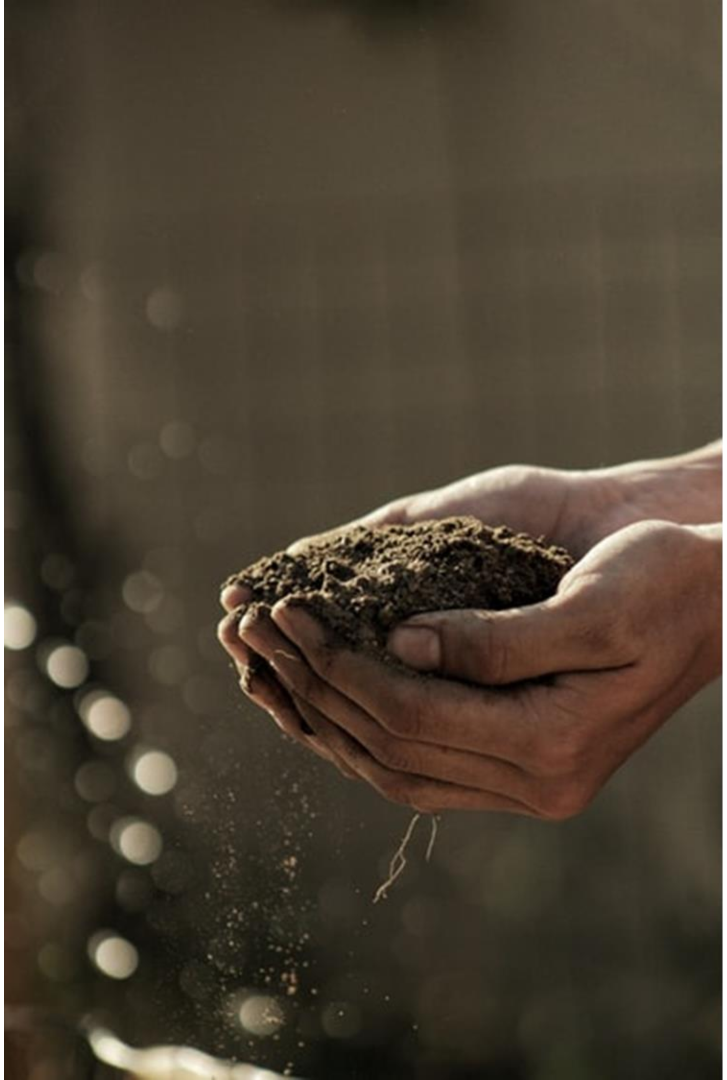


COMPOST DIALOGUES

Session 2: Evidence for the effects of compost application

There are many expectations regarding the effects of compost application and a win-win-win scenario is often promoted. But what does the scientific evidence tell us about the effects of compost application? In this second session of the Compost Dialogues, we will dive deep into this discussion in an interactive and dynamic session with experts across the globe.

Thursday, 27 October from 1-3 PM (CEST)

Programme

13:00-13:30	Presentation by Marie Wesselink
13:30-13:50	Presentation by Mark van der Poel
13:50-14:00	Break
14:00-14:30	Discussion
	Break-out 1: Crop yields
	Break-out 2: Carbon sequestration
	Break-out 3: Soil biodiversity
14:30-14:45	Plenary
14:45-14:50	Power Message manual
14:50-15:00	Closing remarks

