8 Compost for soil application and compost for growing media

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In short

- Soil properties of importance are dry bulk density, organic matter content, nutrient content and water holding capacity.
- Rooting media properties of importance are pH, EC, water retention, water uptake rate, porosity, stability, shrinkage and nitrogen fixation.
- Miscommunication between producers and user groups can be avoided by measuring the relevant properties using methods users are familiar with.
- Special attention is needed to interpret total nutrients, extracted nutrients and organic matter content.

8.1 Introduction

Composts are used as soil improvers and as constituents of potting soils to grow plants. Soils and potting soils require composts with different properties. The required properties differ partly because of differences between mineral soil and growing media and partly because of differences between the way water and nutrients are added during the growing period. In some countries the term compost includes mixes with peat products. Confusion may arise where others refer to compost in a stricter sense. Compost in the stricter sense is defined as organic material which has been stabilised by an aerobic exothermic microbial conversion. Composts added to soils are generally finer graded materials with lower stability and higher salt contents than composts added to potting soils. As most composts tend to be more suitable for addition to soil than for use in potting soils, prices for the grades suitable for potting soils are higher.

The use of composts in growing media is restricted by certification bodies in some countries. The certification restrictions aim to not only avoid cultivation risks carried by composts such as salinity, high pH and instability but also limit the possible content of weed seeds, plant diseases and human pathogens. The restrictions often describe a maximum quantity of compost allowed in mixes such as the 20%-v/v in the Netherlands used as a maximum by RHP (www.rhp.nl) certification. The certification requirements also include detailed instructions to avoid cross contamination during mixing, as well as tests to determine compost quality. There is however a tendency to make organic materials more suitable for use in rooting media by improved and more advanced processing[1]. It is therefore hoped future regulations granting access to markets will focus more and more on the intrinsic properties of the material rather than base restrictions on the general term compost. In experiments quantities up to 40%-v/v compost produced equally well for Begonia and chrysanthemum while strawberry and melon were grown on mixes with over 80%-v/v of compost[2].

8.2 Influence of soil and growing media properties

8.2.1 Soil

Soils may be characterised in numerical terms as predominantly mineral particles ranging from 2 µm to 1000 µm. The material is dense (900-1500 kg/m^3) and the pore volume is limited (max 20-40%-v/v).
These quantified mineral soil properties have consequences for other properties:

1. The water permeability, especially in soils with small particles, is low (40 mm/h down to 1 mm/h).
2. The water holding capacity is also low, with values well below 40%-v/v.
3. Soils with less than 1%-w/w organic matter tend to compact and consequently become water logged.
4. Soils low in organic matter content easily loose top soil material by wind erosion and water erosion.
5. Soils low in organic matter are prone to soil-borne diseases either through a lack of disease resilience incorporated in organic matter or because diseases are favoured by the more extreme temperature / flooding circumstances caused by low organic matter contents. Arbitrarily organic matter levels of <2%-w/w are to be regarded as low although there is no fixed level for problems and dry bulk density and mineral composition interact with the critical organic matter content.

8.2.2 Growing media

Growing media or substrates may be characterised as predominantly organic material with particles ranging from 50 to 5000 µm. The material is light (100-400 kg/m^3) and the pore volume is high (60-90%-v/v). In large parts of the world, notably more arid areas, potting soils may be based on the use of porous inert materials like tuff, perlite, vermiculite, and plastic waste.
These quantified growing media properties have consequences for other properties:

1. The water permeability is high, with values higher than 1 cm/min (which is roughly 10-times higher than that of mineral soil).
2. The water holding capacity is high, with values of 50-85%-v/v.
3. The organic particles, in contrast to some (but not all) mineral particles, have internal porosity. This affects properties like water and air storage but also offers micro shelter for microbial life. Levels of life expressed as number of colony forming units (cfu) are typically 10^8 cfu/cm^3, a factor 100 times higher than in mineral soils[3]. When proper numbers of specific species of microorganisms are present, diseases caused by other microorganisms are supressed by several mechanisms of microbial interaction (see chapter 6).

