GUDP project: Biobased growing media for plant production (BioSubstrate 2.0)
Aarhus, 6 sept. 2022

Increasing the circularity of growing media: the challenge of new materials and reuse

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Need for renewable biomass …

rich in organic C

with high C/N and C/P ratio

Need for renewable biomass …

rich in organic C

with high C/N and C/P ratio

Low bulk density

The Settlers fra Catan

Topics for growing media

New materials

Amendments

Processing

Interaction with fertilizers

Reuse of growing media

End-of-Life and C storage

Conventional	**Alternatives**	**Alternatives (test phase)**	**Circular use?**
peat	Bark (compost)	Biodegradable polymers	**Direct reuse**
Coir products	Wood fiber	**Woody compost**	**Conversion to composting**
mineral wool	Green compost	**Biochar**	**Conversion to biochar**
perlite	Peat moss	**Plant fibers**	**Conversion to soil improver**
…	Rice hulls	…	…
	…		

(fælde)

Growing media:

Sustainable?

Available (amounts/price/quality)?

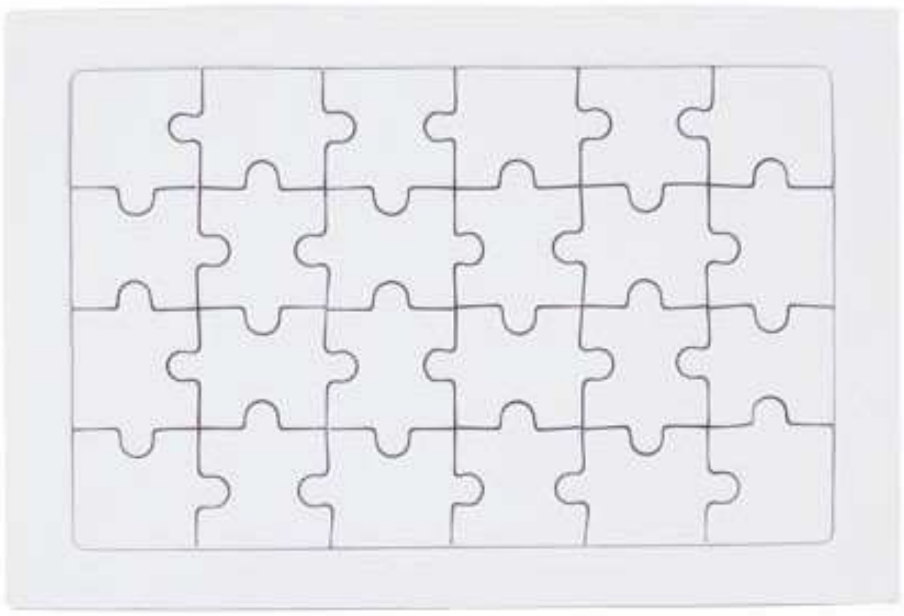
Renewable?

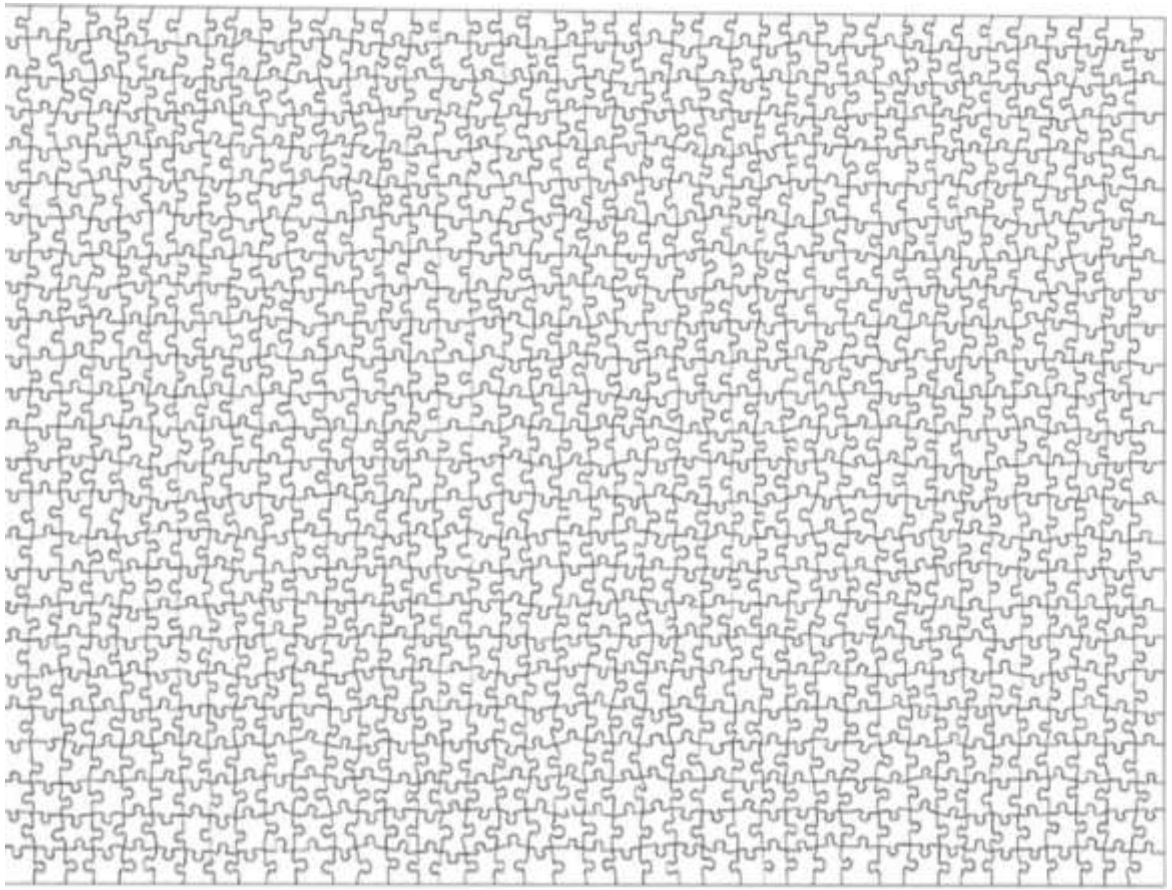
Ready to switch to alternatives?

