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The use of compost in urban green areas – A review for practical application

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Abstract

The use of compost for soil amendment and mulching can increase quality during the establishment and management phases of plants in urban green areas. Costs can be reduced, especially in the management phase, but a number of conditions have to be met before benefits from the use of composts can be fully realised. Descriptions of the quality of the composts must be comprehensive enough for the green industry to be able to predict the effect their products will have on the growth and development of plants at the point of use. Users in urban green areas must be able to make specific demands on the quality of compost based on how it is to be used and in relation to the effects planned. General quality factors that have to be fulfilled concern high stability, the absence of unpleasant smell, a low or medium salt content, and absence of polluting substances or particles inhibiting germination and growth. The specific quality demands on compost have to be related to nutrient content and particle size. There is no such thing as the "perfect" compost, but several types, each designed for a site-specific purpose.

- As a soil amendment to shrubs and trees, composts should be limited to an amount that supplies the plants with no more than 100–120 kg of plant available nitrogen per hectare.
- For mulching, the total compost thickness has to be no more than 10 cm. The lower layer (2–5 cm) should consist of small particles of nutrient-rich compost and the top layer (5–8 cm) of nutrient-poor particles larger than 20 mm. In this way, nutrients are supplied to the trees and shrubs and weeds are given a seed bed poorly conducive to growth.

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Introduction

The main cultivation problems with plants in urban green areas usually relate to soil conditions (Craul, 1992), which are seldom tested (Urban, 1998). Cultivation in poor quality soils, often compacted, with little aeration and drainage, without organic material and too small volumes, is one of the reasons that street trees die long before reaching maturity. Costs to the owners of green areas and to entrepreneurs in the urban green sector are massive. Despite much research on the quality of growing media for trees (Couenberg, 1994; Craul, 1994; Grabosky et al., 1998; Kristoffersen, 1998), the use of good quality soil is still not widely adopted in practice.

Composting decreases environmental problems related to the management of wastes by decreasing the volumes of waste and by killing potentially dangerous organisms. A target for European Union countries is to decrease the quantity of organic waste going to landfill sites by 20% by 2010 and by 50% by 2050 (Council

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Directive 1999/31/EC). The follow-up of this directive could result in a large increase in the composting of organic wastes (Crowe et al., 2002). While green wastes from gardens and parks previously made up the largest proportion of materials for composting, now other materials have become even more important; e.g., separated household wastes, organic wastes from agriculture and the food-processing industry, among others. Urban green areas can benefit from the availability of compost products because of the large potential for improvement of the growing conditions of trees and shrubs often cultivated in urban soils low in organic matter. The composts supply nutrients and organic matter, but, even more importantly, they bring beneficial micro-organisms and sustain their life in the soil (Amlinger et al., 2003). These microbes are important for the good structure of the soil, for nutrient cycling and, often, for the good health of plants (Dumontet et al., 1999; Fichtner et al., 2004; Hoitink and Krause, 2003). The many important properties of compost, the substantial use of compost in urban soils and low cost are among the reasons that landscapers are the largest purchasers of compost in the United States (Alexander, 2001).

Since composts differ in content (Gouin, 1998) there is a danger that they are misused, the resulting damage to plants being inhibited growth, low plant quality and plant death. These are "accidents" that do not occur when planners and practitioners are aware of the quality demands put on the compost and on how the different composts are to be used. However, there is still a large potential for improvement of compost products (Tyler, 1996), but only if research on developing good mixes of composts and soils continues. The dissemination of information on their correct use in urban green areas has to be more far-reaching. Tyler (1996) distinguishes between the high-price (and high-quality) market and the volume market. In the future, the marketing of raw compost will be directed at farms and at the manufacturers of soil and compost mixes, and probably only to a minor degree at end-users in the urban greening business. The aim is not just composted wastes, but a resource highly appreciated by the green industries in particular. Generally, this is still not the case today. In an urban context, city planners and practitioners are looking for new ways of increasing the quality of urban green areas, and the producers of compost are looking for customers willing to pay for a good product. The aim of this article is to review current knowledge about the use of compost, focusing on the qualities of composts and their proper application in urban green areas.

