SELECTION OF TREES AND PLANTING TECHNIQUES FOR FORMER REFUSE LANDFILLS [1]

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ABSTRACT. --Sanitary refuse landfill sites are unsuitable for purposes requiring the building of permanent structures due to the amount of settling likely to occur. For this reason they are generally given over to some open space or recreational usage requiring the planting of vegetation. Numerous stress conditions, including oxygen depletion, elevated temperature, soil compaction, moisture deficiency and the presence of toxic or growth inhibiting gaseous or metallic constituents have been known to confront plants attempting to grow in landfill cover soils. In order to identify woody species most adaptable to the conditions prevailing in such soils, a tree-screening program was conducted on a typical former landfill site. Trees planted at the Edgeboro Landfill 4 years previously, produced less shoot and stem growth and shallower root systems than those on an adjacent non-landfill control. Of nineteen species replicated ten times, black gum and Japanese black pine appeared to be most tolerant and green ash and hybrid poplar, most sensitive to the landfill conditions. Root systems of the former were more shallow than those of the latter. Smaller planting stock (1-2 ft. tall) appeared better suited for landfill planting than larger trees (l0-12 ft. tall). Balled and burlapped trees made better growth on the landfill than bare-rooted material. Of five gas-barrier systems tested, a backfilled soil trench lined with plastic sheeting over a gravel base and vented with vertical PVC pipes and 3-ft soil mounds with or without a l-ft clay base proved effective in preventing the penetration of landfill gas into the rhizosphere of the test species. Inoculation of the roots of Scots Pine seedlings with the ectomycorrhizal fungus <u>Pisolithus tinctorius</u> caused increased growth of the seedlings over uninoculated controls.

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[1] Metro Tree Impr. Alliance (METRIA) Proc. 3:107-117, 1980.

SANITARY REFUSE LANDFILL sites present unique stress environments for vegetation. The anaerobic conditions underlying the soil cover may be likened to those produced in flooded soils, but without the presence of excess water.

Oxygen deficiency is one of the principal causes of poor growth or death of plants in landfill soils, as it is in water-logged terrain. Combined with 02 depletion is the presence in the soil of a number of gaseous decomposition products (Table 1) primarily carbon dioxide (CO_2) and

Table 1. Landfill Gases

Methane	60%
Carbon Dioxide	85%
Carbon Monoxide	Tr.
Ethane	Tr.
Ammonia	Tr.
Hydrogen Sulfide	Tr.
Ethylene	Tr.
Propylene	Tr.
Hydrogen Cyanide	Tr.

methane (CH,$, either of which may accumulate to concentrations greater than 50% of the soil atmosphere at any given time (4). Methane has been considered relatively inert for plants (11,13) but CO2 at high levels can be deleteterious to root systems per se, or indirectly by replacing 02 or by lowering soil pH (3,6).

Problems with toxic soil gases are not confined to the soil immediately over the refuse layers. Such gases have been known to migrate laterally from a landfill for hundreds of feet into adjacent farmland with consequent damage to crops (10).

Another effect of poor soil aeration is the lowering of the redox potential to a point where toxic trace elements may be solubilized and made more readily available to plants (11,12).

Landfill cover soils, characteristically shallow in depth, and of poor nutrient quality, are generally lacking in moisture, having no water continuum through the refuse strata to replenish that lost from surface layers (Fig. 1). Increased soil temperatures, whether from refuse decomposition or combustion, can lower the existing moisture level, stressing plants even further. (2) Decreased soil moisture will also tend to depress the flow of essential plant elements from soils already deficient in nutrients (7).

