Tree Root Growth Control Series:

Soil Constraints On Root Growth

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Introduction

Managed tree root growth control is required to minimize impacts on infrastructures. To constrain root growth, identification of soil attributes that limit growth is required. By understanding what soil conditions limit growth, various tools and techniques can be used to stop, redirect, or slow tree root elongation. Tree-literacy incorporates soil and tree health into a single concept for quality management.

Compaction Constraints

For soils to hold infrastructures, whether on footings, foundations, or floating on the soil surface, soil is compacted. Compacting soils prevent progressive settling, minimizes soil changes over time, and increases soil strength. Traditional compaction specifications try to attain 96-99%, which means that soil strength is maximized and pore space is minimized (25). At the compaction rates used for infrastructures, tree-essential oxygen, water, and pore space are not available and mechanical impedance is great (1,48). (Figure 1 (46)) Water is present but, depending upon soil type, may be held too tightly for tree use.

Oxygen supply to the roots remain a major problem around infrastructure. Accessible pore space needed for root growth combines the essential resource features of low mechanical impedance for elongation and a readily available supply of oxygen. Interacting with these resources are soil microorganisms quickly using oxygen. In poorly drained or compacted soils, oxygen can be used-up quickly and not resupplied (Figure 2 (42). In addition, microorganisms quickly use oxygen for respiration which cannot be readily resupplied due to micro-pores filled with water. Water filled pores allow oxygen diffusion at a rate 10,000 less than air-filled pores (42). As oxygen drops below 2-5% of atmospheric content, root growth and the root’s ability to generate elongation force precipitously declines (48).

Need To Breath

Oxygen is required for root elongation. In order for respiration to occur, oxygen must move to the living root tissues through the soil matrix. Along any open soil pore path will be a myriad of aerobic organisms using any available oxygen. If all of the oxygen is used before it can reach the tree root, changes occur in the root system. For short periods of time, trees can generate energy using carbohydrates in low or nor oxygen, but this process is approximately 20 times more inefficient than aerobic respiration (42). The non-water filled, larger pores must be able to move carbon dioxide gas out and oxygen gas into the root or growth slows. Table 1 summarizes by soil texture class, the root-limiting, air containing pore space in soil (10).

Soil Pore Sizes

As roots elongate, they continually encounter a range of pore sizes. Pore sizes larger than the root tip provide little resistance to elongation. Pore sizes almost the same size as the root tip but smaller, provide increas

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ing resistance to root elongation depending on soil strength and capability of the root to generate force to deform the soil. Soil pores much smaller than the root tip may easily deform with root pressure in weak soils, but may be unattainable in strong soils (31,42,46).

Roots can not "squeeze" into small, rigid pores where soil strength prevents soil deformation (46). Unless there are fissures, cracks, or other large pore spaces, a strong soil (compacted soil) will resist roots from expanding and deforming pores (46). One means of assisting with proper root functions in compacted soil is the use of mychorrizal fungi additions (16,47). The fungal hyphae are smaller in diameter than tree roots and can utilize more small pore space areas.

Table 1. Root growth limiting air-pore space values by soil texture. (9,10, after 38)

soil texture	root-limiting % pores normally filled with air
sand	24%
fine sand	21
sandy loam	19
fine sandy loam	15
loam	14
silt loam	17
clay loam	11
clay	13

Table 2. Root growth limiting bulk density values by soil texture. (9,10, after 38)

soil texture	root-limiting bulk density (g/cc)
sand	1.8 g/cc
fine sand	1.75
sandy loam	1.7
fine sandy loam	1.65
loam	1.55
silt loam	1.45
clay loam	1.5
clay	1.4

Soil Strength

When soils are purposely compacted for construction, or collaterally compacted around infrastructures, more square feet of soil particle surfaces are present per unit volume, and pore space declines. This process provides more frictional, adhesive and cohesive forces holding the soil together, or greater soil strength (42). Water movement and aeration pathways are constrained. As water content declines in soil, strength increases and root elongation declines (46) (Figure 3 (46)) The mechanical impedance offered by a soil, as given by bulk density measures, is summarized in Table 2 (10). Tree roots can penetrate into soil with mechanical impedance levels of up to 3MPa (28,29). (Figure 4 (42), Figure 5 (48)).

Exploiting Space

In and around infrastructures, roots grow and survive where there are adequate resources. Oxygen, adequate water, pore space, and a healthy, ecologically balanced rhizosphere are needed (56). Compacted zones, anaerobic zones, dry zones and dead zones in soils associated with infrastructure will prevent new root colonization. Depending upon the extent and duration of these anti-root conditions, roots already present can be killed.