Why use compost in urban green areas?

Soil depth required for young plants to develop into large and healthy trees is between 40 and 80 cm (Perry, 1994). Soils on construction sites, often with compaction problems, hinder the growth of shrubs and trees. Urban soils often lack the natural topsoil, where organic matter and microbial life are found. At many urban sites, the leaves and other natural waste from the plants are raked up and disposed of at dumps or in compost bins, rather than left to form a natural mulch, as found in forests. Thus, the soil is deprived of new organic material. Although the use of mineral fertilisers replaces the nutrients removed with the organic materials, the content of the organic matter in the soil decreases (Amlinger et al., 2003; Craul, 1994). Since micro-organisms and many important soil processes are linked to the organic matter, this makes urban soils less favourable for root growth. The most important benefit of using compost is the long-term effect in soils in relation to the high content of organic matter (Alexander, 2001). The effects of soil amendments are of most value at sites where it is difficult to restore vegetation (Brown et al., 2003).

High-quality compost consists of many compounds that influence the biological processes in the soil positively, thus improving the physical and chemical soil characteristics (Obreza et al., 1989). Humates, which are the organic substances (acids) that remain in the soil after the breakdown of organic matter, improve the soil structure, resulting in a soil that is easier for the plant roots to penetrate. The optimal soil texture also has a pronounced effect on the water-storing capacity of the soil, which is important in dry areas (Stuckey and Hudak, 2001) and in coarse-textured (sand) soils. With improved root growth, the stability of trees increases. The larger soil volumes explored by the roots lead to better nutrient status and less water stress. Organic molecules act as sites for cation exchange, thus increasing the adsorption and retention of nutrients in the soil. The micro-nutrients added to the soil by composts may replace an expensive micro-fertiliser. Rivero et al. (2004) suggested that compost increases the quality of the soil organic matter by contributing to a higher level in the soil of the most beneficial humic substances, which may change the balance between beneficial and detrimental micro-organisms. Pascual et al. (2002), too, pointed to the humate fraction from composts as one of the likely important factors for the effect versus pathogens. The micro-organisms may thus lead to: better plant resistance to disease after an effect on the plant, effects on harmful disease organisms or changed competition between soil organisms such that the effects of disease are less detrimental to the plants (Fichtner et al., 2004; Hoitink and Krause, 2003; Pascual et al., 2002). Reuveni et al. (2002) found the disease-suppressing effect on *Fusarium oxysporum* to be biotic rather than abiotic in nature. *Pseudomonas syringae* symptoms were reduced in *Arabidopsis thaliana* (L.) Heynh. grown in soil amended with composted wastes from paper mills (Vallad et al., 2003). The response was due to an increase in disease resistance in the plants. Labrie et al. (2001) showed that the bacteria present in the final compost are products of both the materials composted and the composting process. Hoitink and Krause (2003) pointed out that composts might be contaminated with harmful plant diseases, and that their correct handling is important for the positive effects against plant diseases. However, when the temperature in the compost is high enough over some time, plant pathogens will effectively be killed (Bollen et al., 1989). The water content of the compost should always be above 35%, since the bacteria grow as a biofilm on the surface of compost particles. If the compost has been dry for a long time, it may be difficult to wet the particles after water repellent fungi have infected the compost (Hoitink, 1998). The compost has to mature with a water content of 45–55% if problems with fungi are to be avoided. However, the effect of compost extracts on plant diseases may depend on a diverse set of factors, and these have to be subjected to more research before the use of such compounds can be an integrated means combating plant diseases (Scheurell and Mahaffee, 2002).

