Pathways to phase-out contentious inputs from organic agriculture in Europe

Organic Innovation Days, 30th November – 1st December 2021

Soil & Nutrients

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coordinating WP SOIL in Organic-PLUS

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Output from Organic-PLUS WP5 Task 4:

Examination of promising alternatives - fertilisers

With co-authors

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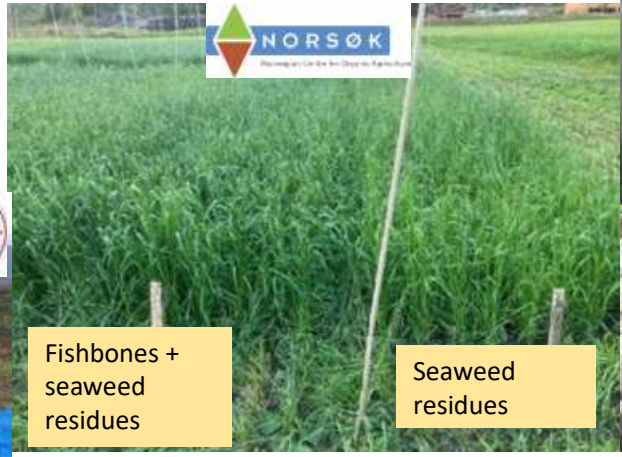

From the large perspective to possible solutions

- The demand for nutrients and organic matter to be applied in OA will increase signficantly (F2F, 25% organic area by 2030)
- OA needs new types of soil amendments to supply, or replace, amendments derived from conventional farming, e.g. due to risk of pesticide contamination
- OA should increase its integrity by purchasing less inputs from conventional animal husbandry
- The volume of animal husbandry production globally will likely decrease, to reduce eutrophication and losses of GHG (incl. NH_3)
- Even large chemical fertiliser companies are becoming interested in recycled nutrients, e.g. Yara

Organic agriculture= OA

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The tomato plants in the middle tray were severely stunted after application of a fertiliser containing clopyralid. (Photo: Kirsty McKinnon)

https://orgprints.org/id/eprint/40065/

Yara's roadmap for putting Europe's Farm to Fork Strategy into action

Yara's solutions and knowledge related to best nutrient management practices and improving land use efficiency are relevant for all farming systems, including organic farming. To meet the goal of the Farm to Fork Strategy and to avoid soil depletion in the long run, **greater research on suitable nutrient sources for organic farming will be needed.** Several studies[xxiii] show that organic farms often have negative balances for phosphorus and potassium, particularly in specialist arable organic farms

https://www.yara.com/siteassets/crop-nutrition/sustainable-agriculture-in-europe/yara-europe-putting-farm-to-fork-into-action.pdf/

Initial mapping of inputs - peat, plastic, fertilisers, (and Cu, S, mineral oil –with WP3)

- Organic growers use as much plastic and peat as conventional
- Broad use of conventional poultry manure enriched with vinasse + meat-and-bone meal
- Broad range of plant-based and animal-derived commercial fertilisers, varying between countries

Crops/ Countries	Apple	Broccoli	Cabbage	Carrot	Cereals	Citrus	Cucumber	Eggplant	Lettuce	Olive	Potato	Pepper	Straw-berry	Tomato	SUM
Denmark	1	1			1						1		1	1	6
France				1				1	1	1	1			4	9
Germany			1		2						1			1	5
Greece	1	1				1				1	1			1	6
Italy						3				2	2			2	7
Norway	1			1							1		1	1	5
Poland							1				1		1	1	4
Spain						3				3				3	9
Turkey						1		1		1	1	1	1	1	7
SUM	3	2	1	2	3	8	1	2	1	8	9	1	4	15	60
UK	2	2	2	2					1				1		8

Inputs in important organic crops in 10 European countries were recorded by asking experts (advisors, farm managers) to fill in a detailed questionnaire covering all inputs such as plant protection, fertilisers, peat and plastic. Autumn 2018.

Objectives of Organic-PLUS for fertilisers

- Characterize relevant fertiliser alternatives and compare them with conventional animal manure

- Develop system approaches to integrate them in organic growing

Main activity:
Trials to compare fertilisers from locally available resources with current contentious inputs

System approach

The Organic-PLUS project works with URBAN, VEGAN and RESID inputs

- ✓ **Closing rural urban cycles** by using e.g., digestate from household waste (**URBAN**)
- ✓ Improving **internal nutrient cycles, using legume and non-legume plant materials (VEGAN)**
- ✓ Using residues from non-contentious sources like **organic food production** or **marine materials (RESID)**

URBAN fertiliser: food-waste digestate

kg NH_4-N/ha, aiming at 90

Field study at 3 organic farms across Denmark 2019, comparing, in spring barley:

- Pig slurry (89)
- Digestate from 100% HW produced by VARGA, 3% DM (81)
- Digestates from 100% HW produced by DAKA, 3% DM (92)

..with a non-fertilised control , only 1 step of N

Yield levels of barley grain=
Control: 4 ton/ha
Fertilized: 5.6 ton/ha
HW gave equal yields to pig slurry

