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Research Institute of Organic Agriculture
Forschungsinstitut für biologischen Landbau
Institut de recherche de l'agriculture biologique






# Composting process management and compost benefits for soil fertility and plants

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BioGreenhouse

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EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

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# Composting process management and compost benefits for soil fertility and plants

- Introduction: composting in Europe
- Process management and compost quality
- Composting benefits for soil fertility
- Composting benefits for plants' growth and health
- Choice of compost in relation to its target use
- Conclusions

# Introduction: composting in Europe

# Introduction: composting in Europe

- **Composting of organic waste: well established over the world**
- **Municipal waste practices: great variation between countries**
  - EU (Eurostat 2009): 522 kg municipal waste per person and year, 17% of them composted
  - composted waste proportion varies between 0 and 38%in the different EU countries!
- **Motivations:**
  - meaningful closing of nutrients' cycles
  - supply of organic matter to the soil
  - cheap disposal of organic waste
- **Compost characteristics can vary greatly :**
  - inputs material
  - composting techniques
  - process management

# Process management and compost quality

# Process management and compost quality

- **Compost: result of the aerobic decomposition of organic residues**
- **Numerous microorganisms are involved in this process**
- **Roles of the composting process management**
  - Creates the conditions that are favorable for the inactivation of the harmful microorganisms and promotes the development of the beneficial ones
  - Avoid the losses of fertilizer (nitrogen)
  - Avoid emission of gases damaging for the environment (such as greenhouse gases, odors, …)
  - Production of high quality composts appropriate to the target utilization

# Process management and compost quality

## › Importance of the raw materials

### › Raw materials used influence the communities of microorganisms present during the composting process

**Table 1.** Mean ± 1 SD ($n = 8$) of dominant bacterial phyla and sub-phyla, expressed as percentage of sequences in cured manure, hay and hardwood compost recipes.

| Taxon | Manure | Hay | Hardwood |
|---|---|---|---|
| Acidobacteria*** | 1.2±0.7 | 0.7±0.1 | 7.4±2.7 |
| Actinobacteria* | 4.9±2.0 | 9.9±3.8 | 6.8±2.0 |
| Bacteroidetes* | 27.0±4.8 | 27.7±2.7 | 21.0±3.6 |
| Chloroflexi*** | 5.5±3.9 | 2.3±0.6 | 11.8±8.5 |
| Firmicutes** | 5.2±2.7 | 6.8±1.6 | 1.5±0.5 |
| Gemmatimonadetes** | 1.9±0.8 | 4.4±0.6 | 2.9±0.8 |
| Planctomycetes n.s. | 2.6±1.4 | 1.8±0.3 | 3.0±0.7 |
| α-Proteobacteria n.s. | 7.8±1.6 | 6.2±2.4 | 6.3±1.7 |
| β-Proteobacteria n.s. | 7.0±3.7 | 4.1±0.7 | 4.0±1.9 |
| δ-Proteobacteria n.s. | 7.0±1.7 | 7.0±2.3 | 7.2±1.5 |
| γ-Proteobacteria* | 12.5±5.9 | 13.5±1.5 | 9.2±2.8 |
| Verrucomicrobia*** | 1.7±1.0 | 1.5±0.3 | 4.6±1.1 |

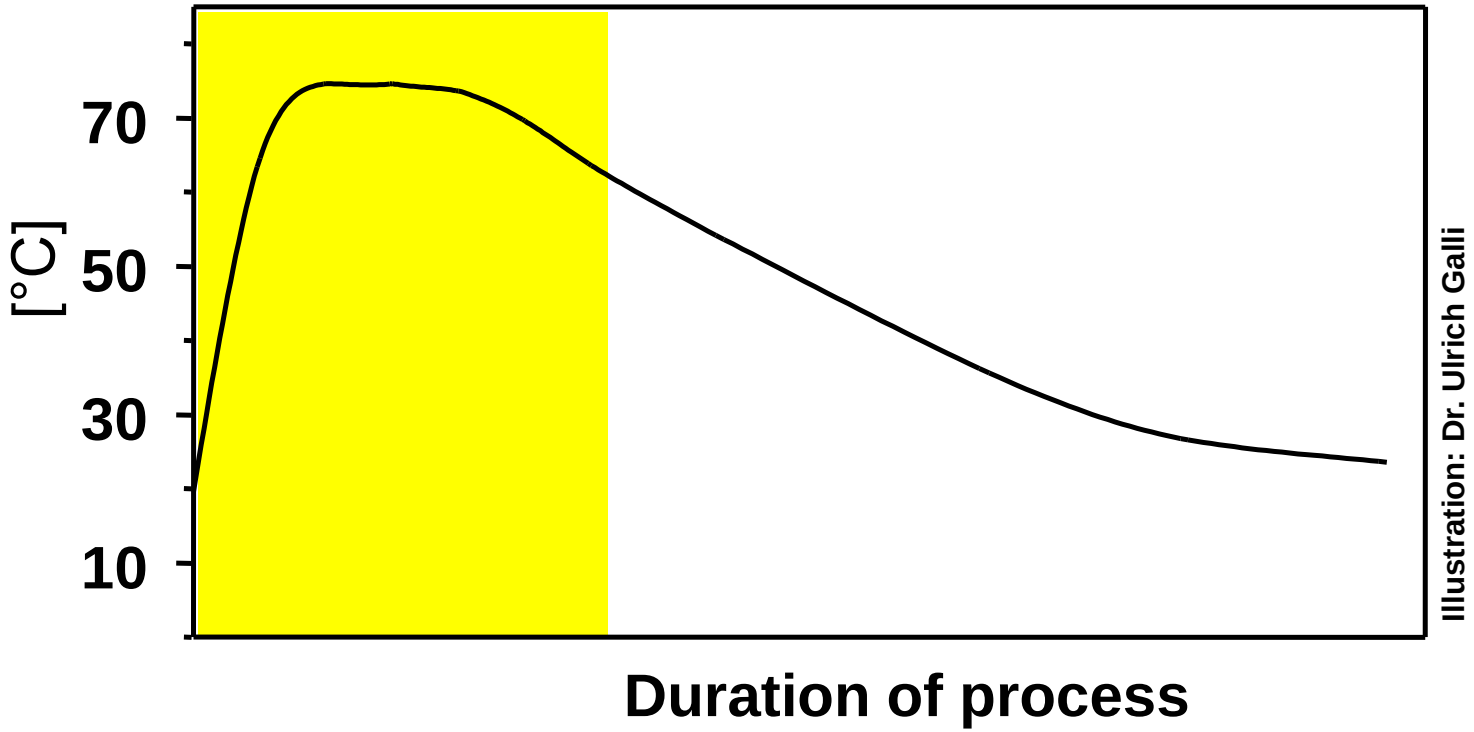
Neher et al., 2013

# Process management and compost quality

- **Importance of the raw materials**
  - Raw materials used influence the communities of microorganisms present during the composting process
  - Raw materials affect the  characteristics of the compost produced
    - fertilizer content and availability
    - capacity to suppress plant diseases
  - Initial C/N ratio is an important parameter, which influence on one hand the composting process and on the other hand the characteristic of the compost produced (e.g. the degree of humification, (Nada, 2015))
  - Physical characteristics of the initial mixture has also a great influence on the composting process (should allow a sufficient air permeability in the whole material)

# Process management and compost quality

- **Importance of the process temperature**
  - Evolution of temperature during composting



# Process management and compost quality

## › Importance of the process temperature

- › Temperature of a compost pile can increase up to 90˚C. This is not desirable!
- › Optimal temperature for the degradation of organic substrates lies around 55 ˚C

**Table 2. Carbon dioxide emissions at 40, 55, and 67°C.**

| Process temperature | Maximum decomposition rate | Time to decompose 40% of initial C† | Decomposed organic C after 6 d† |
|---|---|---|---|
| °C | % of initial C $d^{-1}$ | d | % of initial C |
| 40 | 13.3‡ | 6.5‡ | 33.7‡ |
| 55 | 17.1 (0.49)§ | 3.5 (0.4)§ | 45.7 (1.6)¶ |
| 67 | 13.5 (1.8)§ | 6.2 (1.0)§ | 34.9 (2.1)§ |

Eklind et al., 2007

# Process management and compost quality

- **Importance of the process temperature**
  - Temperature of a compost pile can increase up to 90˚C. But this is not desirable!
  - Optimal temperature for the degradation of organic substrates lies around 55˚C
  - The temperature has to be high enough so that weeds and pathogens can be eliminated
  - Good compromise: temperature between 60 and 70 ˚C in the compost pile during the thermophilic phase

# Process management and compost quality

- **Importance of moisture and optimal aeration**
  - Microorganisms need water to be active. The microbial activity is reduced when moisture content is below 45%
  - Moisture content up to 75% has no significant effect on the compost quality if the aeration of the material is secured
  - Moisture content can be used to control the temperature of the process
  - Composting is an aerobic process: sufficient oxygen has to be present in the rotting material
  - Passive or active aeration
  - Too low oxygen level in the pile: a negative shift in the population of microorganisms. Consequence on the compost quality
    - pH of the material decreases following the formation of organic acids
    - phytotoxicity
    - odor emissions
  - Emission of climatic gases such as methane when the oxygen content in the pile is equal or less than 2.5%