Different composts

Not all composts are described in this article. The main interest of the green industry concerns the compost and derived products required to support and serve the high-quality standards of urban green areas. The most used is the green compost produced from yard wastes, composted bark, wood chips and waste materials from breweries and the pulping industries. Manure is often added to speed up the process and to increase the nutrient content of green composts. Food residues and other organic materials from households and the food-processing industry are usually composted along with bulking agents such as wood chips, paper and so on. Occasionally, municipal sludge is incorporated during the composting process, adding nutrients to the composted product. The benefits of including diverse feeding materials in the compost are in the possibility of adding nutrients and in producing an end product with good structure. However, the composting process is usually optimised towards the production of a hygienic and stable material, in as short time as possible, with qualities in accordance with government and/or regional regulations. Since composting is increasing, new feeding materials will be included during the process, perhaps producing composts of slightly uncommon properties. Further improvement of compost into useful products in the green industry has to be based on adjustments (product development) to the end product. Only in this way can soil amendments and mulches be optimised to meet the needs of the planners and practitioners in urban greening departments.

Compost quality

The quality of composts has to be tested according to established methods (e.g., Thompson et al., 2001) so that different products can be compared. Large variations in quality can be expected within and between deliveries (Roe, 1998). Worker safety, environmental protection, maintenance of the composting and humification processes and suitability of the composts for different uses all have to be taken into consideration when determining quality (Roe, 1998). Compost qualities include many parameters (see recommendations given earlier by Watson, 2003, among others). We suggest that the recommendations mentioned in Table 1 be used mainly for raw compost. These recommendations are only a guideline for how to obtain a final product, since the quality demands on commercial growing media, soil mixes or compost mulches need to be for the specific use of the products.

Composts can seldom be used alone as pure growing media. A germination test or compost analysis to determine its suitability always has to be made before such uses are recommended. Compost as the only constituent of the growing media will often kill or seriously damage plants. Mixing compost with soil, sand or other constituents modifies the pH, conductivity and nutrient concentration, and improves the physical properties of the medium. For example, the conductivity of a growing medium for horticultural crops has to be about $2.0\,\mathrm{mS\,cm^{-1}}$ in order to yield good growth. In many types of raw compost, the conductivity is much higher.

In addition to the parameters in Table 1, Davidson et al. (2000) mention availability of a consistent product containing an active population of beneficial micro-organisms. Particle sizes may be very different, depending on how the composts are to be used. High-quality growing media are best made by mixing different materials based on what is known about the properties of the different fractions (Guérin et al., 2001). Soil at the site has to be analysed for nutrient content and pH before compost is used, and the plant species to be established needs to be evaluated. This is important in the choice of compost for a particular situation and in the amount to be applied, as well as in determining what other amendments are needed for control of pH (see Alexander, 2001).

Stability

'Maturity' and 'stability' are expressions often used in descriptions of high-quality compost. However, they are

Table 1. Quality parameters of raw composts for horticulture and arboriculture (modified after Watson, 2003)

Parameters	Ranges
Stability	Stable (complicated to measure in a simple way, but different methods are given; Thompson et al., 2001)
Phytotoxicity and inhibiting compounds	No inhibition of germination or growth of plants should be tolerated
Conductivity and content of nutrients	Conductivity must be monitored. A level less than 3.5 mS cm^{-1} (saturated media extract) is wanted in the compost applied and the C:N level should be 15–25
Content of pollutants	The content of heavy metals or organic pollutants must meet the national regulations. The content of glass and plastic must be low
pH	5.5–8.0. A high pH may be critical only at a high Ca content
Particle sizes	Depending on the use