Blok et al. (2021):
https://doi.org/10.17660/ActaHortic.2021.1305.46

Volume of growing media x4 in 2050

From the past to the future: more materials and more growing media





Growing media and climate

Climate adaptation

- Urban greening
- Soilless cultivation
- Pre-planting substrates

Climate mitigation

- Using local & renewable materials

  = protect carbon stocks in peat areas

- Biochar as C-negative solution
- Upcycling spent growing media
- Avoiding energy-intensive products: mineral products, chemical crop protection, chemical fertilizers

Mineral materials/peat:

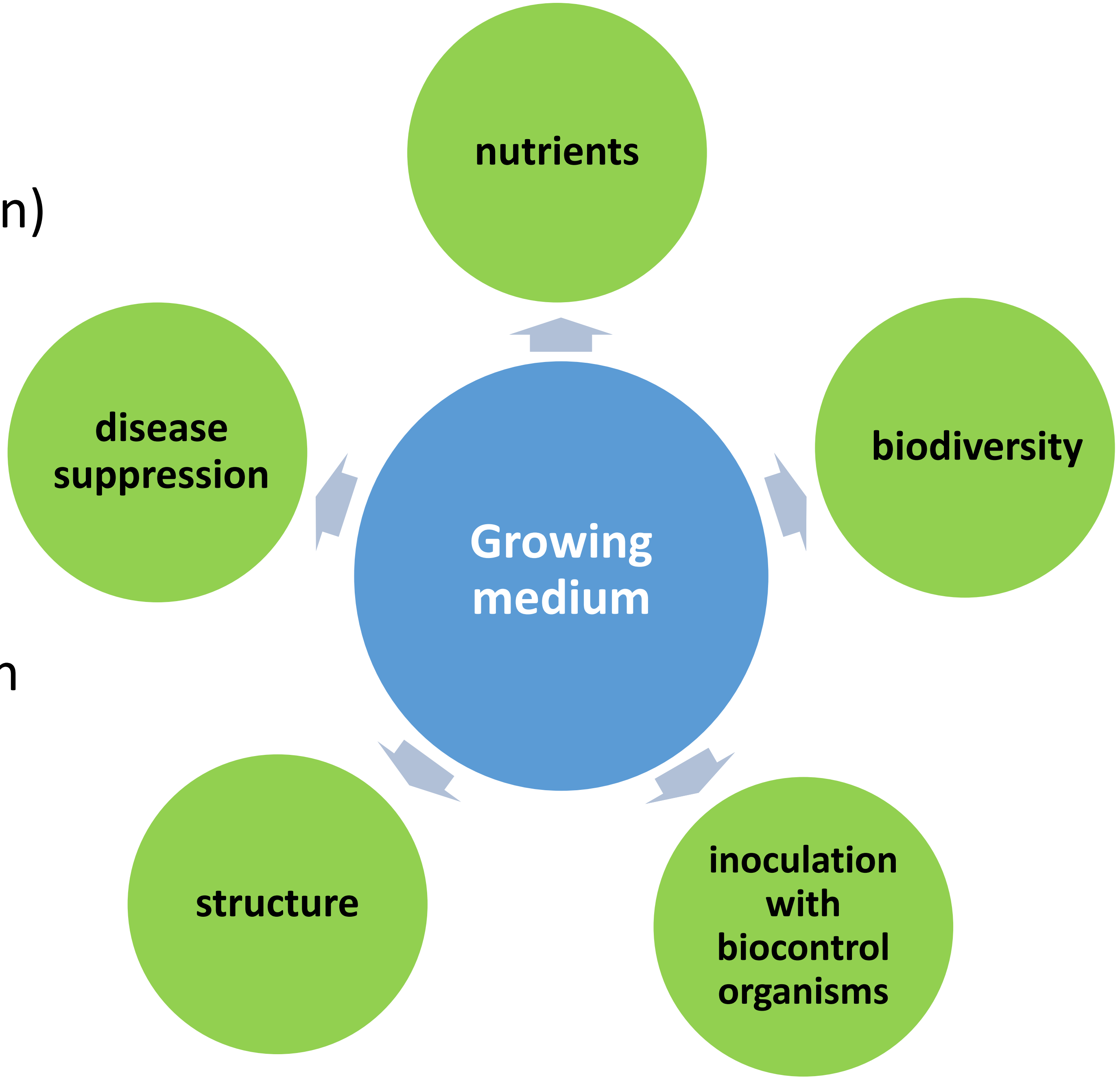
Let the roots grow

(technological intensification)

The power of the blend:

Growing media interact with plant growth

(ecological intensification)



Biochar

Mode of action: chemical
Effect: microbiological

Chitin

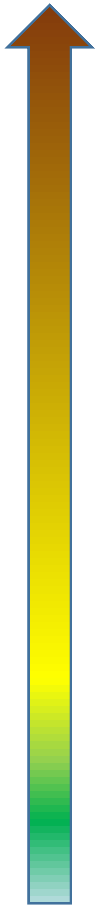
Mode of action: microbiological
Effect: chemical

Elemental S

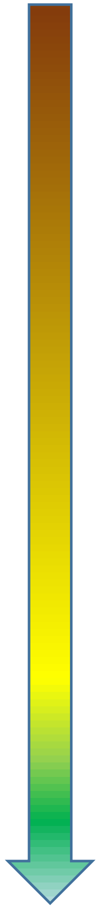
Mode of action: microbiological
Effect: chemical

Plant fibers

C:N ratio



Wood fibres
Chopped heath biomass
Flax shives
Miscanthus straw
(Cattail straw)
Reed straw
(Hemp fiber)
Soft rush
Fresh grass clippings



Biodegradability

NPK content

Growing media: microbiome

	n	N-immob. risk	Microbial biomass	CO_2 release
		%	nmol fatty acid/g OM	mmol CO_2/kg OM/hr
peat	9	15	166	1,2
wood fiber	6	7	77	1,5
bark compost	5	20	341	2,6
green compost	9	23	968	3,6
plant fiber	9	**60**	550	7,0

New materials = more microbiology => positive or negative?

More info:
10.3390/agronomy12020422

Flax shives

Rich in organic matter (>95%)

Rich in C (>50%)