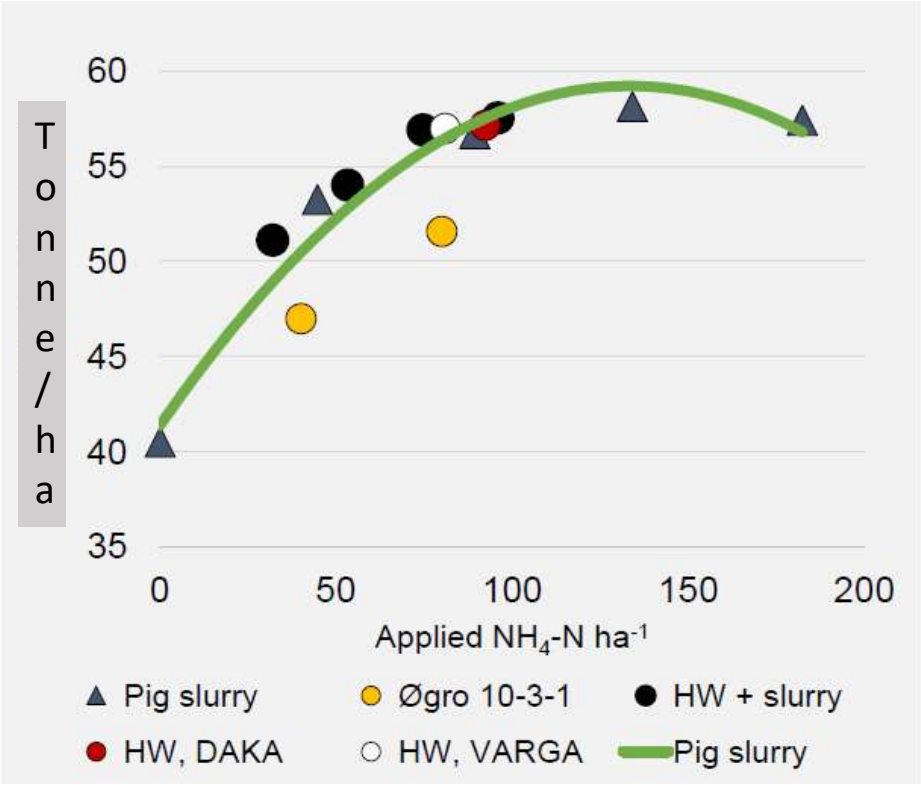
HW = source-separated organic household waste for digestion

Further: Field study at 5 organic farms across Denmark 2019,comparing, in spring barley:

- Pig slurry 4.5% DM (43-172 kg NH_4-N/ha, 4 rates)
- Meat-and-bone meal «Øgro» 10-3-1 (40 and 80 kg NH_4-N/ha, 2 rates)
- Digested HW (12.5%) + cattle slurry (32-96 kg NH_4-N/ha, 4 rates)

..with a non-fertilised control

HW digestate very similar to slurry-mixed



Results from the 3 trials with 100% HW digestate (DAKA, VARGA) in 2019 fit well to results with 5 trials and more N steps in 2020

Innovation Centre for Organic Farming

Plastic and heavy metals

Danish quality criteria for HW pulp (ready for digestion):

- For particles > 2 mm, max 0.5% of DM other materials (glass, metal, plastic..)
- Plastic may > 2 mm comprise max 0.15% of DM
- Plastic particles > 2 mm may cover up to 1 cm^2 per % of DM per litre pulp
- With 3% DM and 80 kg NH_4-N/ha: 8.6 m^2 plastic > 2 mm/ha permitted
- VARGA HW pulp had 0.01% of DM as plastic > 2 mm
- With 80 kg NH_4-N/ha this would cover 2.86 m^2/ha
- Farmers still think this is too much

- Significantly less cadmium in digested HW than pig slurry: 0.12 vs. 0.37 mg Cd/kg DM

VEGAN UoH: How to use legume-based fertilisers efficiently?
URBAN UoH: Digestate from HW for vegetable production?
RESID UoH: Food industry residues as alternative fertilisers?




- VEGAN: Clover-grass silage, clover grass in digestate with pig slurry, clover pellets
- URBAN: Digestate from HW
- RESID: Organic tofu whey
- Controls: Horn grit, composted farmyard manure (FYM)+ no fertilisation

