LEX4BIO – optimising bio-based fertilisers in agriculture

PA Nutri Talks – Nutrient recycling in the Baltic Sea Region
23.9.2024

Kari Ylivainio
Principal Scientist, coordinator of LEX4BIO-project
Natural Resources Institute Finland (Luke)

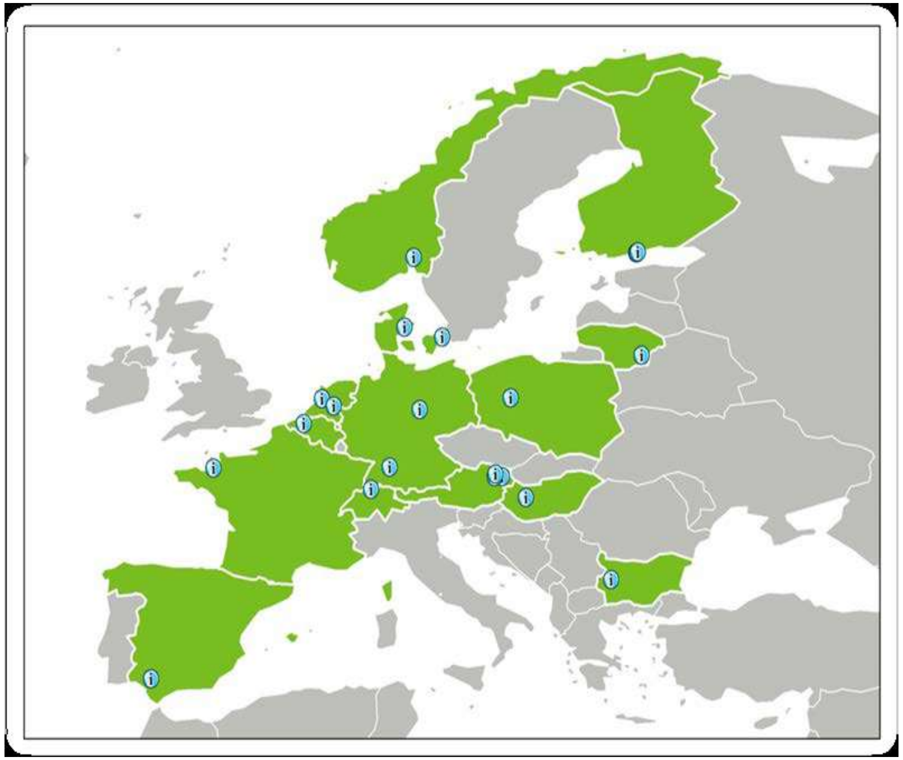
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 818309 (LEX4BIO).
This output reflects only the author's view and the European Union cannot be held responsible for any use that may be made of the information contained therein.

Luke
NATURAL RESOURCES INSTITUTE FINLAND

LEX4BIO

Project duration and consortium

- LEX4BIO: Optimising bio-based fertilisers in agriculture – Providing a knowledge basis for new policies
- Project lifetime: 1.6.2019 – 31.5.2024
- 20 partners, 14 countries
  - Research institutes (6), Universities (8), SMEs (4) and industry partners (2)

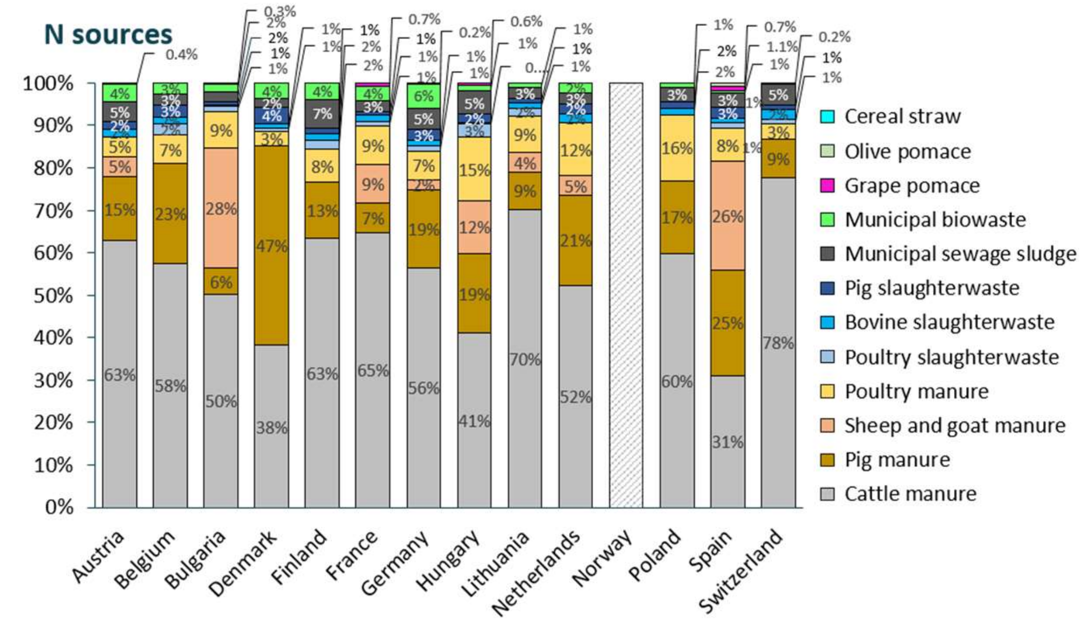


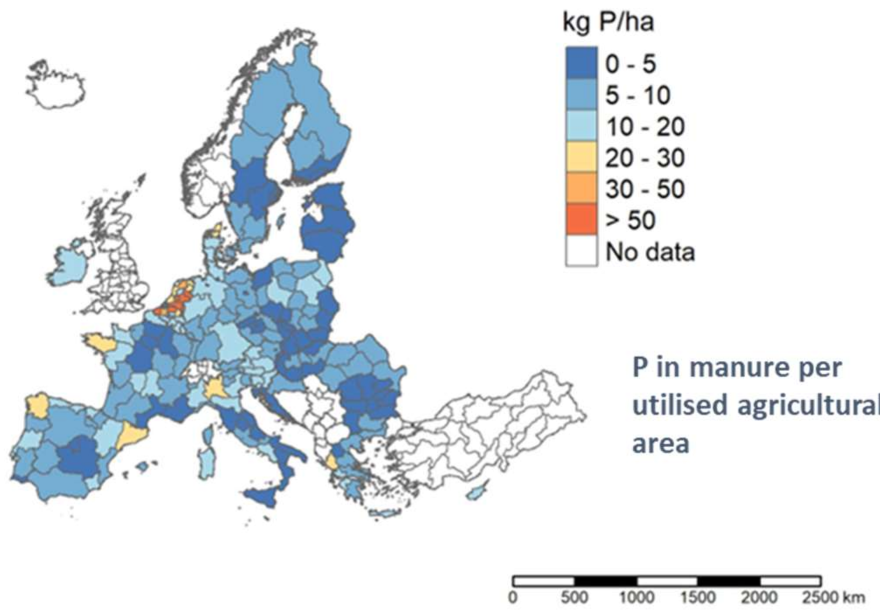
Content of the presentation

1) Available raw materials for producing bio-based fertilisers (BBFs)
2) Selection of BBFs
3) Agronomic efficiency of P- and N-BBFs
4) Potential P losses from BBFs
5) Potential ammonia losses from N-BBFs
6) Organic contaminants of BBFs
7) Dissemination of antimicrobial resistance genes
8) Conclusions