High C/N (90) and C/P (>500) ratio

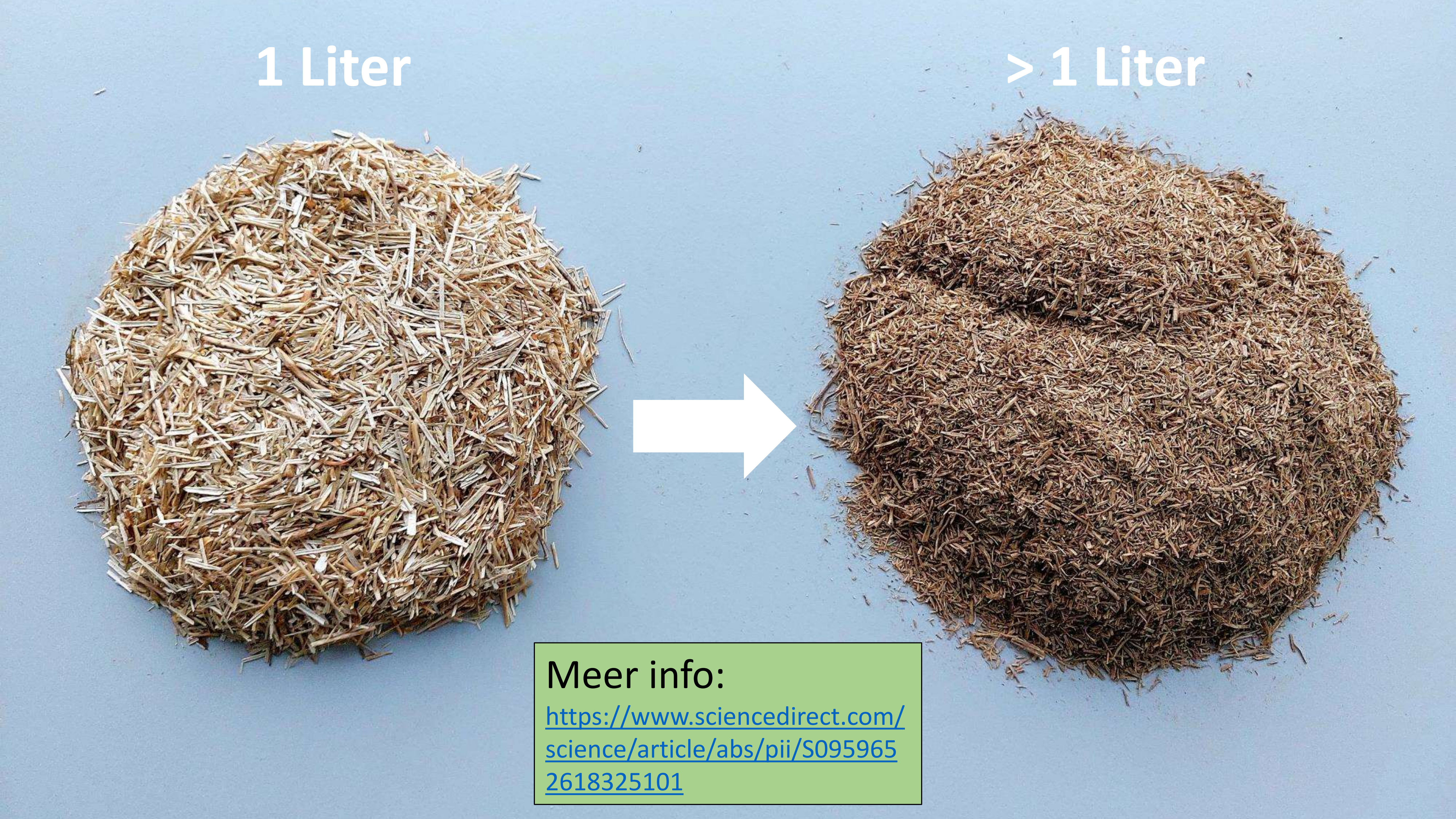
Risk for high N immobilization

Low bulk density

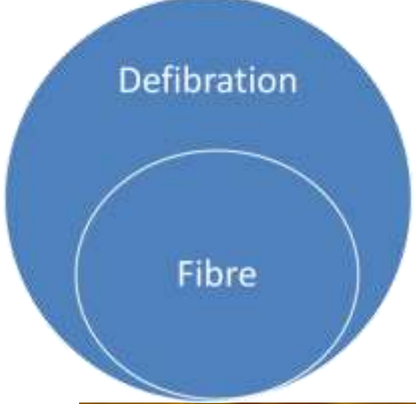
Contains *Verticillium dahliae*

Microsclerotes

High availability (in Belgium)

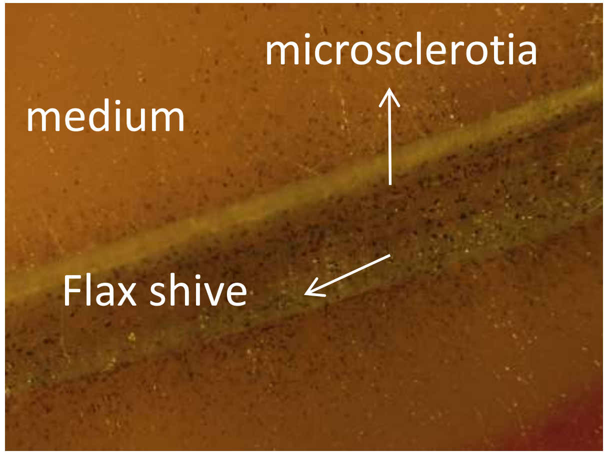


Meer info:
https://www.sciencedirect.com/science/article/abs/pii/S0959652618325101



Plant pathogens

- Effect fiberisation
  - Tested with selective medium (5x)



Fiberisation	Surviving pathogens (# colonies)
Untreated	10.0±2.4
technique 1	0.0±0.0
technique 2	0.0±0.0
technique 3	0.0±0.0

No surviving pathogens!

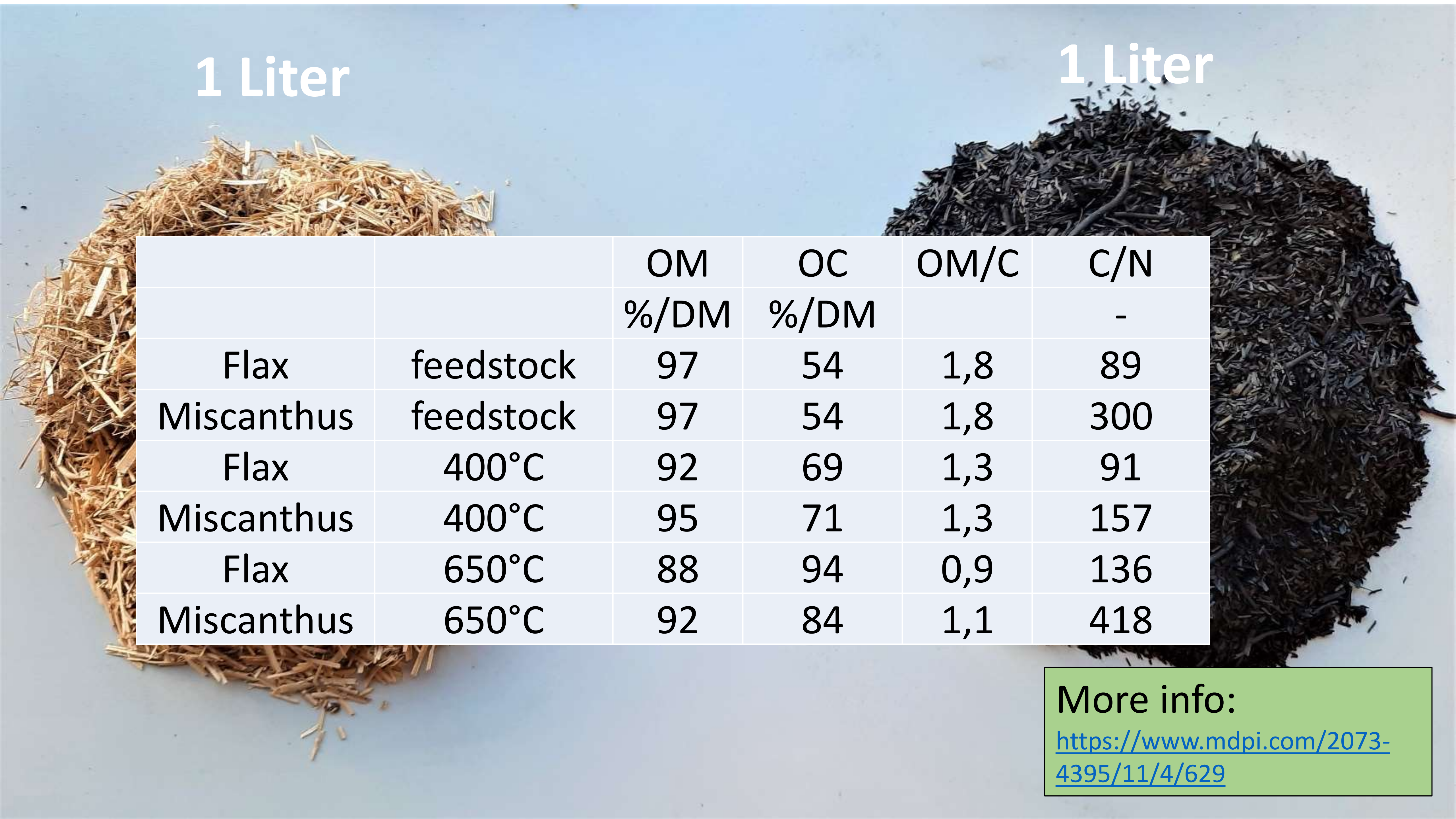
Elemental S: fast pH decrease (> 2 pH units in < 2 weeks)

