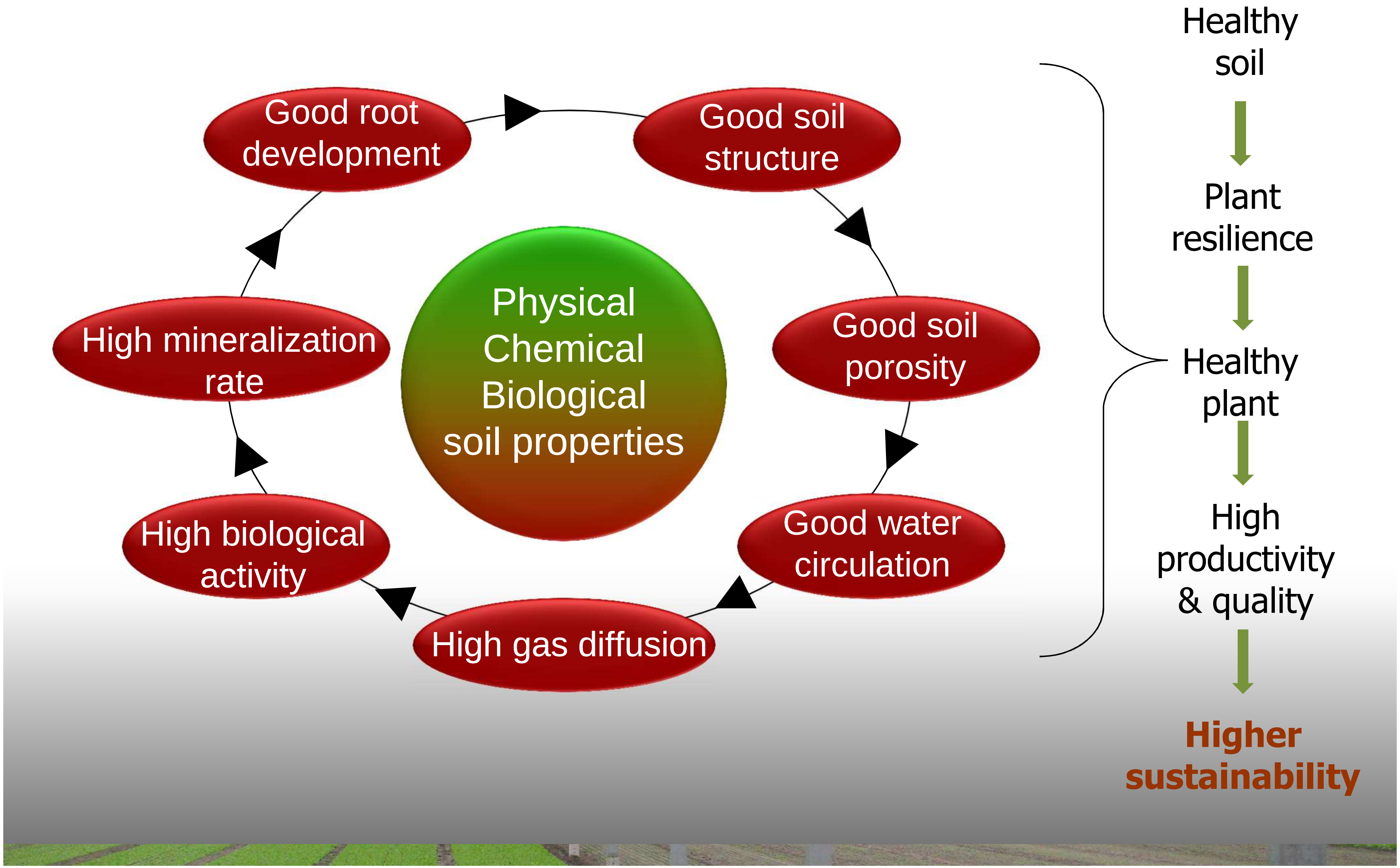


Quality
Safety
Equity
Traceability
Food security

Energy
Irrigation
Fertilization
Pest management
Crop production systems
Waste management
Packaging/Processing
Transport

« system development that meets the needs of the present without comprising the ability of future generations to meet their own needs »

Optimal soil characteristics



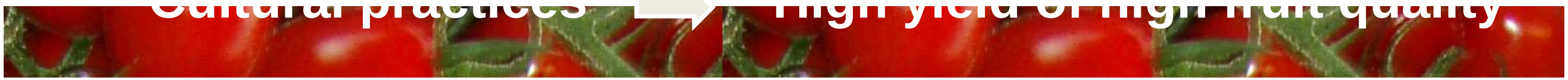
Challenge of organic horticulture farming

Soil nutrient release that will perfectly match plant nutrient uptake, without any leaching or emissions into the environment

- ✓ Balanced fertilizers/amendments

  ↳ Plant nutrient uptake

- ✓ High mineralization rate ➡ High nutrient plant demand
- ✓ Optimal fertilization ➡ Limit salinization + GHG emission
- ✓ Optimal irrigation ➡ No nutrient leaching (*e.g.* N, Ca, Mg)



Organic farming – productivity

Commercial level : Yield in organic growing systems is generally **20%** lower than in conventional crops

In the **scientific literature** yields of organic field fruits and vegetables reached on average **90%** of conventional yields, and yields of **organic high-tunnel and greenhouse crops** are slightly higher or **similar** of conventional yields

- Suitable cultivars and rootstocks adapted to organic
- Long-term beneficial effects on soil
- New biological control agents (e.g. predators, biopesticides)
- Appropriate know-how (fertilization, innovative growing systems)
- Demarcated bed-grown growing systems

Productivity of organic fruits and vegetables may perform as conventional crops

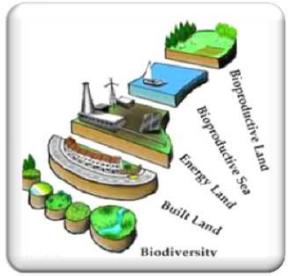
(Dorais and Alsanius, 2015)

Organic farming – productivity

Examples of relative organic greenhouse vegetable yields of organic and conventional agricultural practices

Crop	Unit	Organic	Conventional	Org/Conv	Country
Pepper	g/fruit	176	200	0.88	Spain[1]
Tomato	Kg/m^2	45	65	0.69	NL[2]
Tomato	g/plant/wk	373–376	313–442	0.85–1.19	NL[3]
Tomato	g/plant/wk	690–948	707–1,168	0.81–1.00	Canada[4]
Tomato	kg/m^2	49–53	52–53	0.94–1.02	Canada[5]
Tomato	g/plant	3.5–2.0	3.0–1.8	1.15–1.18	USA[6]

