THE IMPACT OF URBAN SOILS ON VEGETATION

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ABSTRACT.--Urban soils can have a dramatic effect upon urban vegetative plantings. It is felt that 80% of urban vegetation problems can be traced to and/or caused by a poor soil environment. Topics to be discussed are the mapping of urban soils, compaction, characteristics of urban soils, and methods of dealing with stressed situations.

Experience gained working with the urban stress situation in Washington, D.C. and other sites has led us to project that about 80% of urban plant problems which develop can be initially traced to and/or caused by a poor soil environment. This poor environment renders a plant or planting susceptible to the synergistic effects of other dehabilitating urban stress factors producing an overall decline in plant vigor. If in fact this observation is valid, then it illustrates a severely neglected environmental condition. Further, the nurserymen’s contention supporting “the $1 tree in a $10 planting hole” takes on some validity. For any urban planting site, the dollars must be available to accomplish the prescribed soil amendment activities. It cannot be overstated that we as urban plantsmen and greenspace engineers must be directly involved in the initial design and planning phases for all proposed planting sites in which vegetation becomes an integral part of that design. This is not to say that due to involvement, all of the plantings will be

successful, rather that a large majority of these sites will likely achieve their ultimate design concept. Secondly, at all activity sites, on site evaluations are imperative and contract change orders may be warranted as work progresses. Certainly it becomes frustrating when your task is simply to address the problem of what happened and what can be done to improve a poor situation. Recommendations which are directed toward the ultimate aesthetics of the proposed planting must be “engineered” into the design concept and implemented as directed during construction.

Extensive work in Washington with urban soils and our cooperative work with the detailed Soil Survey of the District of Columbia (Smith et al. 1976) has taught us many lessons and defined many of the major characteristics of urban soils. Over the years we have convinced traditional agronomists and others that: 1) there are soils existing within cities; 2) these soils have been neglected and concentrated efforts should be undertaken to understand them; 3) major physical and chemical characteristics of these soils have been verified (Patterson, 1976; Smith et.al. 1976; Stein 1978); 4) urban produced organic “wastes” can be recycled back into these soils as organic soil amendments either reducing or totally eliminating the need to purchase "topsoil" and peat moss-like materials (Cook et.al. 1979; Hammerschlag & Patterson 1978; Hornick et.al. 1979; Murray et.al. 1979 & 1980; Patterson 1975; Patterson & Short 1976; and Short & Patterson 1976); 5) these modified soils can and will provide support and nutrients for urban landscape plantings (Cook et.al. 1979; Hammerschlag & Patterson 1978; Murray 1980; and Patterson 1975); and 6) these organic materials can be highly beneficial with regard to maintenance of the plantings (Cook et. al. 1979; Hammerschlag & Patterson 1978; and Patterson 1975).
Mapping Urban Soil

The Soil Survey of the District of Columbia has illustrated that we can map urban soils and soil types with a great deal of reliability (scale 1" = 12,000') (Smith et al. 1976). Even though the soils may not be completely identified with their natural counterparts, much can be inferred from observed mapping units or complexes with regard to utilizing existing soil information. Geographical distribution of soil types extend into urban centers. In some cases a soil scientist can delineate individual soil series with a high degree of accuracy. More commonly however is the observance of two or three soil series which have been intermixed by man's activities. This trait does yield some complexity with regard to interpretations, but, being able to recognize a mix of two or three soil series does provide a wealth of detailed soil information from which many sound judgements can be made. The ultimate extreme is the heterogeneous mixture of numerous soil materials or urban land complexes. This occurrence creates the most difficult management situation in that interpretations may need to vary extensively from planting situation to planting situation even over very short distances. However, if these urban land complexes are mapped, and in the mapping unit description some reference is made to the predominant soil series which makes up the complex, there is a wealth of basic information already available. Further field observations are necessary to confirm the degree of complexity and ultimately to determine the best method to handle the proposed planting. Soils information in addition to the knowledge of plant types and their soil requirements will mesh into a picture of how best to perform the vital soil preparation work.

Presence of heterogeneous soil complexes necessitates extensive planning and anticipation of problems. Experience has dictated that the best soil
preparation method For urban land complexes is to achieve soil homogeneity over the site. Homogeneity of the soil mantle is a valued objective where urban plant requirements are similar. The implication is clear, the soil planting medium must be “engineered” into the urban planting site.