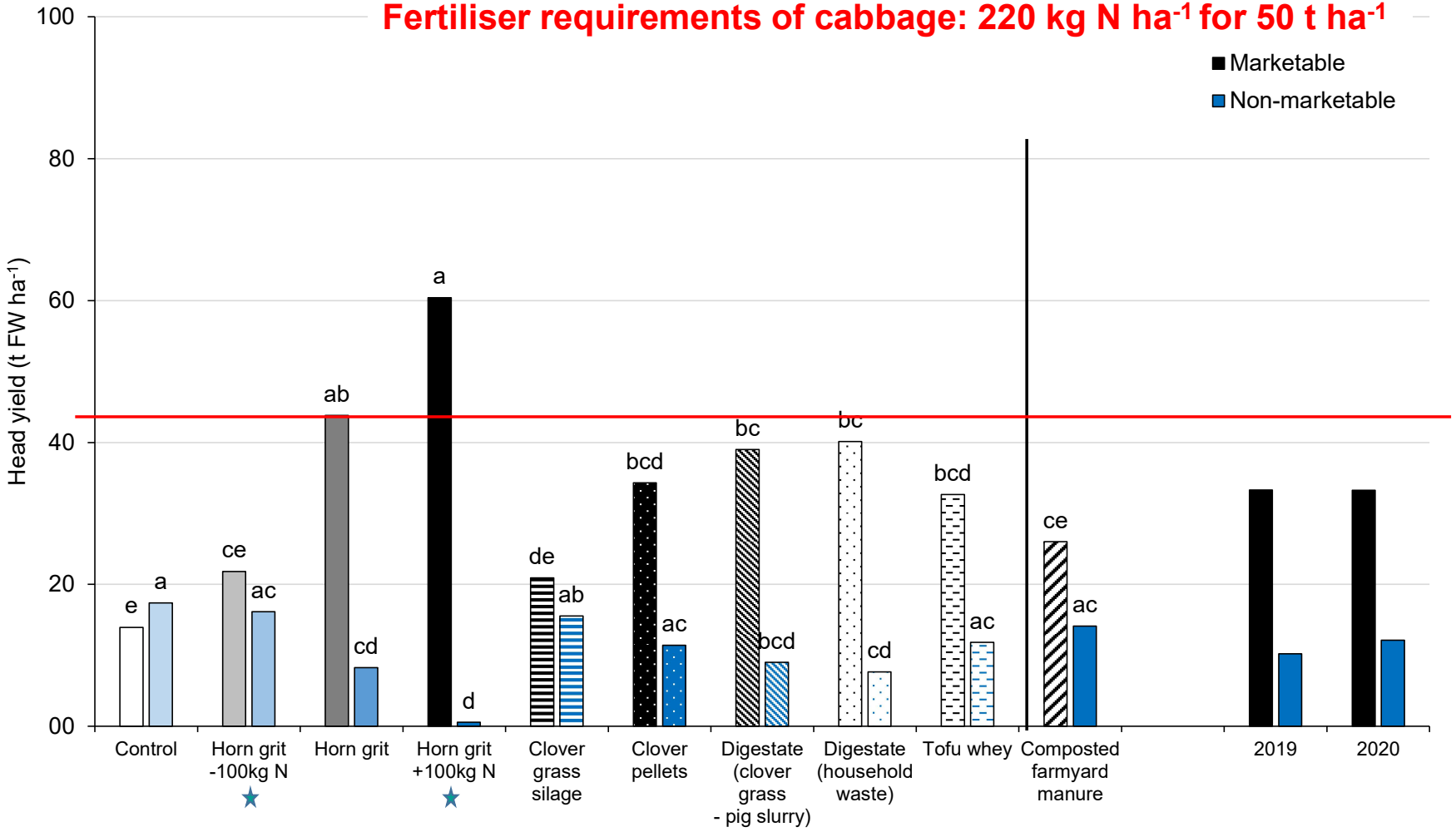
Tested in 2019 and 2020 with a 2-year crop rotation: early cabbage, spinach, winter wheat

UNIVERSITY OF HOHENHEIM

Fertilisers from legumes and recycled waste products for cabbage, spinach and winter wheat

Carolin Weiler, Sadia Sana, Sabine Zikeli

Cabbage – Head yield (t FW ha^{-1})



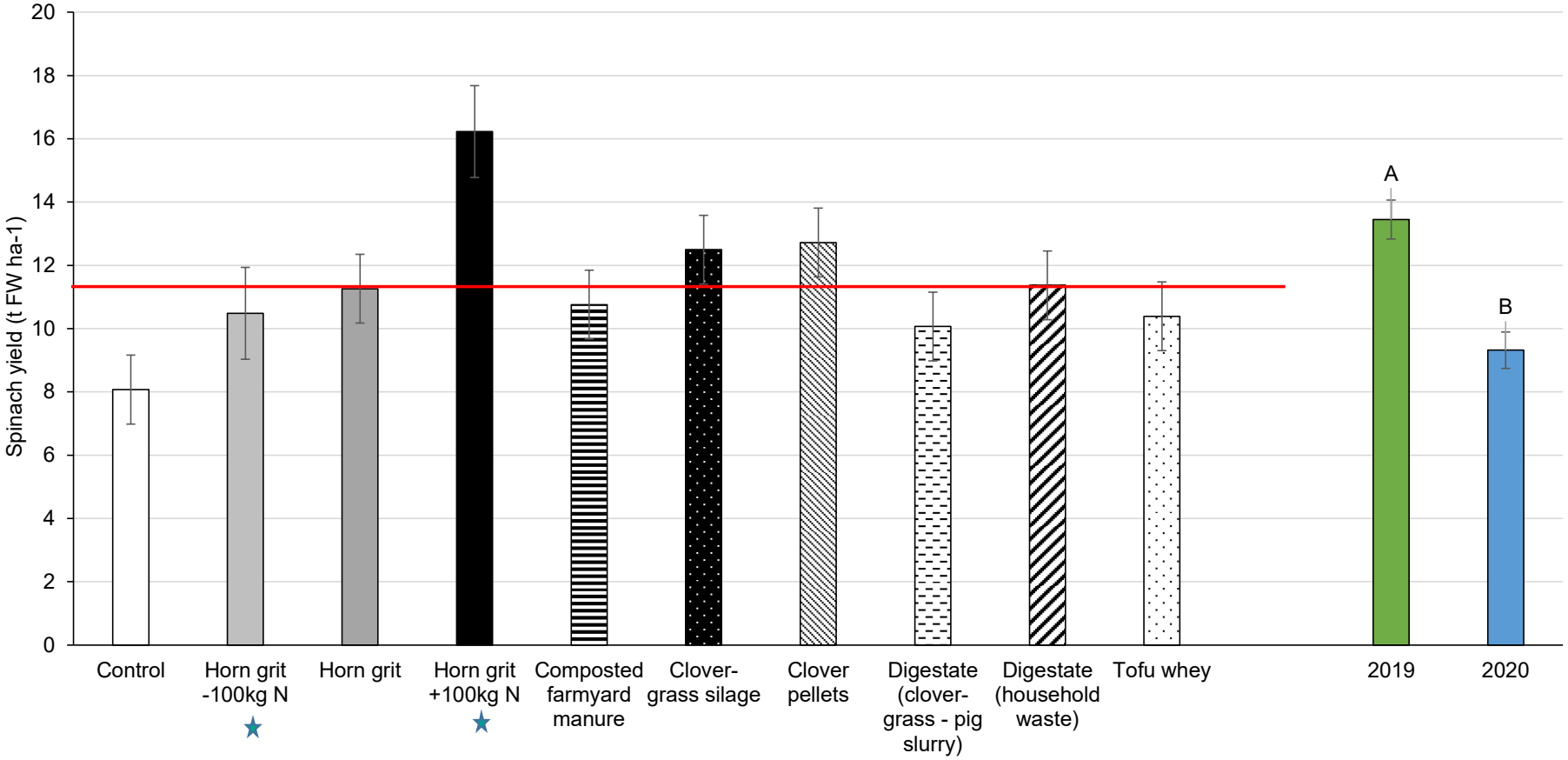
Different lower case letters indicate significant differences of treatments for P < 0.05; Different capital letters indicate significant differences between the years for P < 0.05.