not easy to define (Brewer and Sullivan, 2003; Domeizel et al., 2004) and cannot be described in a single parameter (Cooperband et al., 2003; Goyal et al., 2005). Some authors claim, e.g., that the C:N ratio is a good indicator of compost stability (Goyal et al., 2005), others that this factor is no longer used in the evaluation of compost stability (Domeizel et al., 2004). The stability of compost lies in its ability to support biological activity, and therefore it has to have certain characteristics if stability is to be established (Suzuki et al., 2004). Physical and chemical analyses may not reveal unstable composts, which often have an unpleasant smell. Testing for percentage germination and plant growth reveals composts of low quality, but it is difficult to find plant species ideal for bio-assays (Emino and Warman, 2004). Unstable composts that support further breakdown at high rates should never be considered as end-product compost. Composts can appear to be stable at delivery, without this necessarily being the case. One or several factors, e.g., the lack of oxygen or water, may have slowed the composting process. However, when the missing constituents are supplied, the process will resume normally, but potentially creating problems such as high temperature, unpleasant smell and the release of harmful gases and organic acids. Two simple methods (Bilderback and Powell, 1996) for the initial testing of stability are: (i) A handful of compost (moist but not wet) kept in a plastic bag for 24 h should not have an unpleasant smell. (ii) A compost heap of about 1 m^3 should not increase substantially in temperature during the course of 24 h. However, laboratories offer analysis that gives a more accurate value of stability, measured as O_2 used, CO_2 released by the compost or the rise in temperature in defined volumes of compost (Thompson et al., 2001). Indices of compost respiration have been shown to be sensitive indicators of quality in compost (Brewer and Sullivan, 2003; Cooperband et al., 2003), as have humification parameters (Domeizel et al., 2004; Gigliotti et al., 1999; Suzuki et al., 2004). NO_3–N is often high in mature composts (Cooperband et al., 2003; Suzuki et al., 2004). However, Goyal et al. (2005) conclude that no single parameter can be taken as an index of compost maturity.

Phytotoxicity, inhibition of germination and growth

Mature composts are characterised by the absence of substances inhibiting seed germination and plant growth (Roe, 1998). Acetic acid is probably the most damaging organic acid released from fresh compost, but there are also other compounds (among them acetaldehyde, ethanol, acetones and ethylene) that contribute to the phytotoxic effect (Ozores-Hampton, 1998). High concentrations of salt and the release of organic acids into the composts are also correlated to inhibition of germination and growth. Phytotoxicity is often best evaluated by conducting germination or growth tests (Gariglio et al., 2002; Brewer and Sullivan, 2003), but the test plants have to be chosen with care (Emino and Warman, 2004). Watson (2003) has overviewed the various tests that composts can be subjected to before use.

Conductivity and content of nutrients

The conductivity of compost varies depending mainly on the feeding materials in the composting bin. However, when conductivity is higher than 5 mS cm^{-1}, the inclusion rate in soils has to be no more than 20% when salt-sensitive species are to be established (Alexander, 2001). Mixing with other materials is one way to reduce conductivity to an acceptable level, i.e., to maximum 2.0–3.0 mS cm^{-1}, measured in saturated media extract (Watson, 2003). Different plant species have different preferences and tolerance levels. Species with a superficial root system (e.g., *Rhododendrons*) are especially vulnerable to high salt levels. High levels of salt will increase the effect of infection with disease (*Phytophtora* and *Phytium*, Hoitink and Krause, 2003) and decrease the availability of soil water. Symptoms of plants growing in media with high salt levels are wilting and necrotic leaves or leaf edges. Compost suppliers should always declare the salt and nutrient content of their products.

Of the total nitrogen content of compost, more than 90% can be bound in organic components. Therefore, the conditions for mineralisation are crucial for the amount of nitrogen that is released from the compost to the plants. A good indicator of nitrogen availability is the relationship between organic carbon (C) and total nitrogen (N), which should be lower than 20; otherwise there will only be small amounts of nitrogen available to the plants. Little effect can be expected from either compost or nutrient supply if the soil is already rich in organic matter and nutrients. Lloyd et al. (2000) found dramatic differences in the amount of available nitrogen to plants, depending on the type of mulch material. There is often a concern about winter hardiness if trees and shrubs are supplied with too much nitrogen at a time when the plants terminate growth and increase winter hardiness. However, there is little evidence that nitrogen supplied in the autumn decreases winter hardiness (Smiley and Shirazi, 2000). But soil soluble nutrients in late autumn and winter may end up in drainage or runoff water, thus polluting groundwater, streams and lakes. The use of very large amounts of compost is not good practice, especially on well-drained soils (Amlinger et al., 2003). In addition, there is good reason for limiting the application of nutrients released when the plants are unable to retrieve the nutrients from the soil; spring is therefore the best time for applying compost. Pickering and Shepherd (2000) found C:N-content and K-content to be good indicators of how well the composts supplied the soil with nutrients. They suggest that the content of K and P and the content of metals in the compost are good guides to what amounts to apply. However, if the composts contain high concentrations of Fe or Al (from sewage sludge), the P will not be available to the plants because of immobilisation (Krogstad et al., 2005).