Another extremely valuable source of information is the historical records for that site. Knowing the original landscape, presence or lack of high water tables, etc. provides valuable resource information (Patterson 1975).

During the planning processes the topic of topsoil often arises. What is topsoil? Within the urban system, topsoil is the soil-like material which occupies the soil surface. Topsoil is a dubious term and the commodity itself is more so. Experience has suggested that the best method of obtaining topsoil is to manufacture it from urban soil and organic resources. Purchased topsoil nearly always requires extensive modification to meet plant requirements. These modifications may include sterilization, stone removal, fertilizer additions, organic matter additions, debris removal, liming agent additions, etc. Much success has been realized in Washington utilizing urban produced organics to amend existing urban soils to produce a Fertile soil mantle economically (Cook et.al. 1979; Hammerschlag and Patterson 1978; and Patterson 1975).

Composted sewage sludge has been used extensively in Washington, D.C. as a major soil amendment, top dressing mix, for potting mixes and many other uses. Although nutrient analyses of U.S.D.A. compost are generally low (Table 1), its value is considerable with regard to amending soil physical properties (Table 2) and the soil chemistry is generally enhanced (Table 3) (Murray et.al. 1980).

Table 1. represents what is considered a good sludge for many uses.
Table 1 Composition of sewage sludge compost used in studies at Beltsville, Maryland

<table>
<thead>
<tr>
<th>Property</th>
<th>Raw Sludge compost</th>
<th>Property</th>
<th>Raw Sludge compost</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.3</td>
<td>Zinc</td>
<td>770 ppm</td>
</tr>
<tr>
<td>Total, Nitrogen</td>
<td>1.38%</td>
<td>Copper</td>
<td>300 ppm</td>
</tr>
<tr>
<td>(\text{NH}_4), Nitrogen</td>
<td>0.02%</td>
<td>Nickel</td>
<td>300 ppm</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>1.57%</td>
<td>Cadmium</td>
<td>10 ppm</td>
</tr>
<tr>
<td>Potassium</td>
<td>0.16%</td>
<td>Lead</td>
<td>290 ppm</td>
</tr>
<tr>
<td>Calcium</td>
<td>1.42%</td>
<td>Manganese</td>
<td>480 ppm</td>
</tr>
<tr>
<td>Magnesium</td>
<td>1.73%</td>
<td>Cd/Zn</td>
<td>1.3%</td>
</tr>
<tr>
<td>Organic carbon</td>
<td>23.0%</td>
<td>Sol. Salts</td>
<td>3.28 mho/cm</td>
</tr>
</tbody>
</table>

*Values based on several analyses of sludge from the Blue Plains Treatment Plant composted at the Beltsville composting site. Percentages are on a dry weight basis. Compost screened using 1.58 cm mesh screen. Murray, et. al. (1979).*
Table 2 Effects of composted sewage sludge additions on soil moisture content

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Soil moisture - % by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>April 22</td>
</tr>
<tr>
<td>Dry mT/ha</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>17 b</td>
</tr>
<tr>
<td>50</td>
<td>23 ab</td>
</tr>
<tr>
<td>100</td>
<td>23 ab</td>
</tr>
<tr>
<td>200</td>
<td>26 a</td>
</tr>
</tbody>
</table>

$^1$Samples were taken from tall fescue plots growing on a sandy loam soil about 2 years after treatments were applied. Means within columns Followed by the same letter are not significantly different (0.05 level DMR). Moisture content near field capacity on April 22. Control plots showing moisture stress on July 28. August 3 all plots were showing moisture stress symptoms. Murray et al. (1979).
Table 3 Effects of composted sewage sludge additions on soil, pH, cation exchange capacity, and organic matter content

<table>
<thead>
<tr>
<th>Compost mT/ha</th>
<th>Silt Loam Subsoil</th>
<th>Sandy Loam Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pH</td>
<td>CEC</td>
</tr>
<tr>
<td>50</td>
<td>5.6</td>
<td>6.0</td>
</tr>
<tr>
<td>100</td>
<td>6.7</td>
<td>6.7</td>
</tr>
<tr>
<td>200</td>
<td>6.5</td>
<td>8.3</td>
</tr>
<tr>
<td>Fertilizers (AV)</td>
<td>6.3</td>
<td>4.2</td>
</tr>
<tr>
<td>Control</td>
<td>4.4</td>
<td>5.0</td>
</tr>
</tbody>
</table>

1Compost treatments were incorporated with the top 10-15 cm soil. Samples were taken for analysis approximately 2 years after compost treatments were applied. Values are averages of 3 samples from 6 replications of Kentucky bluegrass and tall fescue turf plots. Murray, et al. (1979)
Composting of this material produces a nearly sterile organic amendment with relatively few problems. In general, the soluble salt content is elevated and the potassium and phosphorous levels are somewhat low; however, each of these parameters are easily altered.