# Process management and compost quality

## › Importance of moisture and optimal aeration

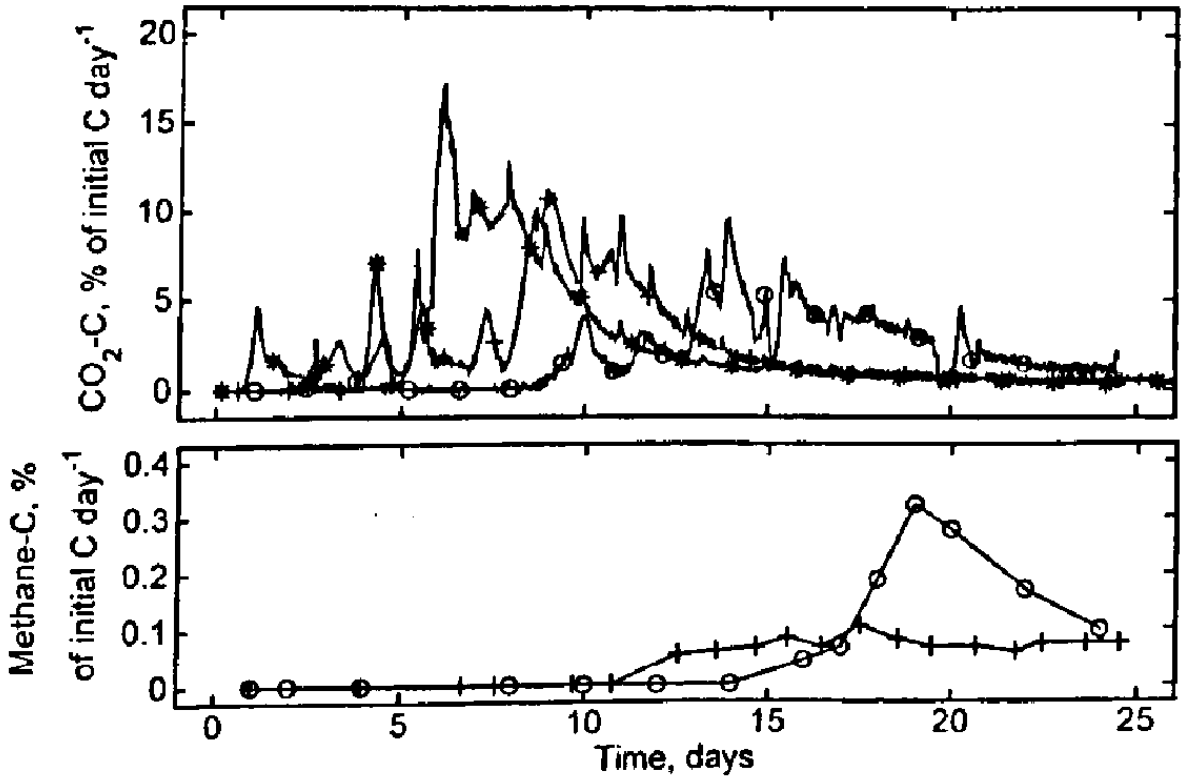
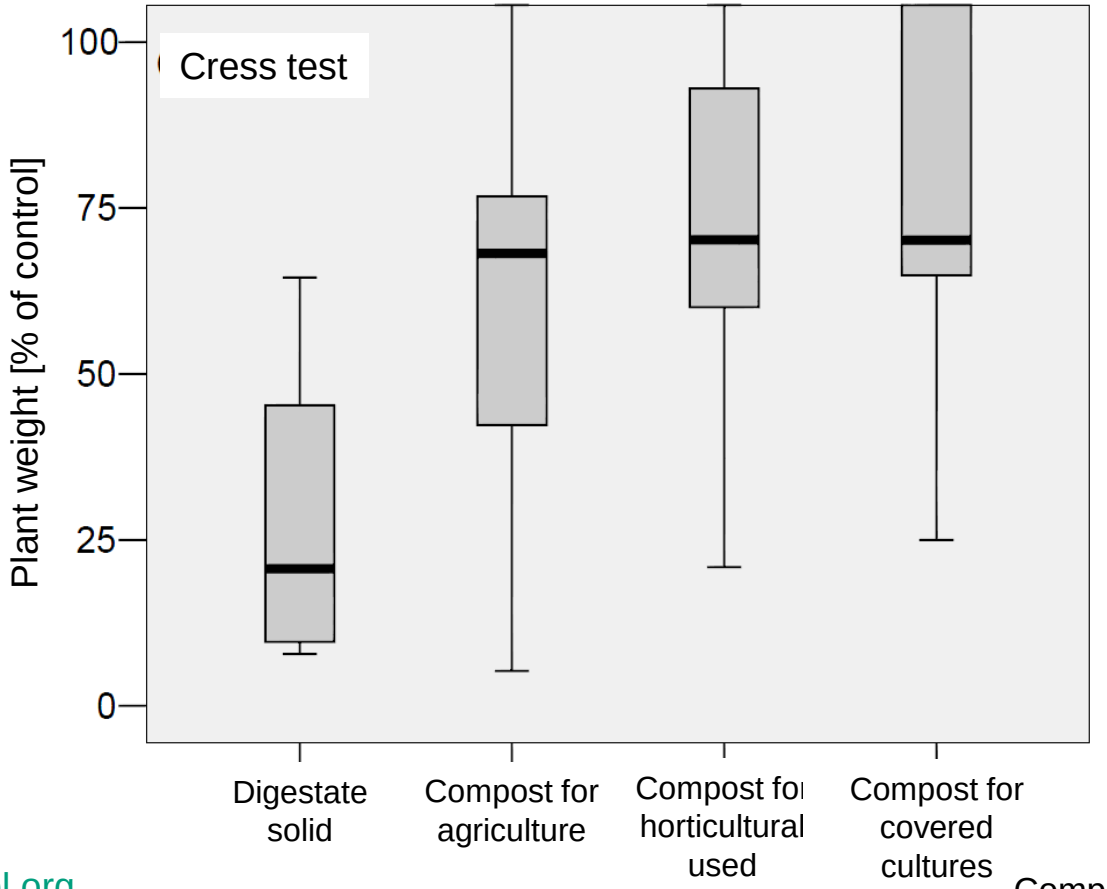



Figure 2. Formation rates of $CO_2$-C and $CH_4$-C as percentages of initial C, at the following $O_2$ concentrations in the compost gas: 16% (*), 2.5% (+) and 1% (o). Methane analyses with 16% $O_2$ is only available from day 0 to day 6.

Beck-Friss et al., 2003

# Process management and compost quality

- **Importance of maturity on compost quality**
  - **Influence on phytotoxicity**




Fuchs et al., 2008

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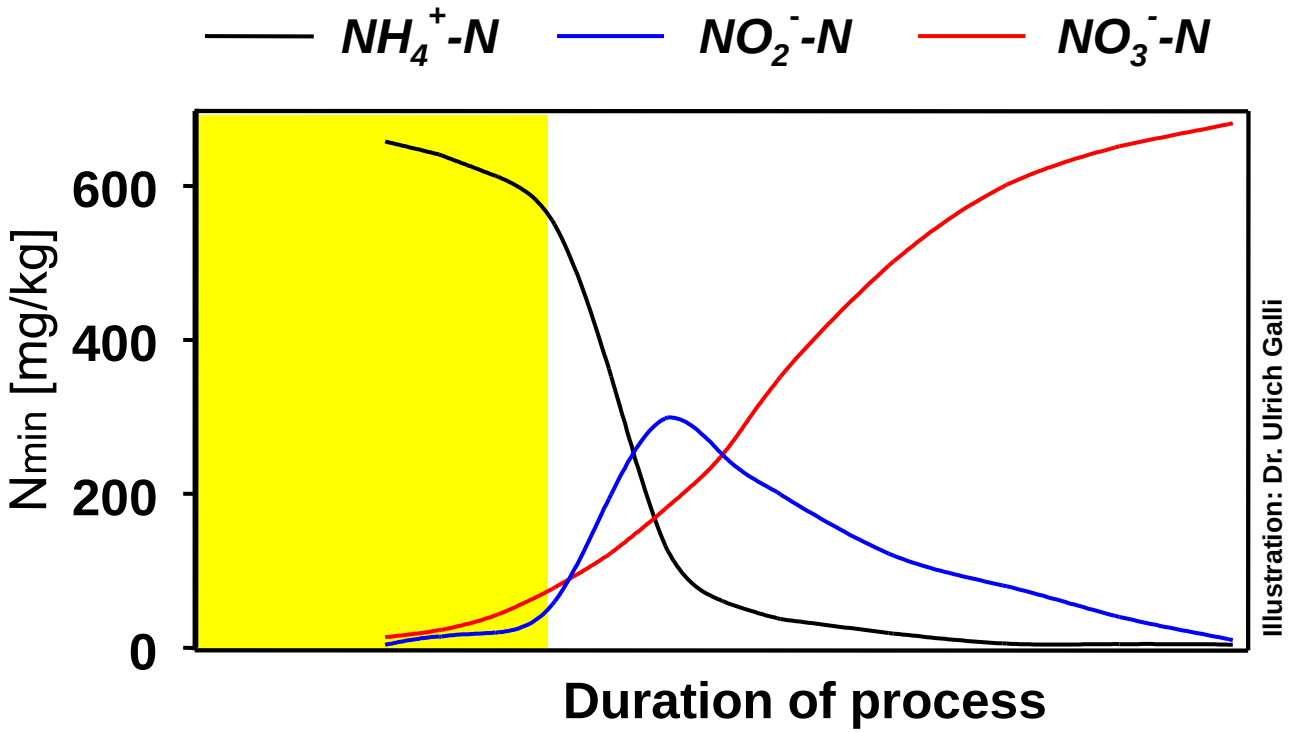
  - **Influence on nitrogen immobilization in soil**



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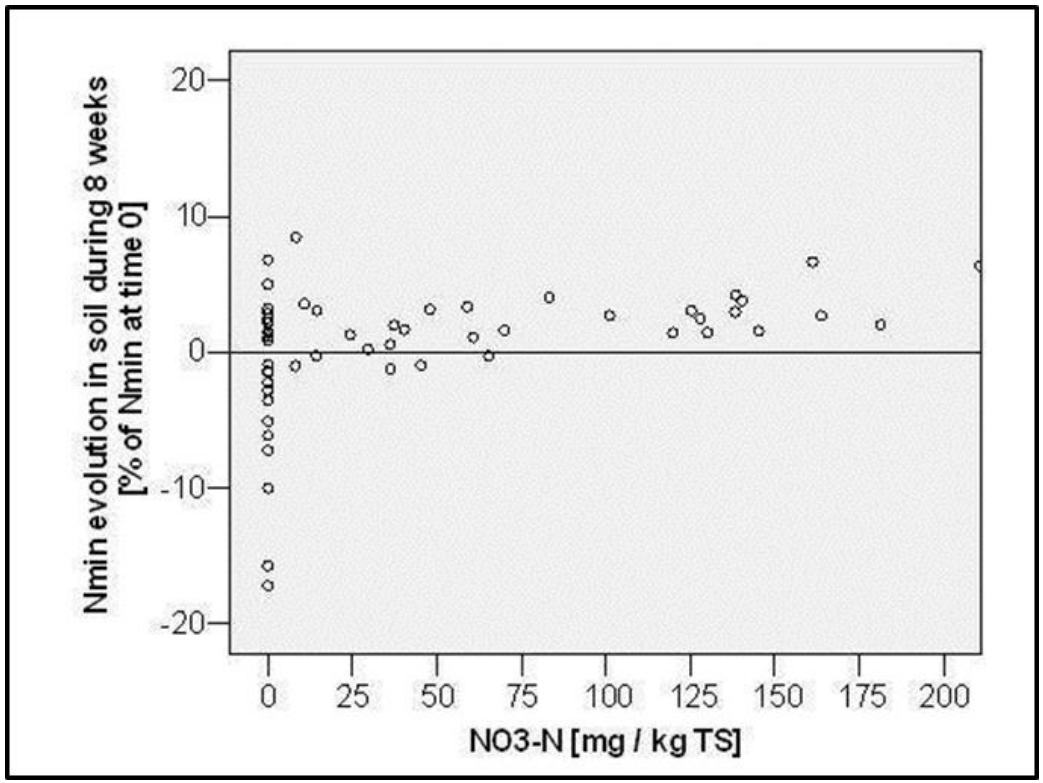