8.2.3 Conclusion

It is understandable that compost properties such as density, total pore space, organic matter content, water permeability, water holding capacity, compaction and air content are more relevant to mineral soils than potting soils. The levels of these properties are already considerably higher in potting soils, to the extent that compost can add little in respect to those properties.

8.3 Influence of water and nutrient supply systems

8.3.1 Soil

In soil systems, water supply may be restricted to naturally occurring rain or supplemented by flooding, drip or overhead irrigation with irrigation intervals of several days to several weeks. In some more intensive cropping systems, micro-irrigation is used with intervals of hours or days.

In the less intensively irrigated systems, nutrients are applied as a large base dressing of solid fertilising material and followed up with a few maintenance applications of solid fertilising materials or more frequent application of liquid fertilising materials mixed in the irrigation water (a.k.a. fertigation). In the more intensive micro-irrigation systems, the base dressing may still be applied as solid fertiliser material but more emphasis is on the frequent application of liquid fertiliser mixed in the irrigation water.

8.3.2 Growing media

In substrate systems, water supply is either by overhead irrigation or by micro-irrigation. Typical irrigation intervals are hours and days. In potting soil systems, a relatively small part of the crop nutrient needs is applied to the potting soil as base dressing and a relatively large part is applied as a series of maintenance applications, usually of liquid fertilising materials mixed in the irrigation water.
The shorter intervals for irrigation and nutrient application are a consequence of the often very small rooting volume assigned to a plant which may lead to much faster depletion than in soil systems.

8.3.3 Conclusion

It is understandable that the nutrient content of compost is more important for soil applications than for potting soil applications even though the difference is gradual rather than absolute.
Some typical uses with pictures are provided below (Figures 8.1-8.4). Note that material in use for propagation is usually fine textured (<1 mm) and with a high water holding capacity (>80%; Figure 8.1C; Figure 8.3D). Composts for propagation must be fine, have a high water holding capacity and at the same time excellent water uptake rates after drying, as well as a low EC content.
Potting plants (Figures 8.1B, 8.3A, 8.4A-C) require medium-sized particles (1-10 mm) and a fair rewetting rate (50% in 15 minutes). Composts in such mixtures should be stable and low in EC and should display a fair water uptake rate as well.
In nurseries for outdoor ornamentals (Figures 8.1D; 8.2A; 8.3C-D) compost used should be even more stable and still rewet on drying.
Composts used in strawberry (Figures 8.2 B-C) are wet at all times as drip irrigation is used so should have enough pore space for air transport, especially so because they are used in percentages of over 80%-v/v.

Figure 8.1 *A) Under glass, drip irrigation, compost, cucumber, The Netherlands, 1999. B) Outdoor, overhead irrigation, geranium, France, 2005. C) Plastic house, overhead irrigation, propagation in cell trays France, 2005. D) Plastic house, overhead irrigation, ornamentals, France, 2005.*

Figure 8.2 *A) Outdoor, micro irrigation, tree crops, France, 2005. B) Plastic house, drip irrigation, compost, strawberry, Angers, 2005. C) Plastic house, drip irrigation, compost, strawberry, Angers, 2005. D) Compost production, raw materials, 2006, Alphen, The Netherlands.*

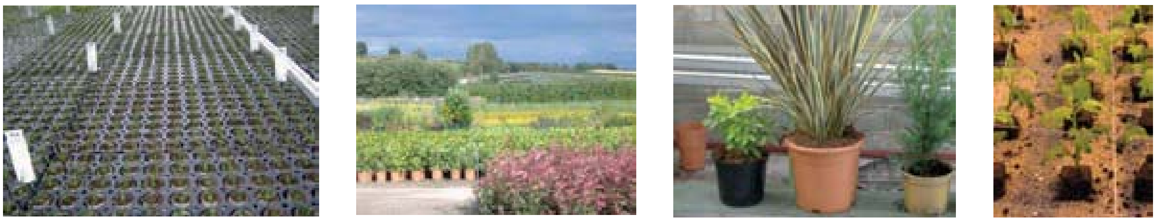

Figure 8.3 *A) Under glass, overhead irrigation plus nutrients, Bromelia propagation, Bleiswijk, Holland 2007. B) Outdoors, cultivation of shrubs on peat free, Nottingham, England 2007. C) Outdoors, cultivation of shrubs on peat free, Nottingham, England 2007. D) Under glass, sub irrigation, peat press pot on sand, chrysanthemum, Holland, 2010.*