Compost can and does produce a marked positive effect upon the moisture holding capability of urban soils (Table 2). Therefore, better rooting of plants has been characteristically observed with turf and other plants. Nursery studies are indicating more vigorous growth of potted plants and some nurseries are tending to favor use of compost over peat moss. A recent symposium focused on the utilization of these kinds of materials for production of Horticultural Crops. (American Society for Horticultural Science, 1980).

From the soil chemistry aspect there is an increase in pH, cation exchange capacity and organic matter percentage of the top 10-15 cm. of soil (Table 3). Each of these increases will provide added soil benefits to urban plantings and continue the philosophy of recycling urban produced organic soil amendments through urban soils (Cook 1979; Patterson 1976; Patterson & Henderlong 1970; and Patterson, 1975). The vehicle used to produce compost has been well defined elsewhere and the reader is referred to the literature (Epstein et al. 1976; Patterson & Short 1976).

Compaction

Soil compaction is perhaps the most vivid and severely limiting factor associated with urban soils and yet it goes unheeded by many urban plant men. Compaction can deal a harsh blow to any urban planting (Hall 1.979; Young & Gilmore 1976; and Zisa et al. 1979). Anyone associated with urban vegetation should attempt excavating a planting hole in an urban site, it is a blister
raising experience. What is compaction and what are its effects upon urban vegetation?

Soil compaction is an integrated highly complex problem. Urban plantsmen must make sound judgments of how to deal with it. There are perhaps three important questions which must be addressed early in the planning phase: how many people will the site be expected to support; what is the intended use and desired effect for the site; and finally, how will the urban plantsman deal with soil compaction?

We as greenspace engineers have the task of maintaining an attractive and vigorous planting, and generally little say about visitation and its related impacts; therefore, we must have significant input with regard to the question of compaction during planning operations. Soil composition and its measurement barometer - bulk density - is the laboratory tool used to quantify the degree of soil compaction. Normal or ideal soil bulk densities range between 1.30 and 1.40 g/cc. A soil bulk density in excess of 1.60 is considered compact and many urban soils in Washington greatly exceed this density; the same is true for other cities.

Further, subjecting the bulk density and particle density (normally 2.65 g/cc) to a simple calculation yields a measure of total pore space for a soil. The total percent pore space for a "normal or ideal" soil is about 45% or more; however, we have commonly observed pore space percentages of 35% and less (Table 4 and 5; and Figure 1). In table 4 it is interesting to compare the total pore space For the "forested" vs "urban forested' soils presented. Comparing the grand means of the two conditions, the result is a loss of about 270% pore space for the urban setting. This is not a wholly valid comparison;

\[ \% \text{Pore space} = \left(1 - \frac{\text{Bulk density}}{\text{particle density}}\right) \times 100 \]
<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Profile Depth (cm)</th>
<th>Sand (pct)</th>
<th>Silt (pct)</th>
<th>Clay (pct)</th>
<th>Bulk Density (g/cc)</th>
<th>Particle Density (g/cc)</th>
<th>Total Pore Space (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASH LOAM</td>
<td>0-15</td>
<td>62.0</td>
<td>29.7</td>
<td>8.3</td>
<td>1.26</td>
<td>2.65</td>
<td>47.55</td>
</tr>
<tr>
<td></td>
<td>23-46</td>
<td>63.45</td>
<td>22.7</td>
<td>13.7</td>
<td>1.58</td>
<td>2.65</td>
<td>59.6</td>
</tr>
<tr>
<td></td>
<td>58-94</td>
<td>75.7</td>
<td>14.6</td>
<td>9.7</td>
<td>1.79</td>
<td>2.65</td>
<td>67.55</td>
</tr>
<tr>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>58.23</td>
</tr>
<tr>
<td>MANOR LOAM</td>
<td>0-10</td>
<td>51.6</td>
<td>33.9</td>
<td>14.5</td>
<td>1.23</td>
<td>2.65</td>
<td>46.4</td>
</tr>
<tr>
<td></td>
<td>30-46</td>
<td>52.8</td>
<td>24.6</td>
<td>22.6</td>
<td>1.44</td>
<td>2.65</td>
<td>54.3</td>
</tr>
<tr>
<td></td>
<td>56-79</td>
<td>76.4</td>
<td>13.5</td>
<td>10.1</td>
<td>1.49</td>
<td>2.65</td>
<td>56.2</td>
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<tr>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Profile Depth (cm)</th>
<th>Sand (pct)</th>
<th>Silt (pct)</th>
<th>Clay (pct)</th>
<th>Bulk Density (g/cc)</th>
<th>Particle Density (g/cc)</th>
<th>Total Pore Space (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDORTHENTS (MAN-MADE) (S71-DC-1-2)</td>
<td>10-15</td>
<td>29.8</td>
<td>53.1</td>
<td>17.0</td>
<td>2.12</td>
<td>2.56</td>
<td>17.2</td>
</tr>
<tr>
<td></td>
<td>28-81</td>
<td>41.5</td>
<td>34.25</td>
<td>24.2</td>
<td>1.98</td>
<td>2.54</td>
<td>23.2</td>
</tr>
<tr>
<td></td>
<td>81+</td>
<td>59.6</td>
<td>25.6</td>
<td>14.8</td>
<td>2.18</td>
<td>2.59</td>
<td>19.7</td>
</tr>
<tr>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>21.0</td>
</tr>
</tbody>
</table>