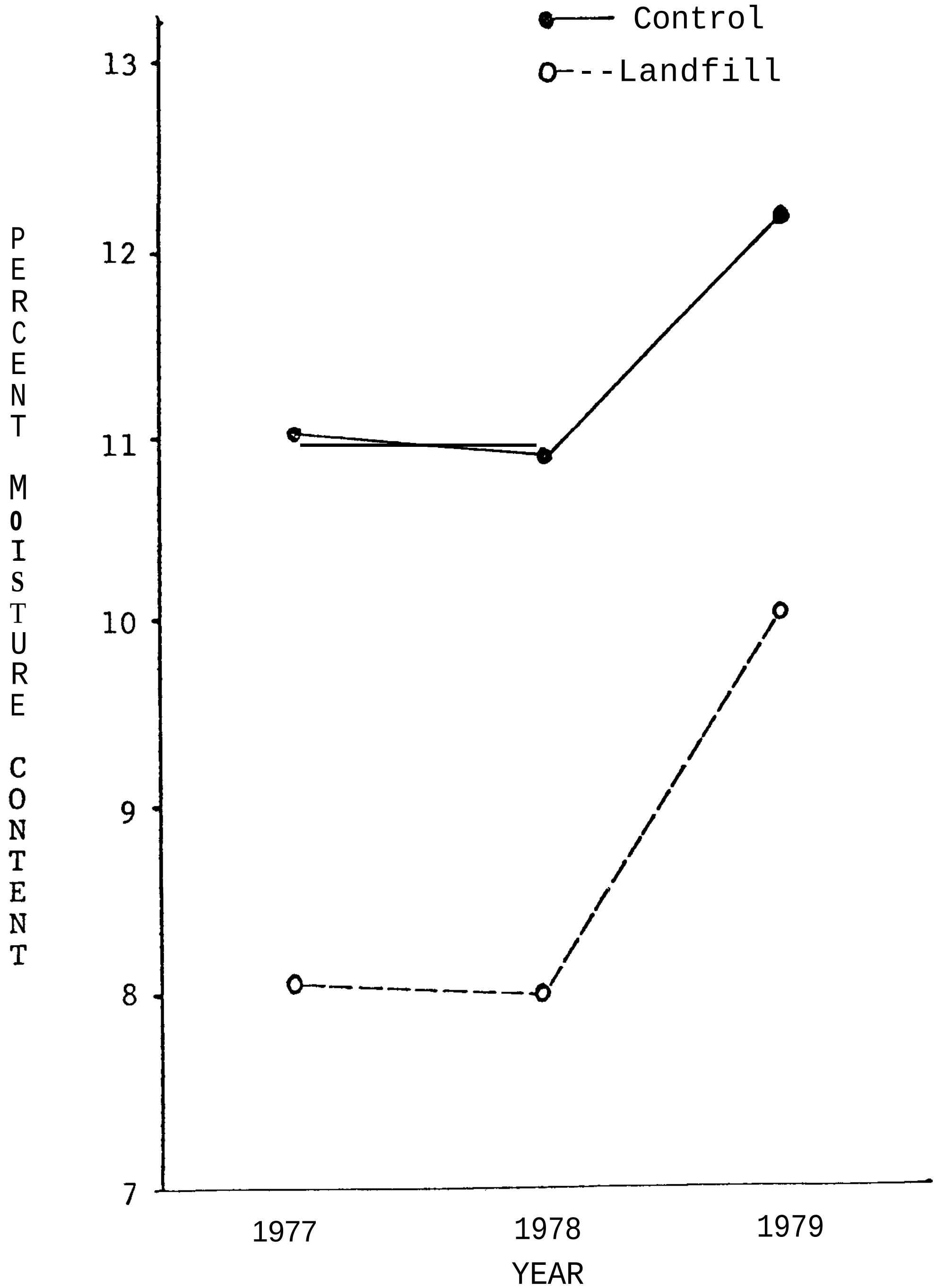

Fig. 1. Moisture content of landfill and control plots.

Soil compaction, initiated by the constant traffic of heavy motorized equipment and aggravated by continuous settlement, can further stress plants in landfill cover soils by decreasing total pore space and/or pore size (7).