Available NRSS for producing BBFs in Europe

- The amount and nutrient content of relevant NRSS in the EU were quantified into a database using Eurostat-statistics and literature
- Of all NRSS studied, manure is the main source of N and P
- A significant P surplus per utilised agricultural area was identified for some EU regions, especially Belgium and the Netherlands





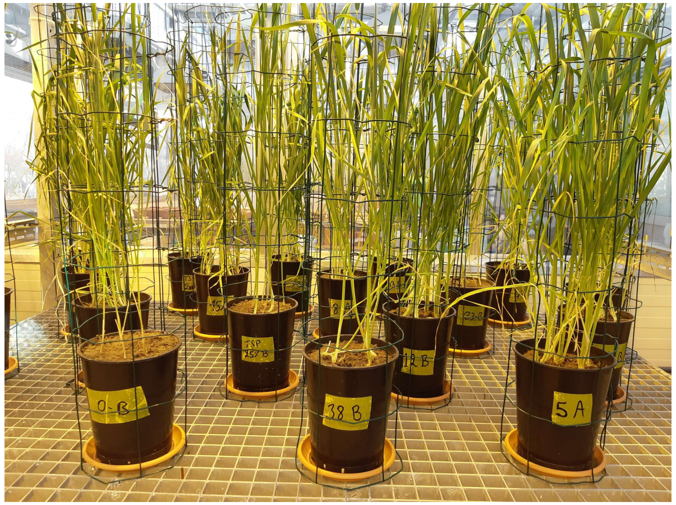
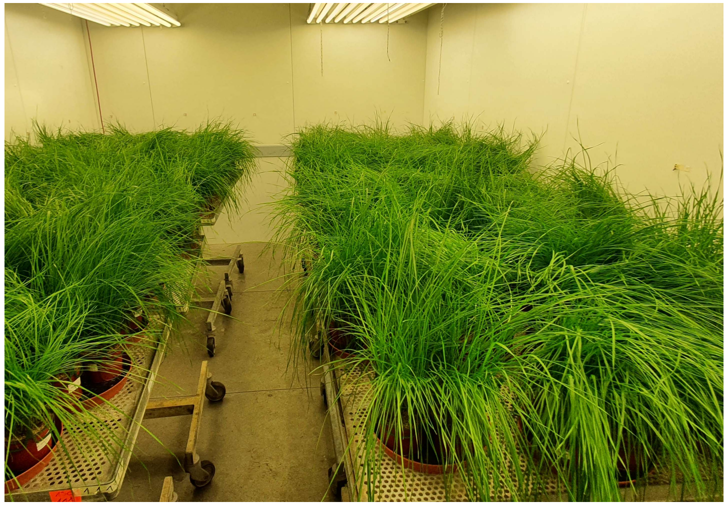
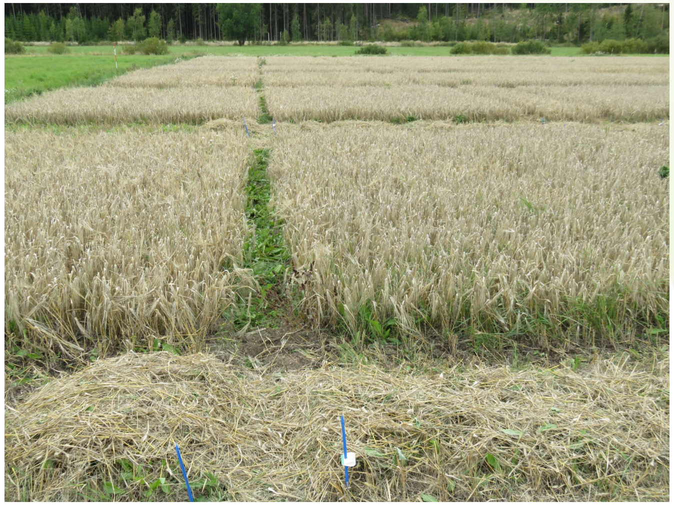
Database: https://px.luke.fi/PXWeb/pxweb/en/maatalous/
Nutrient maps: https://projects.luke.fi/biomassa-atlas/en/biomasses-in-eu/

Selection of BBFs

- Focus on those BBFs already on the market or near commercialization
- Total of about 80 BBFs evaluated (40 N-BBFs and 40 P-BBFs)
- Selection of BBFs to cover different CMCs (component material categories) and PFCs (Production Function Categories) according to the Fertilising Products Regulation (2019/1009)
- Same batch of BBFs tested in field/greenhouse/laboratory trials