Footprint of organic farming



Meta-analyses
Life cycle assessment

Energy analysis
Decision support systems

Environmental benefits

Higher biodiversity

Water & soil conservation

May reduce soil CO_2 emission

Increase C sequestration

Environmental disavantage

Lower land-use efficiency

- lower yield

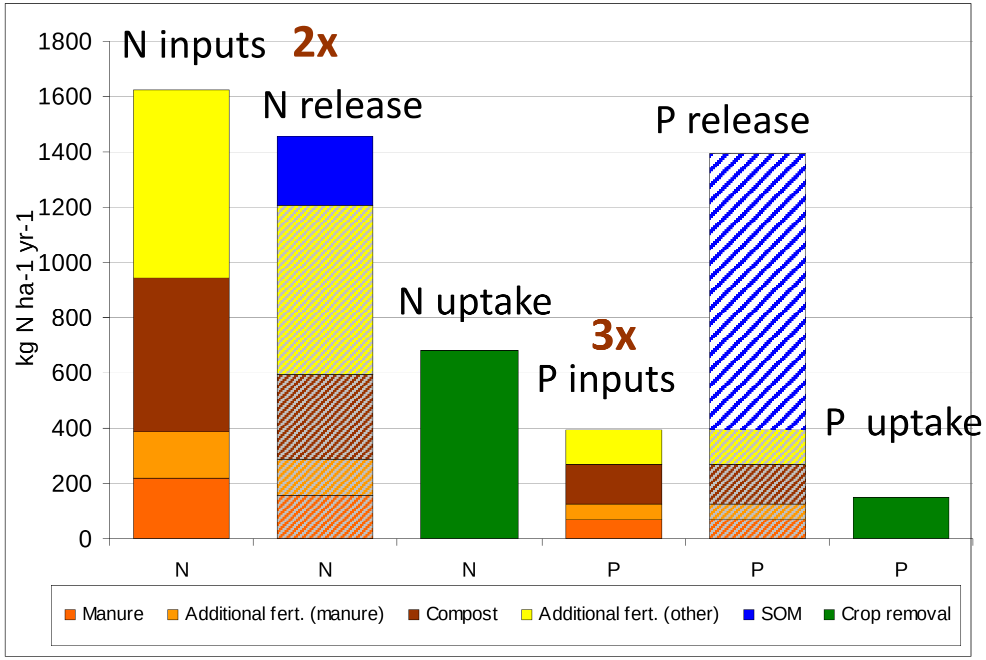
Per unit cultivated area

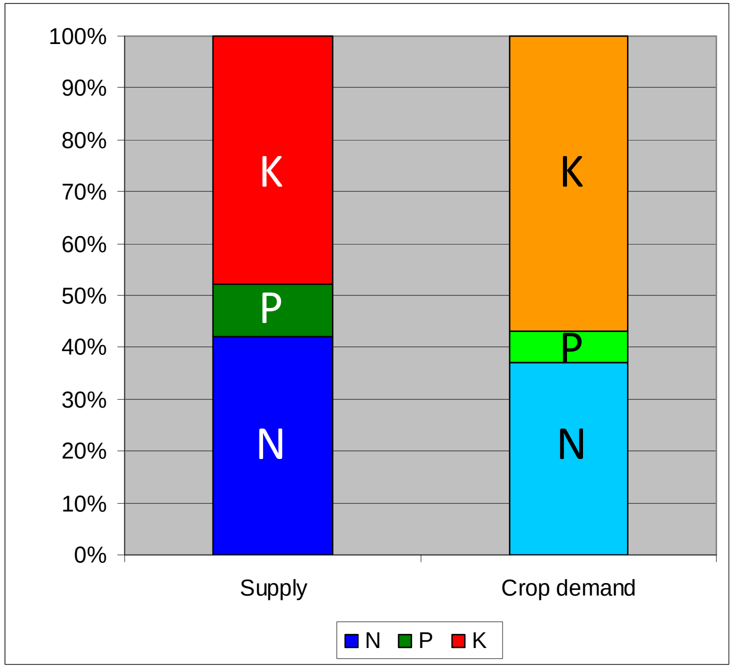
- Higher soil organic content
- Lower nutrient losses
  - N leaching
  - N_2O & NH_3 emission

Per product unit

- **Higher N losses**
- Lower energy requirement (field)
- **Higher energy requirement** (greenhouse)
  - ✓ Prevent foliar disease
  - ✓ Control higher air humidity

Soil fertility – Organic greenhouse fruit vegetables





Average yearly N and P inputs and uptake, in eight organic vegetable greenhouses (2002–2009). Inputs are divided over total manure, compost and additional fertilizers, compared with the estimated available N and P by fertilizer mineralization and soil organic matter (SOM) and the soil buffer (for P the hatched bar). The uptake is the result of the monitored crop N and P removal.

Mutual ratios of the N P and K supplied in total by fertilizers and soil amendments and of the crop demand, based on the crop removal, at the eight monitored greenhouses.

(Voogt et al., 2012)

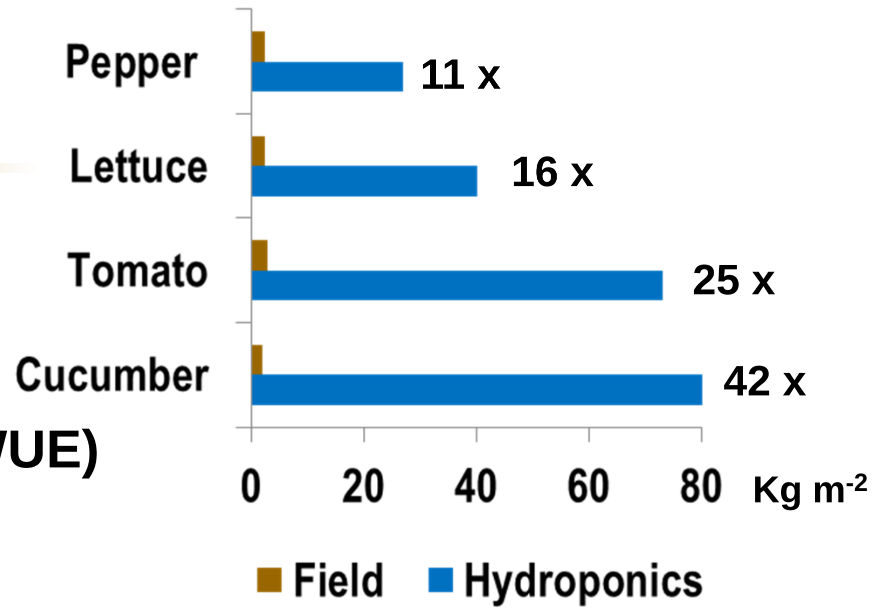
Soilless organic growing systems

Why?

- To reduce any risk related to soil-borne diseases
- To achieve high yield & high fruit quality
- To reduce nutrient run off into ground water
- To recycle crop effluent
- To achieve optimal nutrient crop management

Soilless hydroponics

⇨ Up to 108 900 ha (23%)



Sustainability improvement:

- **Use 70 to 90% less water (>WUE)**
- **Limited nutrient run off**
- **Higher nutrient use efficiency**
- **Better control of root diseases**
- **No culture limitation on unproductive soils**
  - ⇨ **salinized, contaminated, degraded or arid soils**
- **Substrate moisture content uniformity**
- **Higher yield & higher fruit and vegetable quality**

Gary W. Hickman, 2013; www.cuestaroble.com

Main organic greenhouse regulation

USDA NOP

- ✓ Living soil & growing media
- ✓ No minimal volume
- ✓ Hydroponics is allowed

CAN/CGSB-32.310-2015

- ✓ Living soil & growing media
- ✓ > 70 L/m^{-2}
- ✓ Hydroponics is prohibited

EC 834/2007

Max supply of animal manure
170 kg N /ha ≠ 1,250 kg N/ha

No EU regulation for:

- water use – leaching
- energy use (country-specific)
- CO_2 & light (country-specific

IFOAM EU GROUP

⇨ Soil fertility : based on crop rotation and green manure – plan on soil fertility : NUE, soil health
⇨ Max of 50% of nutrients provided after planting
⇨ Max of 25% of fertilizers allowed in liquid form
⇨ CO_2 coming from by-product
⇨ Energy analysis if > 130 kWh/m^2 fossil fuels

EGTOP recommendations (2013)

- ✓ More efficient use of external inputs
- ✓ Responsible energy use
- ✓ Artificial lighting (max. 12h) and CO_2 enrichment are acceptable
- ✓ Nutrients from slow release fertilizers – input/output balance
- ✓ Sustainable water management
- ✓ Irrigation to flush surplus nutrients is not acceptable
- ✓ Peat should not be use for soil conditioner

Organic growing system using raised bed containers and nutrient recycling

⇨ 70-100 L soil per m^2	Yield		Marketable fruits #1
Treatment	Fruit size (g)	Total (kg m^{-2})	(kg m^{-2})
Organic 1th crop	140c	44.6b	38.3b (86%)
Organic 2nd crop	158a	53.5a	45.2a (84%)
Conventional	147b	52.6a	47.2a (90%)
P value	*0.001*	*0.003*	*0.009*

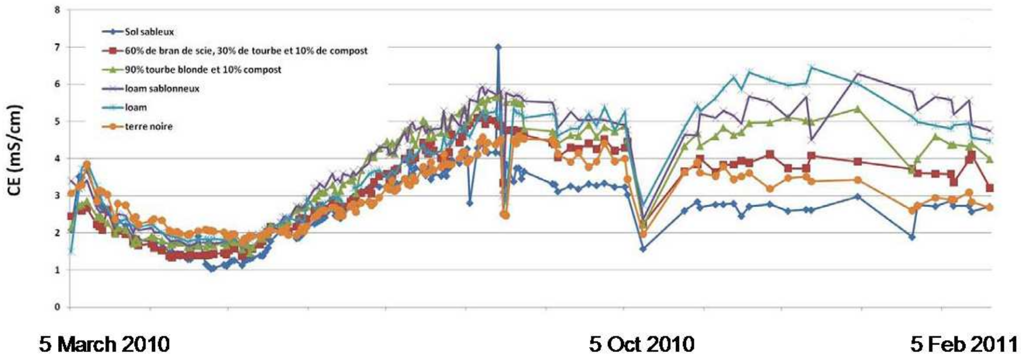
Values within a column followed by the same letter are not significantly different (Tukey test P≤0.05).
Values are a mean of 3 replicates.

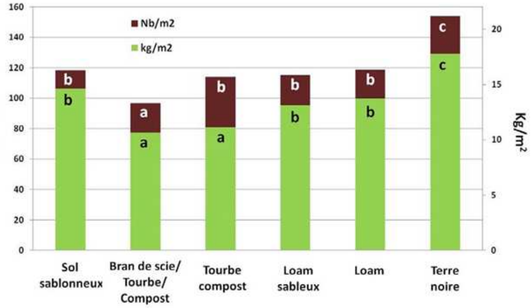
	% Dry matter	Lycopene (mg/kg)	b*	Titratable acid	Antioxidant capacity
Organic 1th year	4.8 a	42.7 a	18.0 b	0.41 ab	22.9 a
Organic 2nd year	4.4 a	45.5 a	18.8 b	0.39 b ↓	18.1 b ↓
Conventional	4.7 a	45.8 a	27.2 a	0.44 a	23.8 a
P value	0.074	0.366	0.002	0.006	0.002

Gaia Green 4-4-4
Seaweed extract 0,5-0,2-17 (Distrival Ltd)

Acta Hort 915:69-74
Acta Hort 915:83-89

Effluent recycling – build-up of salinity





Increase in anion concentration in the soil solution sampled using suction lysimeters during the production period.