★ HG -100kg N and HG +100kg N yield data only of one year available

Marketable heads ≥1kg

Non-marketable heads <1kg

Spinach yield (t FW ha^{-1})



Different capital letters indicate significant differences between the years for P < 0.05; Error bars: Standard error

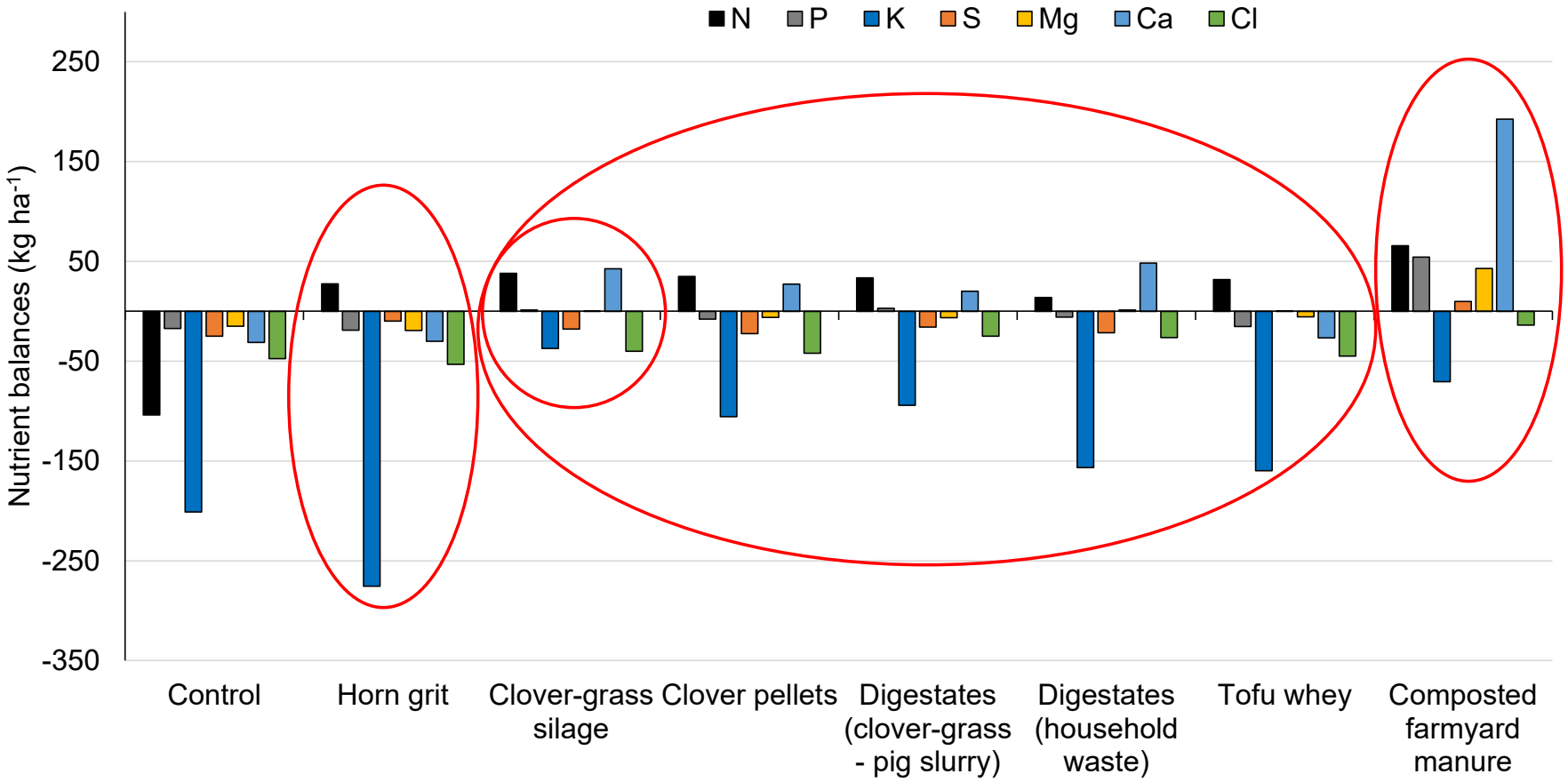
★ HG -100kg N and HG +100kg N yield data only of one year available

→No stat. significant differences between fertilisers

→ Residual effect of clover-grass silage and manure compost

Alternative fertilisers perform well, but need better balancing

Nutrient balances = Nutrient input (fertiliser) minus nutrient output (cabbage (head) + spinach)