Agronomic efficiency of P-BBFs

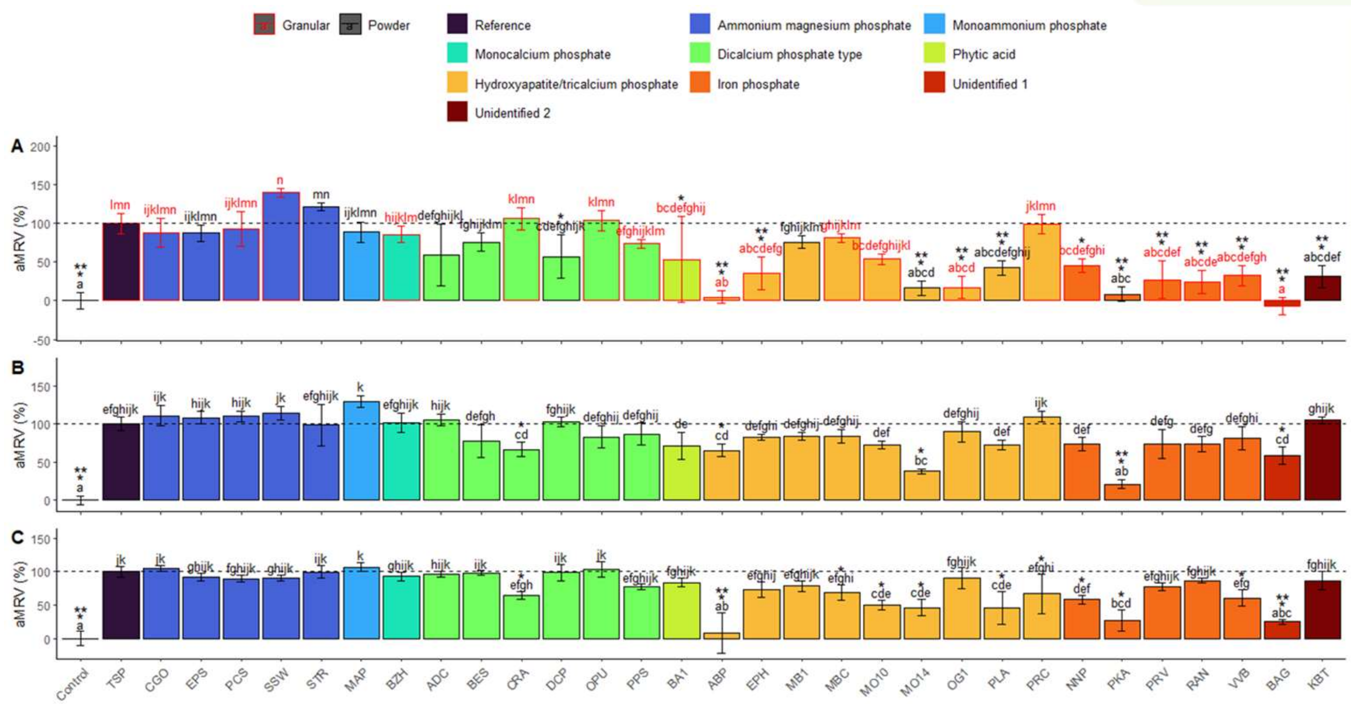
- Agronomic efficiency of BBFs was tested both in greenhouse (Finland, Austria, Switzerland) and field trials (Finland, Austria, Hungary, France and Spain)

Agronomic efficiency of P-BBFs: pot trials

- Total of 30 BBFs tested in greenhouse trials
- Soluble, inorganic BBFs, and struvites equal to TSP
- Thermochemical treatments reduced agronomic efficiency
- Sewage sludge (Fe-P) and apatite-based BBFs less efficient

Agronomic mineral replacement values



A = Jokioinen, Finland (barley)
B = Tulln, Austria (wheat)
C = Frick, Switzerland (ryegrass)

Hernandez-Mora et al.2024, https://doi.org/10.1016/j.jclepro.2024.142957

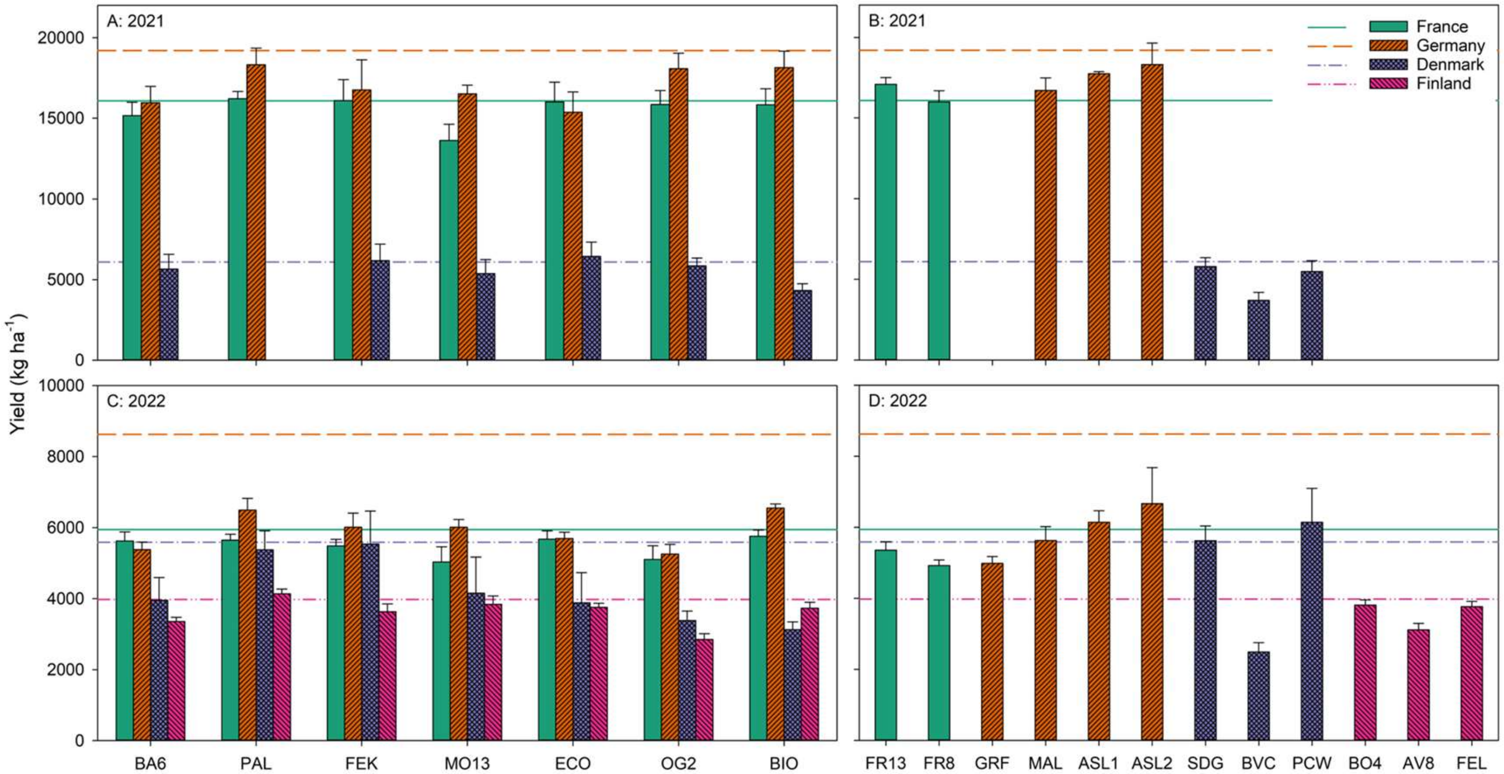
Agronomic efficiency of P-BBFs: field trials