Source: Smith, et.al. 1976; and Patterson 1976.
Table 5  Bulk and particle densities of selected soils sampled in the mapping study.

<table>
<thead>
<tr>
<th>Pedon</th>
<th>Depth cm</th>
<th>Densities</th>
<th>Pore Space (pct.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Bulk g/cc</td>
<td>Particles</td>
</tr>
<tr>
<td>1</td>
<td>0-23</td>
<td>1.41</td>
<td>2.61</td>
</tr>
<tr>
<td></td>
<td>23-46</td>
<td>1.34</td>
<td>2.62</td>
</tr>
<tr>
<td></td>
<td>46-71</td>
<td>1.37</td>
<td>2.62</td>
</tr>
<tr>
<td></td>
<td>71-124</td>
<td>1.34</td>
<td>2.63</td>
</tr>
<tr>
<td></td>
<td>124-165</td>
<td>1.33</td>
<td>2.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0-11</td>
<td></td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td>11-15</td>
<td>2.12</td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td>15-29</td>
<td>1.81</td>
<td>2.65</td>
</tr>
<tr>
<td></td>
<td>29-38</td>
<td>2.02</td>
<td>2.54</td>
</tr>
<tr>
<td></td>
<td>38-81</td>
<td>1.95</td>
<td>2.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stein. 1978.
Fig. 1. A schematic representation of ideal soil composition.
however, it does indicate a strong difference between a forest soil and an urban soil. Are urban soils as dense as concrete? In 1975 we conducted an experiment to determine the density and pore space relationships of four commonly used urban building materials: cinder block, brick, asphalt and concrete (Table 6). Comparing the results of this study vs sane of the data presented in Tables 4 and 5 yields the interesting finding that, urban soils can be as dense as concrete and more dense than cinder block, brick and in some cases asphalt.

There are other deleterious effects of soil compaction. These effects although easily summarized can produce additional synergistic urban stress upon vegetation. Soil compaction can cause a reduction in 1) pore space; 2) total available moisture for plant growth; 3) moisture absorption, and; 4) oxygen content of the soil atmosphere. Conversely compaction serves to increase the thermal conductivity of the soil, increase runoff and erosion; increase the mechanical impedance of roots (i.e. a plant root must expend considerably more energy to penetrate the soil); increase hydrophobicity; and finally increase carbon dioxide content of the soil atmosphere.