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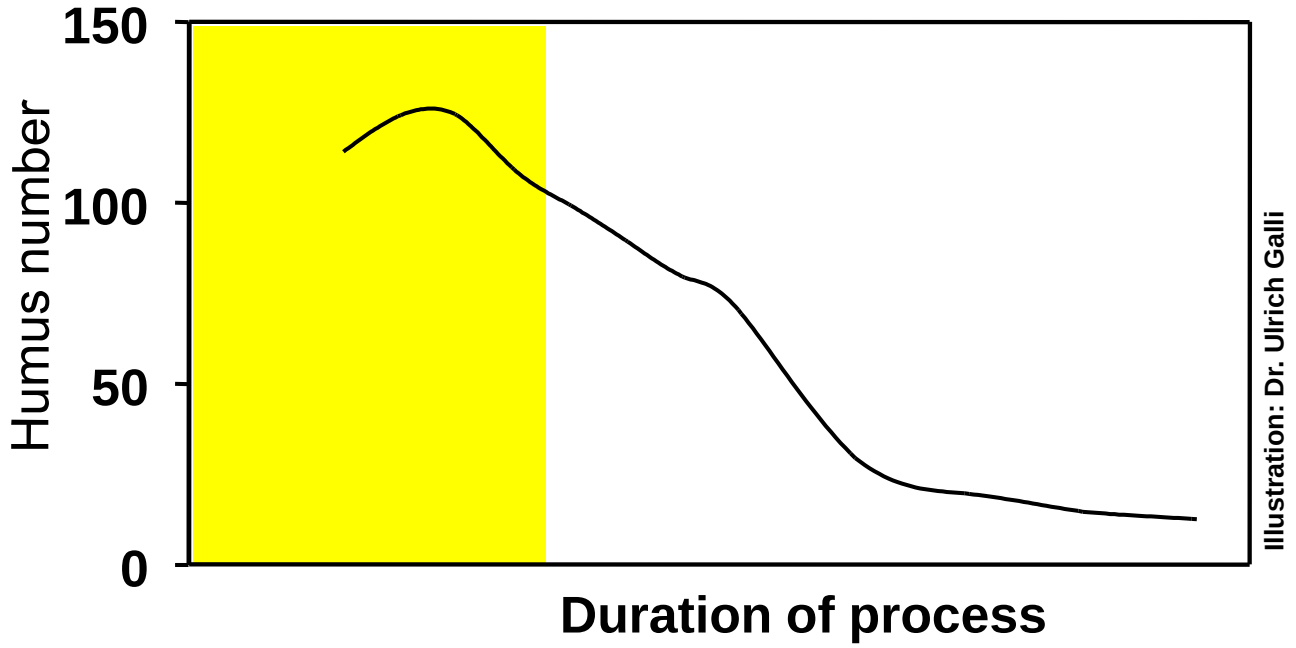
  - **Influence on nitrogen immobilization in soil**
  - **Influence on stability of organic substance**



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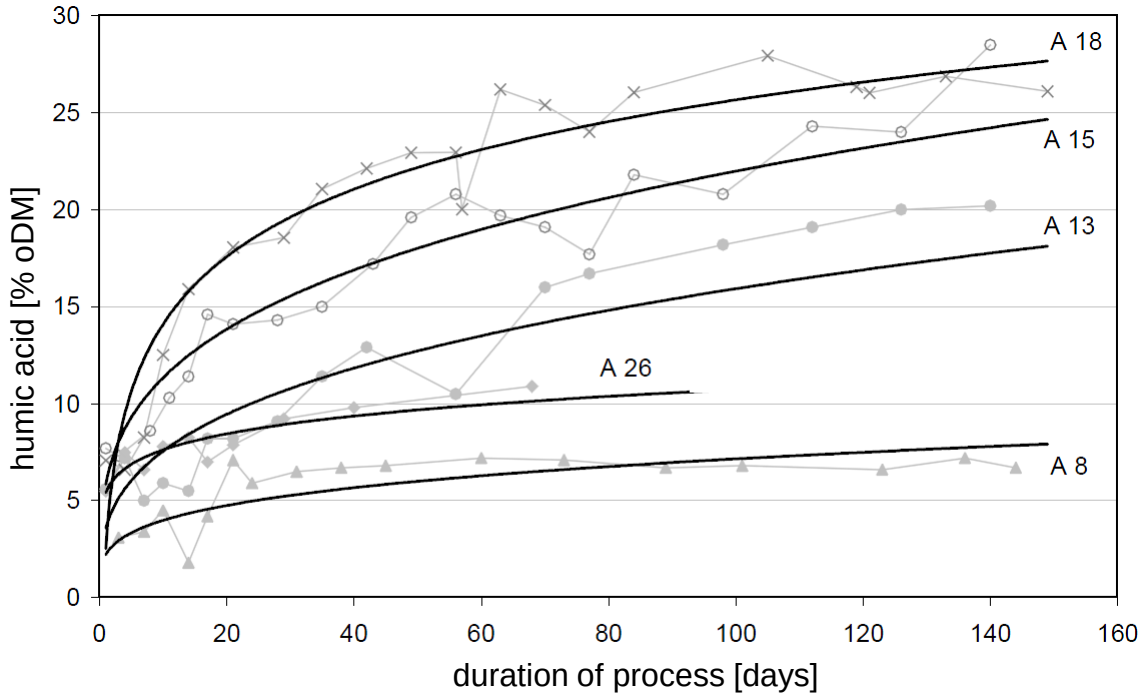


Smidt et al., 2008

# Process management and compost quality

- **Importance of maturity on compost quality**
  - **Influence on phytotoxicity**
  - **Influence on nitrogen immobilization in soil**
  - **Influence on stability of organic substance**
  - **Influence on capacity to suppress diseases**

# Process management and compost quality

- **Control of the compost quality**
  - **Objective: selection of the most appropriate compost according to the specific target use**
  - **Main parameters to control:**
    - **evolution of the temperature (elimination of weeds and pathogens)**
    - **nutrients content (fertilization balance)**
    - **pH and salt content**
    - **mineralized form of nitrogen (NO3-N/Nmin-ratio to predict whether the compost will provide nitrogen to the plant or on the contrary whether it will immobilize the nitrogen present in the soil)**

# Composting benefits for soil fertility

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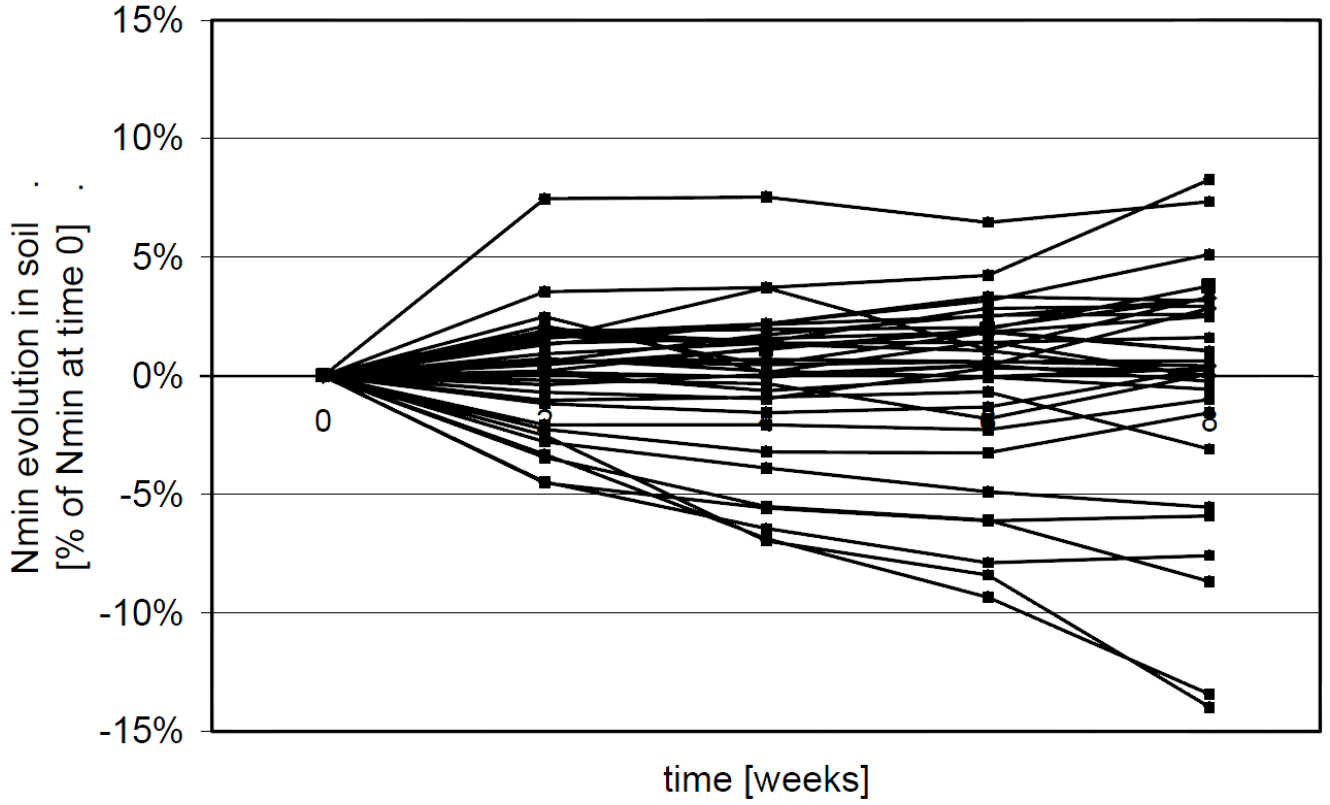
- **Influences on soils chemical characteristics**
  - Supply of all the different nutrients that the plant needs (including trace elements)
  - Nitrogen: immobilization or making it available?




Fuchs et al., 2008

# Composting benefits for soil fertility

- **Influences on soils chemical characteristics**
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  - Effect on soil pH

Fuchs et al., 2014

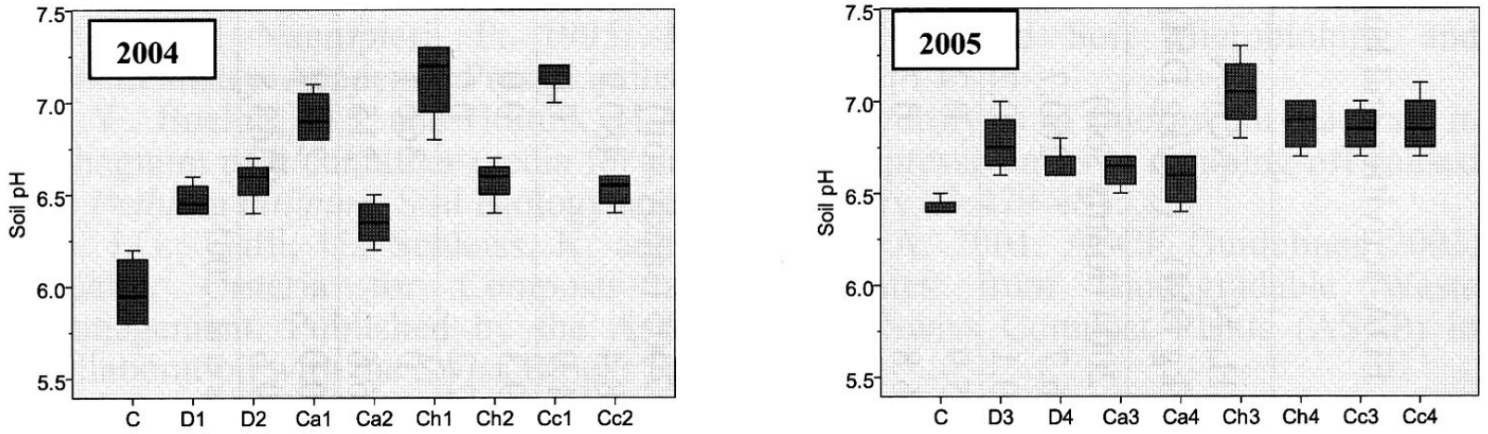


Fig. 2. Influence of application of digestates and composts on the pH of the soil. Application of 100 $m^3$/ha before sowing. Measurement after maize harvest. Products sampled according to ASCP Guidelines 2001 (Fuchs et al., 2001): C: no digestate/compost, D=digestate solid, Ca=compost for agriculture, Ch=compost for horticultural used, Cc=compost for covered cultures and private gardening.