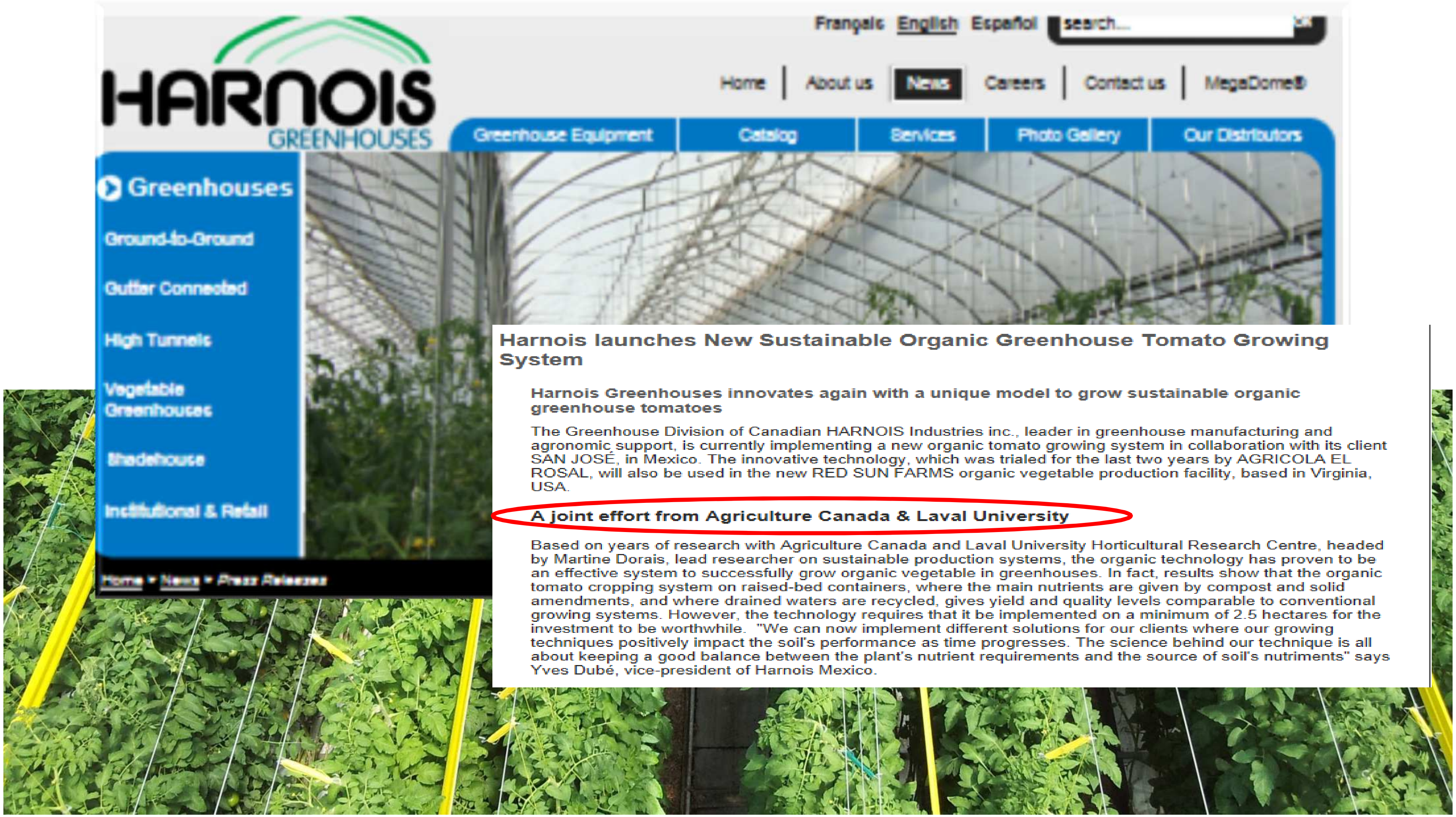
	Anion accumulation increase (x-fold)[1]			
	Cl^-	SO_4^{-2}	PO_4^-	NO_3^-
Sandy soil	3.8±3.6	6.2±3.5	0.4±0.22	17.8±14.1
Peat, sawdust, compost	2.6±1.8	5.0±3.1	0.4±0.27	36.8±33.3
Peat, compost	3.5±0.8	5.5±1.7	0.2±0.04	14.2±6.7
Sandy loam	3.4±0.5	6.4±3.1	0.5±0.01	12.7±3.9
Loam	3.2±0.8	7.0±1.4	0.7±0.19	7.2±1.4
Muck soil	2.4±1.5	9.6±4.7	0.8±0.04	5.2±3.6

SO_4 : 24 to 1157 mg L^{-1}
NO_3: 180 to 1385 mg L^{-1}
Cl: 130 to 330 mg L^{-1}

→ Feather meal
Shrimp meal

⇨ Selection of organic amendments/fertilizers is really important to limit the buildup of salinity

Commercial soilless organic growing systems



Harnois launches New Sustainable Organic Greenhouse Tomato Growing System

Harnois Greenhouses innovates again with a unique model to grow sustainable organic greenhouse tomatoes

The Greenhouse Division of Canadian HARNOIS Industries inc., leader in greenhouse manufacturing and agronomic support, is currently implementing a new organic tomato growing system in collaboration with its client SAN JOSÉ, in Mexico. The innovative technology, which was trialed for the last two years by AGRICOLA EL ROSAL, will also be used in the new RED SUN FARMS organic vegetable production facility, based in Virginia, USA.

A joint effort from Agriculture Canada & Laval University

Based on years of research with Agriculture Canada and Laval University Horticultural Research Centre, headed by Martine Dorais, lead researcher on sustainable production systems, the organic technology has proven to be an effective system to successfully grow organic vegetable in greenhouses. In fact, results show that the organic tomato cropping system on raised-bed containers, where the main nutrients are given by compost and solid amendments, and where drained waters are recycled, gives yield and quality levels comparable to conventional growing systems. However, the technology requires that it be implemented on a minimum of 2.5 hectares for the investment to be worthwhile. "We can now implement different solutions for our clients where our growing techniques positively impact the soil's performance as time progresses. The science behind our technique is all about keeping a good balance between the plant's nutrient requirements and the source of soil's nutriments" says Yves Dubé, vice-president of Harnois Mexico.

Demarcated beds

- 60 cm x 30 cm
- 150-180 L/m^2
- Weekly fertilization
- Active soil
- 3% drained water

