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Action 4 – Development of alternative agricultural practices – Lab experiments (Italy)

Deliverable "Evaluation of effects of wastes application on different Italian soil types. Definition of maximum annual load of nutrients and organic constituents"

Prepared by: Chemical Laboratory of Chamber of Commerce, Industry, Agriculture and Handicraft of Savona

Coordinator: Dr. Luca Medini
Chemical Laboratory of Chamber of Commerce, Industry, Agriculture and Handicraft of Savona
Regione Rollo 98 - 17031 Albenga (SV)
Tel. / Fax: +39 0182 - 50960
email: luca.medini@labsvcamcom.it

Reviewed by: Dr. Diego Bruzzone, Chemical Laboratory of Chamber of Commerce, Industry, Agriculture and Handicraft of Savona, Albenga, Italy
Prof. K. Komnitsas (Project coordinator)

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1. Executive summary

Pot trials carried out in the frame of Action 4 of Wastereuse project allowed to achieve the following results that are described in the relevant Deliverables:

- Deliverable *"Characterization of wastes treated by different technologies regarding their suitability for agricultural use and especially for vegetable and ornamentals cultivation under Italian climatic conditions"* describes the characterization of selected wastes to determine their suitability for agricultural use. On the basis of the analysis performed 2 kinds of composts were selected for the subsequent phases of the project.
- Deliverable *"New cultivation methods with the use of treated or untreated AW. Effects on soil quality (Italy)"* describes the effects deriving from the adoption of a growing media composed by the selected composts and selected natural soils - that were characterized according to their main physical and chemical parameters – on the chemical properties of soils and leachates.
- Deliverable *"Guide for open field and greenhouse cultivation of the tested crops (Italy)"* describes the suitability of the selected composts mixed with natural soils and other materials in terms of promotion of plant growth with specific regards to potted plants outlining practical indications for the proper use of compost for the cultivation of potted plants as well as the management of the composting process starting with the selection of raw materials till the correct handling of the compost pile and stocking.

Considering the procedure above mentioned, the present deliverable provides indications about the possibility to use composts for the cultivation of some key crops defining amounts that can be applied in order to assure a correct establishment of the crop (on average: 25-30 t/ha for open field crops, mixture of 20 to 40% (v/v) compost with natural soil or peat for potted plants). From an ecological point of view the use of compost can have an important added valued due to the possibility of being assigned the ECOLABEL brand that is recognized at EU level.

2. Introduction

Composting of plant left-over materials can represent a suitable technique for the valorisation of agricultural wastes and their exploitation as growing media (Verdonck, 1988). Composting process is basically a process through which the natural process undergone by the organic matter is controlled, accelerated and improved thanks to the presence of the microflora normally present in the environment. Such process is a key component of waste management implemented at European level regarding which the gradual reduction of the percentage of organic matter in the wastes to be disposed. Characterization of composts is crucial in order to determine its nutritional properties and to exclude the presence of toxic compounds in the case it is then used for plant cultivation.

Besides, the presence of metals in traces (that are already regulated in many countries), organic contaminants can accumulate especially during the anaerobic phases involved in the composting processes. Scientific literature is poor in information regarding studies applied to organic pollutants in compost amended soils (and this is true especially for growing media) especially because the European legislation has been mainly focused in the past on heavy metals and inert compounds. In order to reduce the volume of wastes discharged in landfills, any kind of biological treatment such as composting of selected humid fraction deriving from waste collection became of key importance and is promoted by specific laws (ref. article 5 D.Lgs. 36/2003 and following modifications).

Plant materials can also undergo different kind of treatments when they are re-used as matrix in the growing media together with other materials such as peat that represents the major component of professional substrates for ornamental production in pots. It is estimated that in Italy around 15% of the total volume of growing media produced in Europe is used with an annual consumption of 5 million m^3, whose 50% is roughly represented by peat (Zaccheo and Cattivello, 2009).