Staal	pH-H2O	EC	Nimmob	OM	OUR	C/N	Total biomass
	-	µS/cm	%	%/DM	mmol/kg OM/hr		nmol/g OM
Ensiled soft rush 2019	7,9	448	7	89	16	22	1441
Ensiled soft rush jan. 2020	7,8	471	44	92	14	31	949
2019 after acidification (+ S)	**4,3**	708	**-4**	87	**5**	22	1071
2020 after acidification (+ S)	**5,1**	941	**-25**	82	**5**	20	898

Biochar

- Sorption organic pollutants
- Sorption inorganic pollutants
- Reduction toxicity heavy metals
- Reduction GHG emissions
- Reduction NH_3 emissions
- Carrier for microbiology
- Carrier for nutrients
- Catalyst
- Optimisation composting/AD
- Feed additive
- Bulk replacement in growing media

Optimization ← **Biochar production** → **Biochar application in field soils**

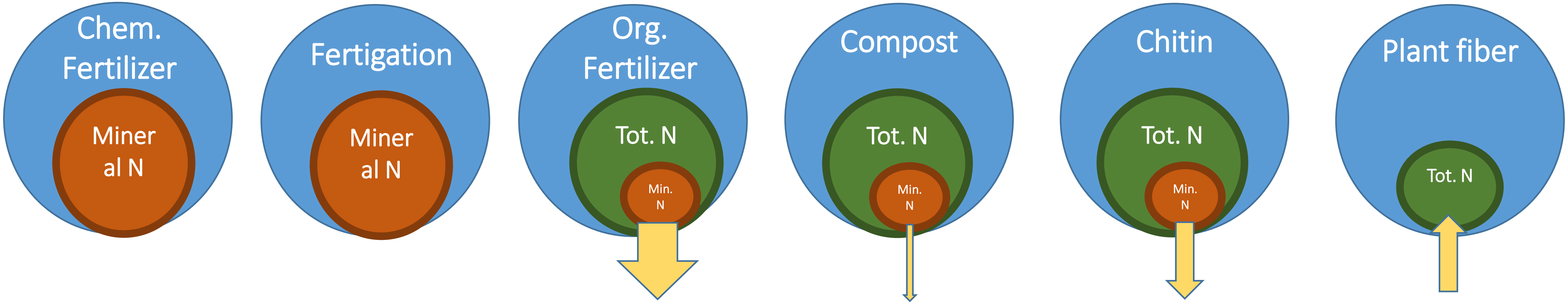


		OM	OC	OM/C	C/N
		%/DM	%/DM		-
Flax	feedstock	97	54	1,8	89
Miscanthus	feedstock	97	54	1,8	300
Flax	400°C	92	69	1,3	91
Miscanthus	400°C	95	71	1,3	157
Flax	650°C	88	94	0,9	136
Miscanthus	650°C	92	84	1,1	418

More info:
https://www.mdpi.com/2073-4395/11/4/629

Feedstock versus biochar

		pH-H2O	EC	P	K	Mg	Ca
		-	µS/cm	g/kg DM			
Miscanthus	Feedstock	7.8	110	0.9	3.1	0.8	4.1
Flax		6.5	89	0.5	1.9	0.3	2.1
Miscanthus	400°C	9.5	160	2.2	9.2	2.1	10.7
Flax		8.7	42	1.2	7.3	1.2	6.1
Miscanthus	650°C	9.8	392	3.6	13.8	3.3	17.0
Flax		9.1	191	2.1	7.9	1.2	4.8



N mineralization: microbial process
Compost in the blend: higher NO_3-N/NH_4-N ratio = more nitrification

N immobilization: microbial process

- Higher risk for materials with higher C/N ratio
- Faster process for materials with a higher decomposition rate

New growing media: guidelines

Blend different materials for successful peat replacement

Differentiate between bulk materials and organic fertilizers (e.g., for composts)

Compost in the blend = more nitrification = positive!

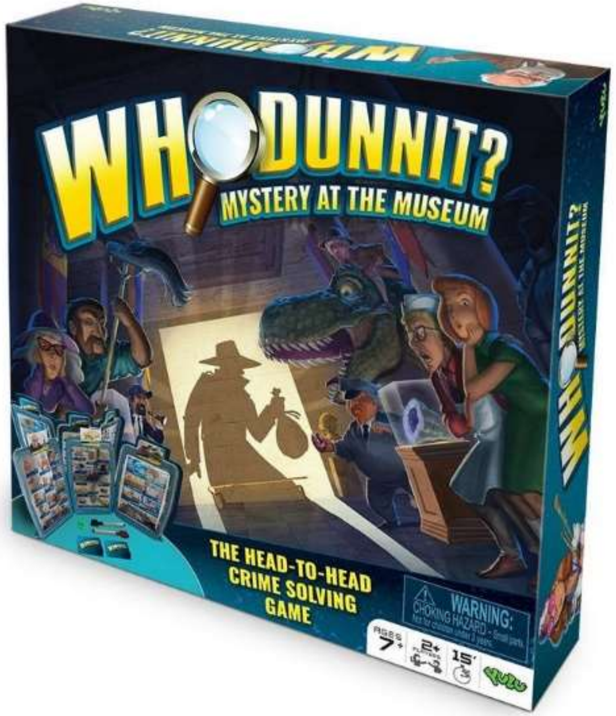
Additional treatments of materials:

acidification, fiberisation, maturation, …

Compost and biochar: fertilizer en lime replacement

Plant fibers: source of nutrients

Let the N mineralisation process start before plant growth



RE-

PROEFCENTRUM HOOGSTRATEN

High potential for recycling water and nutrients

Growing medium

Precise application of resources (water, fertilisers, energy)

	kg/ha	
	Plants	Spent peat
DM	2800	9500
C	1100	4000
N	70	114
P	9	6
K	70	18
Ca	50	163
Mg	12	32

Sustainable Controlled Environment Horticulture

Growing media
- End-of-life impact affects the sustainability (LCA)
- Linear use => circular use: reuse, recycling, soil amendment

Use of renewable biomass (wood fiber, compost, ...) in cascade:
- In growing media for greenhouse cultivation
- As soil improver for C sequestration

Added value of using biochar in growing media:
- For the crop
- For C sequestration
- Use in cascade?