Some recent thesis work (Stein 1978) undertook the task of Mapping, Classification an Characterization of Highly Man Influenced Soil in the District of Columbia. Two distinct soil systems were studied in detail: the first derived from dredged fill and the second was composed of miscellaneous urban fill (Table 5). Bulk density measurements of the two dramatically different soils indicated differences which were concluded to be due to their mode of deposition and basic textural differences. Also, some of these wide differences can be attributed to land use characteristics. However, this degree of difference appears to be more attributable to textural mode of deposition as in all cases the bulk densities of the miscellaneous fill
Table 6 Bulk density and pore space of four construction materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Number of samples</th>
<th>Bulk density Average g/cc</th>
<th>Range g/cc</th>
<th>Particle density g/cc</th>
<th>Calculated pore space percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cinder block</td>
<td>3</td>
<td>1.70</td>
<td>1.67-1.71</td>
<td>2.64</td>
<td>35.6</td>
</tr>
<tr>
<td>Brick</td>
<td>3</td>
<td>1.75</td>
<td>1.43-2.01</td>
<td>2.72</td>
<td>35.7</td>
</tr>
<tr>
<td>Asphalt</td>
<td>3</td>
<td>2.19</td>
<td>2.17-2.22</td>
<td>2.35</td>
<td>6.8</td>
</tr>
<tr>
<td>Concrete</td>
<td>3</td>
<td>2.26</td>
<td>2.23-2.27</td>
<td>2.47</td>
<td>8.5</td>
</tr>
</tbody>
</table>

Source: Patterson, 1976
exceeded that of the dredgings (Stein 1978).

As a result of this detailed study some work has been generated on the taxonomic classification of urban soils, suggesting their inclusion in the overall soil taxonomy system (Fanning, et.al. 1978; Stein 1978). Ultimately it is hoped that urban soils and their sister soils of rural drastically disturbed sites (strip mines, etc.) will be included in the Soil Taxonomy (Soil Conservation Service).

Characteristics of Urban Soils

Over the years some distinctive characteristics of urban soils have been observed and documented. Effects of bulk density have been previously discussed. Other distinguishing characteristics of urban soils are:

1. The mapping unit Urban Land Complexes and those including two or more soil series exhibit soil heterogeneity across the landscape which necessitates on site soil evaluations prior to any development (Patterson 1976; Smith et al. 1976; Stein 1978).

2. There are variable percentages of organic matter with depth in the soil profile. This characteristic is due to mode of deposition and perhaps to a lesser extent use of the landscape before or during deposition (Patterson 1976; Stein 1978).

3. Unoriented coarse Fragment (rock, stones) with profile depth. This feature is likely related to depositional mode (Patterson 1976; Stein 1978).

4. Highly variable soil chemistry with depth and across the landscape. Stein’s work illustrated high extractable Mg and showed variability in pH and extractable...
$K_2O$ with profiled depth. Extractable $P_2O_5$ was low in dredged soils and more variable in the loamy Fill soils. Base saturation was generally greater than 50% For both soils and nearly always exceeded 100% in soils developed in loamy fill (Stein 1978).

S-Textural differences are noted with profile depth. Generally profiles are characterized by lithologic discontinuities owing to depositional characteristics and origins of depositional materials. [Patterson 1976; Stein, 1978]

6-Urban oriented artifacts are common in many soil profiles, particularly the urban land complexes. Artifacts may include bits of concrete, brick, asphalt, cinder block, fragments of steel, china and glass pieces, etc. (Fanning, et.al. 1979; Patterson 1976; and Stein 1978).

7-Diagnostic soil color patterns have been observed with profile depths and landscape positions (Stein 1978).

8-Identifiable drainage classifications can be characterized from soil color patterns and topographic changes (Stein 1978).

9-There is a tendency for the more highly compacted soils to exhibit a hydrophobic tendency. That is, when an event occurs producing any surface water, water droplets will tend to bead on the soil surface. Infiltration patterns into these soils have shown a lag phase initially until the surface tension of the soils is sufficiently reduced to allow water penetration. Once this penetration is initiated, the infiltration curves resemble those of natural soils although the intake rates and total infiltration rates are generally
l0-Compacted soils exhibit the characteristic “platy” structure when observed closely. This characteristic can also cause limited infiltration. Interestingly the platy structure can be observed in burned-over areas as well. Soils developed in the dredged areas exhibited prismatic structure (Patterson 1976; Stein 1978).

11-Rooting patterns in compacted soils are equally interesting. Turf grass roots are observed owing natural cleavage planes within the soil profile and they are present in these fractures in large numbers. Conversely, in more friable soils, roots are well distributed throughout the soil mantle. Tree roots may or may not be confined, depending upon the degree of compaction and other characteristics (Patterson 1976).

12-In highly compacted soils, earthworm activity is less apparent owing presumably to the degree of compaction. (Patterson 1976; Stein 1978).