Different reasons have pushed for the selection of alternative materials, mainly rising energy costs related to peat extraction and environmental reasons (AA.VV., 1996). Moreover, already in 2001 EC has excluded growing media containing peat from ECOLABEL (the most important community label regarding ecological quality and sustainability). Specifically, a growing medium shall only be considered for the award of the European ECOLABEL if it does not contain peat and its organic matter content is derived from the processing and/or re-use of waste (as defined in Council Directive 75/442/EEC on waste and in Annex I to the said Directive. “Processing” is, for example, biological treatment like composting and anaerobic digestion. “Re-use” of waste materials’ is, for example, the use of organic waste from primary manufactures, which can be employed as Soil Improver, or as an ingredient in such products, due to its physiochemical characteristics. Examples of such are: bark remaining from timber mechanical manufacturing; rice hulls; coconut fiber and residuals from the food industry.

Action 4 includes lab experiments aimed to evaluate treated and untreated wastes and wastewaters as derived from different methods/technologies. 30 kinds of solid and liquid wastes have been collected and characterized against different chemical parameters and phytotoxicity tests. At the same time samples of different natural soil types were also collected and analysed during the first phase of the project. The approach adopted for the selection of wastes and soils is shown in Fig. 1. Mixtures of selected natural soils and selected wastes (2 composts) with the addition of other materials (zeolite and fertilizer) were used in pot trials in order to assess waste suitability as soil amendments to promote crop production and quality and their potential effect on soil properties.

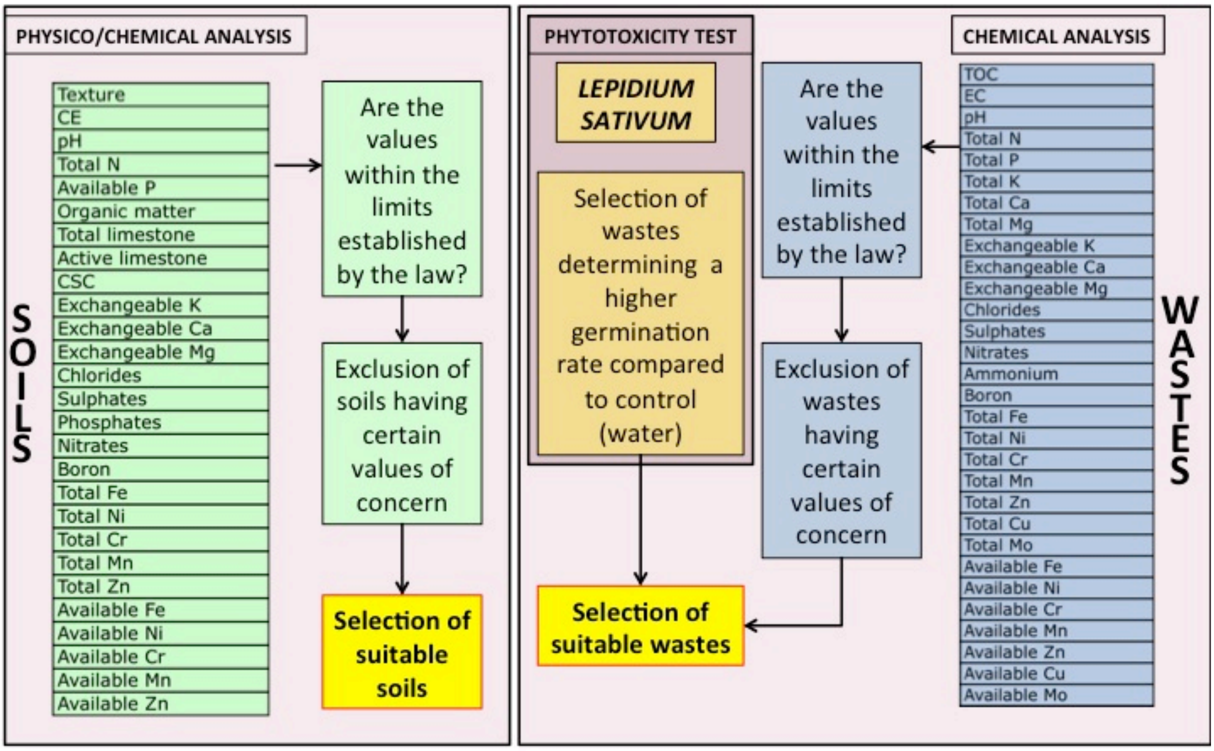

Fig. 1 –Approach adopted for waste and soil selection.