6 full scale trials with different growing media

- 6 full scale trials at Proefcentrum Hoogstraten
  - 3 trials with tomato, 3 with strawberry
  - 4 trials of 10 months, 2 trials of 4 months

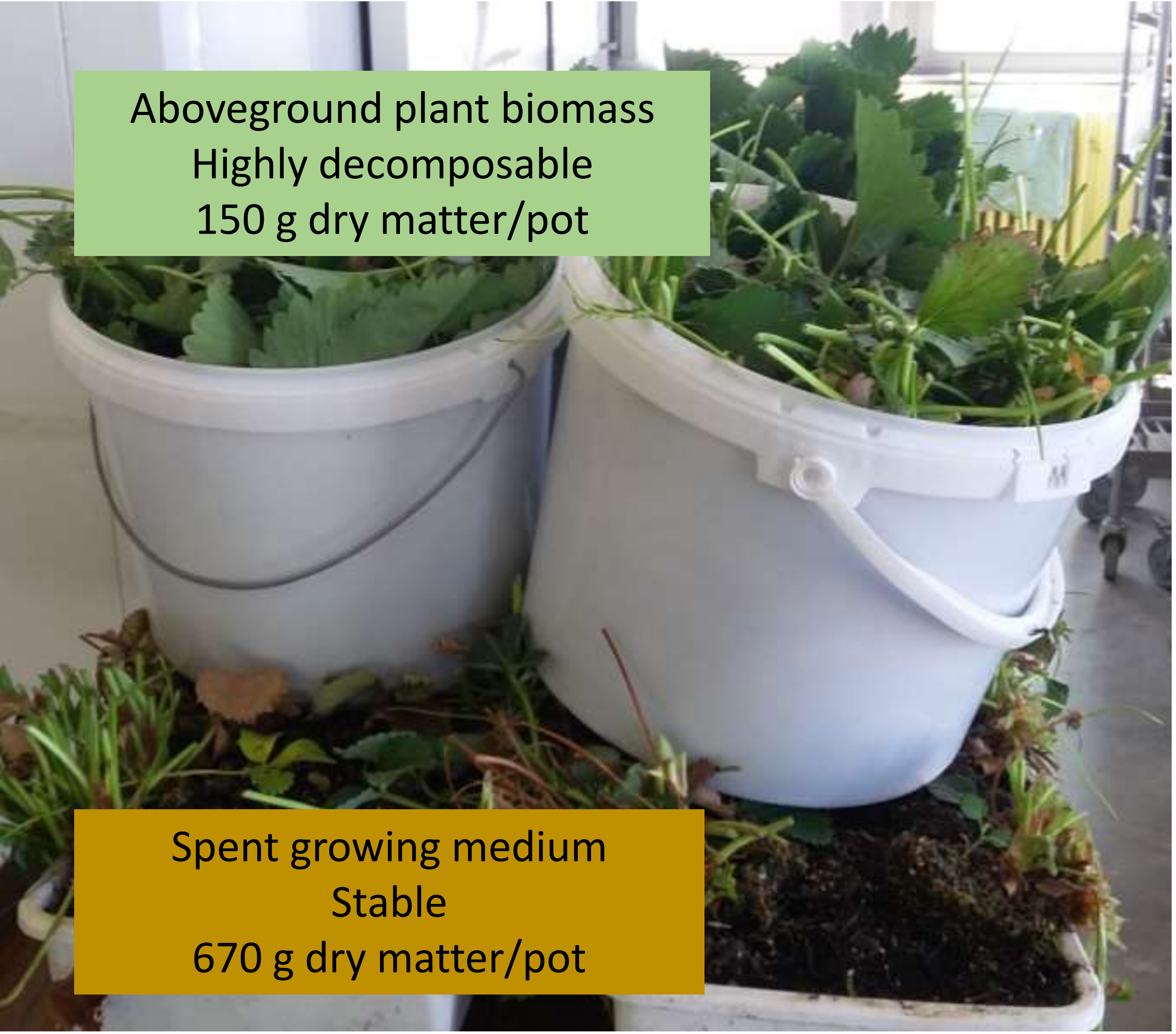
PROEFCENTRUM HOOGSTRATEN

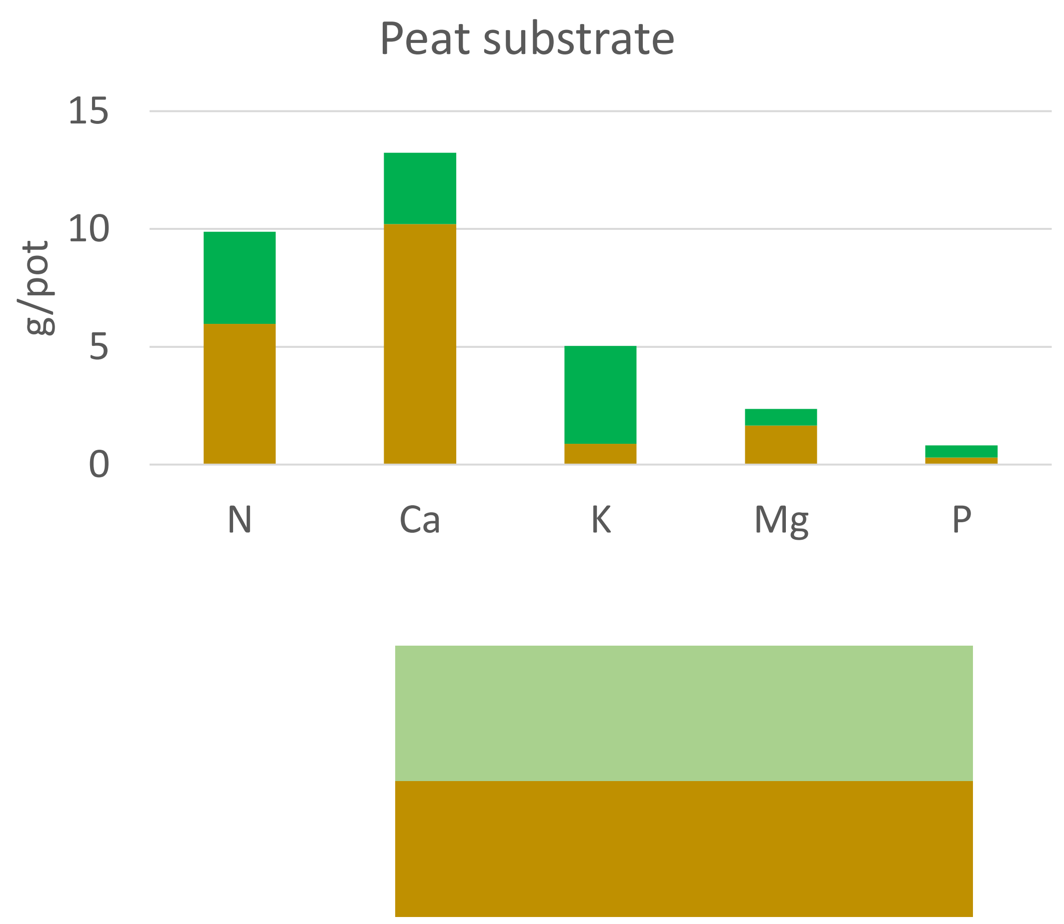
- Comparison of peat-based blends and/or mineral wool with
  - Strawberry: peat-reduced blends (green compost and wood fiber)
  - Tomato: peatfree blends (green compost, coir, bark and wood fiber)