- Results more variable than in pot trials, residual fertilization effect comparable to mineral fertilizer
- None of the BBFs differed significantly from TSP in grain yield or P uptake; no consistent effect of soil or climatic conditions was found
- Struvite (CGO), dicalcium phosphate (ADC, OPU) and phytate (BA1) dominated BBFs performed best
- Tricalcium phosphate/Hydroxyapatite (esp. MO14, PLA) dominated BBFs performed worst
- Most tested BBFs have the potential to replace conventional inorganic P fertilisers across a range of European soils and climate

(Frick et al., submitted)

Agronomic efficiency of N-BBFs

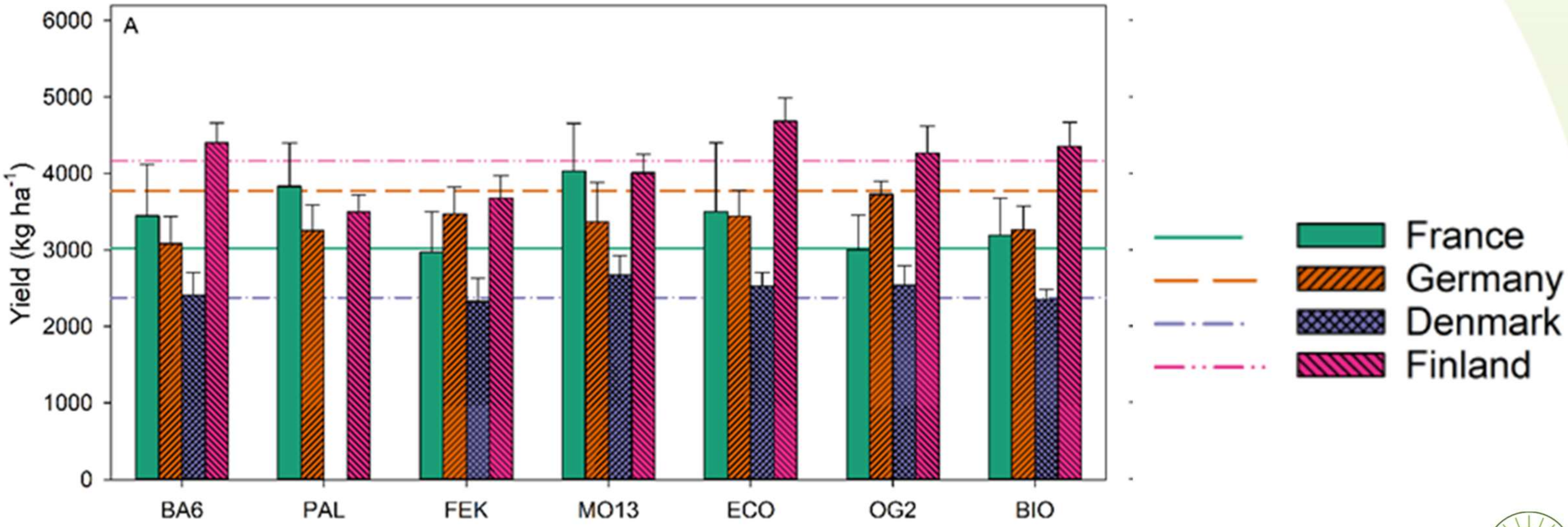
- Efficiency of N-BBFs tested in five two-year field trials (Finland, Denmark, Germany, France, Spain)
- Average nitrogen fertilizer replacement value of 71% across sites and years
- Variations across sites and years were observed
- In general, no significant differences in yields were found compared with the mineral N fertilizer reference applied at the same total N level
- N fertilizer replacement value: Incorporated > broadcasted



Müller et al. 2024, https://doi.org/10.1016/j.fcr.2024.109486

Agronomic efficiency of N-BBFs

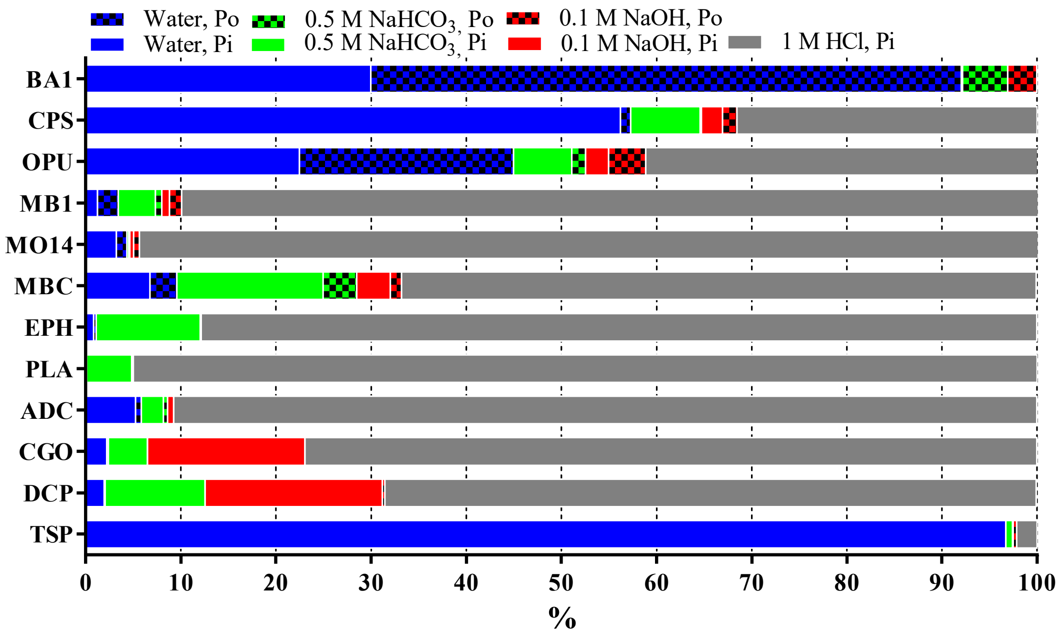
- Second-year residual effect of BBFs detected, but not higher than mineral N reference



Potential P leaching; rainfall simulation

- Experimental soils from Finland, Germany and Spain having different chemical properties