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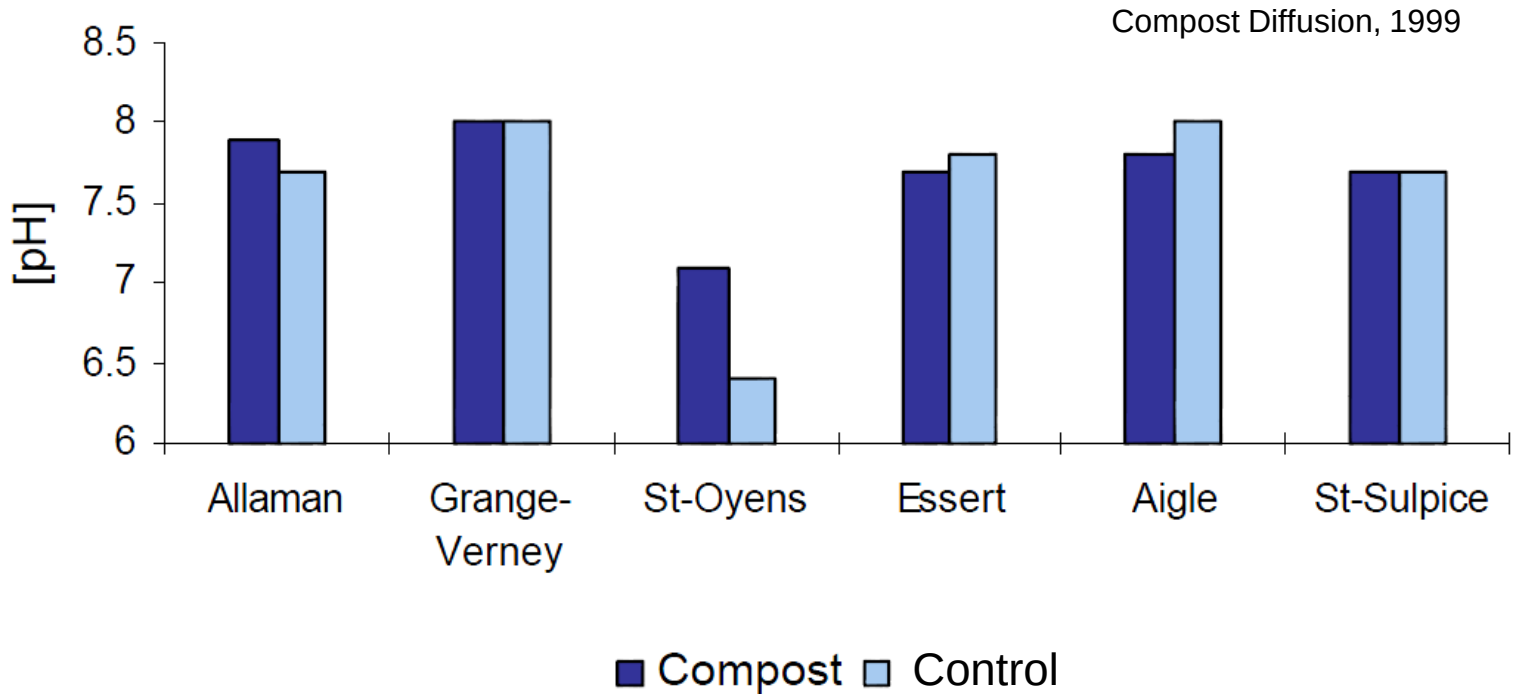

# Composting benefits for soil fertility

- **Influences on soils humus and physical characteristics**
  - Compost brings an important quantity of more or less stabilized organic matter
  - Compost amendments improve the quantity of organic matter in soil

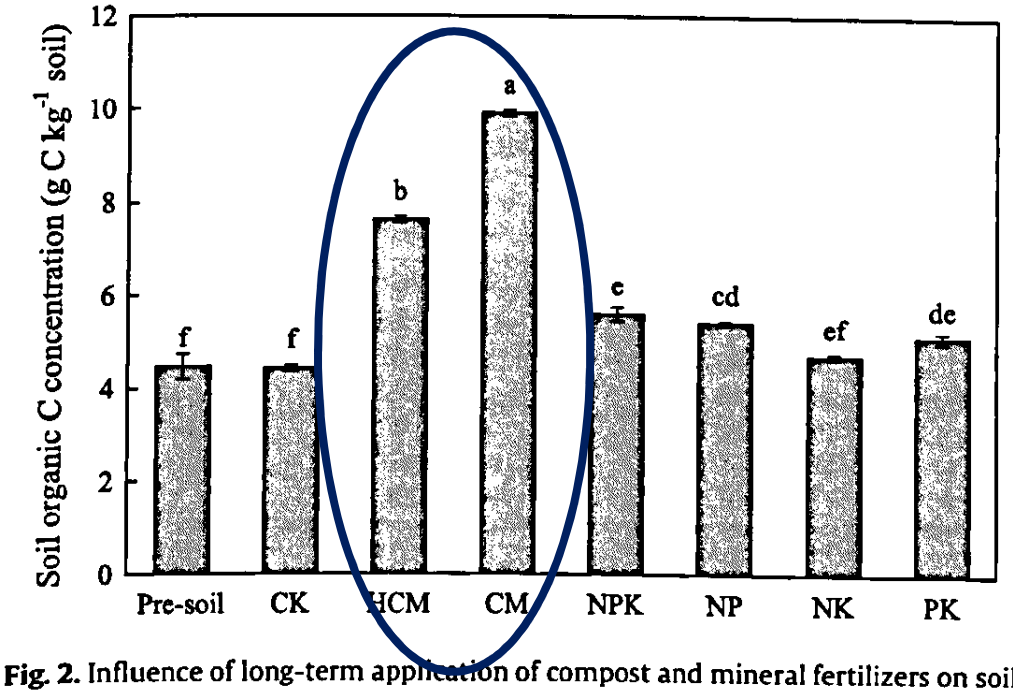


**Fig. 2.** Influence of long-term application of compost and mineral fertilizers on soil organic carbon concentration. CK, control; CM, compost; HCM, half organic compost N plus half fertilizer N; NPK, fertilizer NPK; NP, fertilizer NP; NK, fertilizer NK; and PK, fertilizer PK. Vertical bars denote standard errors of means ($n = 4$). Different letters indicate significant differences between treatments at $P < 0.05$.

Yu et al., 2012

# Composting benefits for soil fertility

- **Influences on soils humus and physical characteristics**
  - Compost brings an important quantity of more or less stabilized organic matter
  - Compost amendments improve the quantity of organic matter in soil
  - Effect of compost on soil organic matter affect positively various physical soil properties
    - soil macroaggregates

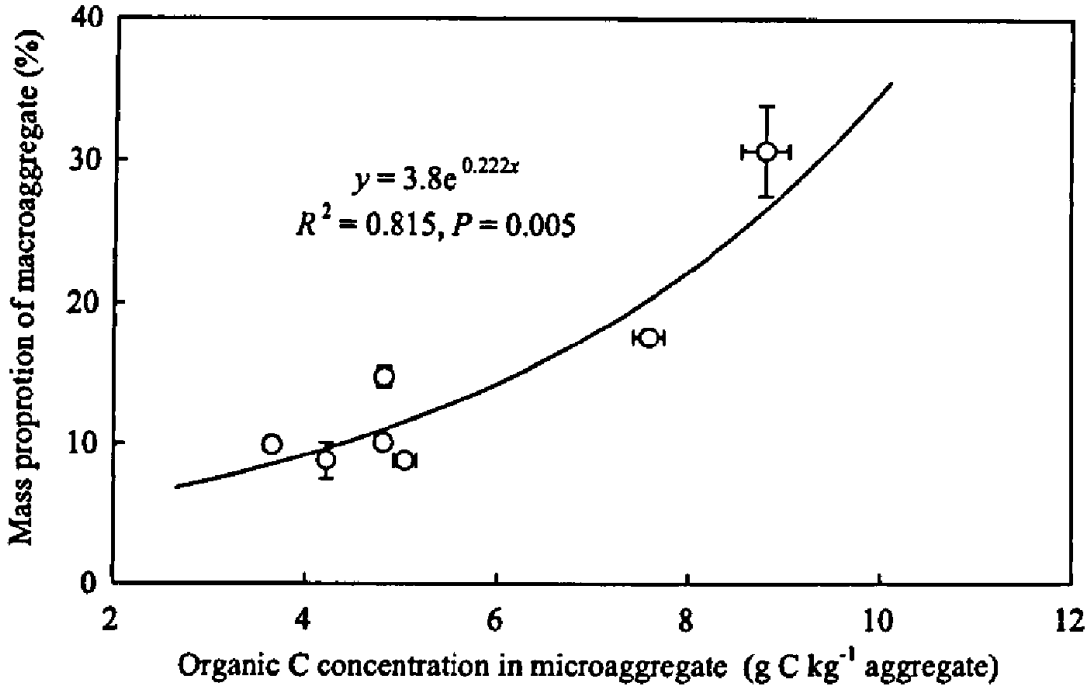


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**Table 3**
C amount and increase rate in aggregates of the 0–20 cm soil layer as affected by long-term application of compost and mineral fertilizers.

| Treatments | Macroaggregate (>250 μm) | | Microaggregate (53–250 μm) | | Silt + clay fraction (<53 μm) | |
|---|---|---|---|---|---|---|
| | C amount ($g C kg^{-1}$ soil) | Increase rate (%) | C amount ($g C kg^{-1}$ soil) | Increase rate (%) | C amount ($g C kg^{-1}$ soil) | Increase rate (%) |
| CK | 0.58 ± 0.02f | | 3.02 ± 0.04bc | – | 0.62 ± 0.01f | – |
| HCM | 2.09 ± 0.01b | 260 | 4.77 ± 1.01a | 58 | 1.42 ± 0.02b | 129 |
| CM | 3.75 ± 0.04a | 547 | 4.85 ± 0.14a | 61 | 1.48 ± 0.03a | 139 |
| NPK | 1.03 ± 0.23d | 78 | 3.54 ± 0.08b | 17 | 1.22 ± 0.01c | 97 |
| NP | 1.11 ± 0.07d | 91 | 3.29 ± 0.03bc | 9 | 0.86 ± 0.01e | 39 |
| NK | 0.86 ± 0.05e | 48 | 2.27 ± 0.02c | −25 | 1.25 ± 0.05c | 102 |
| PK | 1.32 ± 0.13c | 128 | 3.04 ± 0.01bc | 1 | 1.12 ± 0.01d | 81 |

Values are means ($n = 4$) with standard error. Different letters within the same column indicate significant differences between treatments at $P < 0.05$.