- Comparison of 3 blends with or without 10 vol% woody biochar:
  - 3 trials
  - 1 peat-free and 2 peat-reduced

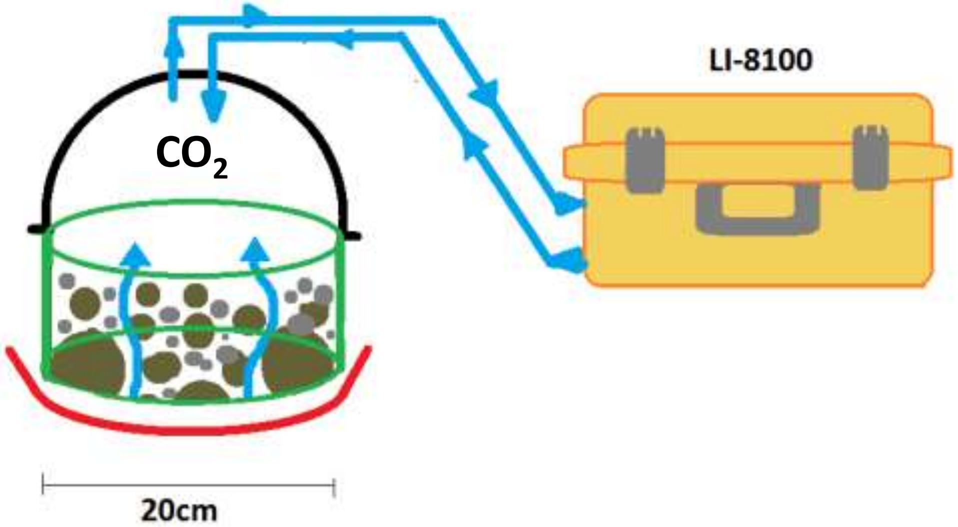
- No yield decrease with peat-reduced or peatfree blends, sometimes higher yields


GREEN COMPOST
WOOD FIBRE
PERLITE
COCO
PEAT
COCO
PEAT
GREEN COMPOST
BARK
WOOD FIBRE
COCO
MINERAL
WOOL


Aboveground plant biomass
Highly decomposable
150 g dry matter/pot
Spent growing medium
Stable
670 g dry matter/pot


Peat substrate
g/pot
15
10
5
0
N
Ca
K
Mg
P

CO_2 emission for screening C stability



Unstable

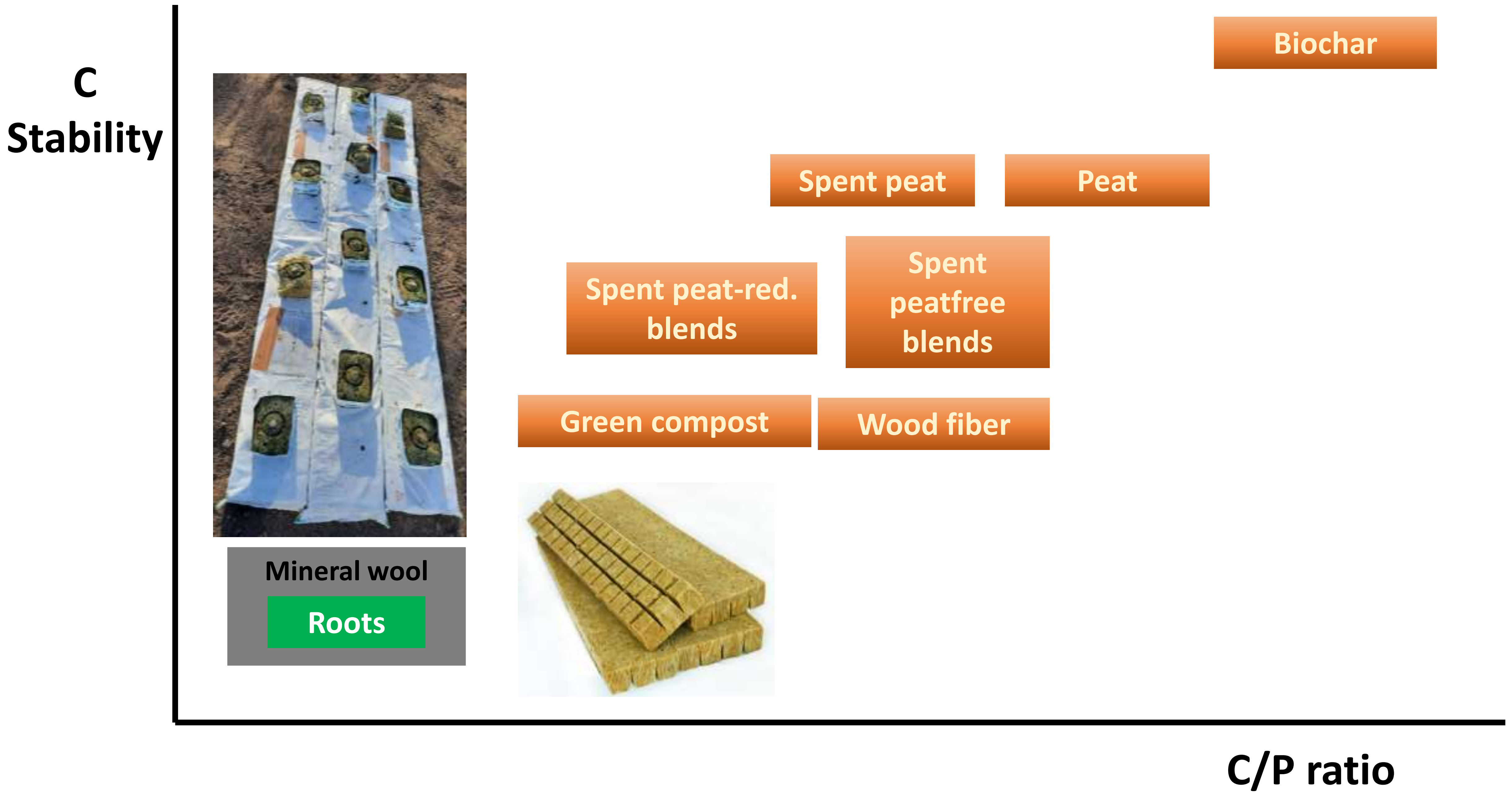
Stable

- High CO_2 release

- Low CO_2 release

Characterisation:

Organic and inorganic C
Total N, P, K, Ca, Mg
pH, EC
Mineral N
% N mineralisation
Cation Exchange Capacity
Available P, K, Mg, Ca, Cl
C mineralization
- Fertilizer added
- CO_2 flux
- 28 days
- 13 measurements
- Expressed as rate


C Stability
Biochar
Spent peat
Peat
Spent peat-red. blends
Spent peatfree blends
Green compost
Wood fiber
Mineral wool
Roots
C/P ratio

Spent media: Peat / Rockwool / Peat-reduced / Peatfree

		Peat	Rockwool	Target Value
Organic C	%/DM	**47 c**	4 a	high
C mineralisation rate	mmol CO_2/kg C hr	**1.4 a**	14.5 b	low