COMPOST DIALOGUES

Session 1

Best practices in compost Preparation

- Pre-process
- During process
- Post-process

Session 2

Evidence for the effects of compost application

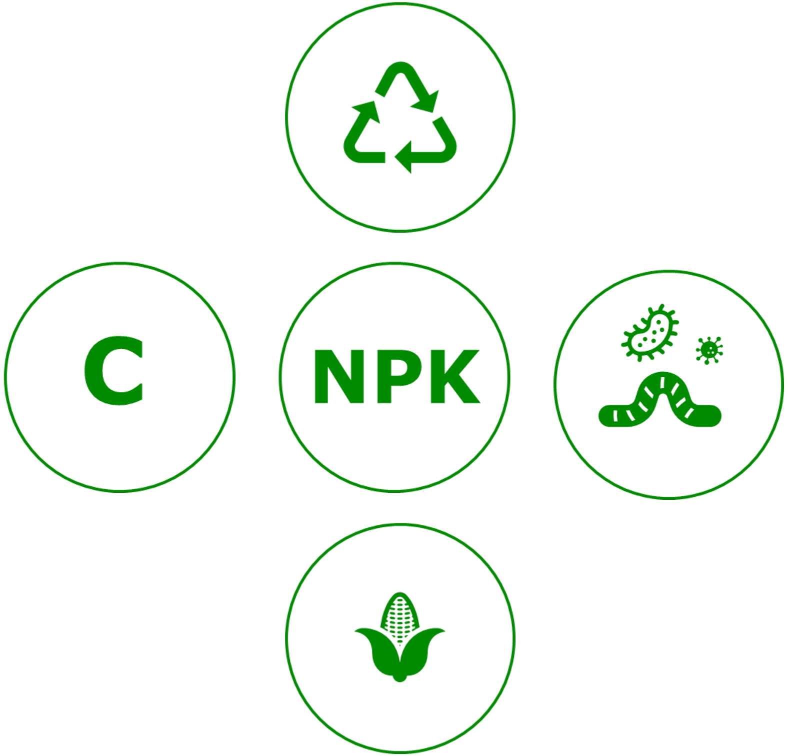
- Crop yields
- Carbon sequestration
- Soil biodiversity

Session 3

Alternatives for compost

- Biogas
- Biochar
- Organo-mineral fertilizer

The potential benefits of compost



Source: Martinez-Blanco et al., 2013

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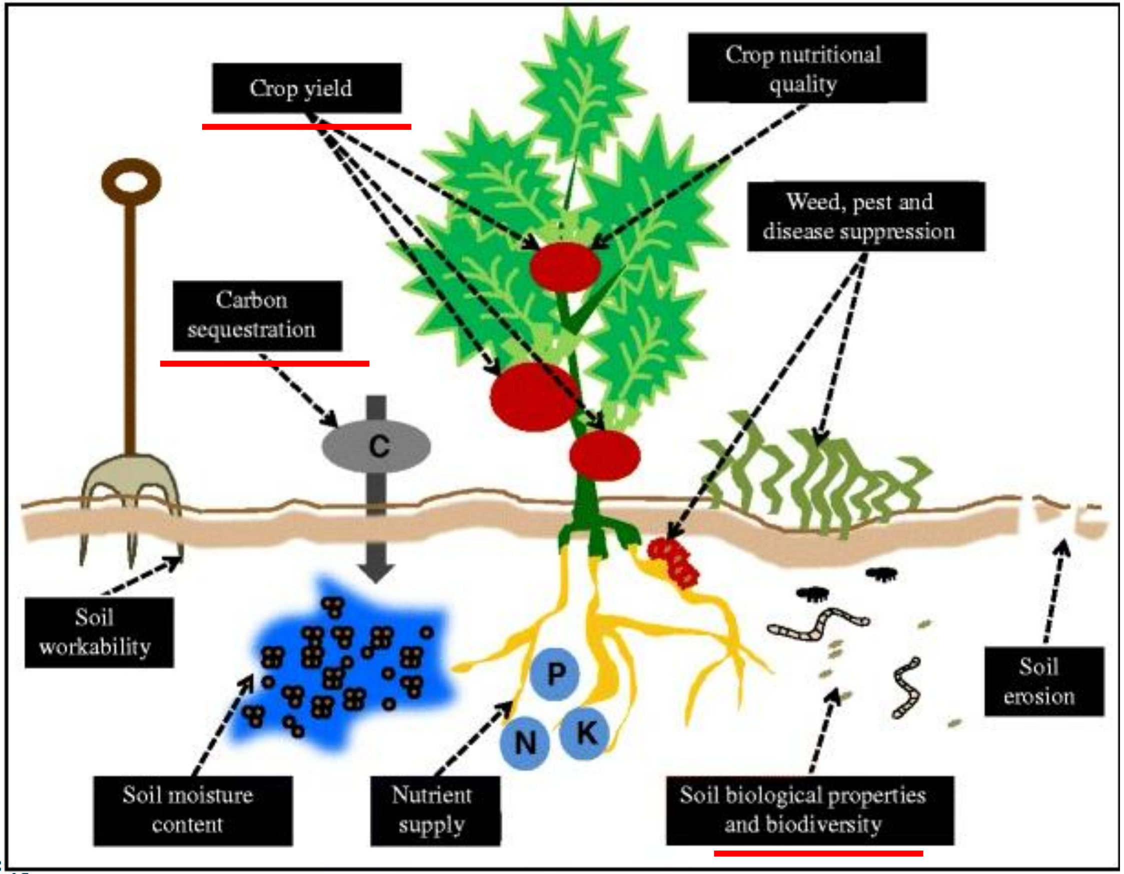