Yu et al., 2012

# Composting benefits for soil fertility

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  - Compost brings an important quantity of more or less stabilized organic matter
  - Compost amendments improve the quantity of organic matter in soil
  - Effect of compost on soil organic matter affect positively various physical soil properties
    - soil macroaggregates
    - reduction of bulk density

Kätterer et al., 2014

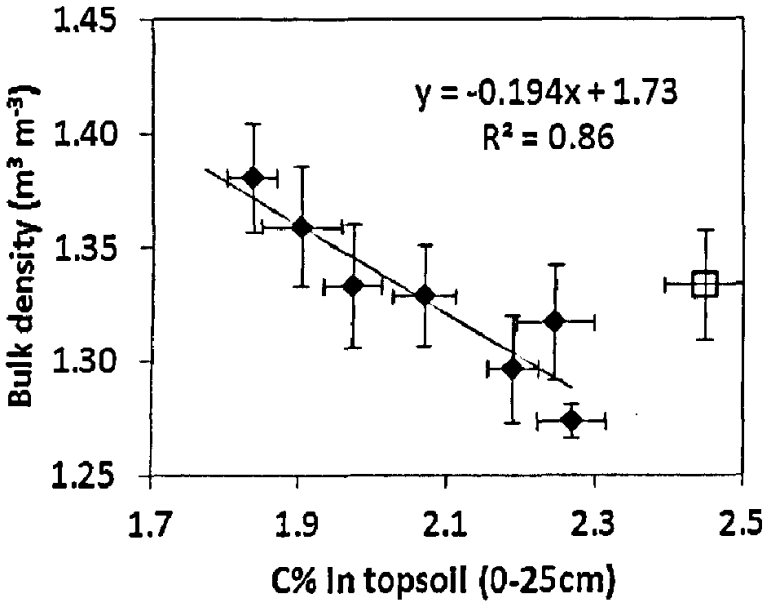



**Fig. 1.** Correlation between bulk density and carbon concentration in topsoil (0–25 cm) in the different treatments (means and standard errors) at Lanna

# Composting benefits for soil fertility

- **Influences on soils humus and physical characteristics**
  - Compost brings an important quantity of more or less stabilized organic matter
  - Compost amendments improve the quantity of organic matter in soil
  - Effect of compost on soil organic matter affect positively various physical soil properties
    - soil macroaggregates
    - reduction of bulk density
    - increased soil macroporosity
    - reduction of erosion

Arthur et al., 2011

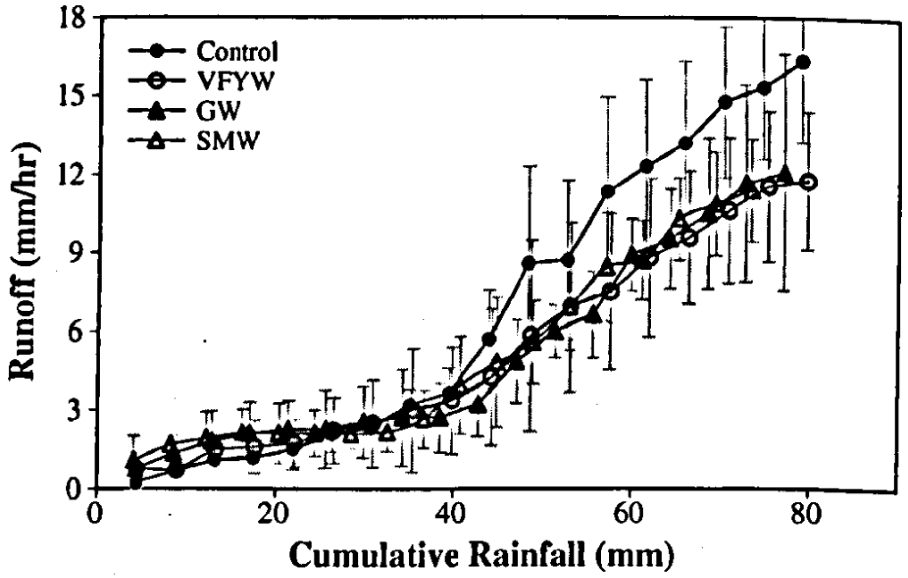



**Fig. 2.** Runoff rate as a function of cumulative rainfall. VFYW: vegetable, fruit and yard compost, GW: garden waste compost, and SM: spent mushroom compost. Error bars represent standard deviations.

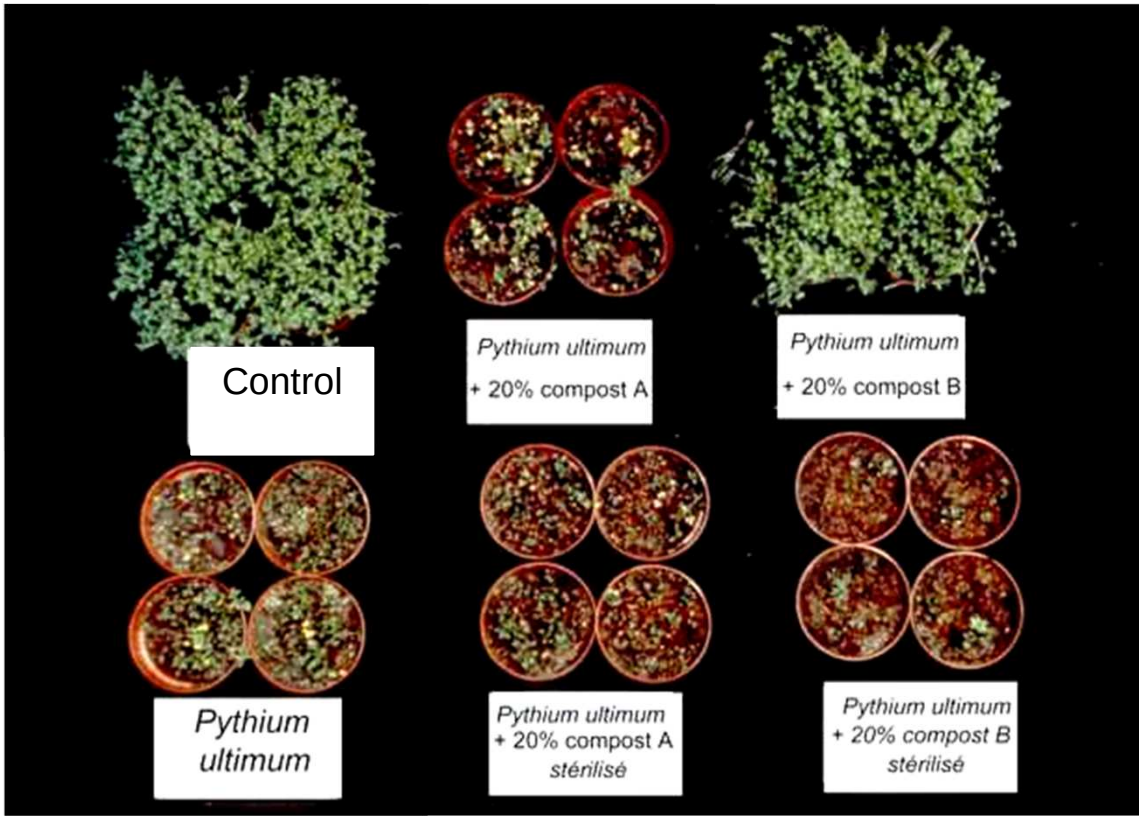
# Composting benefits for plants’ growth and health

# Composting benefits for plants' growth and health

- **Influence on soil characteristics affect plant growth**
  - With the improvement of soil structure, water holding capacity and porosity, the compost creates better conditions for the plant's development, which is then less stressed and can therefore better grow
  - As a result, compost influences positively the yield of the cultures, especially in organic agriculture
  - However, compared with mineral fertilization, no relevant positive differences in yield are observed

# Composting benefits for plants' growth and health

- **Influence on plant health**
  - A good compost comes with the guarantee of absence of pathogens and weeds
  - In addition, compost can protect plants from diseases.



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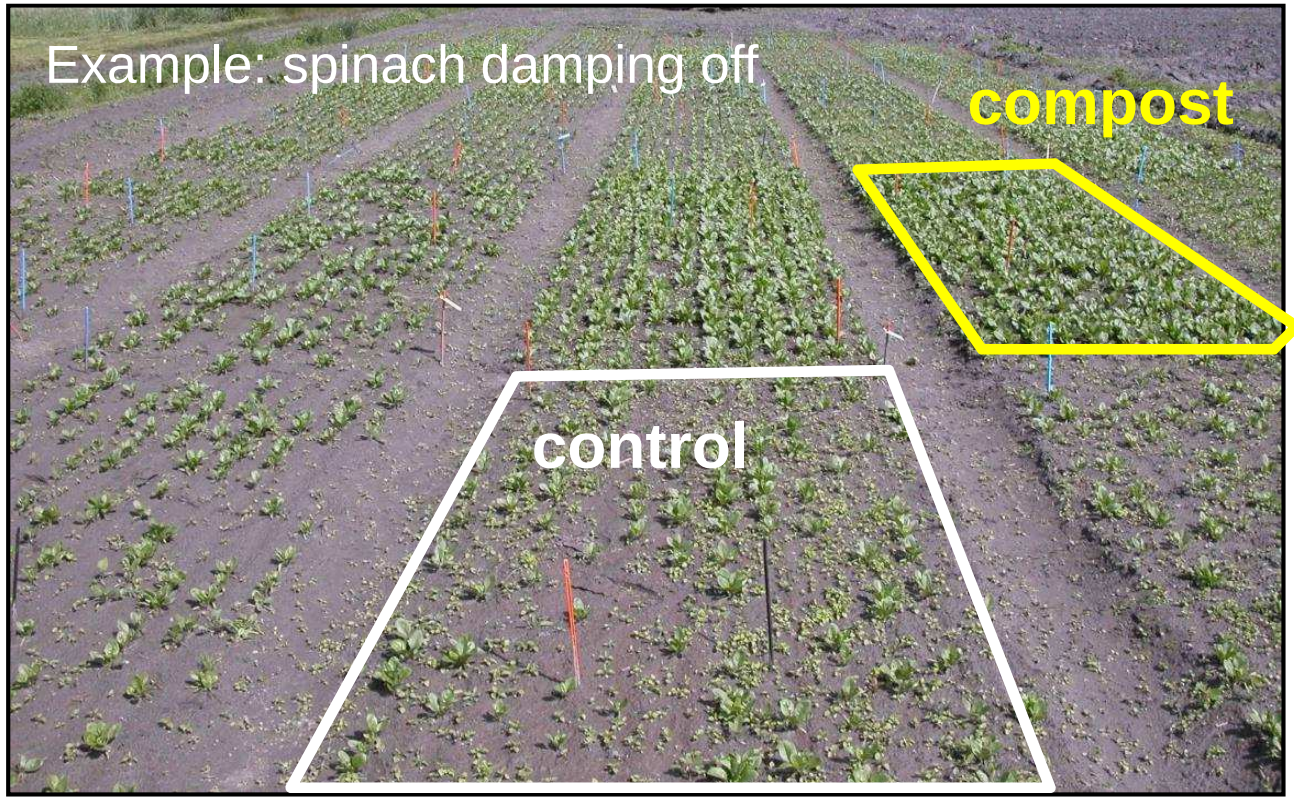