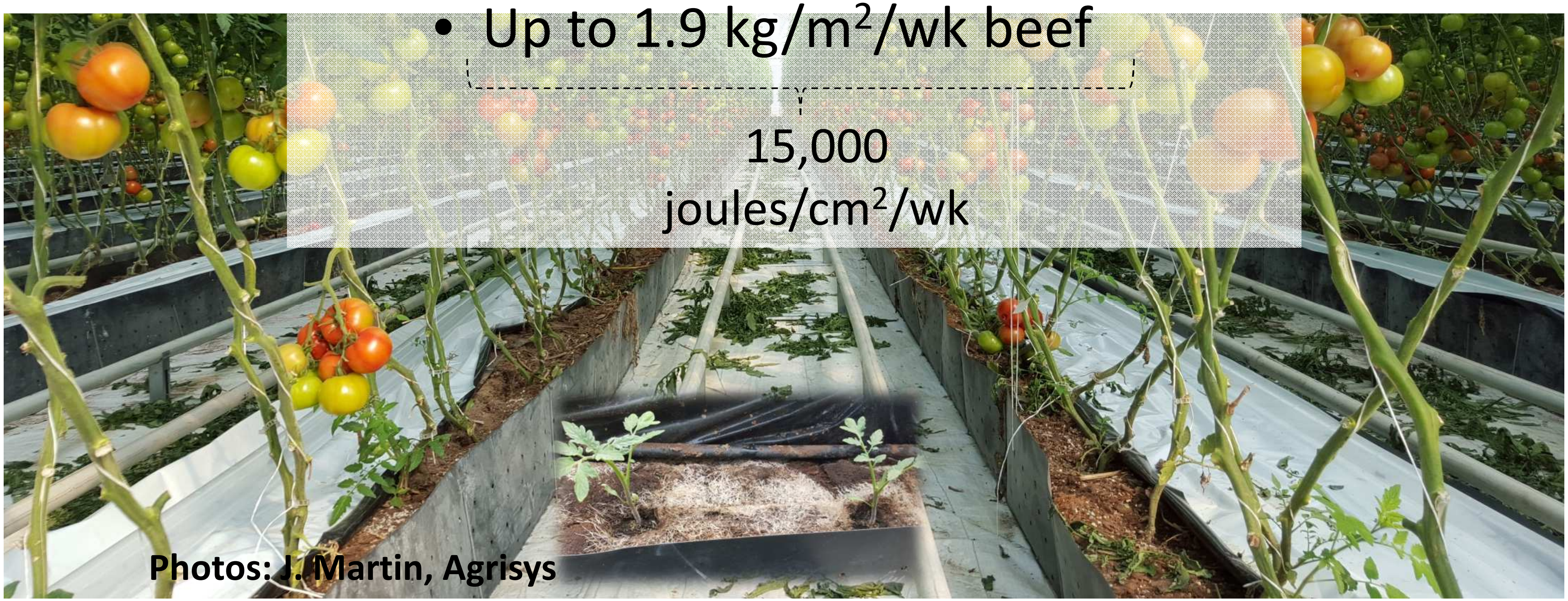
Photos: J. Martin, Agrisys

Commercial greenhouse – soil to demarcated beds

High yield of high quality fruit

- Up to 1.6 kg/m^2/wk TOV
- Up to 1.9 kg/m^2/wk beef

15,000 joules/cm^2/wk



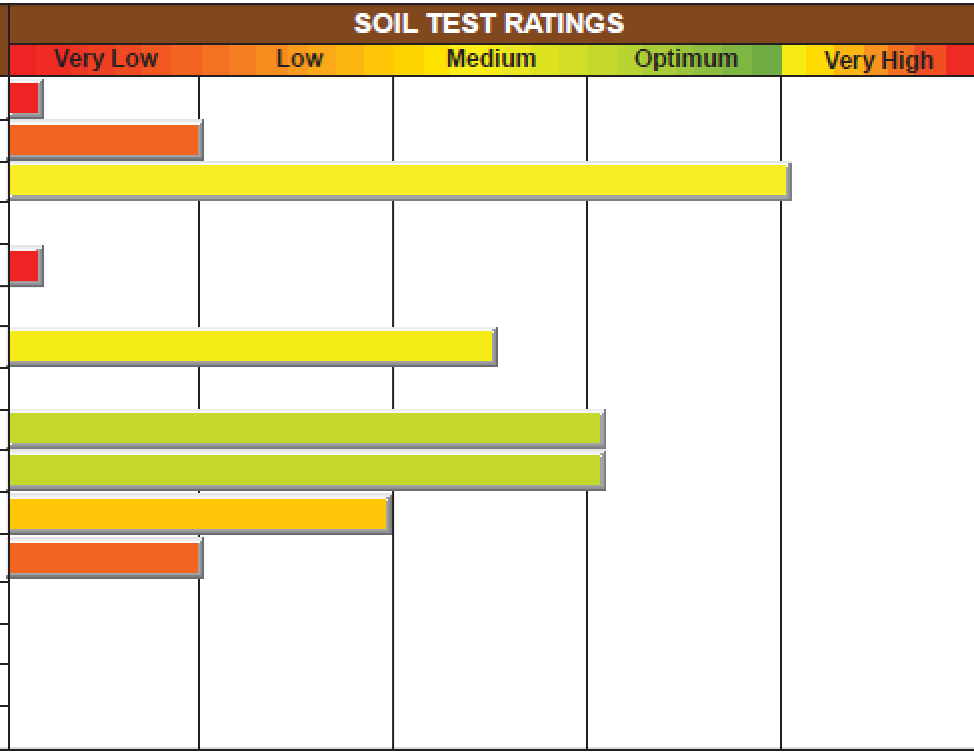
Photos: J. Martin, Agrisys

Other types of soilless organic growing systems

Other types of soilless organic growing systems

EXTRACTABLE NUTRIENTS

Test	Result	Sufficiency Factor
Available-N	5 ppm	0
Phosphorus (P) - Olsen	238 ppm	0.3
Potassium (K)	4128 ppm	2.6
Potassium - sat. ext.	6.2 meq/L	
Calcium (Ca)	247 ppm	0.1
Calcium - sat. ext.	0.3 meq/L	
Magnesium (Mg)	363 ppm	0.6
Magnesium - sat. ext.	0.4 meq/L	
Copper (Cu)	0.8 ppm	0.8
Zinc (Zn)	3 ppm	0.9
Manganese (Mn)	3 ppm	0.4
Iron (Fe)	7 ppm	0.2
Boron (B) - sat. ext.	0.12 ppm	0.4
Sulfate - sat. ext.	0.3 meq/L	0.1
Exch Aluminum		



NO3-N
3 ppm
NH4-N
2 ppm
Total Exchangeable Cations(TEC)
77 meq/kg

Cu, Zn, Mn and Fe were analyzed by DTPA extract.

PARTICLE SIZE ANALYSIS

Half Sat	Organic Matter	Gravel Coarse 5-12	Gravel Fine 2-5	Sand Very Coarse 1-2	Sand Coarse 0.5-1	Sand Med. to Very Fine 0.05-0.5	Silt .002-.05	Clay 0-.002	USDA Soil Classification
574 %									

Weight Percent of Sample Passing 2mm Screen (Sand, Silt, Clay)

Soil & Plant Laboratory, Inc.
Leaders in Soil & Plant Testing Since 1946
4741 E. Hunter Ave, Suite A Anaheim, CA 92807 714-282-8777 (phone) 714-282-8575 (fax)
www.soilandplantlaboratory.com

SOIL ANALYSIS

Send To :	Project :	Report No :	13-030-0006
Patromex	Agrococo	Cust No :	01298
29425 Crown Ridge		Date Printed :	02/11/2013
Laguna Niguel CA 92677		Date Received	01/30/2013
		Page :	1 of 1
		Lab Number :	91637

Sample Id : **PTM/M/00-Medium Grade**

SATURATION EXTRACT - PLANT SUITABILITY

Test	Result	Effect on Plant Growth: Negligible	Sensitive Crops Restricted	Many Crops Restricted	Only Tolerant Crops Satisfactory	Few Crops Survive
Salinity (ECe)	1.3 dS/m					
Sodium Adsorption Ratio (SAR) *	5.37					
Boron (B)	0.12 ppm					
Sodium (Na)	3.3 meq/L					
Chloride (Cl)						
Carbonate (CO3)						
Bicarbonate (HCO3)						
Fluoride (F)						

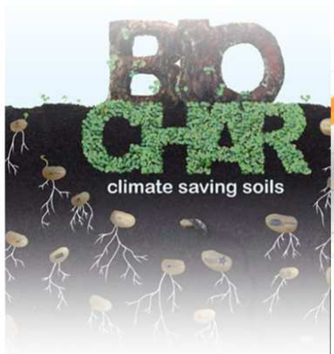
* Structure and water infiltration of mineral soils potentially adversely affected at SAR values higher than 6.

Test	Result	Strongly Acidic	Moderately Acidic	Slightly Acidic	Neutral	Slightly Alkaline	Moderately Alkaline	Strongly Alkaline	Qualitative Lime
pH	6.0 s.u.								None

Biochar soil amendment to improve soil quality

"Charcoal from the thermal decomposition (pyrolysis) of C-rich biomass materials"

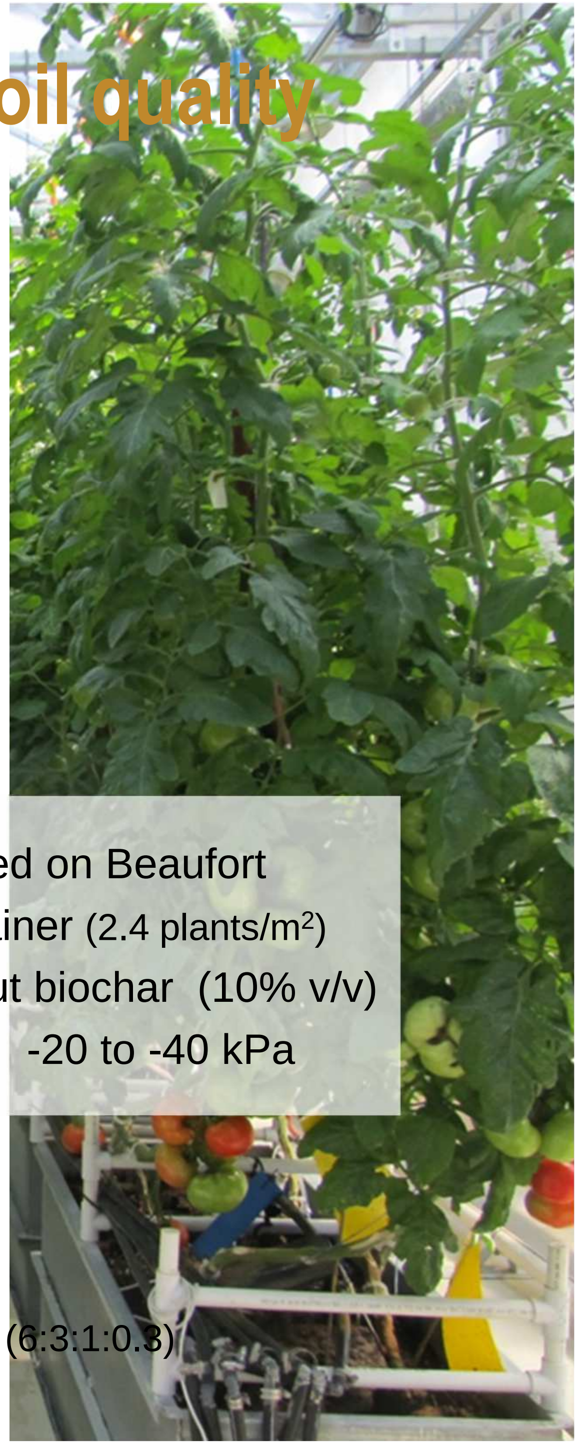
- Promote microbial activity
- High capacity of nutrient retention
- Reduce the GHG