Content of pollutants

The content of heavy metals in composts must be declared and should never exceed the limits stipulated in local regulations. In urban green areas, the soil will seldom be used for food production, and the use of composts should not be a great risk. However, an evaluation has to be made based on whether there is a danger of metals or organic substances polluting the groundwater. This danger is greatest in the case of sandy soils and least in soils rich in humus and clay.

pH

Mature composts have a relatively high pH, even when no lime is added to the compost. This happens mainly because organic acids will be broken down as the compost maturates. But the application of mature composts to soils will seldom substantially increase the soil pH, since the buffering capacity in the compost is low. However, when large amounts of calcium are present in the compost, the $CaCO_3$-pool will be large and the buffering capacity will also be high. This may cause a substantial rise in soil pH if large amounts of compost are applied. Compost low in $CaCO_3$ has low buffering capacity, which explains the poor pH effect of the compost. Pickering and Shepherd (2000) found that the pH of the compost was not a good indicator of how it affects soil pH. However, also compost low in lime can contribute to the prevention of acidification. If the compost has both a high pH and a high content of lime, the high pH may limit the availability of the micronutrients to the plants; large quantities of such composts should not be used, especially on plants that are known to thrive in acid soils.

Safety when used

The content of pathogenic organisms of humans in compost cannot be ignored, especially when the compost is used close to where people spend much time. Both compost and other decomposing organic materials can contain *Aspergillus fumigatus*, an organism that can affect human health. However, this organism is always present in compost and compost facilities (see Dumontet et al., 1999 for references) or other places where organic materials are decomposing. The possibility of plant pathogens must also be evaluated if the compost is to be used in nurseries or places where there is a danger of spreading infection. In general, the composts have to be well treated and the content of potentially dangerous organisms declared before use (Dumontet et al., 1999).

Compost that been through a high temperature process (above 60 °C) will not contain viable weed seeds. Compost stored for any length of time, and exposed to weeds in this period, can be heavily infested with viable seeds at delivery and should not be sold and used in urban green areas. Composts can be stored under cover, thus preventing infestation with weed seeds.

Particle sizes

Composts usually consist of particles of different sizes, but their distribution may vary depending on the feeding materials. However, depending on the expected effect of the compost: large, small or a mixture of particle sizes may be wanted.

The "right of way" use of compost in urban green areas

In order to succeed, one fundamental principle is that the composted products must be used commensurate with the soil properties and the green area (plant species, etc.) to be established or managed (Alexander, 2001; Tyler, 1996). With no evaluation of the total situation, any detail overlooked can bring failure and disappoint both landscaper and property-owner alike. Good examples of how to use composts can be found in Tyler (1996) and Alexander (2001).

Soil amendments

Focusing on the C:N ratio is important because of the relevance to plant available nitrogen (Bar-Tal et al., 2004; Pickering and Shepherd, 2000). Large amounts of compost are needed to satisfy a plant's need for nitrogen, and they suggested that the contents of P, soluble salts and hazardous elements should be the constraints determining application of the compost. However, if the compost is mixed with municipal sludge, the nitrogen content may reach levels that are too high (Sæbø et al., 2005).

When testing different composts, the availability of N is the most important quality factor limiting the growth of cucumber (Wang et al., 2004). However, the mix that gives the best results may be very different from one plant species to the next (Hernández-Apaolaza et al., 2005). In addition, the composts may have different properties of importance for the performance of growing media based on them (Lima et al., 2004).