As tree roots exploit soil resources, they follow low impedance pathways from a mechanical standpoint and from a water supply standpoint. The path (corridors) of least resistance through the soil and around small blocking items will be followed, which include staying close to the surface of the soil (28). As water is pulled into the root, the directional aspects of the lowest resistance flow path is sensed, as long as there is a continuous water film in pores and on soil particle surfaces (19,20,31). Roots can grow toward available water supplies if plenty of oxygen is available.

Growth Model Beneath Pavements

For traditional paving methods, a root growth model has been proposed (Kopinga model (28)). As root growth occurs, the aerobic conditions and moisture contents under the pavement in coarse textured materials, like sand, allow for elongation. The moisture present is quickly used and not replaced. Roots continue to elongate following an oxygen and moisture gradient that “leads” across the pavement area. Roots grow toward soil volumes with open surfaces where water in soil pore space is replaced and where essential element supplies and ecologically rich soils are established. Between one side of the pavement and the other, little root branching occurs, unless moisture and essential element are moving through the pavement and into the soil below. A moisture and oxygen gradient below the pavement keep roots along the pavement interface. Over time, as new areas on the other side of the pavement are colonized, the transport roots under the pavement will continue to radially expand (28). Pavement damage will be the result.

Conclusions

Soils are the physical and biological matrix in which most of the life-sustaining activities of the tree / soil relationship occur. Element transformations, water and element uptake, interactions which a host of other organisms, and the application of mechanical forces that keep trees upright all are soil centered. Soils facilitate survival and thriving of trees. Soil can also stress, strain, and eliminate tree growth through impacts on roots. By understanding how soils interact with tree roots, clearer means of managing tree root growth can be found.

Literature Cited

Full citations in: Coder, K.D. 1998. Selected Literature: Root Control Methods.
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16	Craul 1992a
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20	Cutler 1997
25	Grabosky & Bassuk 1995
28	Kopinga 1994

code number	author / date citation
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38	Morris & Lowery 1988
42	Rendig & Taylor 1989
46	Russell 1977
47	Simmons & Pope 1987
48	Souty & Stepniewski 1988
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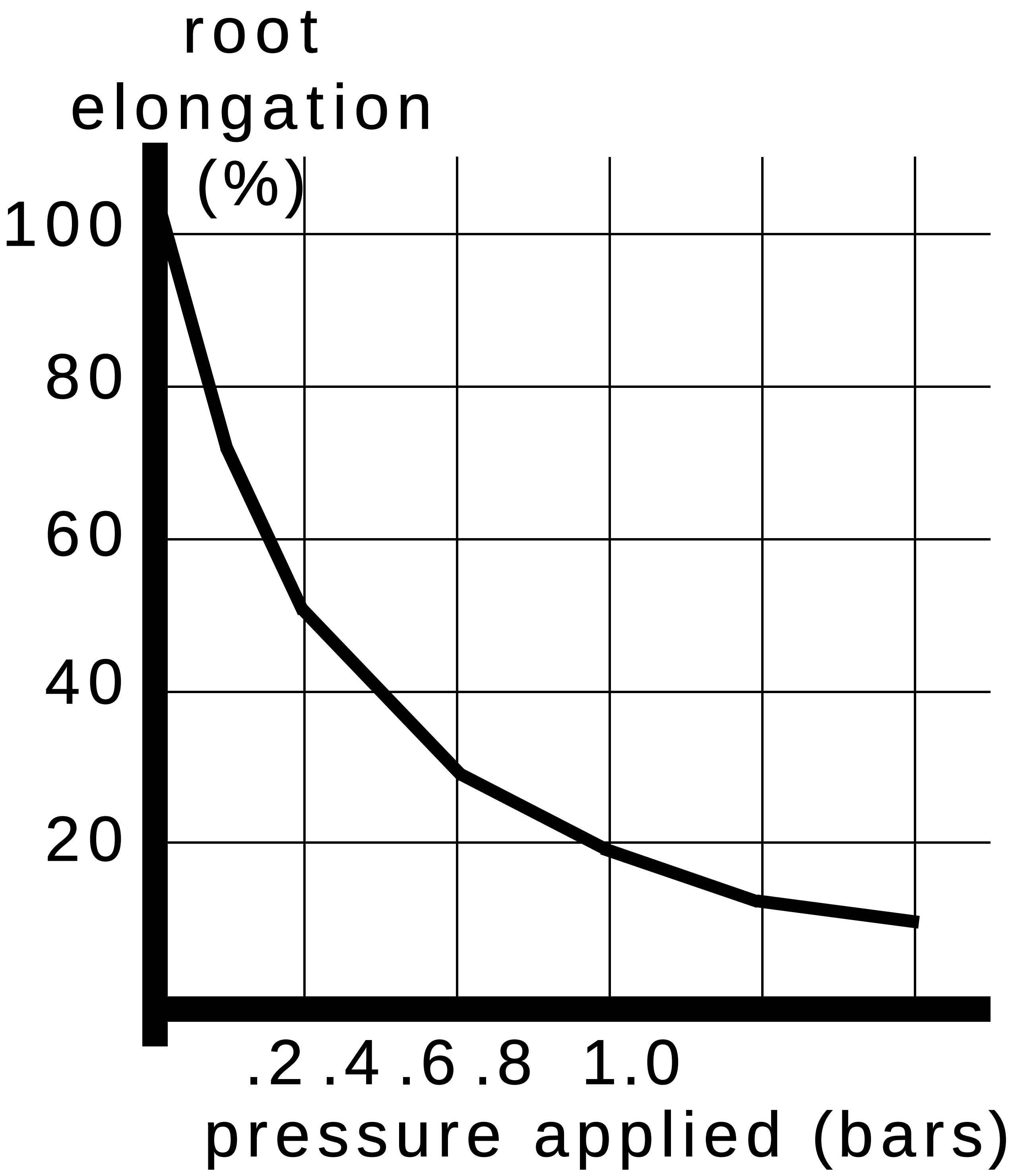