# Composting benefits for plants' growth and health

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Example: clubroot in cabbage

Soil without compost

Soil with 10% compost

# Composting benefits for plants' growth and health

- **Influence on plant health**
  - A good compost comes with the guarantee of absence of pathogens and weeds
  - In addition, compost can protect plants from diseases. Mechanisms:
    - microbiological activity of the compost
    - competition for carbon
    - activation of soil microbiological activity
    - In some nitrogen rich young composts: $NH_3$ effect on pathogens
  - Disease suppressivity capacity vary from compost to compost
  - Different composts can protect plants against different diseases

# Composting benefits for plants' growth and health

## › Influence on plant health

Table 2
Disease suppressiveness (%) of 18 composts in 7 pathosystems[a]

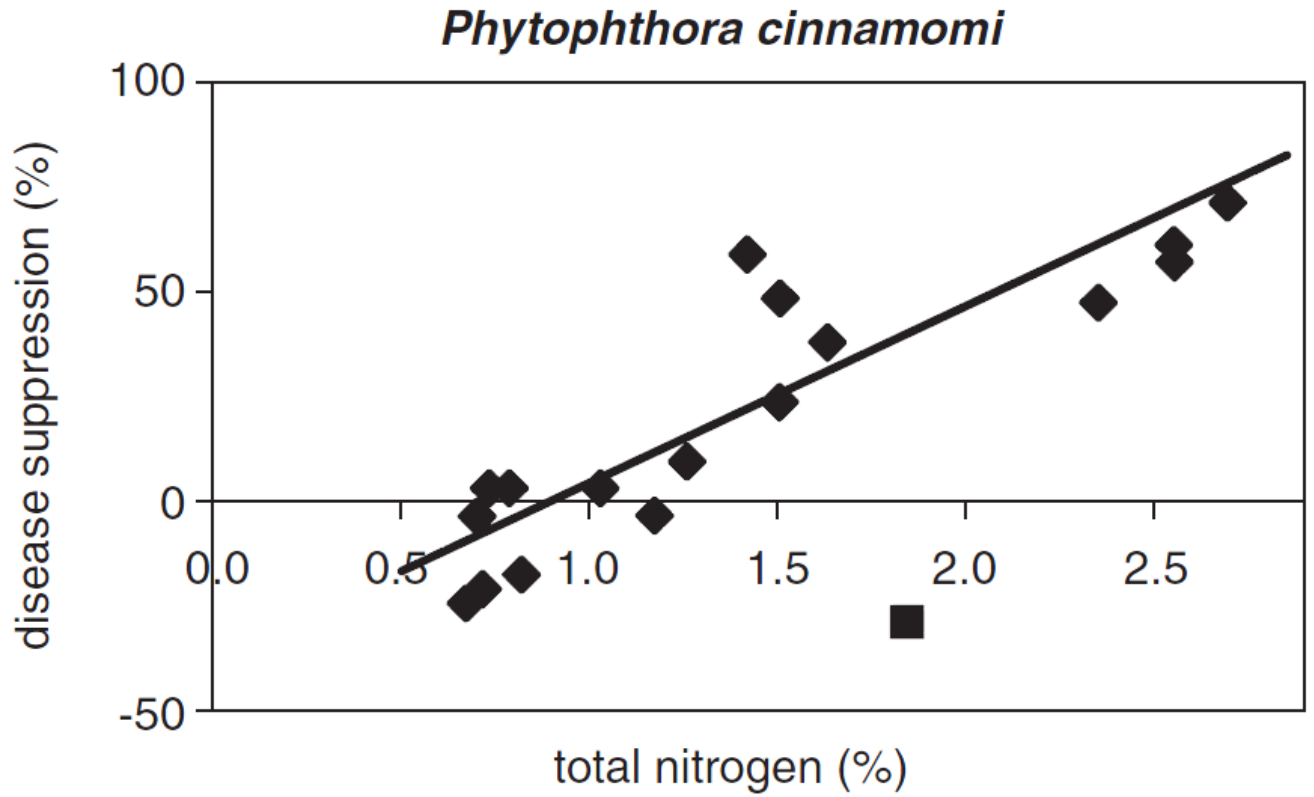
| Compost | *Verticillium dahliae*/ eggplant | *Rhizoctonia solani*/ cauliflower | *Phytophthora nicotianae*/ tomato | *Phytophthora cinnamomi*/ lupin | *Cylindrocladium spathiphylli*/ spathiphyllum | *Rhizoctonia solani*/ pine | *Fusarium oxysporum*/ flax | Average | Median |
|---|---|---|---|---|---|---|---|---|---|
| a | **87.6** | **50.6** | n.d.[b] | 9.7 | −20.2 | −7.1 | **71.9** | 32.1 | 30.2 |
| b | **34.8** | 32.1 | **37.9** | **48.8** | −48.8 | 8.4 | **65.2** | 25.4 | 34.8 |
| c | **46.6** | 2.4 | 28.6 | 38.1 | **32.4** | **92.6** | **56.1** | 42.4 | 38.1 |
| d | **59.1** | −10.1 | **85.7** | 47.6 | **100.0** | 27.2 | **65.9** | 53.6 | 59.1 |
| e | **37.7** | 35.3 | **92.1** | −28.6 | 1.6 | 1.8 | **63.8** | 29.1 | 35.3 |
| f | **56.7** | 8.5 | **92.1** | **57.1** | **47.4** | 4.9 | **32.8** | 42.8 | 47.4 |
| g | **43.9** | **38.0** | n.d. | **61.3** | −34.1 | 1.1 | **63.1** | 28.9 | 41.0 |
| h | **63.1** | −4.2 | **41.3** | **71.4** | **23.8** | 4.5 | **47.9** | 35.4 | 41.3 |
| i | **49.9** | 12.4 | n.d. | −3.2 | −10.3 | 15.4 | **58.2** | 20.4 | 13.9 |
| k | **34.5** | −87.3 | 6.3 | 23.8 | **24.1** | **83.5** | 2.1 | 12.4 | 23.8 |
| l | −1.9 | **67.8** | **45.5** | **58.9** | 22.5 | **57.0** | **68.1** | 45.4 | 57.0 |
| m | **85.4** | **77.2** | n.d. | 3.2 | **58.9** | −1.4 | **63.3** | 47.8 | 61.1 |
| n | **65.2** | **50.3** | n.d. | 3.2 | **43.4** | −1.7 | **66.7** | 37.8 | 46.9 |
| o | **49.5** | **42.8** | n.d. | 3.2 | 21.8 | −0.9 | **45.7** | 27.0 | 32.3 |
| p | −21.1 | **57.8** | **84.8** | −24.3 | −27.9 | 0.9 | **64.2** | 19.2 | 0.9 |
| q | −25.2 | **66.4** | **75.8** | −20.8 | **63.5** | 29.9 | **65.8** | 36.5 | 63.5 |
| r | −15.7 | 49.7 | **78.8** | −3.5 | −28.0 | 21.0 | **70.5** | 24.7 | 21.0 |
| s | 1.9 | **68.0** | **66.7** | −17.3 | −18.5 | −11.3 | **67.2** | 22.4 | 1.9 |
| Average | 36.2 | 31.0 | 61.3 | 18.3 | 14.0 | 18.1 | 57.7 | | |
| Median | 45.3 | 40.4 | 71.3 | 6.5 | 22.1 | 4.7 | 64.0 | | |

[a]Figures in bold indicate significant ($P < 0.05$) disease suppression, i.e., less disease development in the compost-amended compared to the non-amended control. Figures underlined indicate significant disease aggravation as compared to the non-amended control.
[b]n.d. = not determined.

Termorshuizen et al., 2006

# Composting benefits for plants' growth and health

- **Influence on plant health**
  - Regression plots based on pure compost parameters