- Soils incubated with different types of BBFs



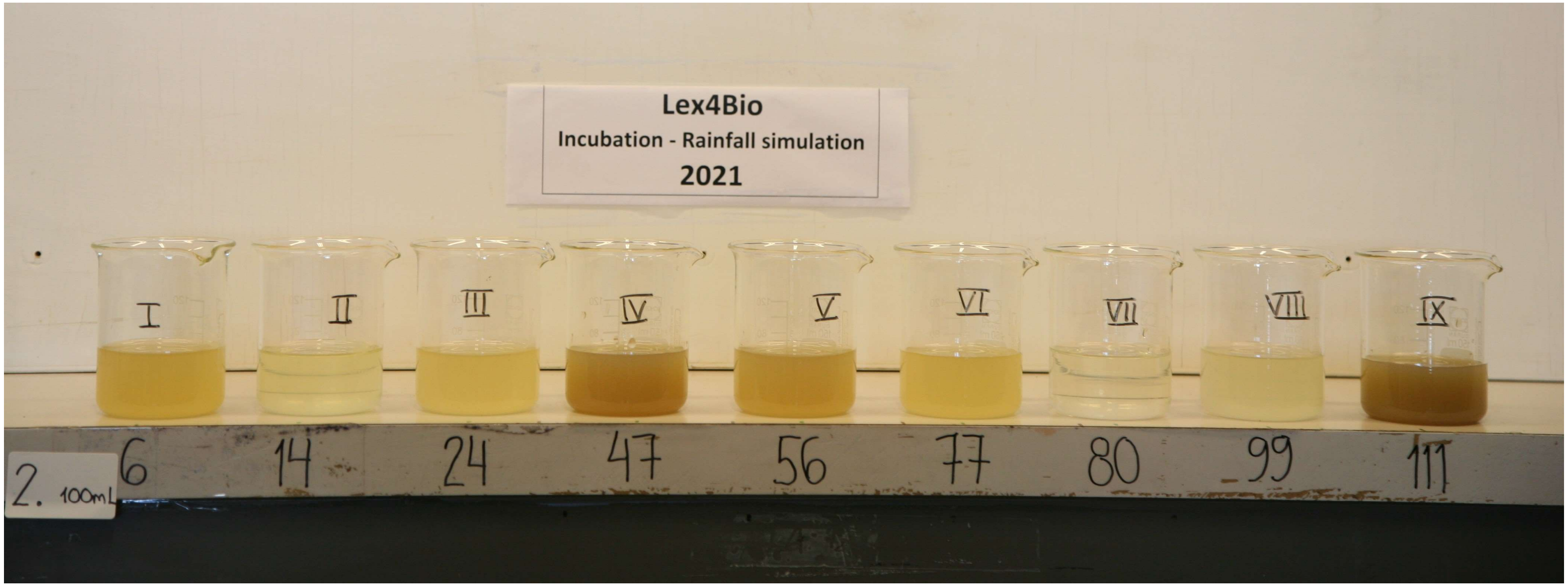
Organic BBFs

Inorganic BBFs

Mineral reference

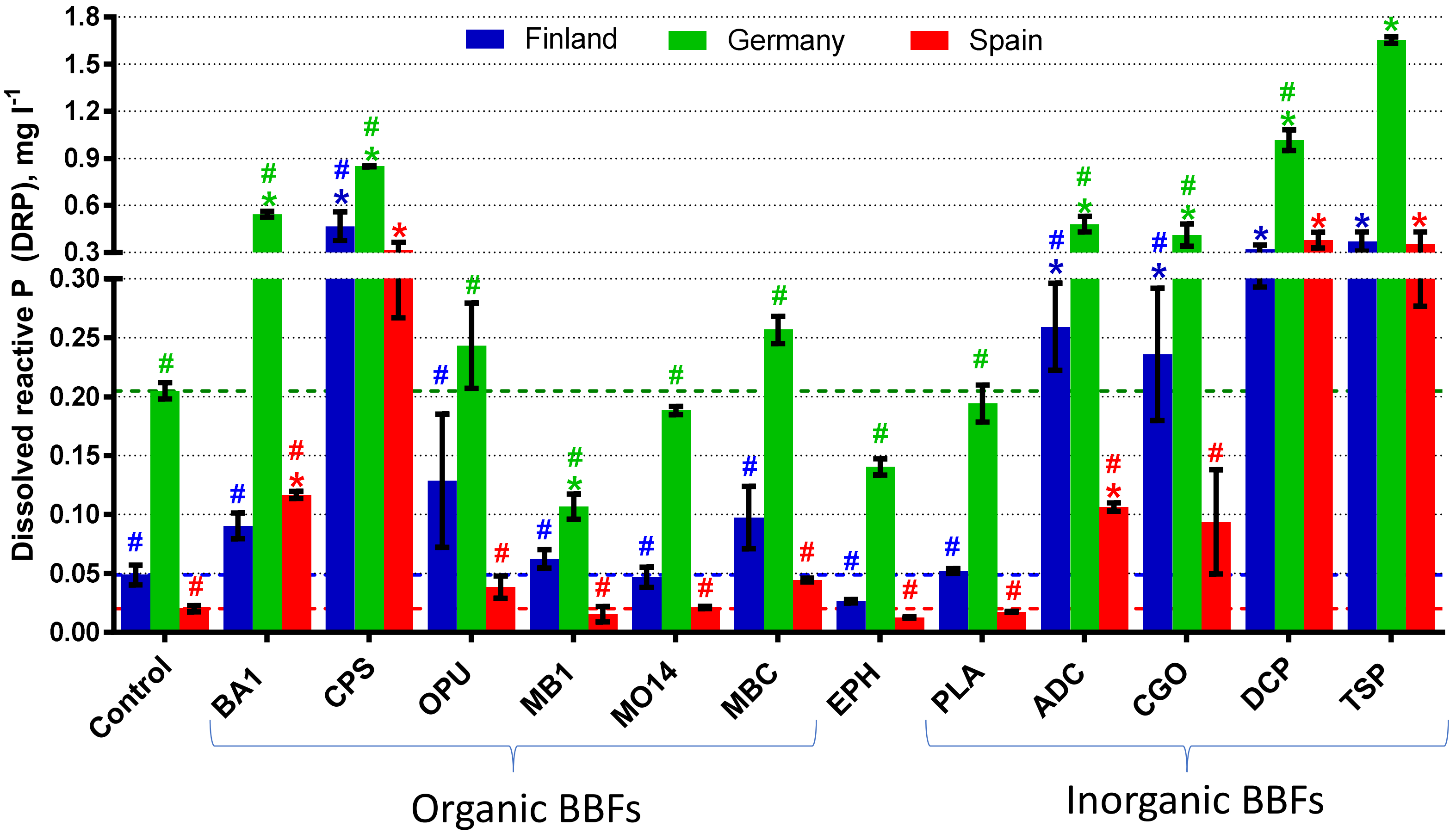
Potential P leaching; rainfall simulation

- Rainfall conducted at intensity of 5 mm/h until 3*100 ml of leachate obtained
- Analyses: pH, EC, turbidity (immediately), N, P and C (samples were frozen)



Potential P leaching; rainfall simulation

- ➢ All BBFs caused lower DRP losses than TSP in GER soil
- ➢ In FIN and SPA soils all except CPS and DCP caused lower DRP losses than TSP
- ➢ Properties of BBFs and soils had a great influence on DRP losses

