CROP RESPONSES TO ORGANIC FERTILIZERS, AND THEIR EFFICIENCY

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Content outline

1. World population rising and agricultural intensification
2. Fertilizers consumption
3. Sustainable fertilization
4. Organic fertilizers overview
5. Crop responses to organic fertilizers
6. Towards a better fertilizer efficiency
WORLD POPULATION TRENDS

....9.6 billion of people by 2050
(United Nations, 2013)

Agricultural production would need to increase, to cope with the world population rising, by:

According to FAO, the growth in crop production would derive from an increase of agricultural inputs.
One of the possibilities to increase yields is to enhance the fertilizer applications
FERTILIZERS CONSUMPTION

World consumption (total)

![Graph showing the consumption of fertilizers over time](image)

FAOSTAT
FERTILIZERS CONSUMPTION

World consumption (in nutrients)

- Nitrogen Fertilizers (N total nutrients)
- Phosphate Fertilizers (P2O5 total nutrients)
- Potash Fertilizers (K2O total nutrients)

FAOSTAT
Trend of fertilizer nutrient use on arable and permanent crop area by continent
and organic fertilizers?

There are not official statistics on organic fertilizers consumption throughout the world maybe because:

- high presence of “on-farm” production and field distribution
- it is difficult to define/identify the organic sources
- poor marketing of standardized products
- characteristics of products restricted by different legislations
and organic fertilizers?

In any case, different Authors indicate that the percentage of organic fertilizers is lower than 5% of the total fertilizers consumption.
... but since there is a higher demand of agricultural inputs (fertilizers) to feed the enhancement of world population a more sustainable production strategies should be found and used
The agricultural intensification will have to be done taking into account:
What is the solution?

Therefore, today to reach **economic profitability**, **environmental safety** and **social fairness**, farming systems should find a compromise among the utilization of inputs, crop yields and environmental risks.

Sustainable agricultural development
What is the solution?

Griggs et al. (2013) suggested six sustainable development goals to be fulfilled to secure human well-being in future. One of them is sustainable food security through sustainable agriculture production systems.

One of possibilities to obtain the sustainable production system is to modify the fertilization strategies though the application of organic fertilizers and amendments.
indiscriminate use of mineral fertilizers.

"sometimes" this is the situation, but this could be "always" in the future

Runoff soil and fertilizers during a rainstorm

Swimming in the seaweed
An effective agro-ecosystem production (including the application of organic fertilizers) can both improve yield and quality of crops and reduce the environmental risks.

A considerable amount of literature has investigated this topic...

Improving fertilizer (organic) efficiency is a fundamental challenge for sustainable production of horticultural, industrial and cereal crops.
Soil organic carbon improvement

- Enhancement of water holding capacity
- Increase in nutrient retention capacity
- Improvement of structure and soil biological quality

- Resistance to drought
- Increase in water use efficiency
- Decrease in loss of nutrients
- Increase in N supply over time
- Reduction in soil loss by erosion
- Increase in microbial and enzymatic activities

- Increase in soil organic matter content and overall soil fertility

ORGANIC FERTILIZERS OVERVIEW

Main effects of raw and composted organic materials

<table>
<thead>
<tr>
<th>Effects</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Release of nutrients</td>
<td>Evolves slowly</td>
</tr>
<tr>
<td>Increasing soil organic carbon</td>
<td>Repeated applications</td>
</tr>
<tr>
<td>Soil organic nitrogen storing</td>
<td>-</td>
</tr>
<tr>
<td>Improving biological functions of soil</td>
<td>Depends on quantity and quality of materials applied</td>
</tr>
<tr>
<td>Increasing soil physical fertility</td>
<td>-</td>
</tr>
<tr>
<td>No negative impacts of heavy metals</td>
<td>Use of high quality organic materials</td>
</tr>
</tbody>
</table>

ORGANIC SOURCES OF NUTRIENTS DERIVE FROM:

- Urban wastes and municipal biosolids
- Agro-industrial wastes
- Livestock production
Urban wastes

Urban wastes and municipal biosolids

Garden wastes

Municipal Solid Waste

Sewage sludges
Agro-industrial wastes

- Dairy
- Beet sugar
- Olive oil
- Wine and brewer
- Fruit and vegetable canning
CROPS RESPONSE: CASE STUDIES

a. Urban wastes and municipal biosolids (MSW and sewage sludges)

b. Agro-industrial wastes (olive mill wastewater and pomace compost; anaerobic digestates)

c. Animal manures
Urban wastes: general comments

a. URBAN WASTES AND MUNICIPAL BIOSOLIDS (MSW and sewage sludges)

😊 The volume of solid waste generated every year is increasing world-wide, and much of this waste is left untreated.