Effect of 10 vol% biochar on characteristics of Spent Growing Media

Comparison of 3 blends with or without 10 vol% woody biochar (3 trials, 1 peat-free and 2 peat-reduced):

- No significant effect on:
  C mineralisation rate, N mineralisation rate, pH, EC, mineral N, Total N, P, K, Mg, Ca, Na, inorganic C, CEC on DM basis, C/P ratio

- **+ biochar** => Significant effect ($p < 0.05$) on:
  - % organic C: increase from 35 to 44 % OC/dry matter
  - C/N ratio: increase from 32 to 40
  - CEC on total C basis: decrease from 175 to 131 cmolc/kg OC

Effect of growing medium on biochar characteristics

Comparison of 3 biochars recovered from the growing medium (3 trials, 1 peat-free and 2 peat-reduced) versus the initial biochar:

- No significant effect on:
  C/N ratio, EC, NH_4-N, Total P, K, Mg, Ca, Na, organic and inorganic C, CEC, C/P ratio

- Significant effect ($p< 0.05$) on **biochar** :
  - pH: % organic C: decrease from 9.2 to 6.2
  - Waterextractable NO_3-N: increase from <5 to 62 mg NO_3-N/L
  - Total N: increase from 0.3 to 0.8 %N/DM

Conclusions for spent growing media as soil improver

Peatfree vs. peat-reduced vs. peat:
- High C stability
- High org. C content vs. high C/N and C/P
- Low N mineralisation

Growing media affect the biochar characteristics
- Decrease in pH
- Increase in N loading

Biochar affects the spent growing media
- increases the org. C content but not the C stability

Work-in-progress for renewable blends

Conformation of trends observed during use as growing medium:
- Increase in C stability of renewable blends
- Decrease in total K content
- No accumulation of P

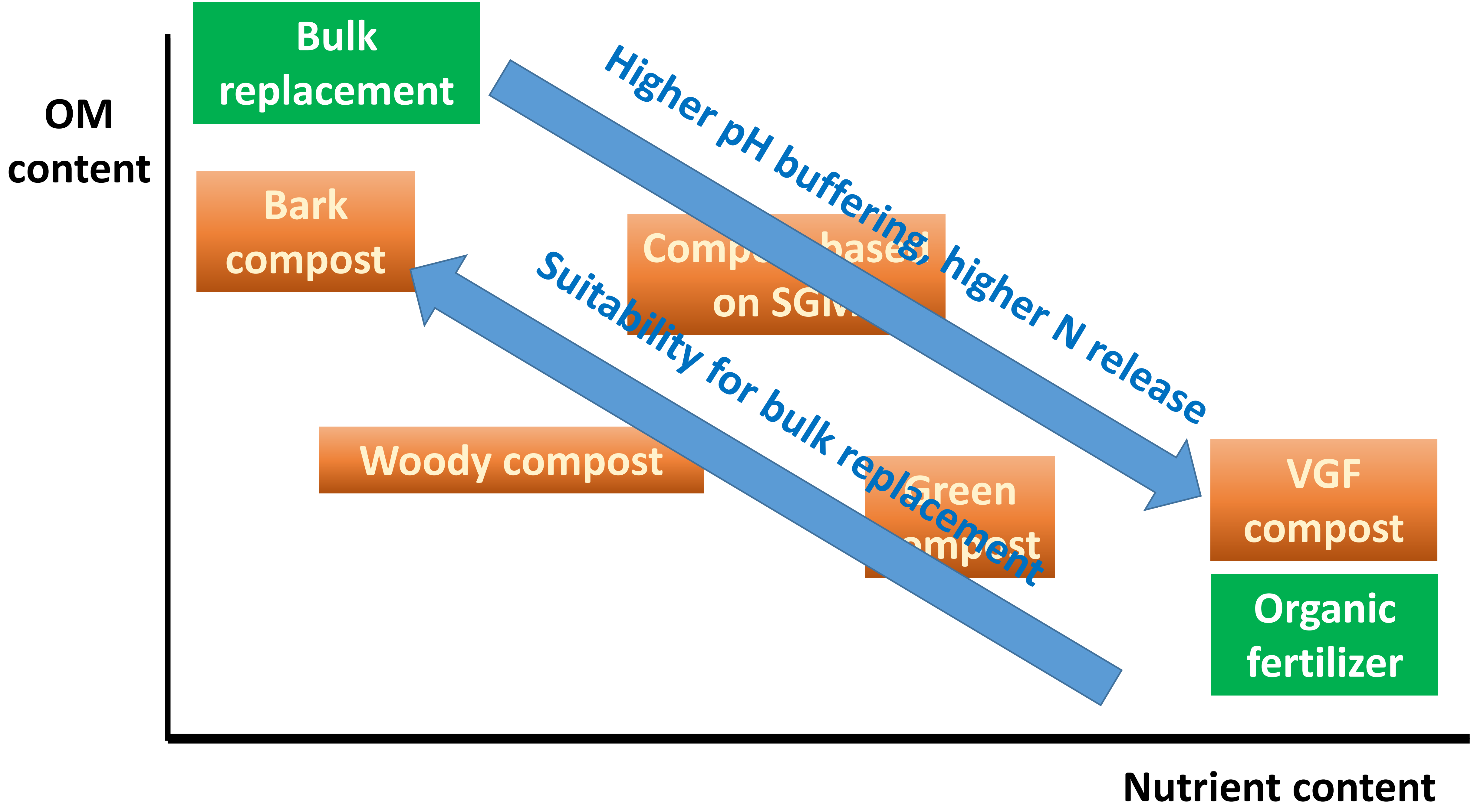
Optimization of use as growing medium:
- Decrease in total P content
- Avoid accumulation of Ca and Mg

Strawberry trials with:
- Peatfree &
- Biochar


New materials

Feedstock versus biochar

Material	pH-H2O	EC	IC	OC	P	K	CEC
	-	µS/cm	%/DM		g/kg DM		cmolc/kg
Spent peat 1	6,3	599	0,06	46	0,8	3,0	112
Spent coir 1	4,2	431	0,01	46	1,7	3,7	84
Spent peat 2	5,7	912	0,08	43	0,8	3,2	109
Spent coir 2	5,7	882	0,08	45	1,1	2,5	101
Biochar, spent peat 1	**8,7**	718	0,08	**78**	**2,4**	**8,3**	**18**
Biochar, spent coir 1	**9,7**	556	0,08	**85**	**3,5**	**13,1**	**37**
Biochar, spent peat 2	**9,6**	747	0,72	**71**	**2,1**	**9,7**	**14**
Biochar, spent coir 2	**9,3**	479	0,53	**68**	**2,6**	**7,3**	**20**



OM content
Nutrient content
Bulk replacement
Bark compost
Woody compost
Green
VGF compost
Organic fertilizer
Higher pH buffering, higher N release
Suitability for bulk replacement

Circular use: reuse, recycling, soil amendment

Peat				
Rockwool				
Peat-reduced				
Peatfree				
Volume reduction	Very low	higher	low	Very low
Value	Bulk material	Organic fertilizer	Organic fertilizer	Soil improver