Soil-grown plants in demarcated beds

1. Sandy Soil
2. Sandy Loam
3. Loam
4. Muck Soil
5. Peat & Compost & Clay (9:1:0.3)
6. Sawdust & Peat & Compost & Clay (6:3:1:0.3)

- cv Trust grafted on Beaufort
- 0.62 m^3 container (2.4 plants/m^2)
- With or without biochar (10% v/v)
- Irrigation : φm -20 to -40 kPa



Biochar effects on soil quality

Limiting Factor	Parameter	Problem	Role of biochar
Physical	Structure	Compaction	• Decreases bulk density
	Erosion	Erodibility	• Higher infiltration capacity
	Humidity	Soil drying	• Increases soil water retention

(adapted from Shrestha & Lal, 2006)

Summary – after 3 years of biochar amendment (10%, 10% and 20%)

Biochar had little or **no significant effect** on :

- Plant growth & total yield
- Root mycorrhization
- Leaf nutrient content

Significant effect of biochar on :

- Higher soil biological activity (FDA)
- Higher soil nutrient content (except Ca and Zn)
- Reduction of CO_2 flux (1^{st} and 2^{nd} years)
- Reduction of 30 to 50% N leaching
- Reduction of fruit cuticle cracking (2^{nd} year)
- Reduction of nb earthworms per m^2

Three year experiment – biochar amendment

Adding 10% to 20% (v/v) biochar to soils of organic greenhouse tomato **increased soil biological activity** and **nitrogen retention** resulting in lower nitrogen leaching and improved crop system sustainability

Different types of soil

No significant effect on productivity

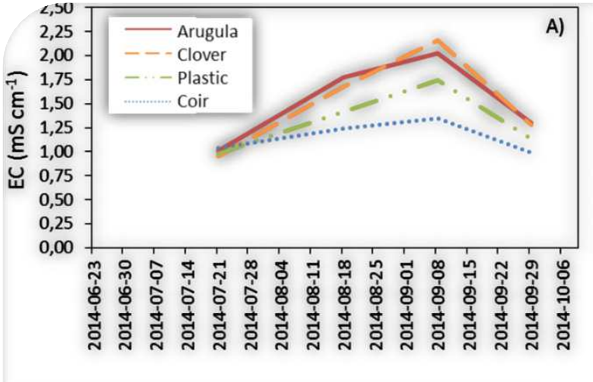
↓ fruit cracking

Organic cucumber grown in demarcated beds

2014-2015 trials
Les Serres Lefort & Laval University

1. Living mulches would increase soil activity and plant nutrient availability;
2. Weekly application of amendments would better match plant nutrient requirement compared to bi-monthly, three week-interval and monthly applications.

Effects of mulch treatments



No effect:

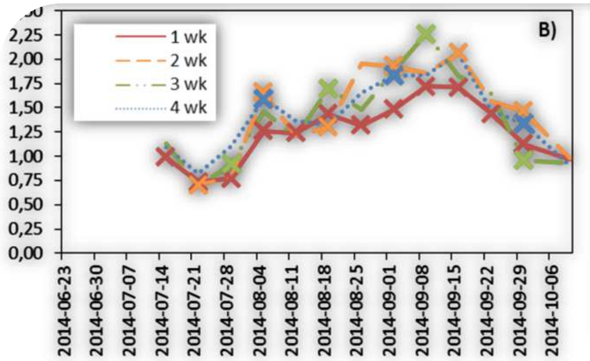
- crop productivity
- fruit quality

Had an effect on:

- soil EC
  Coir < leaving mulches
- microbial activity
  plastic > clover living mulch

Variables (n=8)	Mulch treatments: Plastic	Coir	Arugula	Clover	SEM	P value
FDA (µg fluorescein per g soil h^{-1})	166.9[a]	154.9[ab]	160.0[ab]	151.0[b]	6.6	0.0520
CO_2 efflux (µmol m^{-2} s^{-1})	11.7	11.2	8.2	7.3	1.4	0.1408
Weekly apex growth (length, cm)	65.0[ab]	65.8[ab]	67.1[b]	64.8[a]	2.0	0.0347
Stem diameter (cm)	0.75	0.76	0.75	0.75	0.01	0.8942
Length of mature leaf (cm)	24.5	24.8	25.1	24.9	0.6	0.2163
Fruit size (g)	402	400	397	396	7	0.9111
Yield (kg $plant^{-1}$)	5.9	6.1	5.8	5.7	0.2	0.5629
(fruits $plant^{-1}$)	15.0	15.5	15.0	14.6	0.3	0.4329
Marketable fruits (Nb fruits m^{-2})	35.1	36.3	34.8	34.0	0.3	0.3617
Fruit quality Dry matter (%)	3.6	3.5	3.6	3.6		NS
Soluble sugars (Brix)	2.9	2.9	2.9	2.9		NS
Electrical conductivity (mS cm^{-1})	4.8	4.7	4.7	4.7		NS
Titratable acids (% citric acid)	0.12	0.12	0.12	0.12		NS

Effects of fertilization frequency treatments



Increasing the number of fertilization events did not have any effect on :

- ✓ Soil biological activity
- ✓ Plant growth
- ✓ Productivity
- ✓ Fruit quality

Variables (n=8)		Fertilization frequency treatments 1 week	2 weeks	3 weeks	4 weeks
FDA (µg fluorescein per g soil h^{-1})		160.4	147.2	139.2	154.7
Root mycorrhization (%)		8.9	10.1	19.5	8.6
CO_2 efflux (µmol m^{-2} s^{-1})		11.5	10.6	14.3	13.0
Apex growth (length, cm)		60.1	60.5	60.3	57.6
Stem diameter (cm)		0.73	0.74	0.74	0.73
Length of mature leaf (cm)		25.1	24.8	24.3	24.3
Fruit size (g)		396	392	395	388
Yield	(kg $plant^{-1}$)	5.5	5.4	5.4	5.3
	(fruits $plant^{-1}$)	14.3	14.0	13.9	13.8
Marketable fruits (Nb fruits m^{-2})		33.4	32.6	32.7	32.0
Fruit quality	Dry matter (%)	4.0	4.0	4.0	3.9
	Soluble sugars (Brix)	3.0	3.0	3.0	3.0
	Electrical conductivity (mS cm^{-1})	4.5	4.4	4.5	4.4
	Titratable acids (% citric acid)	0.11	0.11	0.11	0.11

Soilles organic cucumber under SL

Treatments:

1) Control with HPS
2) LED at 70 cm + HPS
3) LED at 140 cm + HPS

120 µmol/m²/s HPS
80 µmol/m²/s LED
(6h to 22h - 16 h)

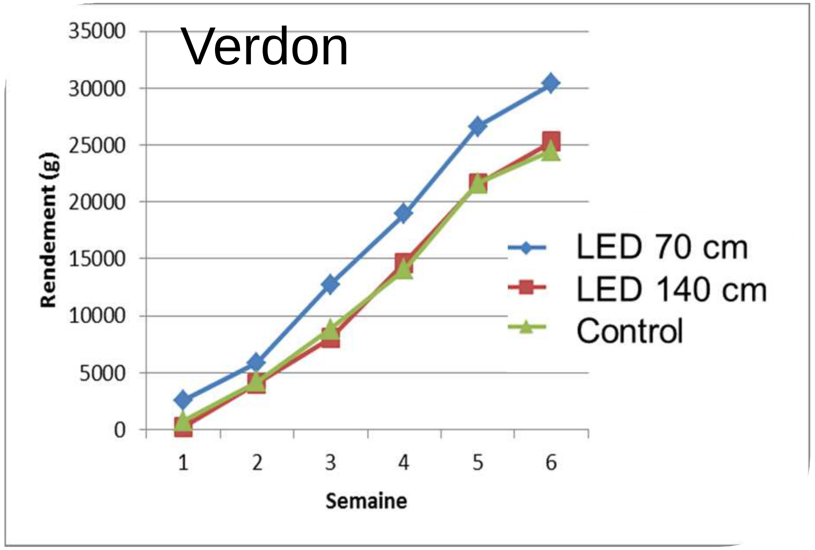
Verdon
Proloog

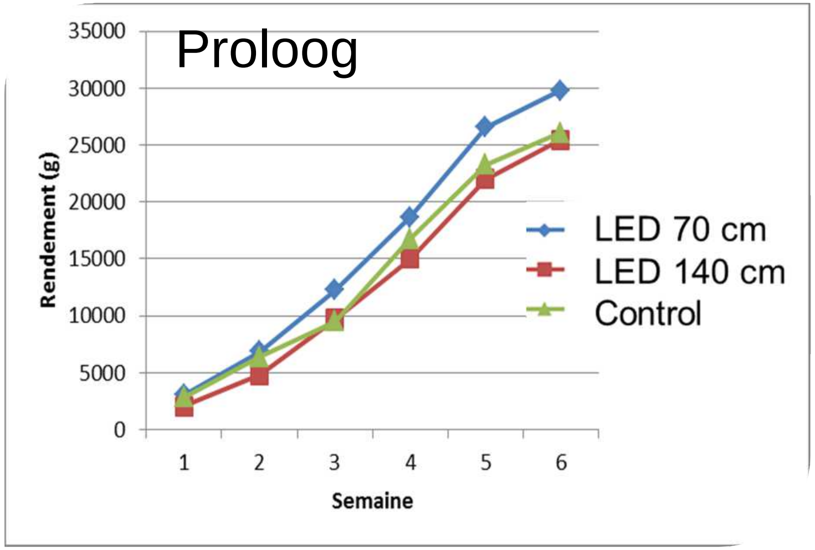
⇨ Peat based substrate
⇨ 1.3 plants per m²
⇨ Plantation - October 23