😊 Only a small proportion of the nutrients contained in these organic materials returns to arable land.
## MSW - Case study 1: wheat

<table>
<thead>
<tr>
<th>Crop</th>
<th>Fertilizers and amendments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter Wheat</td>
<td>1. Mineral N at 100 kg N ha(^{-1}) (N\text{min})</td>
</tr>
<tr>
<td></td>
<td>2. Municipal solid waste (MSW) compost at 100 kg N ha(^{-1})</td>
</tr>
<tr>
<td></td>
<td>of organic N (N\text{comp})</td>
</tr>
<tr>
<td></td>
<td>3. 50 kg N ha(^{-1}) of both compost and mineral N fertilizer (N\text{mix})</td>
</tr>
</tbody>
</table>

The association of organic and mineral fertilizers presented the best results showing the highest yield production and increasing soil fertility.
# MSW - Case study 2: tomato

<table>
<thead>
<tr>
<th>Crop</th>
<th>Fertilizers and amendments</th>
</tr>
</thead>
</table>
| **TOMATO** | 1. MSW compost at 140 kg ha\(^{-1}\) of N (Ncom)  
                2. Mineral fertilizer at 140 kg ha\(^{-1}\) (Nmin)  
                3. Mixed treatment (Nmix, 50% of compost with 50% of mineral fertilizer, MIN) |

No significant difference was found for marketable yield between organic treatments and mineral one.

N mix also showed the least N balance (near to zero) in the soil and it had a positive effect on soil organic carbon.
### Sewage sludges - Case study 1: wheat

<table>
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<tbody>
<tr>
<td>WINTER WHEAT</td>
<td>1. MSW compost at 100 kg ha(^{-1}) of N (Ncomp)</td>
</tr>
<tr>
<td></td>
<td>2. Mineral fertilizer at 100 kg ha(^{-1}) (Nmin)</td>
</tr>
<tr>
<td></td>
<td>3. Sewage sludge (Nss)</td>
</tr>
</tbody>
</table>
No significant difference was found in Nss treatment for grain yield as compared to Nmin.

At the end of the three-year trial, Nss increased Total Organic Carbon and Total N as compared to the initial soil content and to Nmin.

## Sewage sludges - Case study 2: brassica

<table>
<thead>
<tr>
<th>Crop</th>
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</tr>
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<tbody>
<tr>
<td>BRASSICA</td>
<td>1. 50% N from MSW compost and 50% from mineral fertilizer (Nmix)</td>
</tr>
<tr>
<td></td>
<td>2. 100% N from mineral fertilizer (Nmin)</td>
</tr>
<tr>
<td></td>
<td>3. Sewage sludge (Nss)</td>
</tr>
</tbody>
</table>
The sludge treatment increased yield by 37% compared to the unfertilized control.

No significant difference was found in Sludge treatment for yield as compared to mineral fertilizer.

*De Giorgio D. et al. European Biomass Conference 2012: 639-646*
CROPS RESPONSE

b. AGRO-INDUSTRIAL WASTES
olive residue (mill wastewater and pomace); anaerobic digestates from wine industry

Large amounts of olive mill wastewater, olive pomace, and organic residues from winery industry are produced every year in Mediterranean countries: their incorrect disposal may have a damaging environmental impact, due to some polluting characteristics.
# Olive wastewater - Case study 1: fodder crops

<table>
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<th>Crop</th>
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<tbody>
<tr>
<td>RYEGRASS, PROTEIC PEA, CLOVER</td>
<td>Olive mill wastewater (OMWW): at 80 m$^3$ ha$^{-1}$ (80_OMWW), and 120 m$^3$ ha$^{-1}$ (120_OMWW)</td>
</tr>
</tbody>
</table>

OMWW increased yield in ryegrass (at both doses) and in proteic pea (at 80_OMWW but not at the highest dose)

- Clover showed a species-specific sensitiveness (but the OMWW increased protein content)
- The OMWW enhanced total organic content in the soil
Olive pomace - Case study 2: maize

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>MAIZE</td>
<td>1. Mineral N fertilizer at 200 kg ha(^{-1}) (200 min)</td>
</tr>
<tr>
<td></td>
<td>2. Olive pomace compost at 100 kg ha(^{-1}) + 100 kg ha(^{-1}) of mineral N (200 mix)</td>
</tr>
<tr>
<td></td>
<td>3. Mineral N fertilizer at 100 kg ha(^{-1}) (100 min)</td>
</tr>
<tr>
<td></td>
<td>4. Olive pomace compost at 100 kg ha(^{-1}) (100 comp)</td>
</tr>
</tbody>
</table>

the partial substitution of mineral with organic fertilizer (200 mix treatment) did not reduce yield and also ensured the highest increase of Total Organic Carbon and the least N mineral soil deficit at the end of the experiment.