Crop yield
Crop nutritional quality
Weed, pest and disease suppression
Carbon sequestration
C
Soil workability
P
N
K
Soil erosion
Soil moisture content
Nutrient supply
Soil biological properties and biodiversity

Content

- Background
- Methods
- Results
- Discussion
- Conclusions
- Optional: best practices for field experimental design

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Background

→ Compost as soil amendment: idealistic vs scientific evidence

"Organic amendments such as manures, composts and plant residues are frequently used in crop production systems as alternatives to inorganic fertilizers, to restore degraded soils and ameliorate physicochemical constraints"

(Celestina et al., 2019)

"Organic soil amendments (e.g. compost) are increasingly promoted as a sustainable alternative to synthetic fertilizers and as a tool for building soil quality through improved chemical, physical, and biological properties"

(Wortman et al., 2017)

Methods: literature review

- Search queries on Web of Science
  - Resulted in 6 'most relevant' papers
- First search round:
  - n=21 papers

1. Compost + crop + yield + effect
2. Compost + organic carbon OR organic matter + effect
3. Compost + organism OR microorganism OR mirco-organism OR biodiversity OR species OR life + effect

+ Meta-analysis
+ review

→ 2 relevant papers

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Methods: literature review

- 2nd search including non-meta-analysis papers
    - Compost + crop + yield + effect + review ⟶ N=66 papers ⟶ 4 relevant papers

- The papers were then analyzed (using MS Excel) on the grounds of:
    - Type of OM → Crop residues, manure, compost, straw, combi, etc.
    - Experimental setting → Rate & frequency of application, field vs controlled, etc.
    - Measured effects → yields, SOC/SOM, nutrients, soil life, soil structure, etc.
    - Temporality & spatiality → long vs short term, scale, locations, etc

- A final review was conducted, seeking specific information on SOM/SOC, crop yield and soil life

Compost benefits for agriculture evaluated by life cycle assessment. A review

Martinez-Blanco et al., 2013

Type of organic amendment	Compost
Measured effect	9 Benefits, including **crop yields**, **soil life** and **carbon sequestration**
Experimental setting	Multiple (Review)
Temporality/Spatiality	Short-term (<1 year), Mid-term (<10 years) and Long-term (> 100 years) effects

- Extensive literature review & quantitative benefits classified.
- This study delineates the proof, quantifiability, and availability of LCA impact categories per benefit.
- Conclusions:
  - Proved, quantifiable, and LCA impact categories: **carbon sequestration** and nutrient supply.
  - Proved, not quantifiable: increase in **biodiversity**, **crop yield,** crop nutritional quality, and soil workability. LCA categories largely available except for **biodiversity**.

Table 1 Summary of the potential benefits of compost use-on-land in the short-, mid-, and long-term retrieved from the literature review (adapted from Martínez-Blanco et al. 2013)

Benefit	Indicator (unit)	Short-term (<1 year)		Mid-term (<10 years)		Long-term (<100)	
		Min.	Max.	Min.	Max.	Min.	Max.
Nutrient supply	N mineralized (% of N applied)	5	22	40	50	20	60
	P mineralized (% of P applied)	35	38	90	100	90	100
	K mineralized (% of K applied)	75	80	100	100		
Carbon sequestration	C sequestered in soil (% of C applied)	40	53		30	2	16
Weed, pest, and disease suppression	Weed suppression (–)	ns	ns	–	–	–	–
	Pest and disease suppression (–)	nad	nad	–	–	–	–
Crop yield	Crop yield gain[a] (% from mineral fertilizers)[b]	−138	0	−71	52	–	–
Soil erosion	Soil loss[a] (%)[b]	–	–	−5	−36	–	–
	Soil structural or aggregate stability[a] (%)	29	41	0	63	–	–
Soil moisture content	WHC[a] (%)	0	50	–	–	–	–
	PAW[a] (%)	0	34	–	–	–	–
Soil workability	Soil bulk density[a] (%)[b]	−2.5	−21	−0.7	−23		−20
Soil biological properties and biodiversity[c]	Microbial diversity[a] (%)[b]	–	–	–	–	−2	4
	Microbial biomass[a] (%)	22	116	10	242	3.2	100
	Microbial activity[a] (%)	0	344	–	264	0	43
Crop nutritional quality	Crop nutritional quality (–)	nad	nad	–	–	–	–