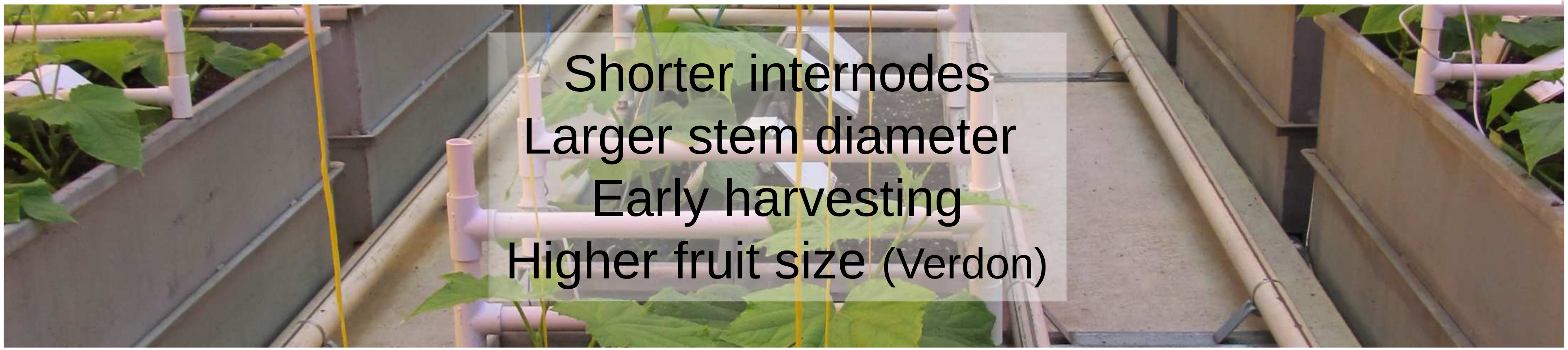
Actisol (5-3-2)
Feather meal (13-0-0)
Blood meal (12-0-0)
Shrimp meal
SulpoMag
$KSO_4 + CaCl_2$

Soilles organic cucumber under SL

LED at 70 cm ⇨ yield ⬆ 20%



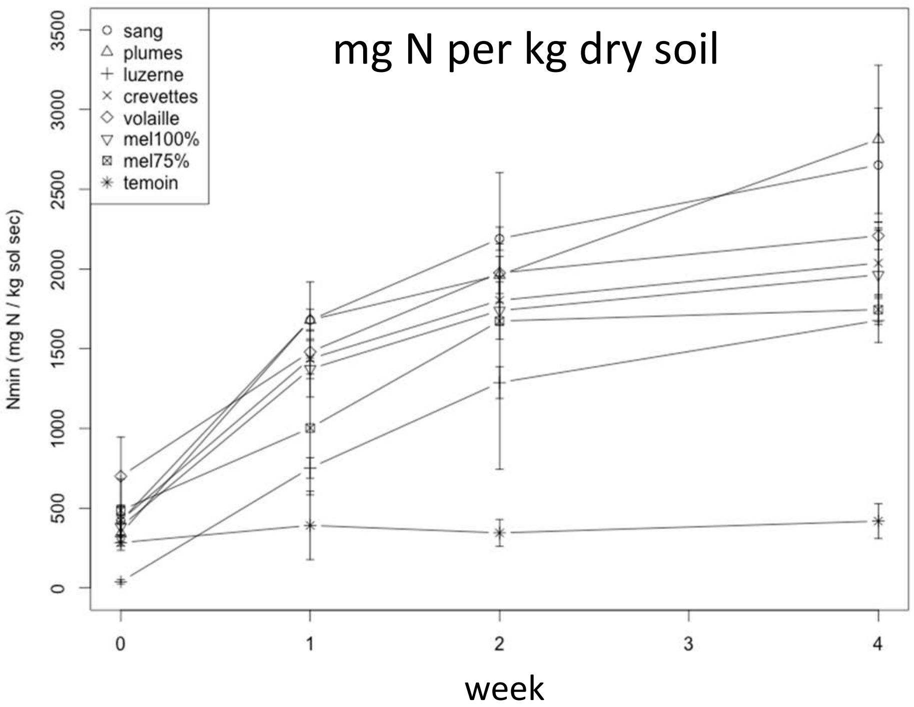




One year soil incubation – mineralization rate

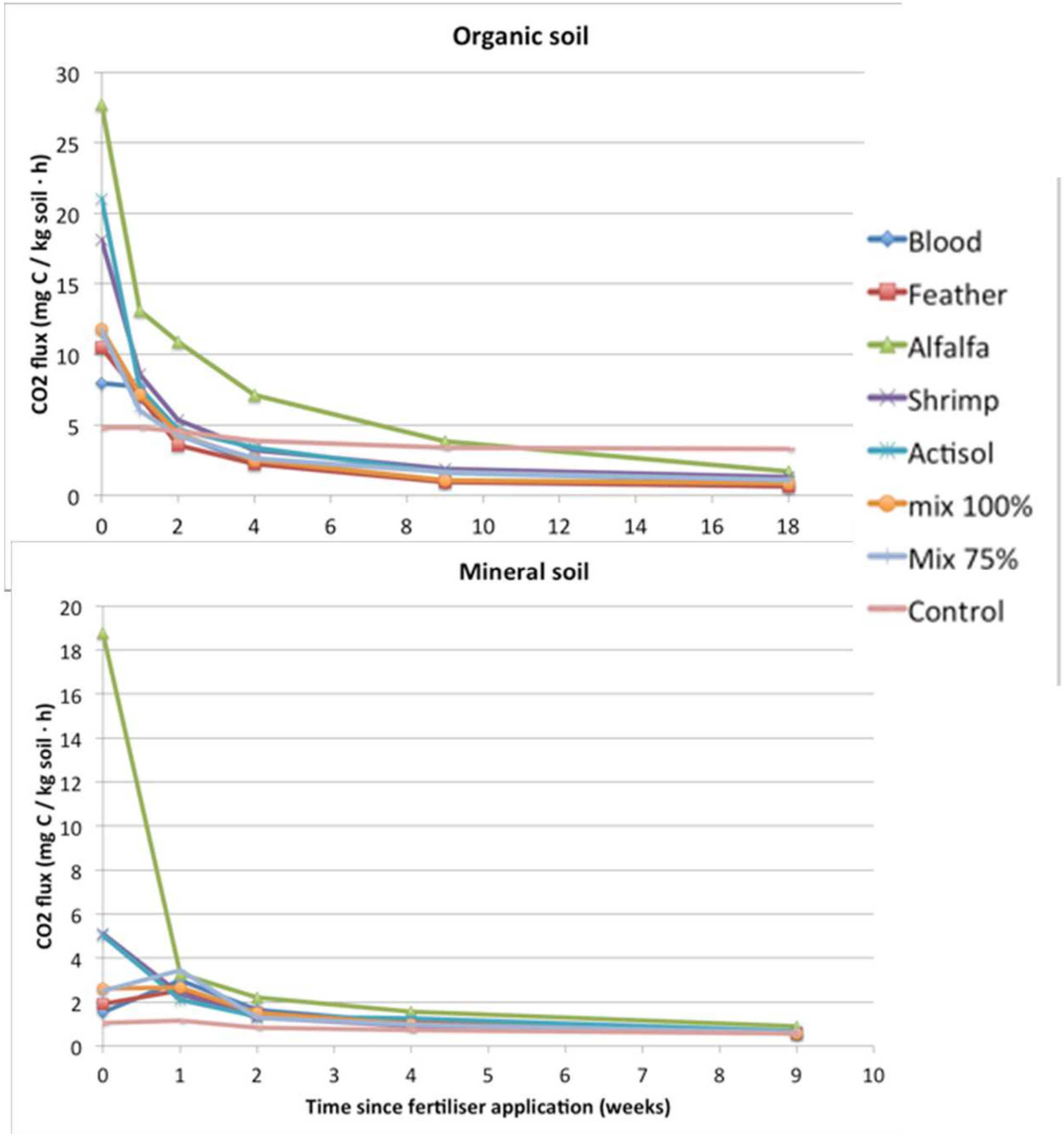
1. Blood meal
2. Feather meal
3. Alfalfa meal
4. Shrimp meal
5. Poultry pellet
6. Mix 100%
7. Mix 75%
8. Control

- 2:1 water extraction (pH, EC, soluble ions)
- Extraction KCl 2M (ions)
- $CaCl_2$ 5 mM (total N, dissolved organic)
- K_2SO_4 0.5M (before and after chloroform fumigation – microbial N and C)
- Gaz flux (CO_2, CH_4 and N_2O)
- Mehlich-3 (ions) and total N