In spite of all these drawbacks, the tendency, when such sites become available, is to attempt to grow vegetation, without considering the aforementioned factors. Whereas there has been some apparent success in establishing vegetation on former refuse landfills, as witness the South Coast Arboretum in Palos Verdes, California, which was built on a land-filled former diatomaceous earth mine (1), a site inspection of more than 60 other vegetated landfills throughout the United States has revealed otherwise (5).

In efforts to alleviate some of the stresses imposed by landfill conditions, our research group initiated a screening program to identify woody species capable of adapting to the adverse situations. Among the criteria for selection of species for the test were the following: (1) easily available (2) suitable for landscaping purposes, (3) tolerant of low O_2 environments and (4) tolerant of other urban stresses. On the basis of these criteria, nineteen species were selected, all of which are commonly used for landscaping purposes in this area (Table 2). Among these, eight were selected for tolerance to low O_2 levels (red maple, green ash, honey locust, bayberry, black gum, American sycamore, and weeping willow.) Particular hope was held for green ash which is reported to transport O_2 from shoots to roots and to be capable of oxidizing its rhizosphere in flooded soils (8,9). Red maple, American sycamore and honey locust are also cited for tolerance to water-logged soils (14). Three of the species (Ginkgo, sycamore, and black pine) are considered tolerant to other urban stresses (7). Two species (American basswood and Japanese yew) represented landfill-sensitive types for comparison (5).

These species were placed randomly, in replicates of ten, on the Edgeboro landfill located several miles from the Cook College campus in East Brunswick, NJ; and in a control plot of similar size which was cleared from a near-by woodlot and topped with the same type and depth of soil as that used to cover the landfill. The trees have been routinely fertilized, limed, irrigated, pruned, and generally maintained for four years. Although a majority of the trees have survived, all the weeping willows, rhododendrons and euonymus on the landfill died by the end of the 3rd year, apparently unable to withstand the periods of drought characteristic of such sites during the summer.

Table 2. Species Selected For Vegetation Growth Experiment At Edgeboro Landfill

Abbre-viation	Latin Name	Common Name	Selection Criteria*
Ar	Acer rubrum	Red maple	1,2,3
Ea	Euonymus alatus	Winged-Euonymus	3
Fl	Fraxinus lanceolata	Green ash	1,3
G	Ginkgo biloba	Ginkgo	3,5
Gt	Gleditsia triacantho	Honey locust	1,3
Ls	Liquidambar stryacifiua	Sweet gum	3
MP	Myrica pennsylvanica	Bayberry	1,3
Ns	Nyssa sylvatica	Black gum	1,3
P	Populus sp.	Poplar (Hybrid)	3
Pe	Picea excelsa	Norway Spruce	3
Pm	Populus sp. m.	Poplar (Mixed Hybrid)	
PO	Platanus ocidentalis	American sycamore	1,395
Ps	Pinus strobus	White pine	3
Pt	Pinus thunbergi	Black pine	3,4
Qp	Quercus palustris	Pin oak	1,3
R	Rhododendron Roseum elegans	Rhododendron	
Sb	Salix babylonica	Weeping willow	1,:
Ta	Tilia americana	American basswood	3,6
Tcc	Taxus cusnidata capitata	Japanese yew	3,6

*Selection Criteria

1. Tolerant of low O_2 environments.
2. Ubiquity.
3. Aesthetic landscaping purposes.
4. Sea salt tolerance.
5. Tolerant to city conditions.
6. Suceptibility to landfill gases.

On the basis of shoot length and stem area increase measured for each species on the landfill and control plots, the surviving trees were ranked in order of decreasing tolerance to the existing landfill conditions (Table 3). From these data it appears that black gum, Norway spruce, and Ginkgo were the most suited for the conditions on Edgeboro Landfill. Species tolerant to low O_2 environments (especially green ash and honey locust) were located very low on the tolerance list. Lack of sufficient moisture may have curtailed the growth of these water-loving species (7). Rapidly growing trees (hybrid poplar, honey locust, and red maple) appeared to be more sensitive to the landfill conditions than slow growers when compared to growth of controls. However, they also produced more absolute growth on the landfill than the more slow-growing trees; so if amount of growth is the criterion rather than relative growth, these species might be considered.