As already mentioned in the Executive summary, characterization of wastes is specifically described in the Deliverable "Characterization of wastes treated by different technologies regarding their suitability for agricultural use and especially for vegetable and ornamentals cultivation under Italian climatic conditions", while characterization of composts and description of their potentialities when used as growing media are taken in consideration in the deliverable “Guide for open field and greenhouse cultivation of the tested crops (Italy)”.

A comprehensive evaluation based on trials carried out and on data collected from literature is hereby presented relevant to the adoption of compost for potted plants and for extensive key crops defining the optimal range of doses. Some indications are also given regarding the application of compost for environmental restoration, a sector characterized by increasing attention by specific professionals.

3. Agronomic properties of compost

When compost is used for pot cultivation in nurseries it is fundamental to carefully evaluate the physical and chemical properties of the growing medium because of the fact that the volume where plant develops is, in this case, extremely small. In this way it will be possible to define correct mixing rate of composts with other materials used in the substrates and better adapt the cultivation techniques optimizing crop yield and quality (Gonzalez and Copperband, 2002).

In Table 1 data regarding a comparison among main parameters used for an agronomic evaluation of different typologies of compost when adopted as soil amendment and growing medium for potted plants (mainly for ornamental plant production) and traditional organic substrates are presented.

Table 1 – Main agronomic characteristics of different organic matrixes – average values (modified from Centemero, 2009).

Parameter	**Manure**	**Chicken droppings**	**ACM* (food waste)**	**ACM* (sewage sludge)**	**ACV****	**ATC*****	**Peat**
Humidity (% wet basis)	65-80	20-70	40-55	40-55	40-55	40-60	40-50
N (% dry matter)	2-2,5	4-6	1,5-2,5	1,78	1-1,5	n.a.	0,5
P_2O_5 (% dry matter)	1,8-2,5	4-6	1-2	2,13	0,5	n.a.	0,1
K_2O (% dry matter)	1,8-2,5	2-4	1-2	0,67	0,5	n.a.	0,1
TOC (% dry matter)	35	35	25	24	20	40	50
pH	8,0-8,5	8,0-9,0	7,5-8,5	7,21	7,5-8,0	5,5-6,5	4,0-6,5
EC (µS/cm)	2500	6600	2700	2500	1000	1850	450
Volatile solids (%dry matter)	55	50	50	48,67	40	60	80
Mg (% MgO)	n.a.	n.a.	1,53	1,23	1,08	n.a.	0,16
Mn (mg/kg dry matter)	n.a.	n.a.	294,32	273,23	303,32	n.a.	63,17
Fe (mg/kg dry matter)	n.a.	n.a.	13600	9490	2690	n.a.	1480

*ACM: mixed composted soil improver; **ACV: plant composted soil improver; ***ATC: mixed peat based soil improver; n.a.: not applicable

Average pH value ranges between neutral and sub-alkaline. Such values do not preclude the use of compost in extensive crop cultivation relevant to which a good content in organic matter and a complete maturation is normally needed. Such pH value is not significant neither when compost is used for environmental restoration (growing substrate for the consolidation of uneven and steep soils) neither for the management of green areas where a good content of humified organic matter and a low humidity are characters normally appreciated. When potted plant cultivation is considered, composts show pH values significantly higher than peats. Electrical conductivity can be a limiting factor for potted plants cultivation in case of values higher than 1500-2000 µS/cm. Composts deriving from wood/cellulose matrixes (ACV – plant composted soil improvers) are normally within such thresholds while ACM composts (mixed composted soil improvers) are usually richer in nutrient elements and, consequently, show higher values of EC. Therefore for the cultivation of potted composts of both typologies plants should be always used mixed with other materials (peats and other) as well as natural soils as described in the other deliverables.

<u>ACV composts</u>

They show good physical/chemical characteristics and a lower salinity than manure (Table 1). Such aspect can lead to a higher compatibility between the organic matrix and the plant and is related to the proved suitability of this kind of compost in all agronomic practices that foresee a direct contact with the root system. That is the reason why they are suitable for the horticultural sector with particular regards to nurseries. On the other hand, and especially with regards to compost deriving from wood matrixes, the content in nutritive elements (mainly N, P and K) is lower than in manure. In this case ACV compost - due to the slow release of nutrients during the mineralization of the organic matter in the soil - can mainly provide humified organic matter so acting as soil conditioner and improving the physical (texture) and biological properties of soil in case of depleted areas with a lack of organic matter.