- High K deficits for most fertilisers
- P surpluses for composted farmyard manure
- Most balanced nutrient balanced for clover-based fertilisers
  (but: lowest cabbage yields for clover-grass silage)

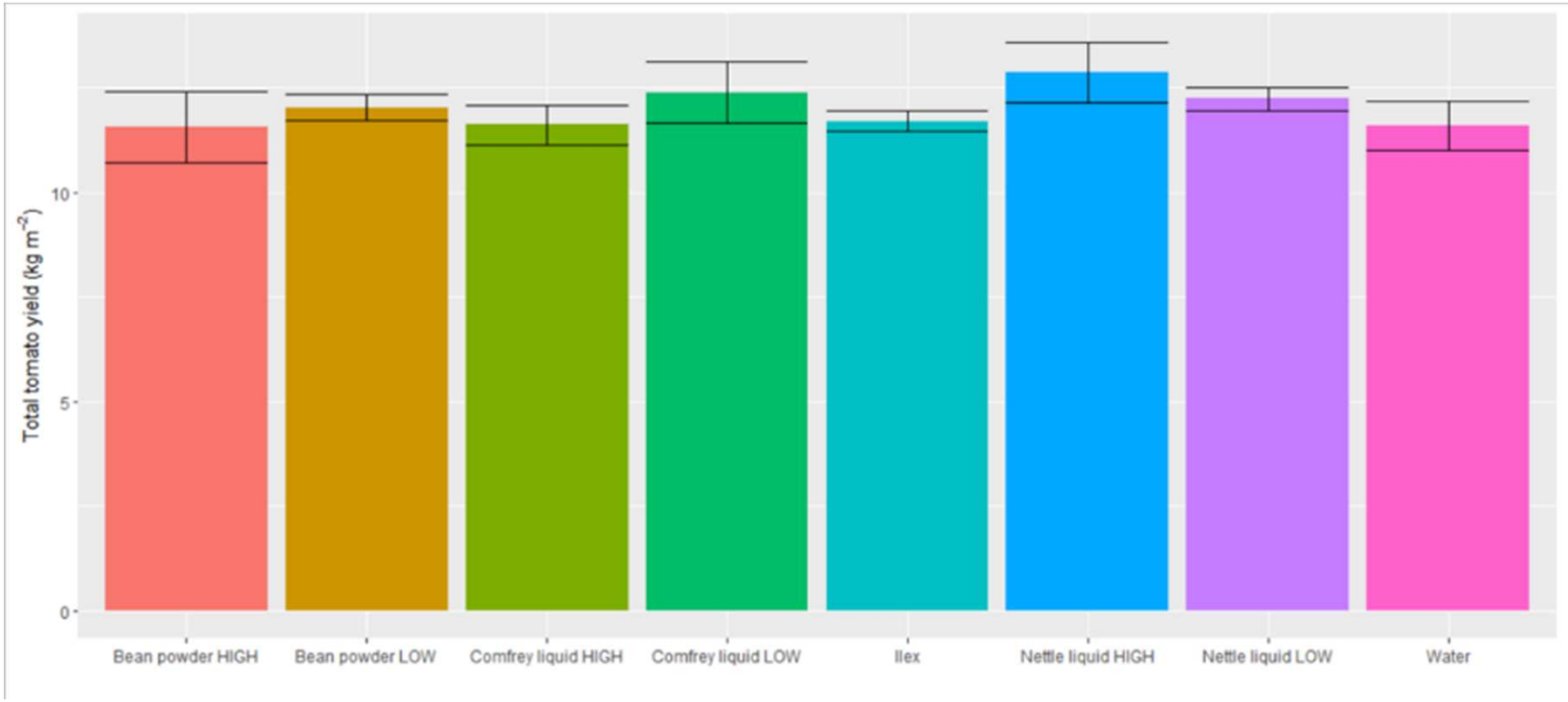
VEGAN protected cropping trial 2020, CU

- Nutrient supply to soil-grown tomato by on-farm produced vegan fertiliser
- Often applied for organic tomato in UK: pelleted poultry manure
- **Fertiliser materials tested:**
- ***Comfrey*** and ***Nettle liquid***: leaves and stems steeped in water for ca. 2 months with no stirring under lid; strained before using (strong odour!)
- ***Bean powder***: *Vicia faba* flour (for cooking) suspended in water
- ***Ilex 'Complete Hi-Fruit' 4-2-6***: commercial plant based feed from cane sugar molasses and "sustainable sources of plant material"; Ilex Environsciences, Lincolnshire, UK

- Tomatoes cv. Douglas planted May 22
- Weekly harvests Aug 8-Nov 11
- Weekly fertilisation over 10 weeks from July 31
- Comfrey, nettle, bean meal in 2 rates
- 4 replicates

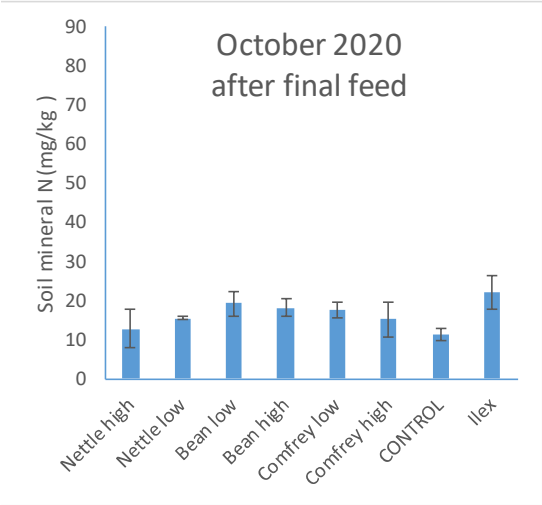
Soil formerly used for vegetables; too fertile to affect yields by fertilisation