Figure 8.1 *A) Under glass, sub irrigation, coir chips, Miltonia, The Netherlands, 2007. B) Under glass, sub irrigation, compost / peat, Begonia, The Netherlands, 2014. C) Under glass, sub irrigation, compost / peat, Begonia, The Netherlands, 2014.*

8.4 Compost functions in soil and growing media

8.4.1 Soil

Compost for soil applications serves a number of functions:

1. Adding nutrients. The compost is valued as it recycles nutrients from prior applications to plants in need of those elements. The value of the compost is rated according to:
   a. The amount of nutrients brought in, relative to the anticipated need of the plant and the soil. Plant need is calculated based on plant analysis and amount to be harvested. Soil need is calculated based on soil analysis and target levels for the specific soil.
   b. The type of nutrient brought in. Nitrate is valued highly but is usually absent in compost material unless it is fully cured. Potassium and phosphorous are usually the most abundant elements and may limit the maximum amount of compost which can be applied.
   c. The level of elements with a negative influence on plant and soil. Sodium and chloride are the most usual unwanted minerals. Their effects may include:
      i. A direct toxicity effect above a threshold level.
      ii. A disruption of the uptake of other elements notably calcium.
      iii. Reduced fresh weight production caused by elevated EC.
2. Increasing organic matter content. A direct physical effect of mixing organic and mineral particles is an increase in the total pore space, resulting from formation of more complex soil aggregates. The increase in total pore space results in:
   a. Lower bulk density;
   b. Higher air content;
   c. Higher water storage;
   d. Higher infiltration rate.
3. Improving soil structure (decreasing soil density, increasing permeability for water, increasing air content, increasing water storage). Apart from the physical effect of mixing minerals with organic material, several other indirect effects take longer to kick in. The organic material can form complexes with clay minerals which increase the coherence of soil aggregates.

4. Increasing the level of microbial activity, biological diversity and resistance against soil pathogens. The organic material offers micro shelters, carbon and nutrients for soil microbial life. Life levels easily reach levels >100 times those in pure mineral soils. The microbes will break down the organic material thus releasing mineral nutrients. The microbes also form fulvic and humic acids which mobilize trace elements such as iron, manganese, zinc and copper thus making these elements more plant available. The microbes form slimes and mucus which bind soil aggregates together into stable sub structures which improve soil structure. Finally the soil microbiological life and the organic matter itself attract meso- and macrofauna like springtails, nematodes and earthworms which may further improve soil structure. The microbiological life may hinder the development and action of plant pathogenic microorganisms through sheer abundance, competition for nutrients and specific interactions.

8.4.2 Growing media

Compost as a constituent for potting soils is evaluated differently compared to compost as a constituent for soil. Especially the functions "nutrient supply" and "organic matter content" are not valued as much as in soil growing, whereas microbial activity and water availability are possibly even more important than in soil:

1. Increasing level of microbial activity, biological diversity and resistance against soil pathogens. The organic material offers micro shelter, carbon and nutrients for soil microbial life. The microbiological life may hinder the development and action of plant pathogenic microorganisms through sheer abundance, competition for nutrients and specific interactions.
2. Increasing water availability. The mixing of organic and other rooting materials only results in a modest increase in the total pore space if the rooting materials are distinctly drier in nature such as bark or rice husks. More important is the possible increase in Easily Available Water (EAW). Materials which hold water with a force larger than -50 cm water column are thought to hinder growth. Soils with >20%-v/v EAW are favoured. Composts also improve the hydraulic conductivity of substrates.
3. Adding nutrients. Compost is valued by society as it recycles nutrients from previous applications to plants in need of those elements. For growers the nutrient contribution in e.g. container plants is relatively unimportant. The growth requirements of pot plants often exceed the maximum amount of nutrient in a container based on compost alone. It is therefore common to add a base dressing prior to growing in the substrate and to also add a maintenance supply of organic fertilizer by mixing organic fertilizers into the irrigation water. The value of the compost as fertilizer is rated according to:
4. The level of elements with a negative influence on plant and soil. Na (Sodium) and Cl (chloride) are the most common unwanted minerals. In many cases, the resulting high salinity (expressed as electrical conductivity of the extract) can limit plant growth.
5. The amount of nitrate immobilisation caused by the degradable part of the organic matter.
6. The fertilizer contribution. Nitrate is valued highly but usually absent in compost materials, unless fully cured. Potassium is usually the most abundant element and may limit the maximum amount of compost which can be applied.
7. Note the negative criteria are covered first, showing high risk awareness in this application.
8. Improving soil structure (decreasing soil density, increasing permeability for water, increasing air content, increasing water storage). This is generally of low importance as the properties of soil density, permeability, air content and water storage are not limiting growth in potting soils.
9. Increasing organic matter content. This is generally unimportant as the potting soil mixes already contain ample organic material.
10. Filler (replacing more expensive materials). This is an economically sound reason for using compost in potting soils though a distinct advantage in the issues 1-3 may be decisive.