WHC water holding capacity, *PAW* plant available water, *ns* no significant differences, *nad* no average data because of complexity of available dataset, *en dash* no reported benefits

[a] Change in the indicator

[b] Negative value indicates a decrease in the indicator

[c] The ranges of benefit for three of the more used indicators are presented

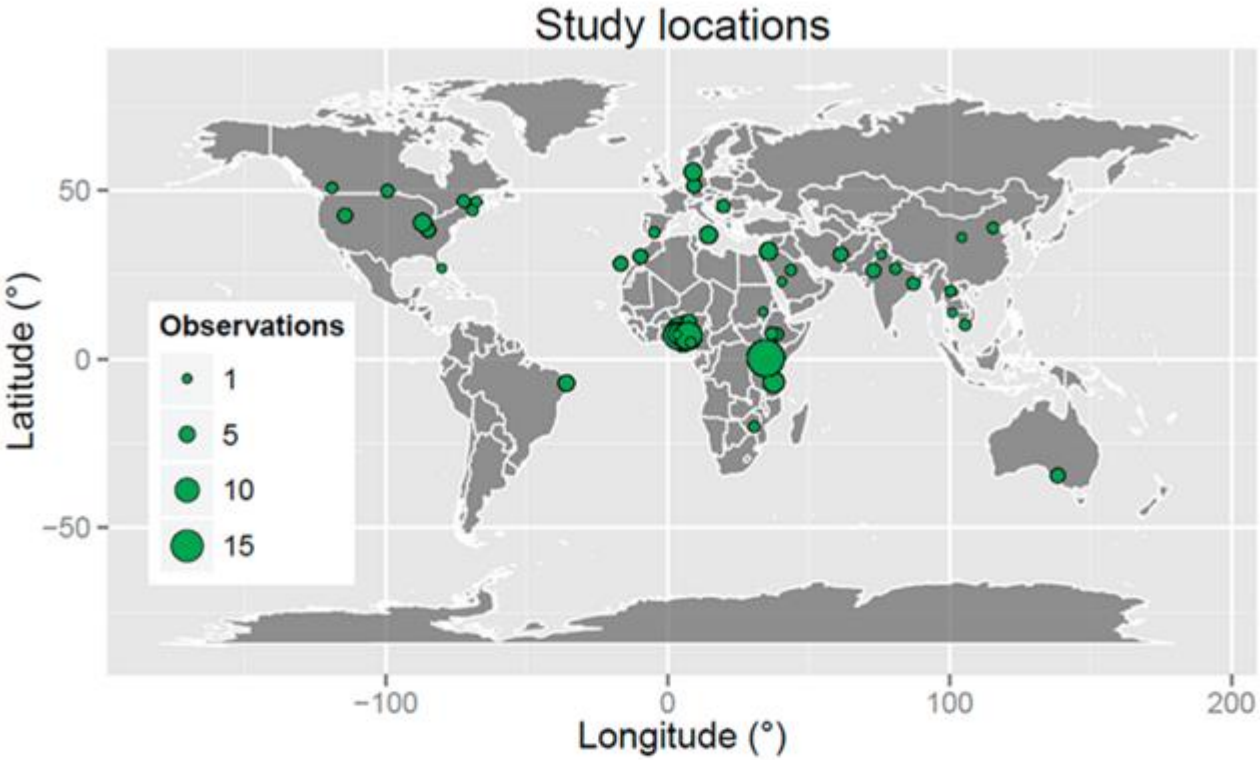
Martinez-Blanco et al., 2013

First-Season Crop Yield Response to Organic Soil Amendments: A Meta-Analysis

Wortman et al., 2017

Type of organic amendment	Multiple
Measured effect	**Crop yields**
Experimental setting	Multiple (Meta-analysis of 53 studies)
Temporality/Spatiality	1st season