Termorshuizen et al., 2006

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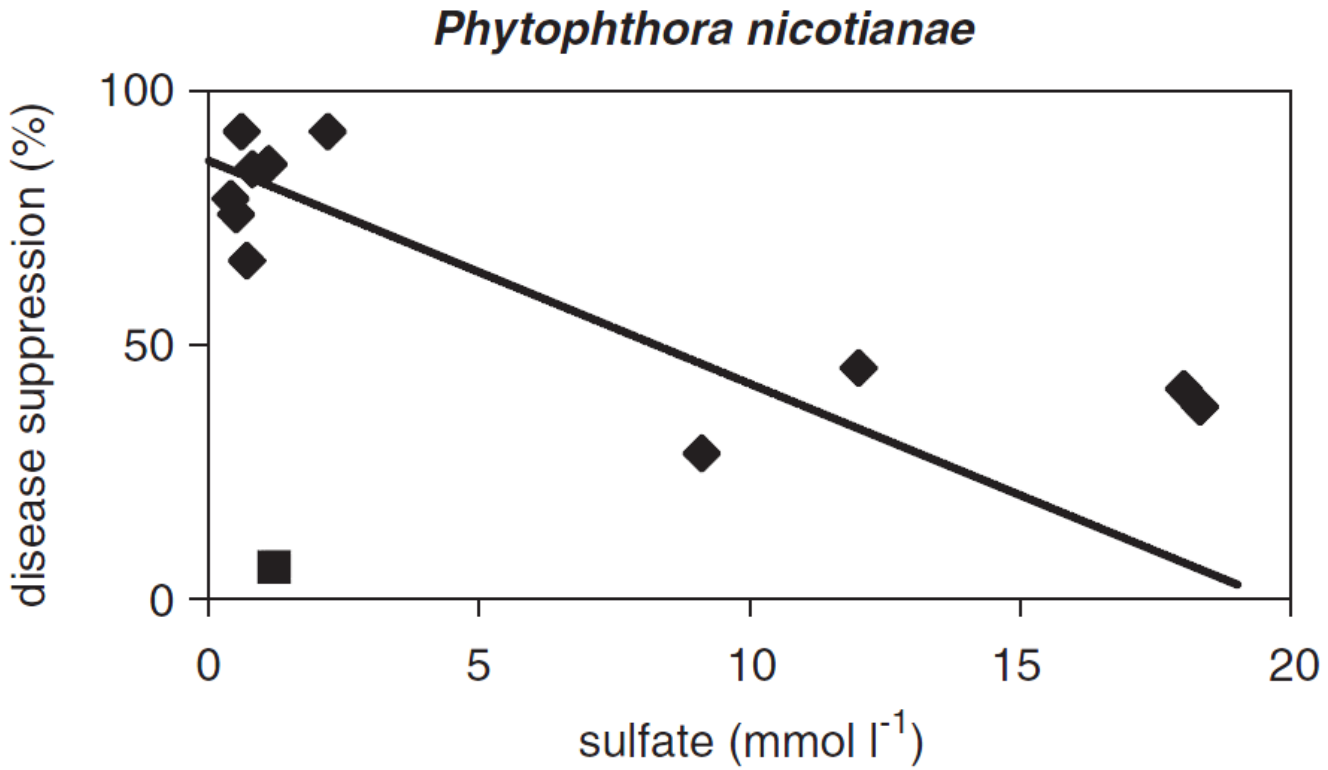
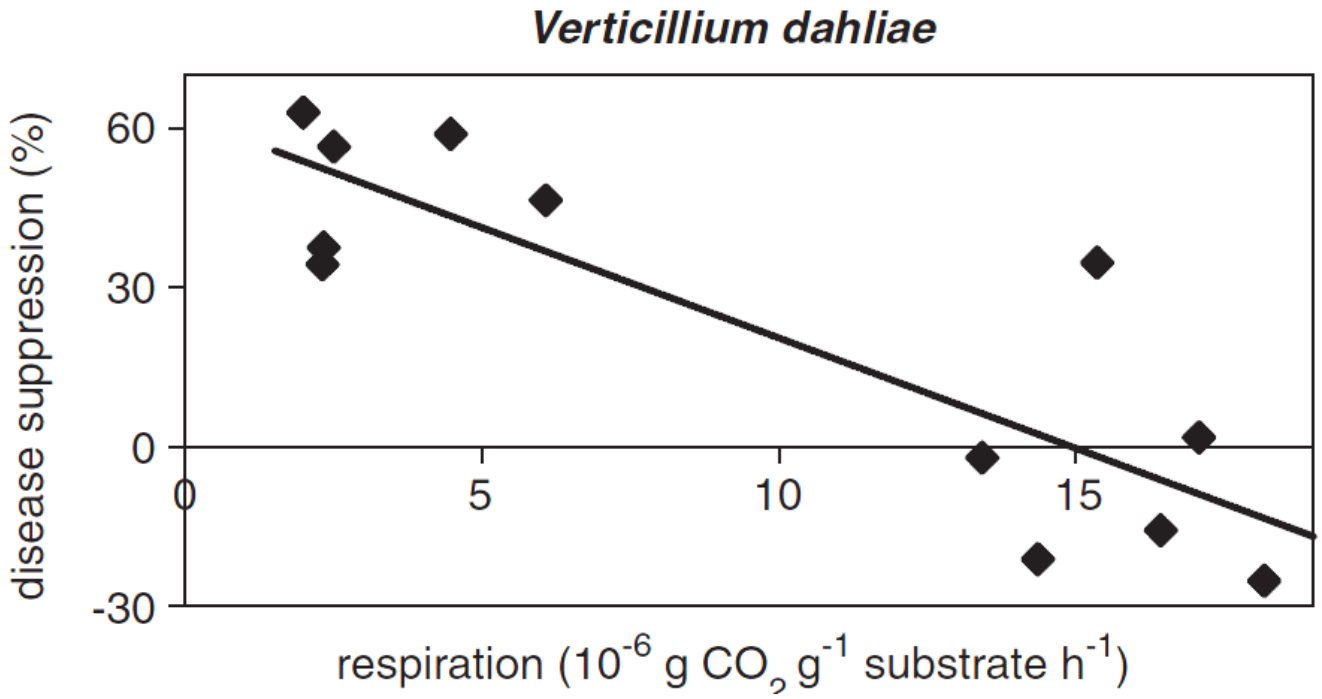



Termorshuizen et al., 2006

# Composting benefits for plants' growth and health

- **Influence on plant health**
  - Regression plots based on pure compost/peat parameters




Termorshuizen et al., 2006

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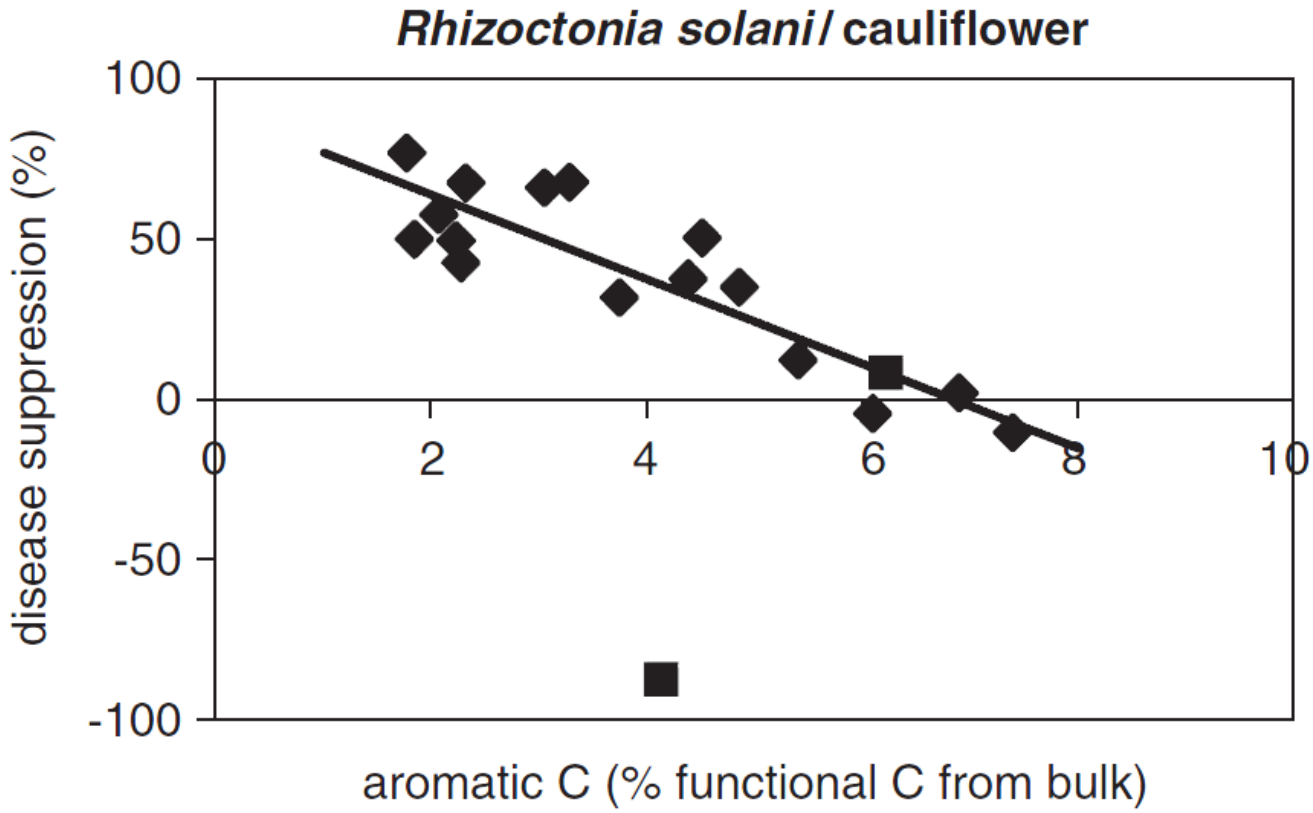


Termorshuizen et al., 2006

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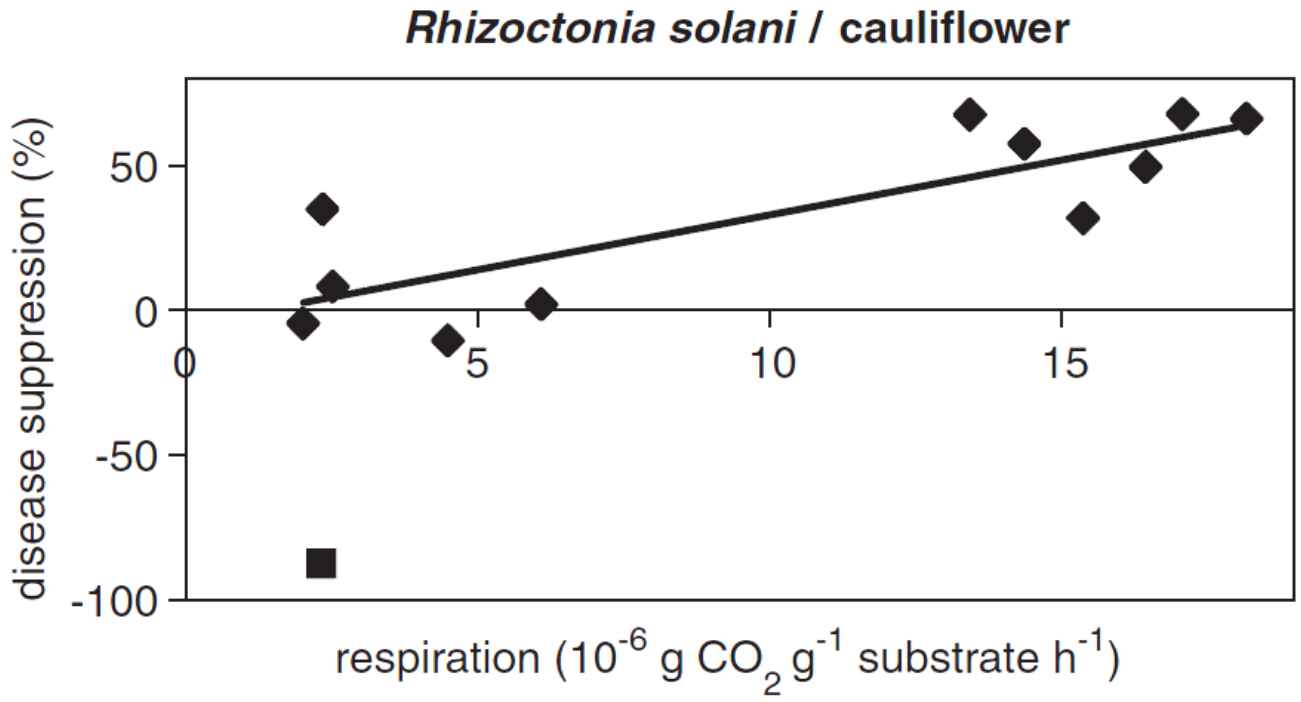