8.4.3 Conclusion

The important functions of compost for mineral soils and extensive management are adding nutrients / adding organic matter / improving soil structure and improving resilience, in that order. The important functions of compost for potting soils and intensive management are resilience / water availability / filler function in that order with much less interest in adding nutrients, organic matter or improving soil structure.

8.5 Negative function indicators

Composts may also decrease the performance of soil or potting soil mixes. Therefore a set of negative function indicators is mentioned. Many of these indicators only need to stay clear of critical values used in the market. Those that are less clear are discussed:

1. Nutrient content. At the moment most potting soil producers do not correct the nutrient spectrum of the base dressing in potting soils to complement the nutrients present in the added compost. The reason is that the fertilizers used by the potting soil producers have fixed NPK ratios and many adjustments for compost require single element additions. The use of single elements requires more expertise than some producers feel they can deliver, although it seems worthwhile to further this issue by supplying information. The reverse situation occurs where some elements in the compost are high enough to negatively affect plant growth or plant quality. The most common elements in excess are potassium and sodium. Often the amount of compost that can be mixed in soil or potting soil is limited by one or other of these elements.
2. Stability. Over time, the organic material may be broken down by microbial action. As a consequence the mix loses the positive influences of lower bulk density, higher air content, higher water storage, and higher infiltration rate. In potting soils the loss of volume and the increase in the downward movement of finer more mobile particles may result in worse properties than without compost. Therefore a certain basic stability of the compost is required.
3. Nitrogen immobilisation. The breakdown of organic matter by microbial action results in a massive uptake of nitrogen by microorganisms. As microorganisms compete for nitrogen more efficiently than plant roots, the nitrogen uptake by the plants can be severely restricted even when the total analysis shows ample nitrogen (immobilised in the microbial mass). An element analysis of the nutrient solution will demonstrate depletion though. Extra nitrogen may need to be added to maintain proper plant growth. To know the proper dose, the Nitrogen Fixation Index (NFI) is measured. More stable compost show less nitrogen immobilisation.
4. Hydrophobicity / rewetting rate. Some compost becomes increasingly hydrophobic upon drying. Especially in potting soils this is a negative property which can cause costly hand worked corrections of water content of plants in the borders of batches or fields i.e. those plants which evaporate slightly more.
5. Mineral matter content. A minimum may be required by certification bodies, usually >20%-w/w.
6. Heavy metal, PCA’s, plant diseases, human diseases are all bound by legal upper limits. They are not discussed here in further detail.
7. Plant growth inhibitors and seeds. These obviously need to be absent altogether. Dedicated tests exist to ensure composts are indeed within the limits[4].

8.5.1 Conclusion

The higher the yields per unit area of crop production get, the more important it is that negative properties are not introduced by the addition of compost, since these properties usually outweigh any positive properties. It is largely up to the producer to ensure his product is within limits but the existence of measurements is crucial for the customers. The measurements offer solid neutral and accepted ways to decide in case of conflicts over negative compost properties.

8.6 Measuring quality

To assess the quality of compost, basic properties must be measured to allow buyers and producers to effectively negotiate a price. Insufficient measurements will result in unfounded decisions, consequent poor results and a slowdown in the development of compost as a product.