<u>ACM composts</u>

They are mainly generated from food wastes and sewage sludge and can therefore provide a good level of humified organic matter (conditioning effect) as well as nutrients (fertilizing effect through N, P, K and microlements supply) and a proper ration among N, P and K. Food waste based composts are also rich in Mg and Fe while composts deriving from sewage sludge show a high P concentration (Table 1). They have therefore suitable characteristics when a supply of organic matter is needed, i.e. vegetable crops as well as crops characterized by the need of deep tillage, viticulture, fruitculture which take advantage from the high nutrient content of such composts. They are also broadly used in organic farming as well as in gardening and landscape management. On the other hand the high content in soluble salts (high EC) of ACM composts limit the possibility of a wide use in the nursery sector (potted plants).

In Table 2 application rates and benefits related to compost application on herbaceous and tree crops are summarized.

Table 2 – Application rates and benefits of compost for herbaceous and tree crops

Use	Dose and mode of application	Benefits
Herbaceous crops		
Catch crop	20-30 t/ha of compost in pre-sowing at main tilling	Improved tillage Higher water retention in light soils Higher porosity and permeability in clay soils Fixation and slow release of nutrients Environmental benefits (against soil desertification, depletion, erosion, temporary C fixation at soil level) Suppressiveness against soilborne pathogens Supply of meso- and microelements
Fodder crops	25-30 t/ha of compost in pre-sowing at main tilling	
Vegetables	20-25 t/ha of compost in pre-sowing or pre-transplanting at main tilling	
Cereals	10-15 t/ha of compost in pre-sowing during main tilling	
Tree crops		
Fertilization in pre-planting	• 50-100 t/ha • application on soil surface in open field and ploughed in through traditional tilling	• Organic matter restoration; • Ploughing of less mobile nutrients (P and K).
Cover fertilization	• 40-60 t/ha every 2-3 years • application on soil surface or localized along planting row with or without ploughing	• Organic matter restoration; • Replacing of nutrients removed with crop production; • Conservation of an adequate balance growth/production.
Mulching	• 30-100 t/ha every 2-3 years • application along planting row; distribute a layer of compost in 4-6 cm of soil	• Weed control; • Improvement of the water balance and reduction of temperature range; • Replacing of nutrients removed with crop production.
Plant-hole application	• 5-20 t/ha depending on spacing • direct application on root systems at transplanting	• Improvement of rooting; • Improvement of the quality of the rizosphere.

4. Nutrients supply and technical specifications according to compost use

In order to take full advantage of the application of compost in the agricultural sector it is important to define its technical specifications according to the sector and the objectives it is used for. For instance, main investigated parameters by the companies dealing with the production of potted plants are: pH, EC, nutrient content in soluble form, physical/hydrological properties.

Taking in consideration a field application of compost and comparing it with manure, it is possible to draw a synthesis regarding nutrients supply and the differences among different kinds of products applied as fertilizers (Table 3) (Centemero and Corti, 2000).

Table 3 – Nutrient supply deriving from 1 t of compost and cow manure

	Water (kg/t)	Dry matter (kg/t)	Organic matter (kg/t)	N (kg/t)	P (kg P_2O_5/t)	K (kg K_2O/t)
Cow manure	750	350	151	5,50	2,73	2,68
ACV	500	500	190	5,35	2,35	2,10
ACM (from food waste)	500	500	215	8,95	6,90	6,30
ACM (from sewage sludge)	500	500	207	8,90	10,65	3,35

Practically it means that, when distributing 1 t of product and comparing it with manure:

- higher amounts of organic matter and N are supplied when using ACM compost from food wastes and sewage sludge;
- similar amounts of N, P and K are supplied when using ACV;
- higher amounts of N, P, K are supplied when using ACM from sewage sludge.