Figure 1: Pressure applied to roots that limit elongation. (42,46)

(1 MPa =100 kPa ≈ 1 bar)

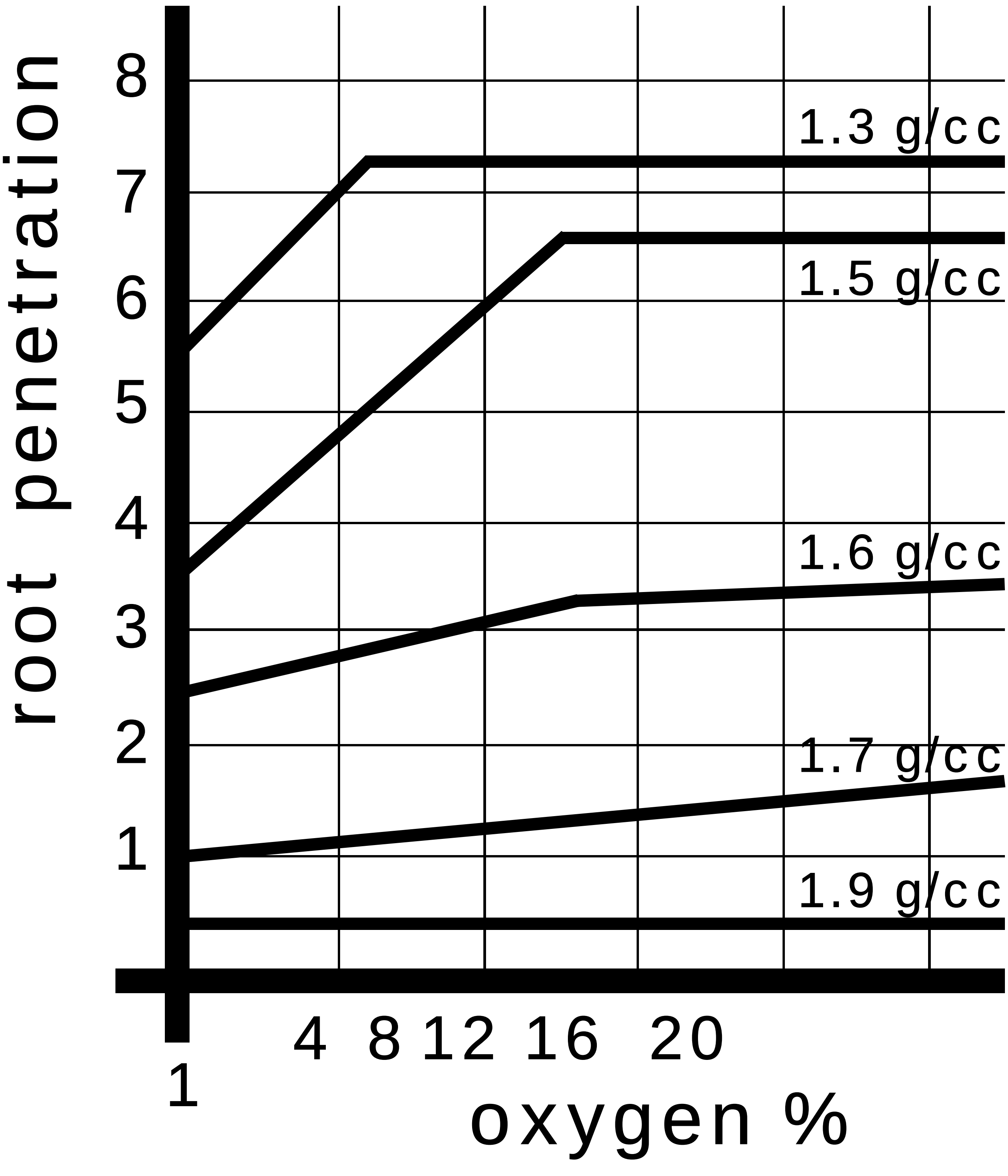

Figure 2: Percent oxygen and bulk density effects on root penetration. (42)