Condensing the above paragraphs, a table of properties is given (Table 8.1). For a description of the nature of the properties and a description of one or more methods to measure them, a reference is made to [5].

Table 8.1

Quality properties for various end users with units.

Nr.	Parameter	Unit
1	Analysis of nutriënt elements	mmol.L^{-1}
2	Acidity, pH	pH
3	Electro Conductivity, EC	dS.m^{1}
4	Cation Exchange Capacity, CEC	meq/100g OM
5	Nitrogen Fixation Index, NFI	mmol/L^{-1}
6	Water Retention, PF1	%-v/v
7	Easily Available Water, EAW	%-v/v
8	Water Uptake Rate, WUR	%-v/v
9	Air content at saturation	%-v/v
10	Total Pore Space, TPS	%-v/v
11	Organic Matter (Content), OM	%-w/w DW
12	Dry Bulk Density, DBD	g/cm^3 DW
13	Stability	mmol O_2/kg OM/h
14	Shrinkage	%-v/v
15	Organoleptic control	unspecified (see 9.2)

OM Organic Matter

DW Dry Weight

Composters sometimes report properties and methods used for the internal process control of a composting plant[1]. This can result in readings that have little or no value for the end users. Examples are composting time and temperatures reached.

Composters also report end user relevant properties of importance using unfamiliar methods. This can results in the failure of end users to understand reported values. Examples are EC, pH and nutrient content. The results are very different and virtually impossible to read if one is not familiar with the exaction method.

Some of the common sources of confusion are: available versus total nutrients; choice of extraction method; reporting units in mg or mmol; Using %-v/v or %-w/w. These will be discussed below.

8.6.1 Available versus total element analysis

Sixteen to twenty elements in the correct ratios need to be present in solution at the root surface. Therefore only the elements actually in the substrate solution are measured as available elements. Many materials, including compost, also contain nutrients which are not readily soluble. These nutrients may become available later during cultivation so a second type of analysis is needed to show the total elements, including the ones in store.

During cultivation periodic analyses of plant available elements help growers to avoid fluctuations by adding maintenance supplies of nutrients. A total element analysis is usually made at the beginning of the cultivation period. When an excess of one or more elements is found, plant growth may be reduced. When a lack of an element is found, additional fertilisation is needed in order to avoid deficiency. When compost is mixed with other potting soil constituents, the amount of fertiliser in the compost must be subtracted from the amount needed by a particular crop. Potting soil producers often administer compensating amounts of nutrients to potting soil mixes prior to delivery taking into account crop, growing system, water quality and grower wishes. This is an important service for growers! If the compost contains more of an element than is needed in the soil or potting soil mix, the total application of compost must be reduced to avoid over fertilising and possible growth reduction.

8.6.2 Choice of extraction

When growers need to know the plant available amount of nutrients, i.e. the amount present in the solution around the roots, an extraction method is used. In an extraction method soluble elements that are washed out of the compost are said to be available. Extraction of nutrients from compost is less easy and therefore a surplus of liquid is used. Results differ depending on the amount of surplus solution used, as the concentrations measured are diluted. The choice of surplus liquid also influences the results. The amount of nutrients in the surplus after extraction depends on the pH of the extractant solution used, the amount and nature of cations used and the use of molecules added to release iron. Many methods exist and among the methods used are extract dilution methods such as the 1:1.5, 1:2, and 1:5 methods as well as extract solvent solutions such as CAT, pH-KCL and $CaCl_2$ solutions. Table 8.2 shows the dilutions expected when using some of the extraction dilution methods.
The EU is currently preparing the certification of soil improvers and rooting materials and proposes to use the 1:5 extract method[6]. The advantage is the straight forward procedure but the disadvantage is a gross over estimation of some poorly dissolvable salts like $CaSO_4$ (gypsum) and lower accuracies reported by the routine laboratories involved.

Table 8.2
Influence of extraction methods on dilution.