Acid-loving plants (Japanese black pine, Norway spruce, black gum, bayberry) were tolerant of the low soil pH (4.5) whereas green ash, red maple, American sycamore were adversely affected.

Root systems of the more tolerant species (Japanese black pine and Norway spruce)were much shallower, both on the landfill and control, than were less tolerant species. The ability to develop a shallow root system may be one of the over-riding factors in the adaptability of trees to landfill conditions. Those more able to move their root systems to a higher soil level may thus avoid contact with the toxic or growth-curtailing gases produced in a landfill.

Other factors which appeared to favor the chances for survival of landfill trees are smaller trees at planting over larger sizes of the same species, balled-and-burlapped roots over bare-rooted stock, extensive irrigation over poor irrigation, gas-barrier systems such as soil mounds or lined and vented back-filled trenches over unmodified landfill areas (7).

A useful guide for the evaluation of potential landfill gas problems is presented in Table 4. "On the spot" examination of soil characteristics such as odor, color, moisture, temperature and friability can aid in the detection of landfill areas likely to present problems for growing plants.

Table 5 summarizes some of the factors to be considered by anyone planning to establish vegetation on a completed landfill, Even before the selection of suitable species and maintenance procedures, attention to the proper

Table 3. Relative Tolerance of Species to Landfill Conditions

Rank a	Species	Σ "t" Statistics b
1	Black gum	2.66
2	Norway spruce	3.22
3	Ginkgo	4.95
4	Black pine	6.59
5	Bayberry	6.62
6	Mixed poplar	a.13
7	White pine	a.94
a	Pin oak	8.96
9	Japanese yew	a.98
10	American basswood	9.43
11	American sycamore	10.66
12	Red maple	10.95
13	Sweet gum	12.62
14	Euonymus	14.25
15	Green ash	14.87
16	Honey locust	15.05
17	Hybrid poplar	20.33
la	Weeping willow	21.20
19	Rhododendron	All plants died

a. Rank 1 = the best growth when experimental plot is compared to the control plot, i.e. most tolerant of landfill conditions.

b. Σ "t" = the sum of the "t" statistics for shoot length in 1976; leafweight, basal area increase, root biomass and shoot length in 1977 comparing the experimental area with the control.

TABLE 4, GUIDE FOR EVALUATION OF LANDFILL SOIL GAS PROBLEM

CHARACTERISTIC	ANAEROBIC SOIL	AEROBIC HEALTHY SOIL
ODOR	SEPTIC	PLEASANT
COLOR	DARKER	LIGHTER
MOISTURE CONTENT	HIGHER	LOWER
FRIABILITY	POOR	GOOD
TEMPERATURE	HIGHER	LOWER

TABLE 5, CONTROL TECHNIQUES

1, SUITABLE SPECIES-

SHALLOW ROOTED, ADAPTED TO ANAEROBIC CONDITIONS,

2, CULTURAL METHODS-

ADEQUATE LIME, FERTILIZER, TOP SOIL FOR COVER, IRRIGATION,

3, SOIL AMENDMENTS-

SHREDDED REFUSE, MULCH, SEWAGE SLUDGE,

4, LANDFILL CONSTRUCTION-

PROPER GRADING, COMPACTION, ADEQUATE DEPTH AND QUALITY OF TOP SOIL,

5, PLANTING TECHNIQUES-

VENTED OR LINED TRENCHES, MOUNDS,

6, GAS COLLECTION,

construction of a landfill can do much to prevent or minimize many of the adverse conditions encountered by plants in completed landfills.

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