The organic application showed intermediate yield response maybe due to a high maize N demand.
## Case study: anaerobic digestate from wine industry

<table>
<thead>
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<th>Crop</th>
<th>Organic fertilizers and amendments</th>
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</thead>
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<tr>
<td>LETTUCE</td>
<td>(i) Stabilized anaerobic digestate from wine distillery wastewater 140 kg ha(^{-1}) of N (SAD); (ii) commercial mineral N fertilizer 140 kg ha(^{-1}) of N (MIN); (iii) unfertilized control (CONTR)</td>
</tr>
</tbody>
</table>

AD - lettuce main findings

- SAD application significantly increased marketable yield compared to the unfertilized control
- Recycling agroindustrial by-products, such as SAD, can also ensure a better lettuce quality (lower leaf nitrate content)
Case study: MSW and anaerobic digestate from wine

<table>
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<td>ORGANIC ZUCCHINI</td>
<td>(i) Municipal solid waste compost (MSW), (ii) anaerobic digestate (WDW) and (iii) commercial organic fertilizer (OAF) + vetch residues (two termination strategies: a. green manure,  GM; b. roller-crimping, RC)</td>
</tr>
</tbody>
</table>

MSW and AD - zucchini main findings

- Using RC and applying organic fertilizers could be an effective approaches to modulate N availability to crop

- Organic fertilizers application in vetch management plots increased marketable zucchini yield. This is crucial, because the organic fertilizers were applied taking into account the biological N fixation of vetch
Crops Response

c. Animal Manures

- Manure characteristics are affected by: species and age of the animal, ration fed, collection and storage method.

- High C:N ratio therefore, when applied to the land directly, the excess of C causes N temporarily unavailable into the soil.

- Soil manure application, often in excess of crop requirements, can cause a significant build-up of P, N and salt.
The industrialization of livestock enterprises has led to other problems linked to the land distribution of solid and liquid animal manures, enhancing the interest in pretreatment technologies.
Composted manure vs fresh manure

😊 Reduced:
- number of viable weed seeds
- weight, moisture content and smell
- volume and particle size, which facilitates land distribution

😊 a better balanced nutrient composition
😊 stabilized organic matter and a slower release of N (less susceptible to leaching)
Manure - Case study: maize

About 25 and 36% of C from applied fresh manure and composted manure, respectively, remained in the soil after 4 years of application, indicating greater C sequestration with composted manure.

Forage dry matter yield increased from 32 to 96% with 11.2 and 179.2 t ha$^{-1}$, respectively, of composted dairy manure in the first of two growing seasons.
TOWARDS A BETTER FERTILIZER EFFICIENCY

It can be suggested that:

- the **mixed fertilization** determines good balance among productive parameters, N utilization efficiency indices, soil N deficit and, consequently, lower pollution risks.

- the **anaerobic digestate** is more suitable than compost in horticultural crops due to a short life cycle of these plants.

- the introduction of **cover crops in association with organic amendments** in crop rotation could reduce the fertilizers use and increase soil fertility.
It can be suggested that:

- shift from the fertilization based of one individual crop to use the nutrient sources on a “cropping-system” or “crop-rotation” basis
- consider the positive indirect residual effects of the agriculture fertilizer techniques (in particular organic amendments) on the whole ecosystems (water and air pollution, soil erosion and nutrient leaching)
- the organic fertilizers (in particular composted organic materials) could be used also alone but......
....we should adopt suitable agronomical practices, i.e.:

✓ selected collection of organic residues (important to understand the initial composition of the organic materials)
✓ composting process suitable for agronomic utilization
✓ proper time of organic fertilizers application
✓ specific fertilization plan (crop, soil, environment)
✓ monitoring the modification of soil chemical properties
✓ monitoring of the soil-plant system
TOWARDS A BETTER FERTILIZER EFFICIENCY

Are we using fertilizers in a more sustainable way?
TOWARDS A BETTER FERTILIZER EFFICIENCY

Many farmers still feel that high mineral fertilizer (especially N) application may be an inexpensive “insurance” for crop production and they did not take into account the “greening”
Is It Important and Possible a Sustainable Production (Fertilization) System?
Conversion to agriculture

Conventional agriculture

Sustainable agriculture

Soil organic matter (%)

Labile organic matter fraction

Refractory organic matter

Turnaround

Source: WBGU Special Report: The Accounting of Biological Sinks and Sources Under the Kyoto Protocol
Is It Important and Possible a Sustainable Production (Fertilization) System?
Yes, It Is!
Thank you for your attention

Francesco Montemurro