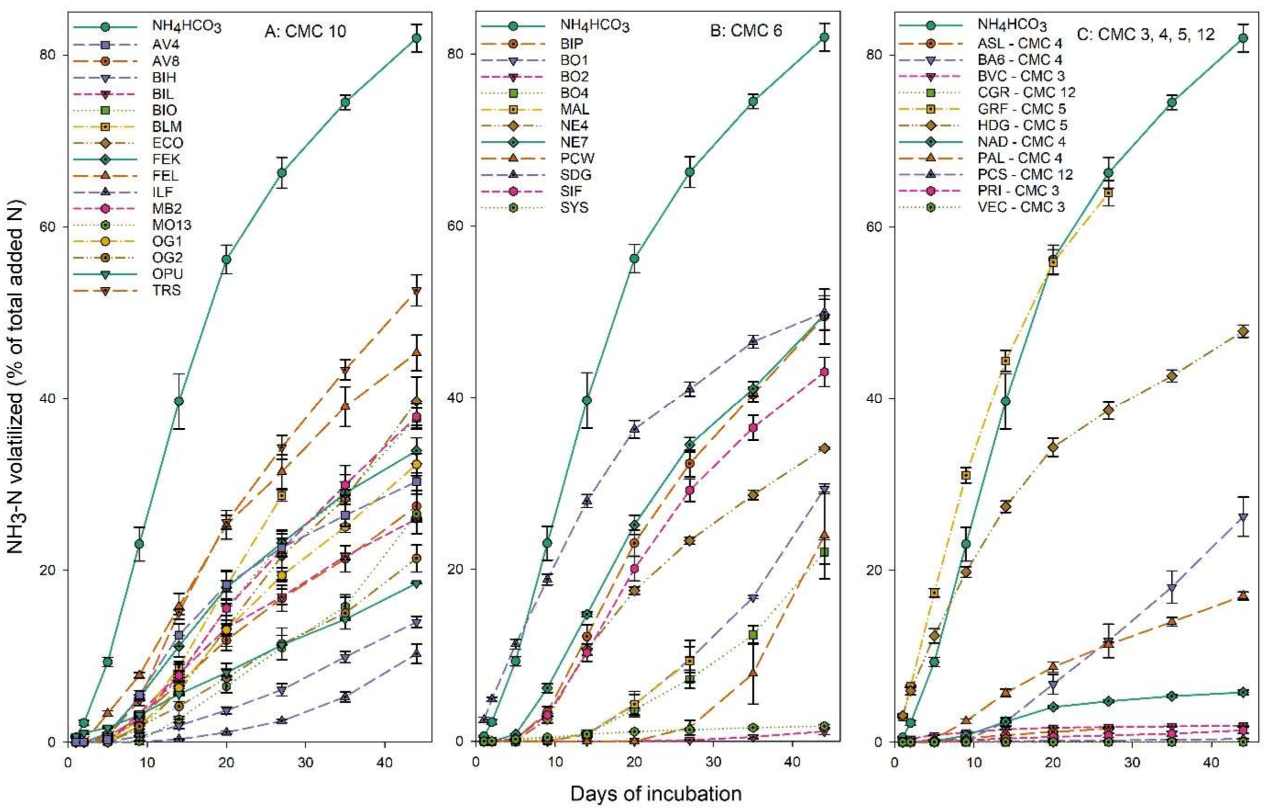


Statistically significant differences ($p < 0.05$) as compared to neg. control (*) or TSP (#) treatments in a given soils are indicated above the bars. Error bars ± SD.

LEX4BIO

Potential ammonia volatilization

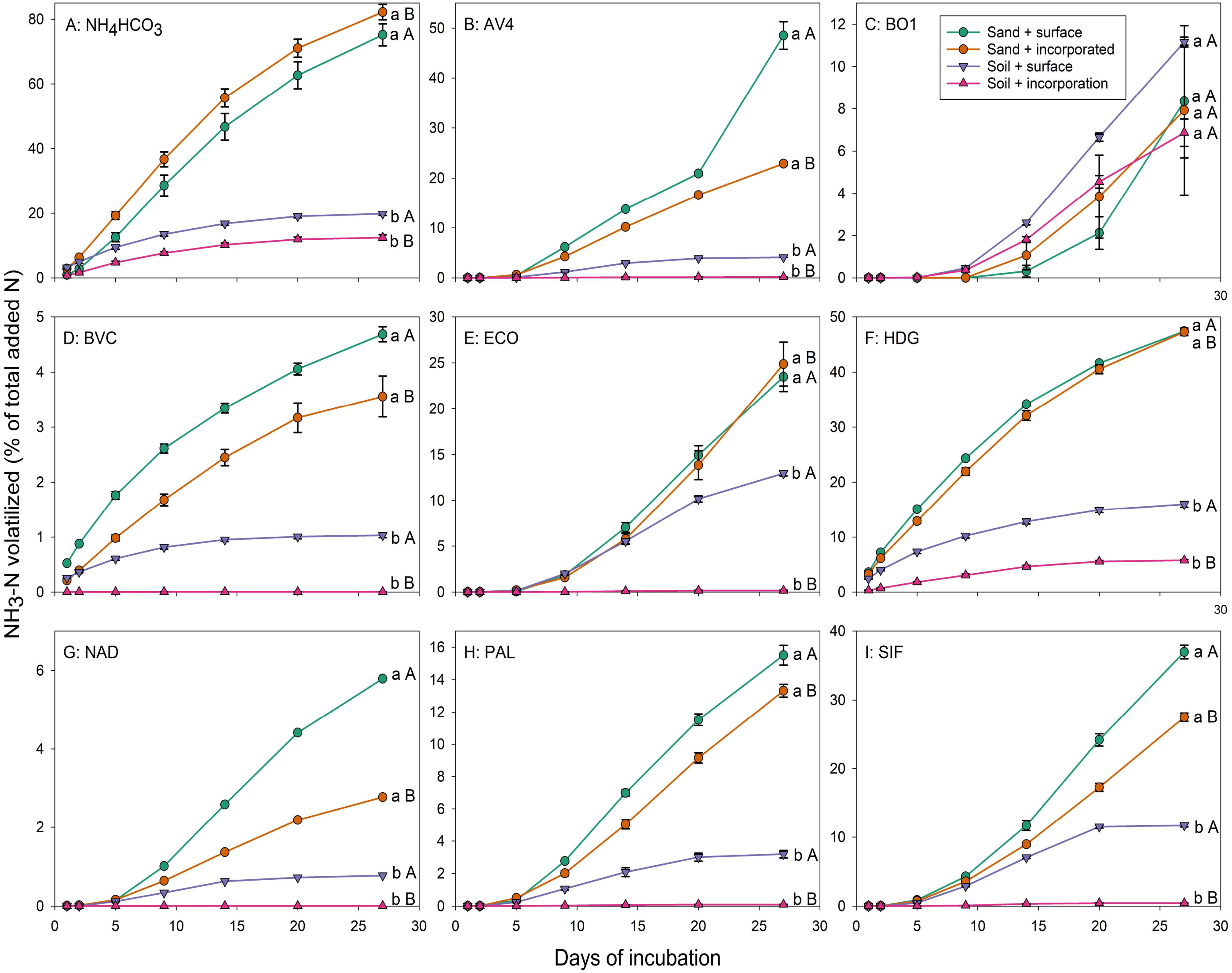
- ➢ Potential ammonia volatilization varies greatly among BBFs
  - ➢ 0.03% - 64% of applied N
  - ➢ High: digestates
  - ➢ Medium: animal and food by-products
  - ➢ Low: mineral concentrates and composts