- literature search conducted using Scopus search engine (Elsevier), with search terms including "organic fertilizer," "manure," "compost," or "meal," and "yield".
- Organic amendments defined as any organic material applied to the soil during a fallow period or immediately prior to planting a cash crop, most commonly animal manure and plant-based composts.
- Conclusions: organic amendment yield compared to a non-fertilized control:
    - **Crop yields** increased 43±7% (leafy crops 71±26%, Root/tuber: 27±9%)
- Crop yields less responsive to OA in soils with high OM and in arid conditions


Study locations
50
0
-50
Latitude (°)
-100
0
100
200
Longitude (°)
Observations
1
5
10
15

Long-term effects of organic amendments on soil fertility. A review

Diacono and Montemurro, 2010

Type of organic amendment	Compost
Measured effect	Multiple, including **crop yield**, **carbon sequestration** and **soil life**
Experimental setting	Multiple (Review)
Temporality/Spatiality	Long-term experiments (3–60 years)

- This paper focuses on recently published data and gives emphasis to long-term field trials, particularly regarding raw and composted agro-industrial and municipal waste application.
- Many effects evolve slowly, e.g., carbon sequestration, highlighting importance of long-term trials.
- **Crop yield** increased by up to 250% by long-term applications of high rates of municipal solid waste compost.
- Long-lasting application of organic amendments increased **organic carbon** by up to 90% versus unfertilized soil, and up to 100% versus chemical fertilizer treatments.

Table I. Summary of the main data of long-term trials (selected data from experiments of ⩾ 10 years).

Site	Organic materials	Application rate	Crop	Trial period	Reference
Punjab, India	Rice straw compost	8 t ha^{-1}	Rice–wheat rotation	10 years	Sodhi et al. (2009)
Obere Lobau near Vienna, Austria	Biowaste compost	9, 16 and 23 t ha^{-1}	Cereals and potatoes	10 years	Erhart et al. (2005); Hartl and Erhart (2005); Erhart et al. (2008)
Turin, Italy	(1) Cattle slurry; (2) Composted farmyard manure	(1) 100 t ha^{-1}; (2) 40 t ha^{-1}	Maize for silage	11 years	Monaco et al. (2008)
Linz, Austria	Composts of: urban organic waste; green waste; cattle manure or sewage sludge	175 kg N ha^{-1}	Maize, summer-wheat and winter-barley rotation	12 years	Ros et al. (2006a)
Bennett, CO, USA	Anaerobically digested biosolids	2.2, 4.5, 6.7, 8.9 and 11.2 t ha^{-1}	Two-year wheat–fallow rotation	12 years	Barbarick and Ippolito (2007)

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Long-term effects of organic amendments on soil fertility. A review

Diacono and Montemurro, 2010

- Repeated application of OM to cropland led to an improvement in **soil biological functions**. E.g., **microbial biomass carbon** increased by up to 100% using high-rate compost treatments, and **enzymatic activity** increased by 30% with sludge addition.
- Other relevant findings include:
- **Best agronomic performance of compost** often obtained with highest rates and frequency of applications. Stabilized organic amendments do not reduce the **crop yield quality**, but improve it;
- Regular addition of organic residues, particularly the composted ones, increased **soil physical fertility**, mainly by improving aggregate stability and decreasing soil bulk density;
- Repeated application of composted materials enhances soil organic nitrogen content by up to 90%, storing it for mineralization in future cropping seasons, often without inducing nitrate leaching.

The use of vermicompost in organic farming: overview, effects on soil and economics

Lim et al., 2015

Type of organic amendment	Vermicompost
Measured effect	Multiple including **SOM** and **soil life**
Experimental setting	N.A.
Temporality/Spatiality	N.A.