The application of large amounts of compost (at ca. 62 ton ha^{-1}, filled into the planting holes) doubled the survival rate of *Pinus taeda* L. and increased growth by 41% (Stuckey and Hudak, 2001). In this experiment, the main positive effect of compost was on the water content of the soil. Gilman (2004) has shown that the use of soil amendments did not influence survival and growth of *Quercus virginiana* Mill. 2 years after planting. He points out that the experiment was done on good soil, and that poor urban soils may have had more use of high-quality organic additives. In another experiment, Wilson et al. (2001) found that *Orthosiphon stamineus* Benth. and *Angelonia angustifolia* Benth. grew well and of high quality in soil modified with 20% and 50% compost but not at 75% and 100%. These authors conclude that compost may be a partial alternative to peat or coir (the inner husk of coconut). If more than 30% compost is to be used, germination tests and possibly other analyses have to be done to ensure the absence of phytotoxicity and the good physical (porosity and water infiltration rates) and chemical quality (conductivity and nutrient content) of the growing media (Asdal, unpublished study). In testing compost, the best results have been found when the soil has been poor in nutrients before the application of compost (Roe, 1998) and little or no effect if the soil has been relatively nutrient rich (Ferrini et al., 2005; Gilman, 2004). Rose and Wang (1996) report that compost and municipal sludge increase growth in most ornamental plants, but that high salt concentrations result in negative responses in some species. Watson (2002) observed more roots in replaced soils amended with compost than in the surrounding soil 14 years after replacement of the soil, but that root growth in the soil beyond the zone of replaced soil was not affected. Compost contributed to both increased growth and a higher content of nutrients in apple trees in the establishment phase (Moran and Schupp, 2003). In urban green areas, rapid establishment is important. Medina et al. (2004) observed that a poor soil responds well to amendment with favourable micro-organisms, especially if the soil is also amended with organic materials as food for the micro-organisms.

Different composts may give very different amounts of nutrients to the soil, as indicated by the nitrogen content of the products and the different N mineralisation (He et al., 2000). Successful application has been found with a compost layer of 2–8 cm (see Alexander, 2001 for references) mixed into 15–20 cm of the top soil. The differences in climate and soil conditions in Europe call for more studies on the expected nitrogen effect of composts. Amlinger et al. (2003) reported that in the first year N-gifts were between −4% and +15% of the total N-content of the different composts and a 2–8% of total N the following years. When 6.3 kg of mature compost from private garden wastes was applied per square metre to forest vegetation of *Fagus sylvatica* L., *Pinus sylvestris* L. and *Picea abies* L. H. Karst, the amount of NO_3^- in the runoff water was increased in the first 17 months after application (Borken et al., 2004). After 17 months, however, no differences could be found. The authors recommend the use of mature compost with a low content of mineralised N.

The most difficult sites for trees and shrubs are along streets and parking lots, where the soils are composed also to bear heavy loads, but the use of structured soils (Grabosky et al., 1998; Kristoffersen, 1998) should provide suitable conditions. However, the quality of the soil in the spaces in the stone matrix must be of high quality and the content of organic matter ought not to exceed 5%. In less demanding situations, compost can be mixed into the existing soil to at least 20 cm depth, but preferably to 45 cm, if the soils are to support good growth in trees and shrubs into high ages. The amounts of compost applied have to be determined according to the content of nutrients, other salts and pH. If the soil mixing depth is 20 cm, a layer of 6 cm will give a proportion of compost that is less than 30%. However, in addition to the analysis of C-content and nutrients before mixing, a further analysis should be made after mixing (before planting). Plant available nitrogen in the establishment phase should not exceed 100–120 kg N ha^{-1} $year^{-1}$ in Northern Europe (Sæbø et al., 2005). In general, the amount of soil amendment should be determined based on the most important characteristics of the composts, whether nitrogen content, lime content or simply the content of organic matter.

Mulching

The use of compost as mulch is an old method of weed control and is still a very good method in certain instances (Ozores-Hampton, 1998; Ozores-Hampton et al., 2002). Mulching is already a much-used practice in urban green areas in contributing to the improvement and success of plant establishment and in decreasing the costs of management in urban green areas. However, the mulching materials have to be of high quality and great care has to be taken in how they are used (Table 2). Erhart and Hartl (2003) found that mulching brought about a decrease in growth of *Picea pungens* Engelm. 'Glauca' in the first year after mulching, and an increase in the second year. Both shoot growth and number of buds were affected by the mulching. This type of response shows how nitrogen may be immobilised 1 year and released the next. The effect of compost as a mulch to inhibit weed infestation is in decreasing the amount of light to the weed seeds ready to germinate in the topsoil. Weed seeds that drop into the mulch are prevented from germinating by the dry top layer of the mulch. Thick layers of compost (10 cm) are often necessary to obtain sufficient effect against the germinating weeds, but this depends on the quality of the compost (Hanslin et al., 2005; Sæbø et al., 2005). A compost of fine-graded material can increase weed infestation in green areas, especially if the composts are rich in nutrients. Before mulch is applied, the areas must be cleared of all established weed plants.