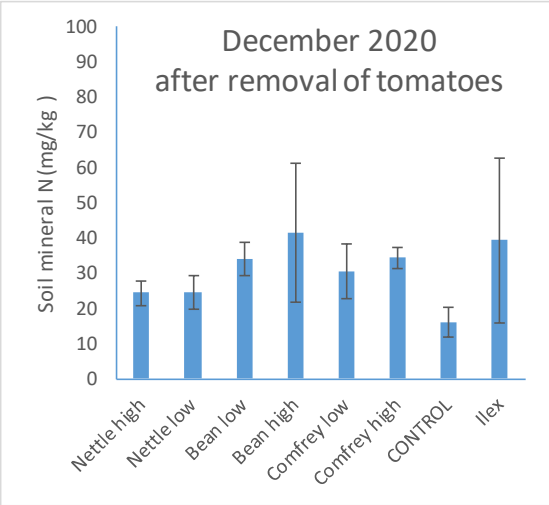
- Accumulated tomato yield: no significant differences between treatments

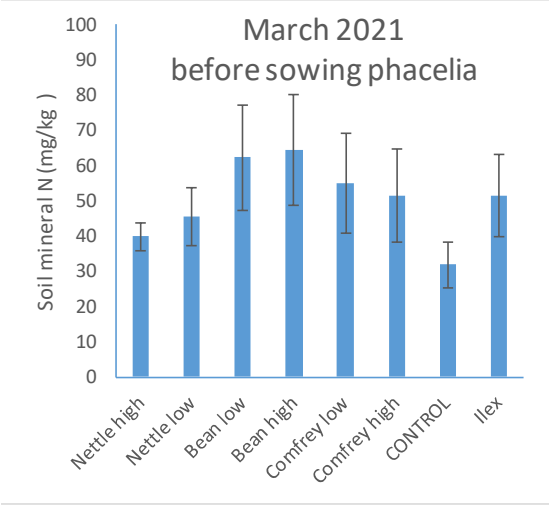


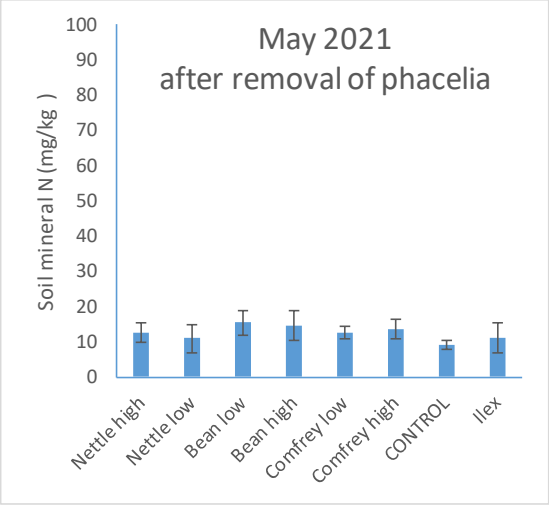
- No differences in biomass of residual phacelia or pak choi (2021)

Soil mineral nitrogen (0-15 cm)









- Fertilisers affected soil mineral N, especially after removing the tomato plants

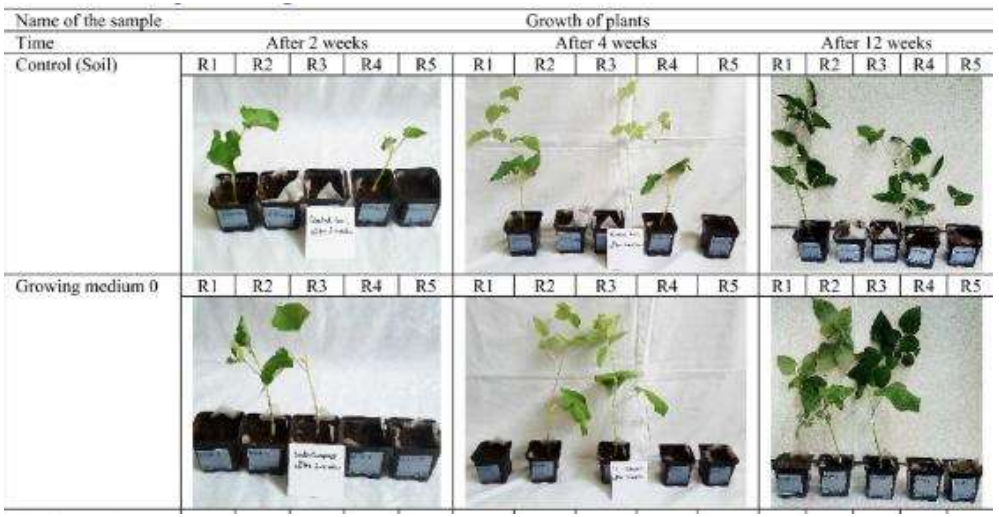
RESID compost from organic fishpond sediments, CUT

Czestochowa University of Technology

- Pond sediments must be regularly removed to ensure O_2 for fish production
- Pond sediments from organic raising of rainbow trout mixed with fresh grass clippings and wheat straw for composting
- 9 kg sediment, 7 kg grass, 0.3 kg chopped straw
- High proportion of mineral material in sediment; ca. 30% organic matter
- Temp. raised to 52°C on day 4, back to 25 °C on day 8