- ➢ Rapid NH_3 loss (from day 0)
  - • Only for the three digestates
- ➢ Delayed NH_3 loss
  - • for many BBFs, 5-20 days
  - • In particular pelletised animal & food industry by-products
- ➢ Initial BBF characteristics explained 89% of variation

Wester-Larsen et al. 2022, https://doi.org/10.1016/j.jenvman.2022.116249

Potential ammonia losses



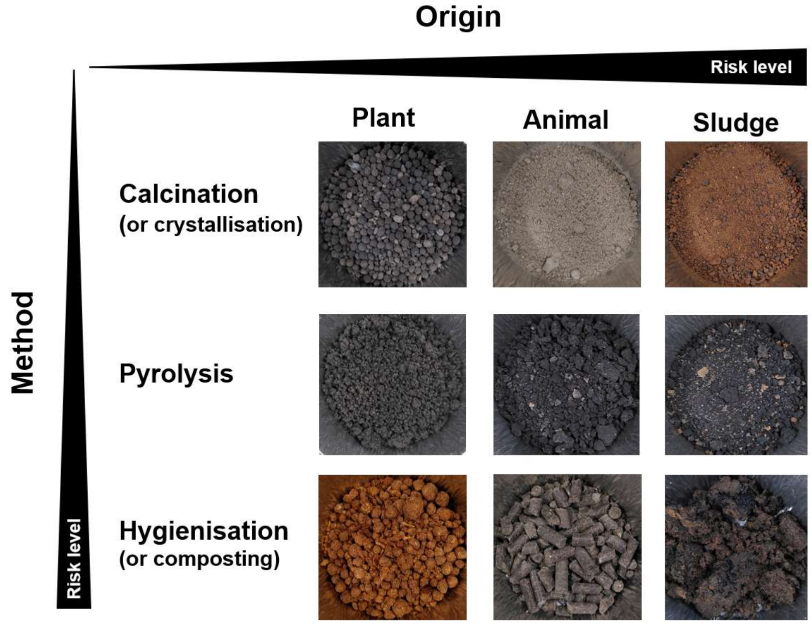
- Pure sand vs. Soil (a sandy, acidic soil)
  - Generally, much lower NH_3 volatilization on soil than pure sand (NH_4^+ adsorption)

- Surface application vs. incorporation
  - Soil incorporation reduced NH_3 volatilization by 37% - 96%

Wester-Larsen et al. 2022, https://doi.org/10.1016/j.jenvman.2022.116249

Organic contaminants in BBFs

- The risk caused by PCBs, PAHs, PCDDFs and PFAS (POPs, persistent organic pollutants) was assessed for nineteen BBFs
- Limit values of POPs in bio-based fertilizers have not been set by the EU regulation
- The strictest values used in individual EU countries were used for the purpose of compliance assessment
- All measured values, except in one BBF (PAHs), were below the limit values
- Significant differences were observed between the BBFs



Estoppey et al., under review

Pesticides and pharmaceuticals in BBFs

- Total of 15 BBFs with different origing were screened for pharmaceutical and pesticides
- Most BBFs contained at least one pesticide or pharmaceutical, concentration ranging from 4.1 to 181 ng/g (one g is 1 000 000 000 ng)
- Most below LOD and some were below LOQ
- Ibuprofen was frequently detected in animal- and plant-based BBFs
- No compounds were detected in ash-based BBFs

LEX4BIO

Dong et al. 2023, https://doi.org/10.1016/j.jhazmat.2023.131992

Degradation of pesticides and pharmaceuticals

- Degradation of pesticides and pharmaceuticals was studied in two contrasting soil (calcareous and acidic soil) before and after BBF application (15 BBFs with different origins)
- Overall, only a very limited number of contaminants were found at low intensities (pharmaceuticals and industrial chemicals as the main groups of organic pollutants)
- Degradation rates of pharmaceuticals (diclofenac, naproxen and ketoprofen) in soil were slightly delayed by the BBFs
- Half-life of ibuprofen was not affected by the BBFs

Das et al. 2023, https://doi.org/10.1016/j.chemosphere.2023.139261
Dong et al. 2023, https://doi.org/10.1016/j.jhazmat.2023.131992

Antibiotic resistance genes (ARGs) in BBFs

Analysis of **80 selected genes** related to resistance and transfer

- **"Poultry waste" BBFs**:
  - contained most of the ARGs
  - can contain antibiotic residues

  => risk similar to manure

- **Composts and digestates:**
  - Resistance against last resort antibiotics (Carbapenems)
  - These are also found in natural ecosystems, source unknown

  => difficult to assess the risk

Antibiotic resistance genes (ARG) in soils

Diversity and amount of ARGs

- Can be high with BBFs from:
  - manure
  - sewage sludge
  - animal-based products
- Mostly returned close to initial concentrations within 6 weeks

=> BBFs in general have a low AMR dissemination potential

Reduction of microbiome diversity:

- Often similar to mineral fertilizers
- Often reversible (by 6 weeks after)

Conclusions

- Both N- and P-BBFs are efficient fertilizers and can be used replacement for mineral fertilisers
- Risk for P losses generally low from P-BBFs, but properties of BBFs and soils needs to be known for minimizing P losses
- Ammonia losses can be greatly reduced by incorporation of BBFs after application
- Concentration of organic contaminants are low in BBFs and degradation of pharmaceuticals in soils are only slightly delayed by BBFs
- BBFs in general had a low antimicrobial resistance dissemination potential

Published results

- https://zenodo.org/communities/lex4bio/records?q=&l=list&p=1&s=10&sort=newest
- https://cordis.europa.eu/project/id/818309/results