The effect of biologically active compost on the O_2 level of the soil, and on soil surface temperature, can seriously affect the weeds (Ozores-Hampton, 1998) and even large and well-established trees (study findings by Sæbø and Hanslin, not yet published). These authors observed a temperature of 48 °C in a layer of 10–15 cm mulch of unstable compost. It is likely that 32 °C is close to the limit of tolerance of tree roots (Graves, 1998). Damage to plant roots may kill the plants immediately, and root rot organisms affecting the plants at a later stage may invade the damaged roots. The positive effect of mulch on the establishment of *Quercus virginiana* Mill. was probably on weeds in an experiment on a relatively dry site (Gilman and Grabosky, 2004). Trees grown with turf grass close to the trunk had decreased growth compared to trees with mulch. However, a negative effect of the compost mulch was found the first time after planting, because the mulch captured some of the rain water, thus decreasing the total water available for the plants in periods of drought (Gilman and Grabosky, 2004).

Good mulch may consist of two layers of composts of different characteristics, i.e., nutrient-rich compost, with small particles, as a lower layer directly on the ground, and a nutrient-poor compost with particles of 20 mm and larger on top. Trees and shrubs will thus be supplied with nutrients from the fine-grade particles and weed seeds will not readily germinate on the coarse and nutrient-poor particles on the top layer of the mulch.

Mulch should be applied no closer than 15–20 cm to the trunk of the trees and shrubs in order to avoid damage from rodents (Perry, 1994) and insects and infection from disease (Alexander, 2001). A mulch of small stones can substitute for compost close to the trunk. If compost is applied repeatedly over several years, care has to be taken to ensure that the accumulated layer of compost does not exceed 10 cm. A dense compost layer can prevent soil aeration. The speed at which the mulch breaks down depends on the quality of the compost and on the moisture level and temperature at the site.

Table 2. Benefits and possible problems with using organic materials for mulching (after Balder, 1998)

Benefits of mulching with organic materials	Possible problems
Depresses weeds	Possible weed infestation
Smaller variations in soil temperatures	Slow thawing of frozen soil in the spring
Decrease in evaporation from the soil	Excessive amounts of humus
Increased water storage capacity in soils	
Stabilising or slightly increasing the soil pH	Phytotoxic effects
Increase in soil life (in poor soils)	Can be contaminated with pesticides
Increase in soil aeration	Possible inhibition of soil aeration
Increase in soil nutrients	Possible binding of nitrogen
Can inhibit plant pathogens	Possible contamination with plant pathogens

Amounts for soil amendments

There may be national or regional regulations on how compost can be used and how much can be applied, but this is beyond the scope of our article. It is impossible to give fixed values for how much compost may be applied to green areas because of the many variables. The compost qualities are different, the soils and climate are important factors and the different species have different needs with respect to soil properties. The compost and soil, as well as the site description and kind of green area, must therefore be evaluated carefully (Fig. 1). Some guidelines for calculating the amounts that can be applied for different uses are given in Table 3.

Growth and development in a green area are usually closely linked to plant management. Although rapid establishment is the aim, the management level may be planned as low as possible in order to save costs. The highway authorities want a roadside that is covered with vegetation to prevent erosion and to give the road a pleasant aspect; at the same time, they do not want strong growth creating the need for frequent management of plants growing over the road. In other more frequented green areas, there is a need for a stronger growth of plants to compensate for wear. The amounts and types of soil amendment can and should be adapted to the planned management and to the plants to be used. Thus, the challenge is to find the correct type and amount of soil amendment to optimise soil conditions with respect to organic matter. At the same time, there is the possibility of increasing the overall quality of the green areas and of decreasing costs in the long term.