- pH increased from 7 to 8.5 over 28 days
- C/N decreased from 26 to 12
- Total N increased from 0.8 to 1.4%

https://link.springer.com/article/10.1007/s12649-020-01074-6#Tab4



- For germinated bean plants, addition of 70 g compost per kg soil compost increased plant growth after 12 weeks
- Mixing the compost with biochar improved plant growth

RESID compost from organic? olive prunings, MFAL

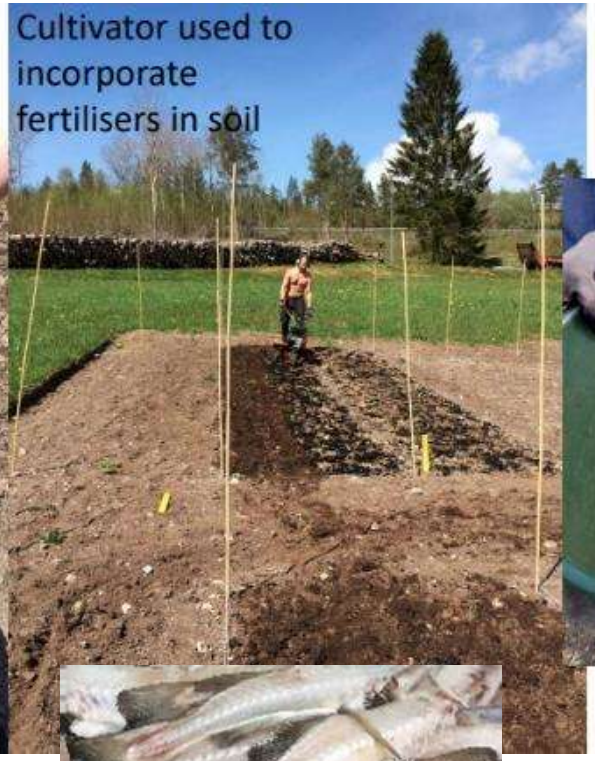
- Mixing chopped olive prunings with 30 % grass clippings, 2% horse manure (% by volume) and beneficial microbes
- Over 8 months, mature compost performing well as growing media to raise olive saplings, and for cabbage and pepper

https://doi.org/10.17660/ActaHortic.2021.1317.4

RESID fertilisers from marine industry residual materials – fishbones and seaweed fibre, NORSØK

Fresh, ground fishbones (rå)

Cultivator used to incorporate fertilisers in soil



Dried fishbones conserved by formic acid

Algae fibre (AF)from wild seaweed

Wild seaweed, bladderwrack (*Ascophyllum nodosum*)

Backbones of cod (*Gadus morhua*)

Very rapid growth effect of fishbones, example from 2019

Treatment	Kg N/ha (aim)	Yield, tonnes of DM/ha	Relative yield
Control (K0)	0	2.7	100
Seaweed fiber (AF)	160	2.5	91
Poultry manure (GO)	160	3.8	138
Mix AF + FB	160	4.4	160
Fishbones, acidified (FB)	160	4.8	174

Oats for green fodder, harvest July 31, 2019
Cover crop for grass-clover ley 2020-

Positive control, GO: Dried poultry manure with vinasse and MBM

AF	Mix	FB	GO	K0
GO	K0	AF	Mix	FB
AF	FB	K0	Mix	GO
K0	AF	FB	GO	Mix

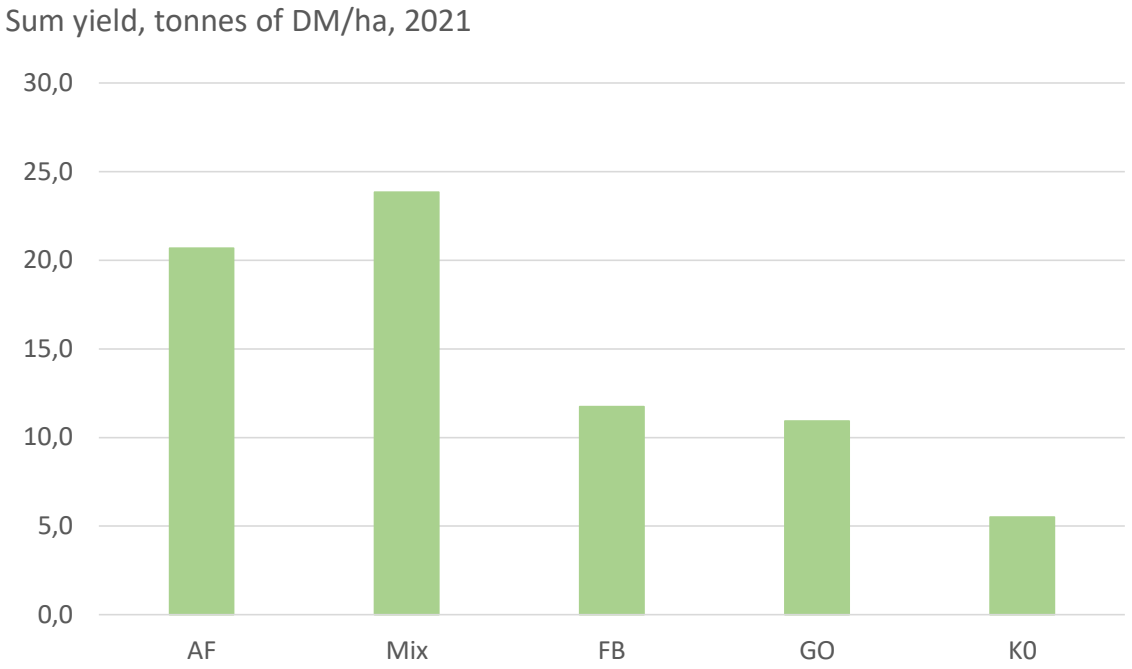
Field plan (4 reps)