Termorshuizen et al., 2006

# Composting benefits for plants' growth and health

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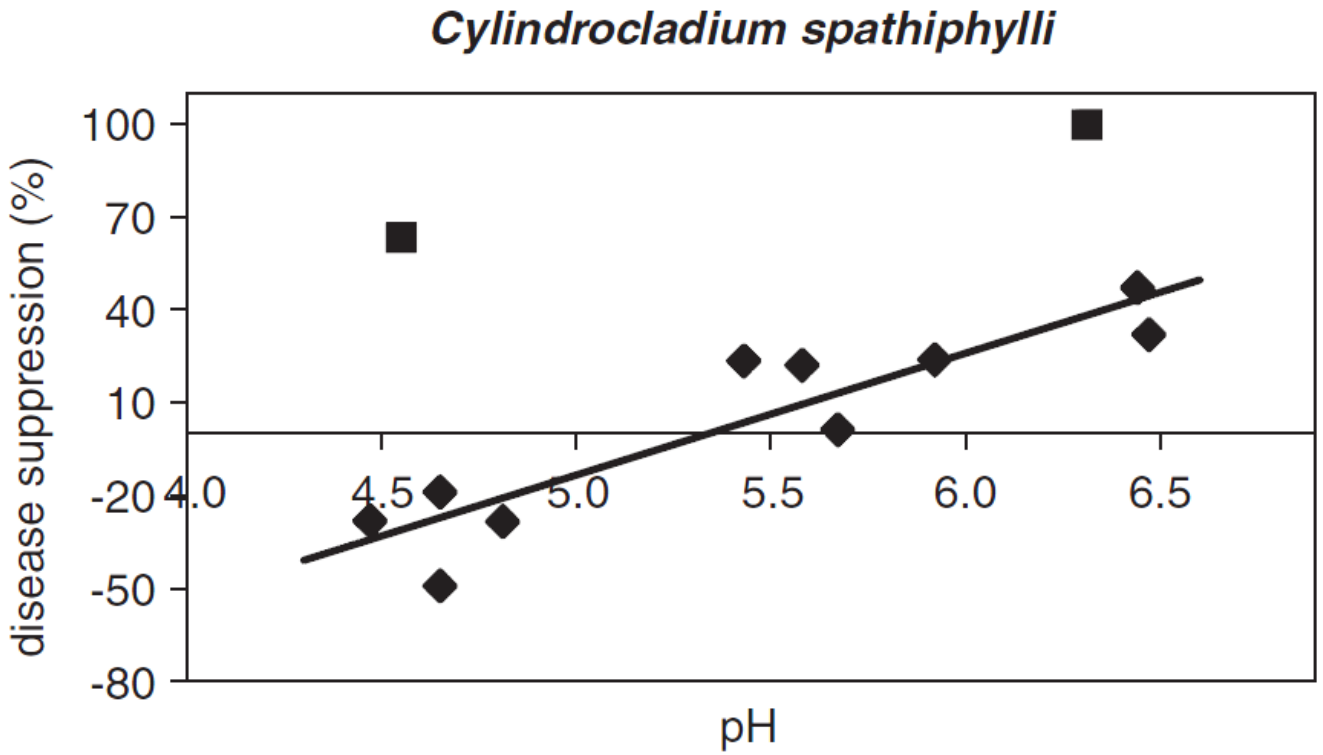
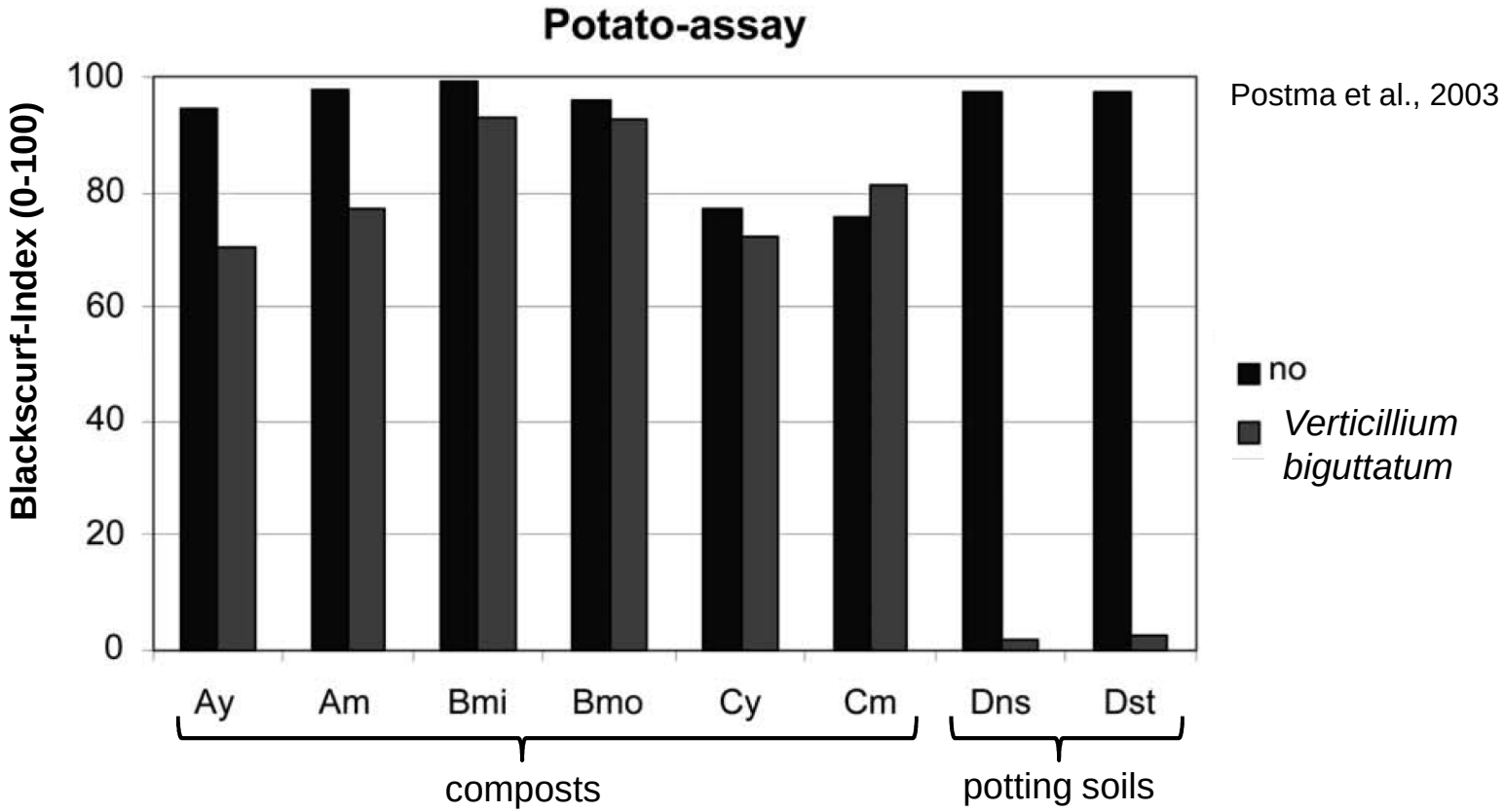



Termorshuizen et al., 2006

# Composting benefits for plants' growth and health

- **Influence on plant health**
  - Addition of antagonistic microorganisms to improve the suppression potential of composts




Postma et al., 2003

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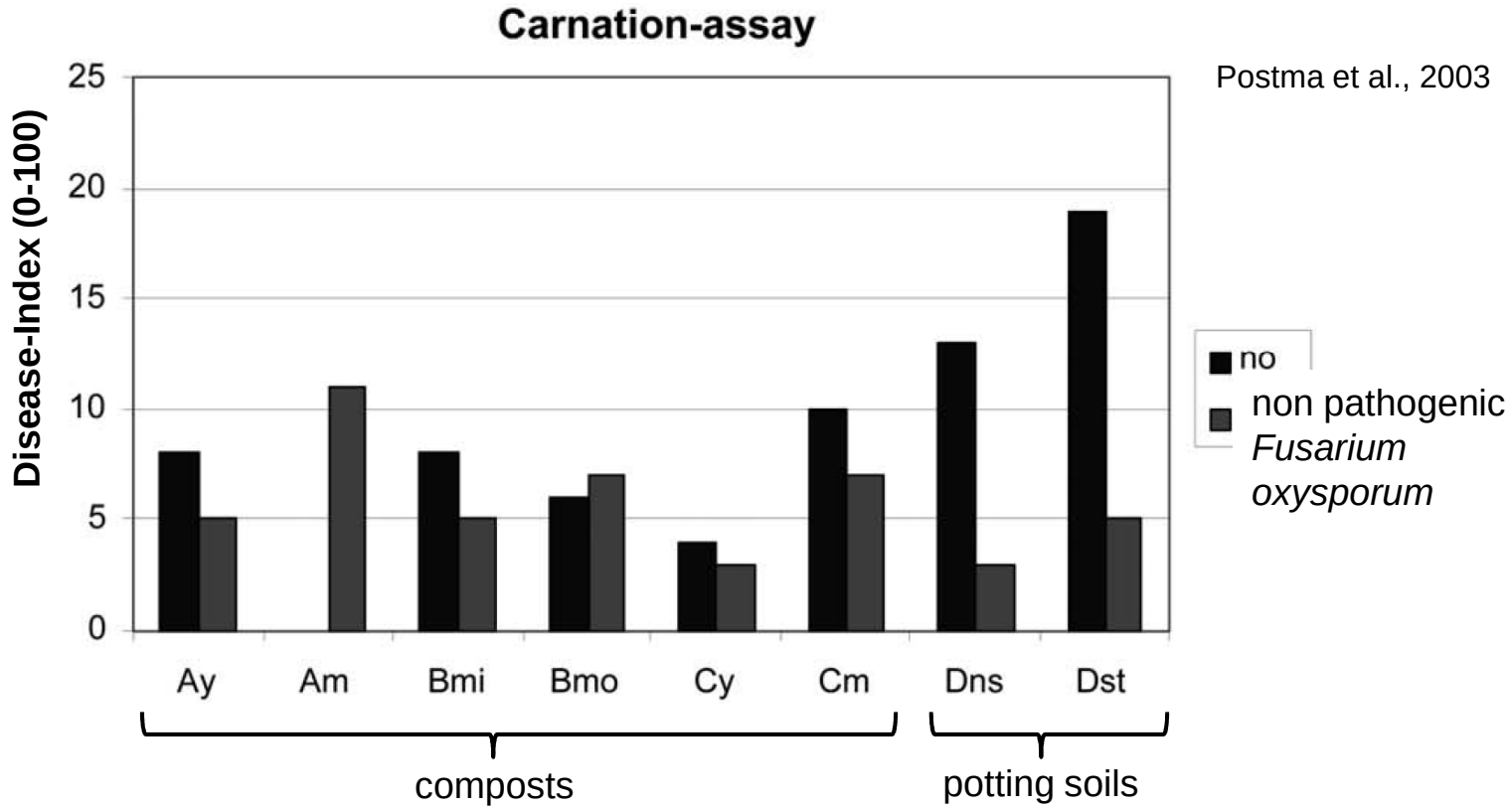


Postma et al., 2003

# Choice of compost in relation to its target use

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- **Characteristics and properties of composts can greatly varied**
  - Nutrient contents
  - Nitrogen availability
  - Stability of organic matter
  - Capacity to suppress disease

- **The characteristics and properties of composts can be influenced by the process management**
  - Input materials
  - Moisture / oxygen management
  - Process duration

# Choice of compost in relation to its target use

- **Define the target use and target effect**
  - Culture, culture system
  - Main target: fertilization / soil structure improvement / disease suppressivity
  - Short time / long time effect

- **Choice of the appropriate products and utilization strategy**
  - Broad application to the whole surface or concentrate on the plant rows
  - One application or split
  - Period of application

# Conclusions

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- **Quality compost can improve soil fertility and plant growth and health**
- **Different composts have different characteristics and properties**
- **Different target uses request different composts**

- **The way to success:**
  - **Control the composting process management**
  - **Choice of the correct product for the target use**
  - **Choice of the optimal strategy of use**

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