- This review paper discusses in detail the effects of various vermicompost on soil fertility physically, chemically and biologically.
  - Physical: better aeration, porosity, bulk density and water retention
  - Chemical: improved pH, electrical conductivity and **organic matter content**
  - Biological: enhanced levels of **soil organic matter**, **soil microbial biomass** and **activities**

Table 3. Microbial counts in various derivatives of vermicompost

	Microbial population					
	Bacteria		Fungi			
Waste	Active	Total	Yeast and mould	Total	Actinomycetes	References
Kitchen waste(cfu × 10^3 mL^{-1})	–	8	5000	–	–	25
Chicken manure(μg mL^{-1})	43.8	–	–	18.5	–	73
Paper mill sludge and cow dung (cfu × 10^5 g^{-1})	–	450–500	–	18–26	750–900	105
Herbal pharmaceutical waste and cow dung (cfu × 10^5 g^{-1})	–	500–1750	–	5–40	400–3000	39
Remarks	Source of diet to earthworms Solubilize nutrients, stimulates plant growth[106] Nitrogen fixation[107]		Promote soil fertility Suppress plant diseases[108]		Waste mineralization and organic matter decomposition[39]	–

The use of vermicompost in organic farming: overview, effects on soil and economics

Lim et al., 2015

- Additional effects:
  - Suppression of the growth of parasitic fungi and plant parasitic nematodes
  - Enhancement of vesicular arbuscular **mycorrhizae activity**
- Generally, vermi-compost provides larger particulate surface areas that help provide many microsites for **microbial activities** and stronger retention of nutrients.
- Availability of macro- and micronutrients is generally higher in vermicompost than in traditional compost and inorganic fertilizer
- Note, due to high concentrations of soluble salts, vermi-composts should be applied at moderate concentrations in order to obtain maximum **plant yield.**

Attribution of crop yield responses to application of organic amendments: A critical review

Celestina et al., 2019

Type of organic amendment	Multiple
Measured effect	**Crop yields**
Experimental setting	N.A.
Temporality/Spatiality	N.A.

- This review considers three scenarios where organic amendments (OA) are used, to highlight common limitations of OA experiments that prevent attribution of **crop yield** response.
- Scenarios (include many case studies but non in Africa):

1. Alternatives to inorganic fertilizers
2. Restoration and reclamation of degraded soils
3. Deep incorporation to ameliorate subsoil constraints

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Attribution of crop yield responses to application of organic amendments: A critical review

Celestina et al., 2019

- **Crop yield** responses to the application of organic amendments can be due to:
    1. amelioration of soil constraints
    2. plant nutrients contained in the amendment
    3. or both factors acting in concert.
- Poor experimental design can lead to difficulties in accurately ascribing crop yield responses
- Nutrients may play a larger role in the **crop yield** response to organic amendments than physicochemical soil restoration or amelioration, although definitive attribution remains out.

Comparing straw, compost, and biochar regarding their suitability as agricultural soil amendments to affect soil structure, nutrient leaching, microbial communities, and the fate of pesticides

Siedt et al., 2021

Type of organic amendment	Multiple (Straw, compost, biochar)
Measured effect	Multiple including **SOM**, soil **microbial communities**
Experimental setting	Multiple (Review)
Temporality/Spatiality	N.A.

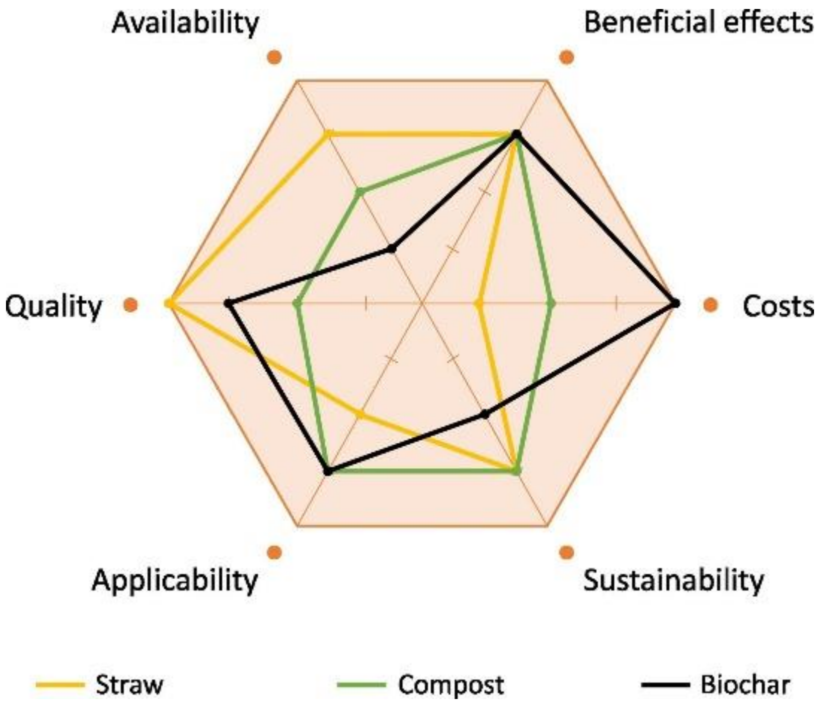
- This review explores to which extent straw, compost and biochar help to retain nutrients and pesticides in agricultural soils.
- Their effects vary greatly depending on e.g., type of soil, application rate, production procedure