Very high residual effect of seaweed fibre, example from 2021

Application of seaweed fibre in field, 16 May 2019

AF	Mix	FB	GO	K0
GO	K0	AF	Mix	FB
AF	FB	K0	Mix	GO
K0	AF	FB	GO	Mix

Field plan

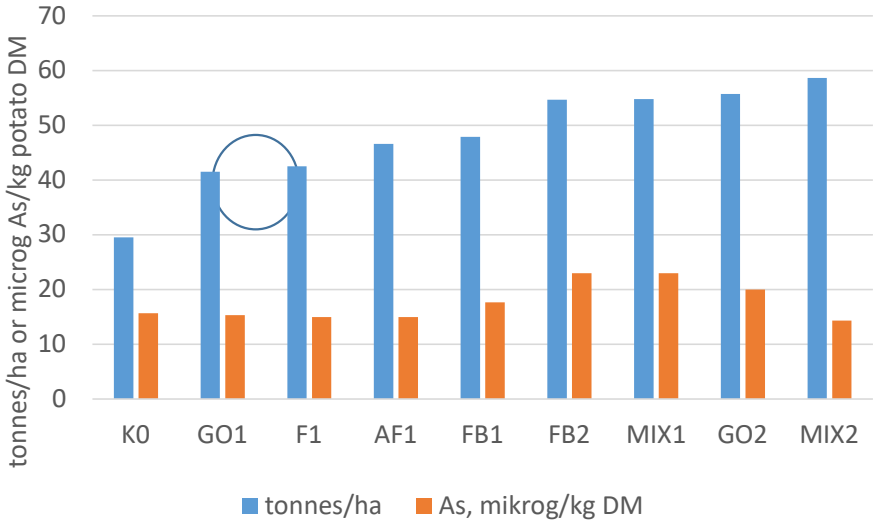


Dry matter yields of 2. year ley in 2021
Fertilisers applied in 2019 (160 kg N/ha)

On the same field:
Plot experiment established 2020, 4 cuts of ryegrass 9 treatments, some with two rates of N (300 vs. 600 kg/ha)

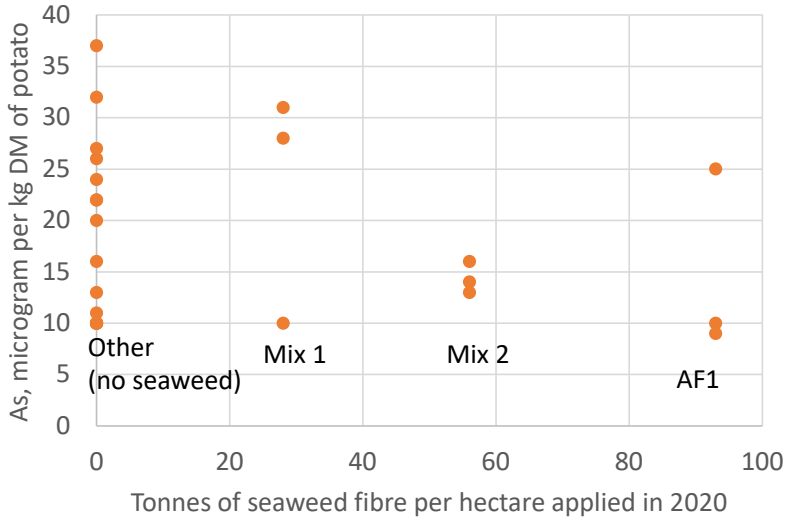
No fertiliser applied in 2021, residual effect in potato

Relative yield,
K0= 100:
AF = 158%



Further: No indication of more As in potatoes grown in soil amended with seaweed →

All treatments well below safety limit of 5 mg/kg FW = about 1.1 mg/kg DM (21.3% DM in potatoes)



Overall results and system considerations

- Fertilisation effect comparable to contentious controls
- Amounts may be significant, but infrastructure and regulations must be adapted and costs may rise

URBAN:

- OK for cereals – what about other crops? (regulations)
- Plastic residues, how serious? Are farmers right to worry?

VEGAN:

- On-farm nutrients - cheap but labour intensive; purchased products (e.g., clover pellets) very expensive
- Internal recycling challenges; what about P, K budget
- Fine tuning for N mineralisation may be challenging

RESID

- Competition for materials for other purpose than fertilisers
- Several materials have high potential
- Marine materials may contain toxic compounds (As, Cd, organic pollutants)
- Fine tuning for N mineralisation may be challenging

Larvae of spring fly, normally building its „nest“ of small wooden sticks or gravel, here from micro-plastic pieces.

Site: Close to Bergen, Norway; Nov. 2021 (NRK)

Whale killed by eating plastic bags
Site: Close to Bergen, Norway; January 2017 (BergensAvisen)

Need for combining «top-down» (RELACS) and «bottom-up» (Organic-PLUS)

- RELACS has demonstrated that many organically managed farms need inputs of P and K, whereas some farms should find N fertilisers with low P
- Organic-PLUS has demonstrated that many materials may be applied for fertilisation
- Reducing the volume of farmed animals, while recycling more nutrients from fork to field, will create new linkages between consumers and farmers
- Organic agriculture needs adapted regulations to support recycling of nutrients while maintaining high food quality standards
- We have a lot to discuss…. at Field Days with farmers, and other events

Field Day at SEGES, now Innovation Centre for Organic Farming, Denmark, 2020

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Thank you

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