Feather meal
Blood meal
Poultry pellets
Shrimp meal
100% Mix
75% Mix
Alfalfa meal
Control

One year soil incubation – CO_2 emission



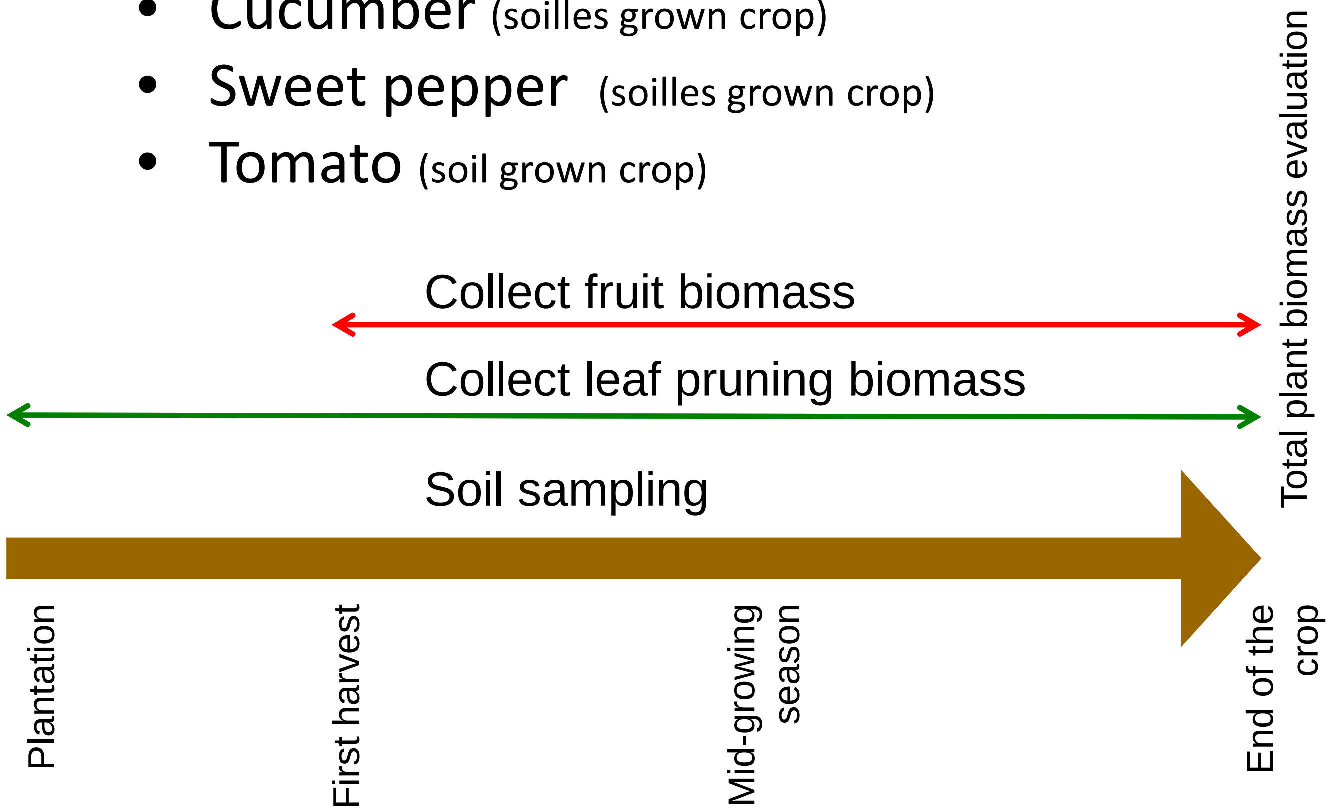
˚C, 90% RH
ganic & mineral soils

1, 2, 4 weeks
4, 6, **9, 12 months**

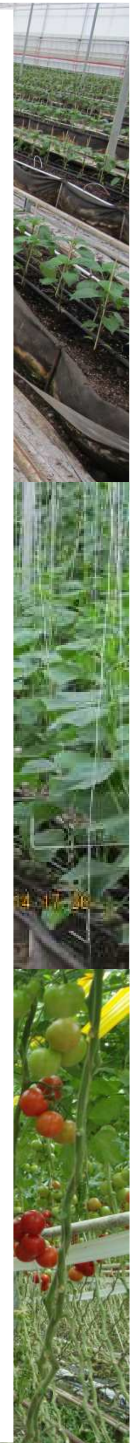
Mineralization rate model

⇨ Validation at the commercial site

- Cucumber (soilles grown crop)
- Sweet pepper (soilles grown crop)
- Tomato (soil grown crop)



- Comparison with the values predicted by the model
- Model adjustment



Biostimulants

1. humic substances
2. hormone containing products
3. amino acid containing products
4. PGPR

*"any substance or microorganism applied to plants with the aim to enhance **nutrition efficiency**, **abiotic stress** tolerance and/or **crop quality** traits, regardless of its nutrients content "* *(Du Jardin 2015)*

- Humic and fulvic acids
- Seaweed extracts
- Chitosan
- Protein hydrolysates
- Inorganic compounds (Si)
- Beneficial fungi (mycorrhiza)
- Beneficial bacteria (PGPRs)

Commercial products :
Mixtures

improves plant performance by activating molecular, biochemical and physiological responses

*"any substance/microorganism beneficial to plants **with-out** being nutrients, pesticides, or soil improvers"*

Humic substances – Quality attributes

⇨ interplay between the organic matter, microbes and plant roots

- Increased uptake of macro- and micronutrients
- Stress protection by promoting the production of phenolic compounds

- Basil ⇨ ↑ essential oil
- Strawberry ⇨ ↑ fruit firmness, S.S.
- Tomato ⇨ ↑ fruit acidity, S.S., vitamin C
- Sweet pepper ⇨ ↑ fruit size, S.S.
- Cucumber ⇨ ↑ fruit S.S.
- Melon ⇨ ↑ fruit size, firmness, S.S.

Soil or foliar applications

Seaweed extracts - Quality attributes

⇨ increase the nutritional value ⇨ Fe, Zn, Cu, Mg, K, S

Plant	⇨ hormonal effects
Growing media	⇨ + effects on CEC, microflora (PGPB)

- Spinach ⇨ ↑ leaf size , post-harvest, Fe
  ↑ flavonoids, phenolic content, antioxidant
- Lettuce ⇨ ↑ Ca, K, Mg
- Strawberry ⇨ ↑ fruit size, total anthocyanin
- Tomato ⇨ ↑ fruit size, ↑ fruit acidity, S.S., vitamin C
  ↑ Fe, Zn, Mn, Ca, K, P
- Sweet pepper ⇨ ↑ fruit size, vitamin C

Soil or foliar applications

Chitin & Chitosan - Quality attributes

⇨ involved in defense gene activation

- Plant protection against fungal pathogens
- Tolerance to abiotic stress
- Quality traits

- Spinach ⇨ ↑ leaf size
- Basil ⇨ ↑ phenol contents, antioxidant activity
- Oregano ⇨ ↑ polyphenols
- Tomato ⇨ ↑ fruit size, phenolic compounds
- Sweet pepper ⇨ ↑ fruit self-life

Soil or foliar applications

Biostimulants – yield & quality

Biostimulants	Mechanism	Species	Quality attributes
Protein hydrolysates	• Modulation of N uptake • Plant hormone balance hormone-like activities • Tolerance to abiotic stress	Sweet pepper	↑ fruit size, capsaicin, chlorogenic acid, p-hydroxybenzoicacid , p-coumaric acid
	• Soil microbial activity	Lettuce	↑ P, antioxidant activity
		Leafy vegetables	↓NO_3
Si	• Tolerance to abiotic stress	Tomato	↑ β-carotene, lycopene
		Cucumber	dull exterior appearance (Si trichomes)
Phosphite	• Improve nutrient uptake	Tomato	↑ fruit S.S.
	• Tolerance to abiotic stress	Strawberry	↑ fruit anthocyanin, vitamin C
	• Quality traits	Rasberry	↑ fruit firmness, dark red color
Beneficial fungi	• Improve nutrient uptake	Tomato	↑ sugars, P, Zn, lycopene
Trichoderma & Mycorrhiza	• Tolerance to biotic and abiotic stresses	Lettuce	↑ anthocyanins, carotenoids, phenolics
		Strawberry	↑ anthocyanins
		Basil	↑ antioxidant compounds

Biostimulants – cucumber on going project

"any substance or microorganism applied to plants with the aim to enhance ***nutrition efficiency****,* ***abiotic stress*** *tolerance and/or* ***crop quality*** *traits, regardless of its nutrients content "* *(Du Jardin 2015)*

Soil application

1. Control (water)
2. Seaweed *Ascophyllum nodosum* extract (ASCO-SSP, OrganicOcean)
3. Chitosan (Soft Guard, Leily, Canada Oceanic)
4. Alfalfa extract (Triacontanol, Nutri-stim, Agriculture Solutions)
5. Vermicompost (Turitek Croissance, Ferme Eugénia)
6. Knotweed extract (Regalia Maxx , Marrone Bio Innovation)
7. Silicate of K (AgSil25, 20.8% SiO_2) – Control Si
8. Wollastonite - $CaSiO_3$ (2% Si plant available)