Type	Limitation	Opportunity
Straw	N-immobilization	Support crops in dry periods
Compost	Diverse qualities	Nutrient delivery without leaching
Biochar	Multiple dependencies	Pesticide sorption, C sequestration

Comparing straw, compost, and biochar [...]

Siedt et al., 2021

- **Straw**: Benefits on **SOM**, water retention and **microbial activity** → soil structure, reduction of nitrate leaching and increase of pesticide degradation. Additionally: **crop yield** increases, weed suppression.
- **Compost**: mostly positive effects e.g., delivering nutrients to soils without increasing nitrate leaching, improving physical-chemical parameters, and contributing to **microbial life** and pesticide degradation, although limited response attributability due to different qualities of composts.
- **Biochar**: most effective in increasing the sorption capacity of soils but does not outperform straw and compost with regards to other investigated aspects


Availability
Beneficial effects
Quality
Costs
Applicability
Sustainability
Straw
Compost
Biochar

Collection of limitations as input for discussion

- **Precise quantification of responses to one factor is difficult without properly designed and monitored experiments** (Martinez-Blanco et al., 2013; Celestina et al., 2019; Lim et al., 2015). Numerous materials in (vermi)compost influence plant growth (Lim et al., 2015).
- **It can be beneficial to combine organic inputs**; already organically fertilized soils still have the potential to be further improved by e.g. straw mulching (Siedt et al., 2021), as well as combining organic with inorganic fertilizers (Kearney et al., 2012).
- Availability and quality of the data for quantification differ largely among assessed benefits, with no data or large variability in the observed benefits (Martinez-Blanco et al., 2013).
- Data concerning **long-term benefits** of compost are particularly scarce. Therefore, there is a need for more long-term studies or estimations (Diacono and Montemurro, 2011; Martinez-Blanco et al., 2013).

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Concluding remarks

- These papers largely explore the **broad trends** of the effects of organic soil amendments on crop yields, soil life, carbon sequestration amongst other effects.
- Although the benefits of OA both long-term and short-term on soil quality and yield have been documented, **effects and trends will vary per field, farm and local context** e.g., climate, soil type, typology, management factors. As such, these should ideally be considered in order to attribute responses of organic soil amendment practices.
- Certain **obstacles** encountered by small-scale farmers cannot be dismissed: for instance, the lack of knowledge and experience in organic fertilizer use; poor ability to react to unpredicted external factors such as drought, sudden arrival of new diseases and pests; high cost; difficulty in assessing organic markets and bias of most legal structures in favor of conventional agriculture (Lim et al., 2015).

Field experiment guidelines

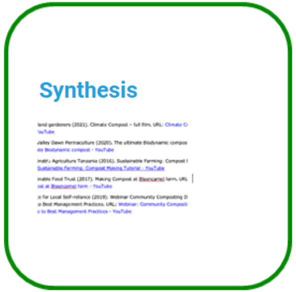
Celestina et al., 2019

Guidelines for the design, conduct and analysis of organic amendment experiments will allow the attribution of yield responses to nutrition, alleviation of physicochemical constraints, or other factors:

1. identify a genuine constraint to crop yield at the experimental site;
2. incorporate proper treatments to control for the effects of nutrient content and method of placement;
3. use appropriate sampling protocols to assess treatment differences;
4. carry out suitable soil and plant analyses; and
5. be conducted over several sites and years.

Controlled environment experiments and modelling approaches may be used to overcome some field limitations and provide a detailed mechanistic understanding of the crop yield response.

Compost Questions



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