Besides, when setting a correct fertilization plan it is fundamental to consider the rate of available N according to the form of nitrogen form at least for the first cultivation year. On the average the N content of composts in the different forms is (Sikora and Szmidt, 2001):

- ✓ Mineral N immediately available = 9,4 – 15%
- ✓ N that can be mineralized during the 1st year = 7,3 – 20%
- ✓ N as reserve = 65 – 83,3%

Such figures are important as reference in order to evaluate the amount of nutrients supplied with compost and, on the other side, the lower dose of fertilizer to use in order to fulfil the nutrient needs based on the removals caused by the crop.

In Table 4 annual application rates [t/(ha*year)] of compost to be supplied to soils having different contents of organic matter in order to maintain a constant level of organic matter are shown with regards to the content of organic matter of the composts (Centemero and Corti, 2000).

Table 4 – Application rates of compost (t/ha) in order to maintain a constant level of organic matter in the soil*

Organic matter content of the soil (% dry matter)	**Organic matter content of compost (% dry matter)**			
	35-40	**40-45**	**45-50**	**50-55**
< 1,5	24-31	21-27	19-24	17-22
1,5-2,0	32-41	28-36	25-32	23-29
> 2,0	42-51	37-45	33-40	30-36

* calculated relevant to the average condition of soils of Northern Italy – Compost main properties: isohumic coefficient 20% - humidity 40-50%

Application rates reported in the table can maintain the organic matter content steady in soils when compost is applied every 2-4 years; in case an increase of organic matter content is desired in soils having a content < 1,5%, application rates should be increased. When large amounts of organic matter are considered (e.g. deriving from compost applications) it is important to verify the maximum level of nutrients supplied; N is the indicator that should be preferably taken in consideration since its mineral fraction can be leached when it is not absorbed by plants.

5. Conclusions

Organic materials like composts can be profitably used as substrates and for the fertilization of soils but they can supply only a fraction of the nutrients that are totally needed by the crop. Therefore mineral fertilization is anyway essential in order to restore the overall needs of the crop.

The use of compost as organic amendment, together with a direct supply of mineral nutrients (N, P, K, Mn, Mg, Fe) that are released during the mineralization of the organic matter, can also:

- cause a mobilisation of the organic sources in the soil;
- increase the availability of the mineral nutrients already present in the soil;
- increase the effectiveness of the mineral fertilizations.

The average dose to be used in open field for crops normally characterized by deep tillage such as corn, sorghum, beet is: 25-30 t/ha of compost to be distribute before sowing at main tilling. When considering potted plants rates of compost (ACV or ACM) variable from 20 to 40% (vol/vol) mixed with natural soil characterized by a medium/high content in meso and microelements or peat are normally the most suitable ones.

The key issue about the possibility to safely and productively adopt composts for cultivation of different crops according to the guidelines given above is its compliance to defined quality standards that apply to all the compost productive chain (plants and equipment, processes and products). Such standards are defined in order to guarantee the production of compost irrespective of the presence of laws or regulations which can be more or less restrictive. With respect to this, ECOLABEL brand was established the Reg. n° 880/92 that was revised by Reg. n. 1980/00. Criteria for the appointment of a EU brand relevant to the ecological quality for soil improvers were established by EC with decision 94/923/CE. Main criteria are the following:

- soil improvers are defined as “products that can improve the physical and biological characteristics of soil without causing harmful effects”;
- the ecological quality brand can be appointed to a soil improver when the use of organic matter deriving from waste treatment is foreseen;
- the use of sewage sludge is not allowed;
- thresholds are set for heavy metals content;
- thresholds are set for *Salmonella* spp. and *Escherichia coli*

Criteria have been recently revised by Decision CE 688/2001. The main new issues introduced are the following:

- aside the “soil improvers” also the “growing media” have been introduced for the extension of the brand due to the extensive use of substrates for the cultivation of potted plants;
- analytical methods for the characterization of the different materials (growing media, soil improvers, etc.) have been revised and unified;
- new key quality parameters have been introduced and relevant thresholds have been established: content of inert materials, maturity stage, presence of weed seeds, salinity, hydrological properties, soluble elements (for substrates);

- the use of peat and peat-based products was excluded by the assignment of brand since peat is a not renewable source whose origin is in protected humid areas.

From this point of view the use of plant based composts can represent a key element in the production of peat-free products that have a broad variety of applications for plant cultivation and that can, at the end, be integrally constituted by recycled/processed wastes and by-products coming from different productive sectors.

6. References

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