Foliar application

1. Control (eau)
2. Chitosan (Soft Guard,Leily, Canada Oceanic)
3. Knotweed extract (Regalia Maxx, Marrone Bio Innovation)
4. Silicate of K (AgSil25, 20.8% SiO_2) – Control Si

- cv Proloog
- OM1, Les tourbières Berger
- Application every 1-2 wk
- October 23 to December 18
- First harvest November 16
- Two plants per unit

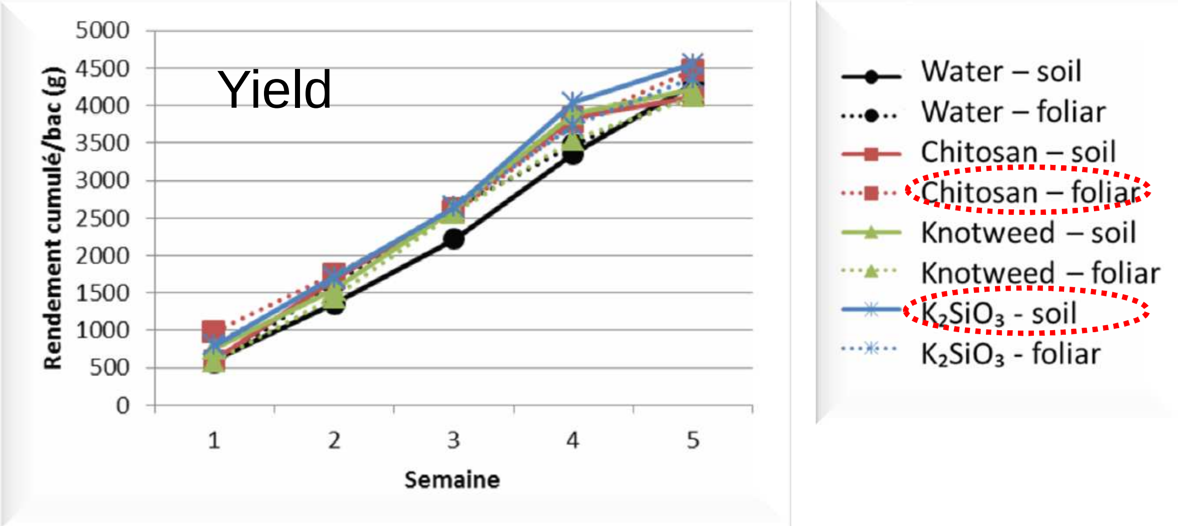
Yield
Fruit quality

Biostimulants – cucumber on going project

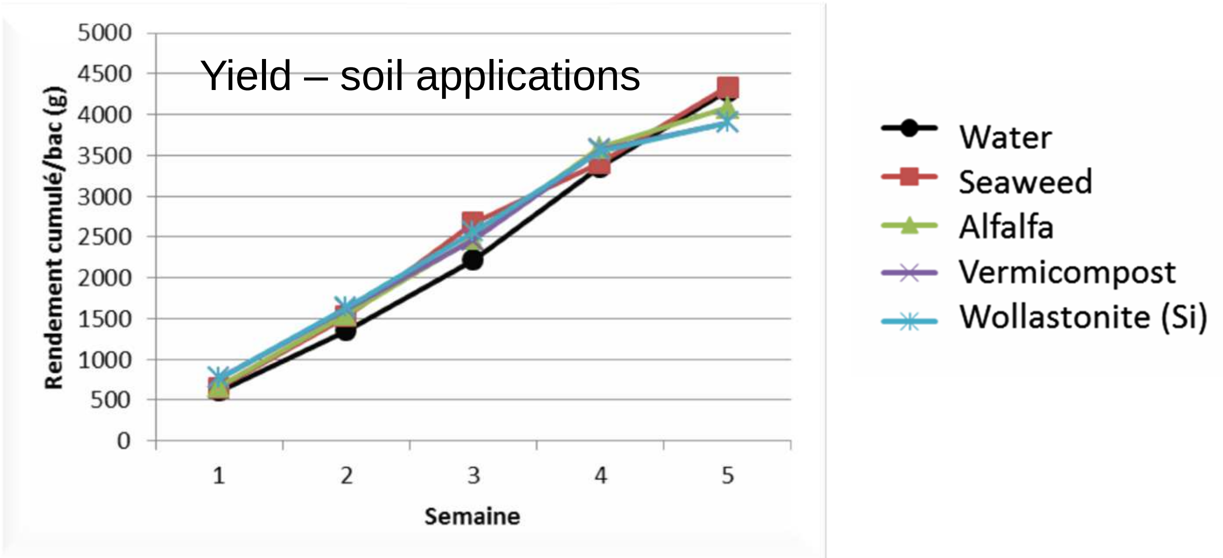
Treatments	Appli	Height (m)	Growth (cm)	Stem diam (mm)	Leaf length (cm)	Internode nb	SPAD (Chl)
Control	S	3.86	61.6	8.0	24.7	5.9	37
	F	3.90	62.6	7.9	24.9	6.2	37
Seaweed	S	3.84	61.4	8.2	24.9	5.9	38
Chitosan	S	3.89	62.2	8.0	24.4	6.2	37
	F	3.99	64.1	8.0	25.1	6.1	38
Alfalfa	S	3.84	61.2	8.0	24.2	6.2	37
Vermicompost	S	3.87	62.1	8.0	24.3	6.0	38
Knotweed	S	3.90	62.3	8.0	25.1	6.0	36
	F	3.96	64.2	8.0	24.8	6.1	38
K_2SiO_3	S	3.87	61.2	7.9	24.6	6.0	37
	F	3.92	62.4	7.9	25.1	5.9	37
Wollastonite	S	3.91	62.2	8.2	24.9	5.9	38

⇨ Plantation October 23 - data until December 18

Biostimulants – cucumber on going project



⇨ 5 wk harvest



No effect on fruit firmness

Most important factors affecting tomato fruit quality

Solar radiation Air temperature **Nutrient supply**	⬆	**Fruit dry matter** **SS/Organic acid** **Lycopene**
CO_2 **EC**	⬆	**Fruit firmness** **Organic acids** **Antioxidant capacity**
EC	⬆	**a* color (green to red)** **Lycopene**

Clément et al. 2014

Integrated farming – sustainable production systems

Greenhouse Production Systems

Nutrient need

Tomato nutrient uptake per day

N	114 mg $plant^{-1}$
P	25 mg $plant^{-1}$
K	252 mg $plant^{-1}$
Ca	91 mg $plant^{-1}$
Mg	17 mg $plant^{-1}$

Recirculating Aquaculture Systems

Nutrient release

Fish effluent nutrient content

N	135-145 mg L^{-1}
P	35-106 mg L^{-1}
K	17-31 mg L^{-1}
Ca	193-311 mg L^{-1}
Mg	33-44 mg L^{-1}

Integrated farming – sustainable production systems

- ✓ Lower NO_3: NH_4 ratios had no negative effect on growth of organically-grown tomato
- ✓ Stimulating effect of fish effluent on :
  - plant height
  - leaf area
  - root dry biomass
- ✓ Higher soil microbial activity
- ✓ Fish effluent nutrients fulfilled plant macronutrient requirement, except for K
- ✓ Suppressiveness effect against *P. ultimum* and *F. oxysporum*

Concluding remarks

- Organic soilless growing systems fulfill North American organic certification
- Respect the organic principles ⇨ *soil feed the plants - active soil - sustainable*
- Yield similar to conventional systems
- High quality products
- Reduce risks for growers
- Lower environmental footprint
- No conversion waiting period

↑ Profitability

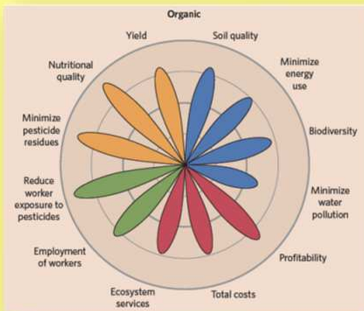
Concluding remarks

Organic soilless growing systems contribute significantly to the expansion of OGH

to fulfill increasing demand by consumers for organic fruits & vegetables

⇨ Global benefits

(Reganold and Wachter, 2016)



Production
Environment
Economic
Wellbeing

Agriculture et
Agroalimentaire Canada

Agriculture and
Agri-Food Canada

Thank you very much

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Gestion de l'eau – recyclage des effluents

Charge nutritive des effluents de serre - tomate

Tomate biologique	NH_4 mg L^{-1}	NO_3 mg L^{-1}	K mg L^{-1}	P mg L^{-1}	Ca mg L^{-1}	Mg mg L^{-1}	SO_4 mg L^{-1}	Na mg L^{-1}	Cl mg L^{-1}
Sol									
10 cm	5	46	45	0.9	48	25	-	20	-
30 cm	0.7	18	36	0.6	51	25	-	22	-
50 cm	0.0	15	24	<0.5	47	21	-	18	-
Bacs									
Site 1	-	9	-	2.4	-	-	-	-	-
Site 2	12	590	198	21	352	91	747	144	153
Site 3	nd	13	488	26	268	81	945	81	293
Site 4	nd	400	111	26	90	31	743	375	4