When deciding how to use the compost and how much to apply, many factors will influence the decision (Fig. 1). A soil rich in nutrients and organic matter should be amended with smaller amounts of compost than a soil poor in organic matter and nutrients. The compost used for mulching may, at least partly, be of assorted qualities with respect to particle size and nutrient content. The products can thus be designed specifically for use in urban green areas.

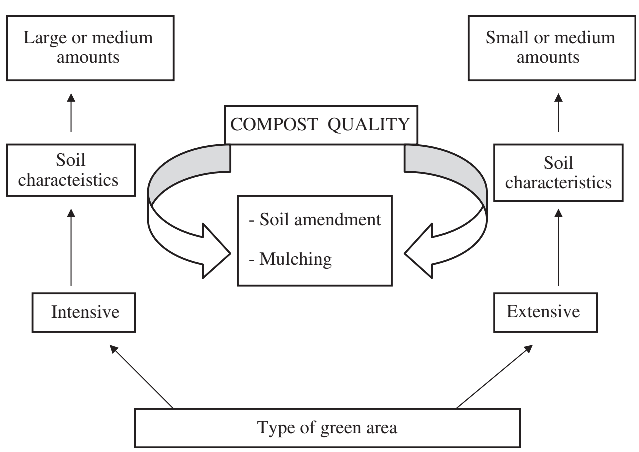

Fig. 1. A synthesis of factors that have to be taken into consideration when determining how much compost to apply, and how to use it, in urban green areas.

Conclusions

The knowledge we have of the importance of the high-quality organic matter content of soils should lead to an increased focus on this factor in the establishment and management of urban green areas. After green areas have become established, there is little chance of adjusting the soil properties, except at great cost. The green industry therefore relies on the soil amendment products they use having a stable quality and producing a predictable effect. Fractioning the compost and mixing into "designed" mixes should give a spectre of products for different uses, as well as the desired visual effects, in urban green areas. The increase in the development of designed compost products is the only way to increased use and benefits of composts in urban green areas.

When the amounts of compost applied are based on nutrient content, trees and shrubs should seldom be given more nutrients than supplied by 100–120 kg of plant available nitrogen per hectare. Urban soils should have about 5% organic matter; amounts that bring soil pH above 7.0 should not be used for most trees

Table 3. The use of different types of compost (modified after Sæbø et al., 2005)

Type of compost	Properties/parameter	Mode of use	Amounts of compost
1. Green compost	Organic matter	Mulching or soil amendment[a]	3–10 cm layer or 10–600 ton ha^{-1}[a]
2. Compost from household waste	N-content, stability and phytotoxicology	Mulching or soil amendment	33–6 cm layer or 100–150 kg N ha^{-1}[b]
3. Compost with municipal sludge	Ca and pH, N, organic matter	Soil amendment	100–150 kg N ha^{-1}, or according to the liming effects
4. Soil mixes	Variable	Growing medium	Depending on the conditions

[a]Dry matter.
[b]Plant available nitrogen.

and shrubs. An annual application of compost, 2–3 cm year^{-1}, may be better than one large application at establishing. This may increase benefits in the management of weeds and thus decrease management costs in urban areas.

Dissemination of the present knowledge is now an important task. Planners and practitioners operating in the urban greening sector, in particular, need to be further educated in the area of compost quality and its use.

One of the major problems of research into compost is that the experimental conditions and the tested composts are so different that it is difficult to condense results into general conclusions. However, as research results continue to accumulate in this field, general conclusions will be made. Research and development in the future should focus on the following topics:

- Development of methods for predicting how much nutrient can be mineralised over a given time (season) and thus support plant growth. The danger of runoff of nutrients to groundwater, etc., must be described in this context.
- Examination of the soil qualities and compost additives that give the best growth, health and general quality in shrub and tree species.
- Development of products; compost mixes should be designed for specific uses for soil amendments and mulches.

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