Reuse of growing media: guidelines

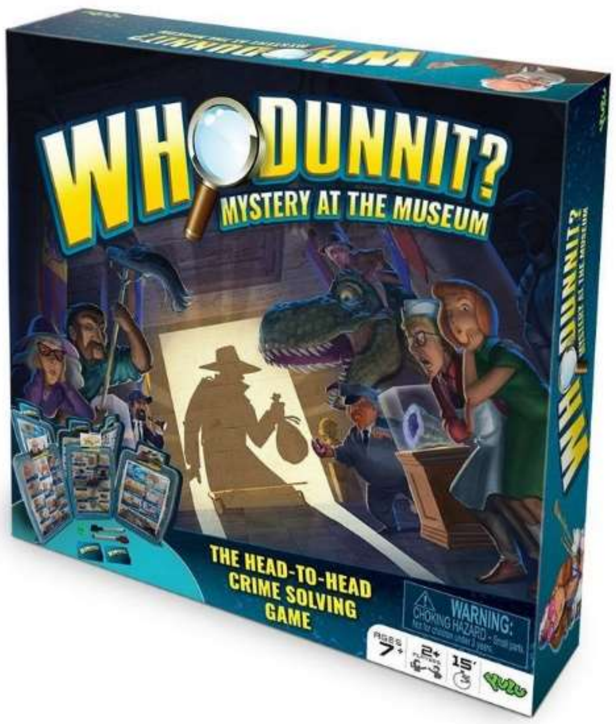
Differentiate between bulk materials and organic fertilizers:

- Compost and biochar: fertilizer en lime replacement
- If nutrient levels are low: bulk, if high: organic fertilizer

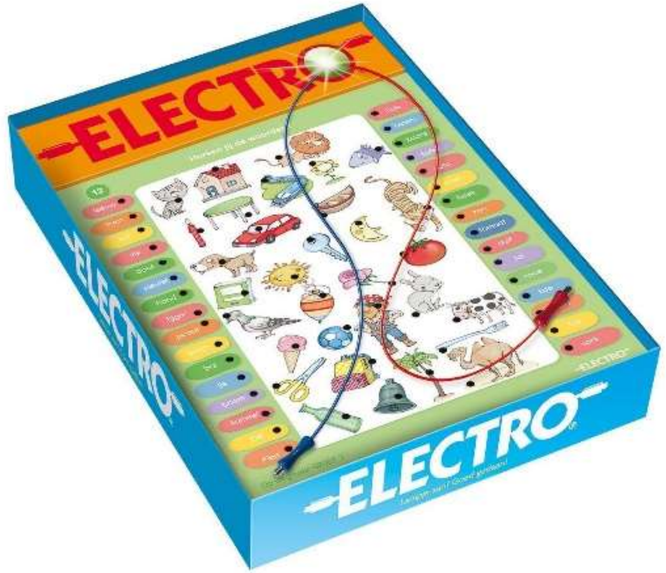
Direct reuse of growing media:

- take residual nutrients into account
- (s)low N mineralization rate
- P and K highly plant available

Aboveground biomass: important source of nutrients



Challenges



- Define criteria for more materials with heterogeneity between batches
- Link a material/blend to a specific application or crop
- Assess the need for changes in the cultivation
  - More frequent irrigation, smaller doses, sensors?
  - Growing medium as source of nutrients?
- Combine growing media with circular fertilizers/nutrients
- Increase the reuse of spent growing media
- End-of-life of growing media = opportunity for C sequestration

Wish list for future research

- Biochar for bulk replacement:
  - further implementation in current practice (higher TRL + higher vol%)
  - Stand-alone material?
  - Circular use
- New fibers from different crops or vegetation
- Potential for using renewable fertilizers in soilless cultivation
- New growing media => interaction with disease suppression?

Circular: what does it mean for you?

Grower:

- Grow your own … growing medium?
- Business model based on soilless cultivation … and C farming?

Growing media producer:

- Provide substrates that can be used for more than one cultivation cycle?
- Collect spent growing media an optimize the material for reuse?

Retailer/consumer:

- Buy C negative ornaments/vegetables/fruits/herbs?

Research and Innovation:

- Ask what a growing medium blend can do for you
- Define a new concept of providing nutrients for the crop

4 Horti-BlueC webinars

Horti-BlueC webinar 1: Large scale gasification for energy and biochar production

More info
Recording
Factsheet

Horti-BlueC webinar 2: Production of chitin from shrimp shells or Chinese mitten crab

More info
Watch recording
Factsheet

Horti-BlueC webinar 3: Spent growing media for direct reuse or as a feedstock for biochar and compost

More info
Watch recording
Factsheet

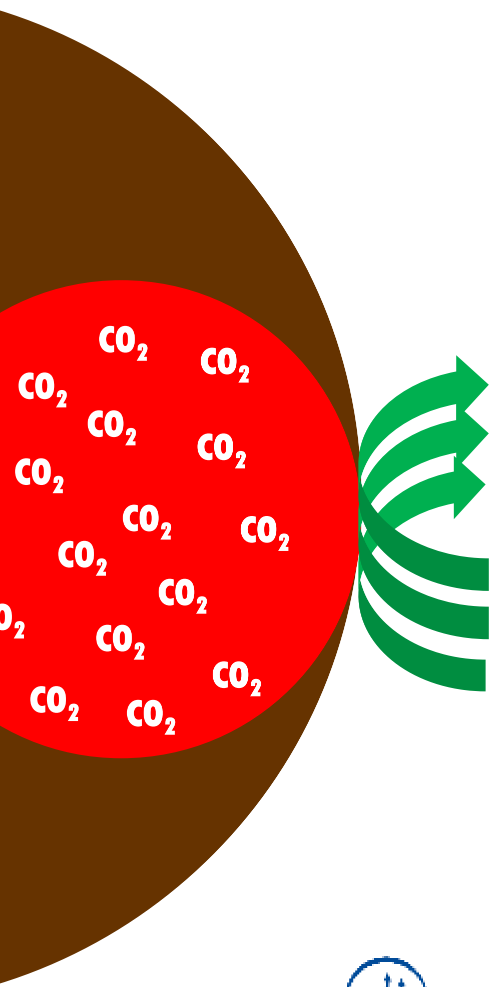
Horti-BlueC webinar 4: New growing media blends for strawberry and tomato

More info
Watch recording
Factsheet

Building blocks for sustainable growing media with a focus microbiology: more info?

	Video	Fact sheet	Paper
Chitin	https://youtu.be/yUymPsQwS44	Chitin fact sheet	Chitin from shrimp shells or crab Chitin in Strawberry Cultivation
Biochar	https://youtu.be/jiccJc9d-Gg https://youtu.be/9YpdSjLu-Zc	Biochar fact sheet	Biochar for Circular Horticulture Strawberry Rhizosphere and Biochar
Spent growing media	https://youtu.be/MXcMc0vS0f0	Spent growing media fact sheet	Grow - Store - Steam - Re-peat
Green compost		Microbiome of growing media	Composts versus woody management residues Woody composts and organic fertilizers
Plant fibers	https://youtu.be/fCiJ_20c8FQ	New growing media fact sheet	Plant fibers for renewable growing media

Thanks for your attention!



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Horti-BlueC YouTube channel
https://www.youtube.com/channel/UCAmlINw5Yndql8UMLsEhLJQ

Horti-Blue

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