Science of the Total Environment 773 (2021) 145618
Contents lists available at ScienceDirect
Science of the Total Environment
journal homepage: www.elsevier.com/locate/scitotenv

Predicting relative agronomic efficiency of phosphorus-rich organic residues

Kari Ylivainio[a,*], Alma Lehti[a,c], Johannes Jermakka[b,d], Hanne Wikberg[b,e], Eila Turtola[a]

Journal of Cleaner Production 467 (2024) 142957
Contents lists available at ScienceDirect
Journal of Cleaner Production
journal homepage: www.elsevier.com/locate/jclepro

Fertilization efficiency of thirty marketed and experimental recycled phosphorus fertilizers

A. Hernandez-Mora[a,b], O. Duboc[a,c], E. Lombi[d,1], E.K. Bünemann[e,1], K. Ylivainio[f,1], S. Symanczik[e], A. Delgado[g], N. Abu Zahra[a,h], J. Nikama[f], L. Zuin[i], C.L. Doolette[d], H. Eigner[b], J. Santner[a,k,*]

Science of the Total Environment 879 (2023) 163076
Contents lists available at ScienceDirect
Science of the Total Environment
journal homepage: www.elsevier.com/locate/scitotenv

Review
Ecotoxicological methods to evaluate the toxicity of bio-based fertilizer application to agricultural soils – A review

Sophia Albert, Elke Bloem *

Journal of Hazardous Materials 458 (2023) 131992
Contents lists available at ScienceDirect
Journal of Hazardous Materials
journal homepage: www.elsevier.com/locate/jhazmat

Simultaneous detection of pesticides and pharmaceuticals in three types of bio-based fertilizers by an improved QuEChERS method coupled with UHPLC-q-ToF-MS/MS

Yan Dong[a,*], Supta Das[a], John R. Parsons[a], Antonia Praetorius[a], Eva de Rijke[a], Rick Helmus[a], J. Chris Slootweg[b], Boris Jansen[a]

CSIRO PUBLISHING
RESEARCH PAPER
https://doi.org/10.1071/SR23213
SOIL RESEARCH

Effects of biobased fertilisers on soil physical, chemical and biological indicators – a one-year incubation study

Lærke Wester-Larsen[A], Lars Stoumann Jensen[A], Johannes Lund Jensen[B,C] and Dorette Sophie Müller-Stöver[A,*]

Environmental Technology & Innovation 36 (2024) 103781
Contents lists available at ScienceDirect
Environmental Technology & Innovation
journal homepage: www.elsevier.com/locate/eti

Prediction of nitrogen mineralization from novel bio-based fertilizers using chemical extractions

L. Agostini[a], E.K. Bünemann[a], C. Jakobsen[b], T. Salo[c], L. Wester-Larsen[b], S. Symanczik[a,*]

Field Crops Research 316 (2024) 109486
Contents lists available at ScienceDirect
Field Crops Research
journal homepage: www.elsevier.com/locate/fcr

Agronomic performance of novel, nitrogen-rich biobased fertilizers across European field trial sites

Benedikt Müller[a,1], Lærke Wester-Larsen[b,1], Lars Stoumann Jensen[b,*], Tapio Salo[c], Ramiro Recena Garrido[d], Mustapha Arkoun[e], Aurélien D'Oria[e], Iris Lewandowski[a], Torsten Müller[f], Andrea Bauerle[a]

Journal of Cleaner Production 379 (2022) 134749
Contents lists available at ScienceDirect
Journal of Cleaner Production
journal homepage: www.elsevier.com/locate/jclepro

Assessing the phosphorus demand in European agricultural soils based on the Olsen method

Ramiro Recena[a], Ana M. García-López[a], José M. Quintero[a], Annaliina Skyttä[b], Kari Ylivainio[b], Jakob Santner[c], Else Buenemann[d], Antonio Delgado[a,*]

Science of the Total Environment 806 (2022) 150486
Contents lists available at ScienceDirect
Science of the Total Environment
journal homepage: www.elsevier.com/locate/scitotenv

Improving the prediction of fertilizer phosphorus availability to plants with simple, but non-standardized extraction techniques

Olivier Duboc[a,b,*], Alicia Hernandez-Mora[b,c], Walter W. Wenzel[a], Jakob Santner[b,**]

Chemosphere 337 (2023) 139261
Contents lists available at ScienceDirect
Chemosphere
journal homepage: www.elsevier.com/locate/chemosphere

Organic contaminants in bio-based fertilizer treated soil: Target and suspect screening approaches

Supta Das[a,*], Rick Helmus[a], Yan Dong[a], Steven Beijer[b], Antonia Praetorius[a], John R. Parsons[a], Boris Jansen[a]

Journal of Environmental Management 323 (2022) 116249
Contents lists available at ScienceDirect
Journal of Environmental Management
journal homepage: www.elsevier.com/locate/jenvman

Research article
Potential ammonia volatilization from 39 different novel biobased fertilizers on the European market – A laboratory study using 5 European soils

Lærke Wester-Larsen[a], Dorette Sophie Müller-Stöver[a], Tapio Salo[b], Lars Stoumann Jensen[a,*]

Org. Agr. (2023) 13:335–350
https://doi.org/10.1007/s13165-023-00432-7

REVIEW

Opportunities and challenges of bio-based fertilizers utilization for improving soil health

Ari Kurniawati · Gergely Toth · Kari Ylivainio · Zoltan Toth

Science of the Total Environment 918 (2024) 170501
Contents lists available at ScienceDirect
Science of the Total Environment
journal homepage: www.elsevier.com/locate/scitotenv

Exposure assessment of plastics, phthalate plasticizers and their transformation products in diverse bio-based fertilizers

Nicolas Estoppey[a,*], Gabriela Castro[b,c], Geril Aasen Slinde[a], Caroline Berge Hansen[a], Mari Engvig Løseth[a], Katinka Muri Krahn[d], Viona Demmer[a], Jørgen Svenni[a,e], Teresa-Van-Anh Thi Tran[a,e], Alexandros G. Asimakopoulos[b], Hans Peter H. Arp[a,b], Gerard Cornelissen[a,f]

Sustainable Chemistry for Climate Action 3 (2023) 100033
Contents lists available at ScienceDirect
Sustainable Chemistry for Climate Action
journal homepage: www.elsevier.com/locate/scca

Understanding the future of bio-based fertilisers: The EU's policy and implementation

Ari Kurniawati[a,b,*], Petra Stankovics[c,d], Yahya Shafiyuddin Hilmi[e,f], Gergely Toth[d,g], Marzena Smol[h], Zoltan Toth[a,i]

Thank you

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 818309.