13-Soil taxonomy is a difficult area and most urban mapping units fall into the broad high category, Entisol-Inceptisol subgroups. However, many of the complexes observed in Stein’s work were classified as Udorthents Following the D.C. Soil Survey. Much work needs to be accomplished with regard to urban soil taxonomy. Generally, to estimate the mean within ±10% with a 95% C.I., the most variable properties within mapping units required between 100 and 700 samples, for example, morphological properties. The least variable properties generally required less than 25 samples For estimation, such as the bulk
density of the second horizon (Stein 1978).

Avenues of Development

To date many recommendations can be generated from existing knowledge. It is essential to design an appropriate soil mantle for support of proposed urban planting. Recommendations must be set forth and observed if any urban planting is to be successful.

1-Planning and design of the soil mantle must be an integral part of the urban landscape design. Most if not all plants, once in place in the landscape, are expected to exist for 10 or more years. Key to this existence is the fact that once plants are in place, especially trees, the soil cannot be modified other than through surficial treatments; the root systems will not permit further modification and yet compaction can severely limit rooting (Patterson 1976; Zisa et al. 1979).

2-Budget dollars must be included within the contract for the total urban planting-soils, plants, etc. The more stressed the situation, the more dollars must be budgeted.

3-Whenever possible within the urban stress situation, amend the soil mantle uniformly; e.g. the desired soil mantle is a homogeneous one. Similarly, when trees are included the minimum depth of modification is 45 cm., turf areas 15 cm. There are many different materials which can be used to physically amend a soil in addition to those organic composts already mentioned. Several of the more popular and effective inorganic soil amendments are sands (Daniel 1978; Davis 1973;
Patterson 1976), sintered fly ash (Patterson and Henderlong 1970; and Short and Patterson 1976), expanded slate (Patterson 1976; and Short and Patterson 1976) and many other similar materials. These particular materials are mentioned because they are moderately priced and effective over the long term.

4-Soil drainage systems for most areas are critical. A soil physics professor once said “you can always add water to a soil system, you cannot always remove it.” Several methods exist with regard to subsurface drainage systems. These subsurface systems should be contoured parallel to the finished soil surface grade. These systems can be basic subsurface grading, tiling, flexible piping, etc.

5-At sites where traffic control (human or other) will be a continual problem and one severe enough to perhaps impose undue stress upon a planting, engineer the soil system to withstand the compactive forces. This planning must be continuously supplemented by proper soil aeration techniques performed during appropriate seasons. If impact will be such that plants will be continually stressed, perhaps paving of the soil surface is the best answer, while handling the plants as potted plants. There are available pavers which permit turf grass growth, porous pavement, wood chips, and other similar materials.

6-Site maintenance will vary directly with the degree of traffic or use imposed upon the site.

7-Experience suggests that it’s better to amend the existing soil removed from a planting hole than to place a “prepared
soil mix" around the tree ball. The implication is that by placing a prepared soil mix around the root ball, there exists three distinct soil physical situations: the ball itself vs the prepared soil mix vs the existing soil. Hasten to mention that this is a site dependent factor.

8-Utilize plant materials which are known to tolerate the urban stress situation i.e.: compaction, wetness, low oxygen, etc. Root systems are vital. An urban tree will never reach its mature crown form if its root system cannot cope with a stressed soil situation (Patterson 1976).

9-Beds of horticultural plants should be raised above surrounding grades such that they are perhaps 45 to 91 cm. above surrounding grades, this is particularly important for high water table situations. Mounding also provides a pleasing three-dimensional effect which with time becomes largely unnoticed (Hammerschlag and Patterson 1978).

10-Should trees be placed into a low topographic situation, a pedestal of existing soil should be left in the center of the planting hole to prevent the tree ball from subsiding below the soil surface. In general, trees should be planted from 10 to 20 cm. above surrounding grades (Hammerschlag and Patterson 1978).

11-Mulches should be avoided in areas where soil drainage and runoff is impaired. These materials can exaggerate plant problems (Whittcomb 1979). Our own experience in Washington reflects this same observation. Plastic mulches should generally be avoided.
Summary

The effect of urban soils upon the success of vegetative plantings cannot be overemphasized. Urban soils are beginning to receive the attention needed to provide the knowledge for proper use of the soils. It has been found that urban soils can be mapped using recognized mapping units with an acceptable accuracy, although field verification is required.

The planning process must include consideration of soil conditions at the planting site which may limit plant growth, such as compaction, wetness, human and vehicular traffic, etc. Alleviation of many limiting soil properties may be effected through the use of compacted urban organic “waste” materials.
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