	Soil moisture	Saturation extract	1:1.5	1:2v	1:5w
Dilution compared to SMC (plant experience)	1	2.3	4.0	4.4	17.7
Dilution compared to pF1	0.6	1.4	2.4	2.7	10.6
Dilution compared to saturation	0.5	1.2	2.0	2.2	8.8
Dilution compared to sample volume	0.3	0.7	1.2	1.3	5.3

Soil moisture: for systems in which extracts are squeezed or sucked out of the sample. Saturation extract: extracts squeezed or sucked out of the sample after saturation (like the Pour Thru method7; 1:1.5: create standard wetness (pF1); add 50%-v/v water to the sample volume; 1:2: saturate the sample; take 100%-v/v water volume and add sample until the total volume is 150%-v/v; 1:5: a laboratory compacted sample is prepared; 500%-v/v water is added (5 times the sample volume).

8.6.3 Reporting mg or mmol

Growers who add solid materials to their soil and use compost as a fertiliser source need to know the amount of nutrients in weight per unit area. Thus they will want to know the amount of single elements in unit weight per unit dry matter %-w/w, as well as the water content in %-w/w of the fresh compost. Growers who add compost to their potting soils need to correct their nutrient solutions for the elements already applied in mg/L and want to know how much of an element is already present in a unit volume of their medium, again in mg/L. In most countries element levels are reported in mg although some countries use mmol or meq. All scientific literature uses meq. Minor advantages are that quality checks on the results are much easier when using mmol or meq and the fact that this method of expression is linearly related to salinity. The amount of cations and anions can be checked for in a balance calculation and the EC can be assessed and checked against a measured EC.

8.6.4 Using %-v/v or %-w/w

Certifying bodies demand a minimum content of organic material of 20-30%-w/w. The quantity is reported in %-w/w rather than %-v/v. As long as the organic material is mixed with mineral soil with densities of 1000-1250 kg/m^3 this is not confusing. Once composts are mixed with materials which are considerably lighter, possibly even lighter than the compost itself, %-w/w becomes meaningless. Table 8.3 illustrates this for a mix with mineral soil and a mix with perlite as potting soil constituent.

Table 8.3

Soil organic matter content in sand-compost and perlite-compost mixes, expressed as %-v/v and %-w/w.

DBD Sand	DBD compost	OM	Minerals	O.M.	DBD	OM
kg/m^3	kg/m^3	%-v/v	kg	kg	kg/m^3	%-w/w
1600	200	50	800	100	900	11.1%
100	200	50	50	100	150	66.7%

DBD Dry Bulk Density

OM Organic Matter

To reach a level of 50%-v/v organic matter in sand 11.1 %-w/w is needed. To reach 50%-v/v organic matter in perlite 66.7%-w/w is needed (Table 8.3). Of course the amount a grower needs to buy is exactly equal. The reason for the apparent difference is entirely caused by the difference in density of the receiving materials. An even more important reason to prefer %-v/v is that roots and soil microbes both experience the amount of organic matter in their environment on a volume basis (how far until the next organic particle). Disease resilience is predicted by the amount of organic matter in %-v/v much more clearly than in %-w/w.

8.6.5 Conclusion

For soil / extensive systems the required analyses are focussed on total analysis, mg/kg and organic matter in w/w. For potting soils / intensive systems more and more emphasis will be on extract analysis in the 1:1.5 extract in mmol/l or mg/kg, and organic matter in %-v/v. Developments in the EU seem to require the 1:5 extract method but may allow recalculating the 1:5 to the 1:1.5 method.

8.7 General conclusion

1. It is important for producers to report data using methods the user is familiar with. Table 8.1 provides a list of information of relevance for growers.
2. For nutrient elements two analyses are advised: a total analysis in element quantities in mg/kg and a 1:1.5 analysis in mg/L or mmol/L as is customary.
3. Differences in application have a lot of influence on which quality measurements are important. Compost added to mineral soils is valued as a nutrient source and for immediate amelioration of physical properties. Compost added to organic mixes is valued for improving disease resilience.
4. Differences in delivery systems of water and nutrients and the rooting volume also influence the required properties. Systems with ample rooting volume and large storage capacity for water and nutrients value the nutrient supply by composts; systems with small rooting volumes and small storage capacity for water and nutrients depend more on frequent input of small quantities of water and nutrients.
5. The organic matter content needs to be reported in %-w/w for soil applications but in %-v/v for growers who are dealing with rooting materials other than mineral soils.

8.8 References

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