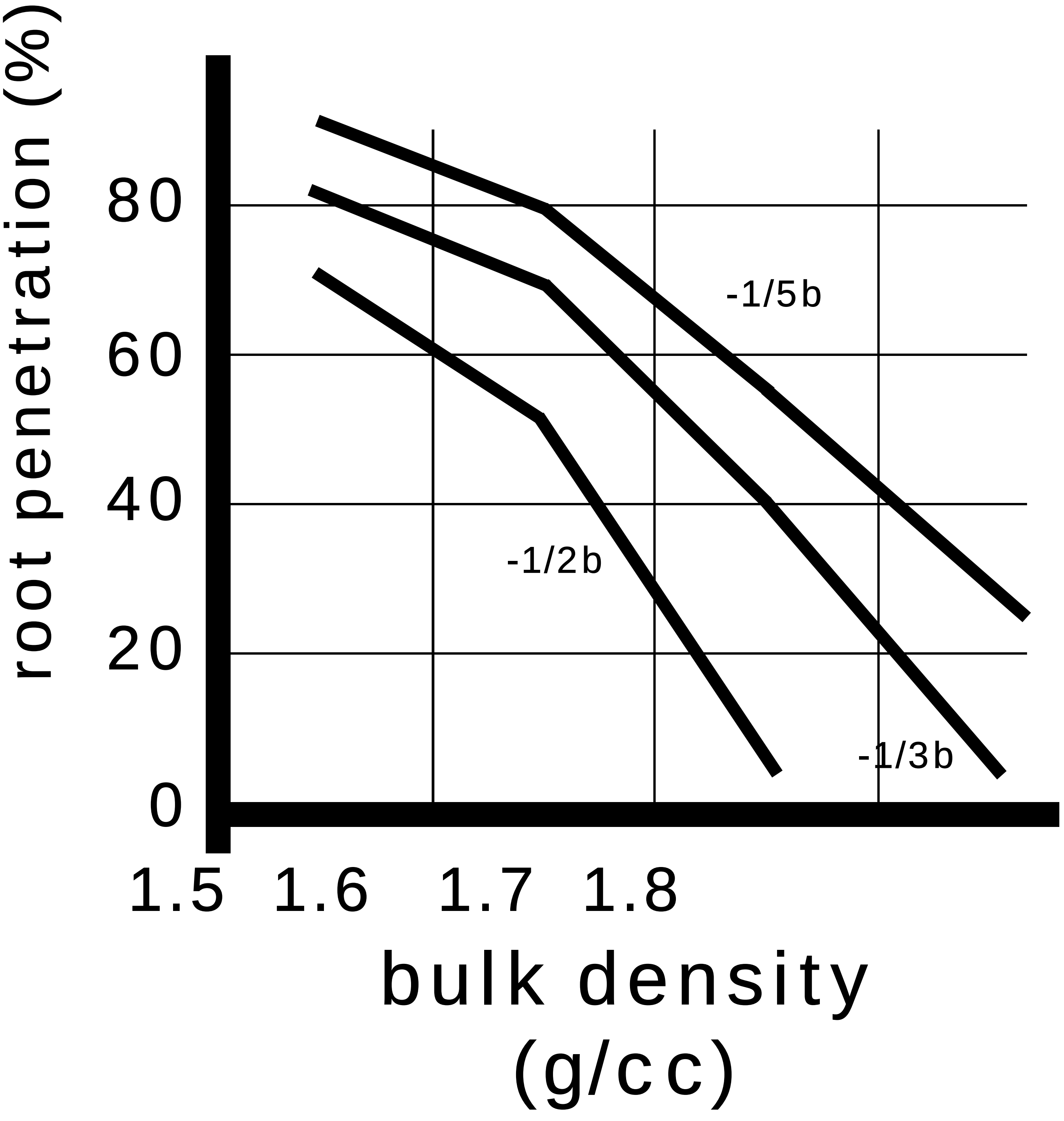

Figure 3: Soil bulk density and water potential effects (in bars) on root penetration. (46)

(1 MPa =100 kPa ≈ 1 bar)

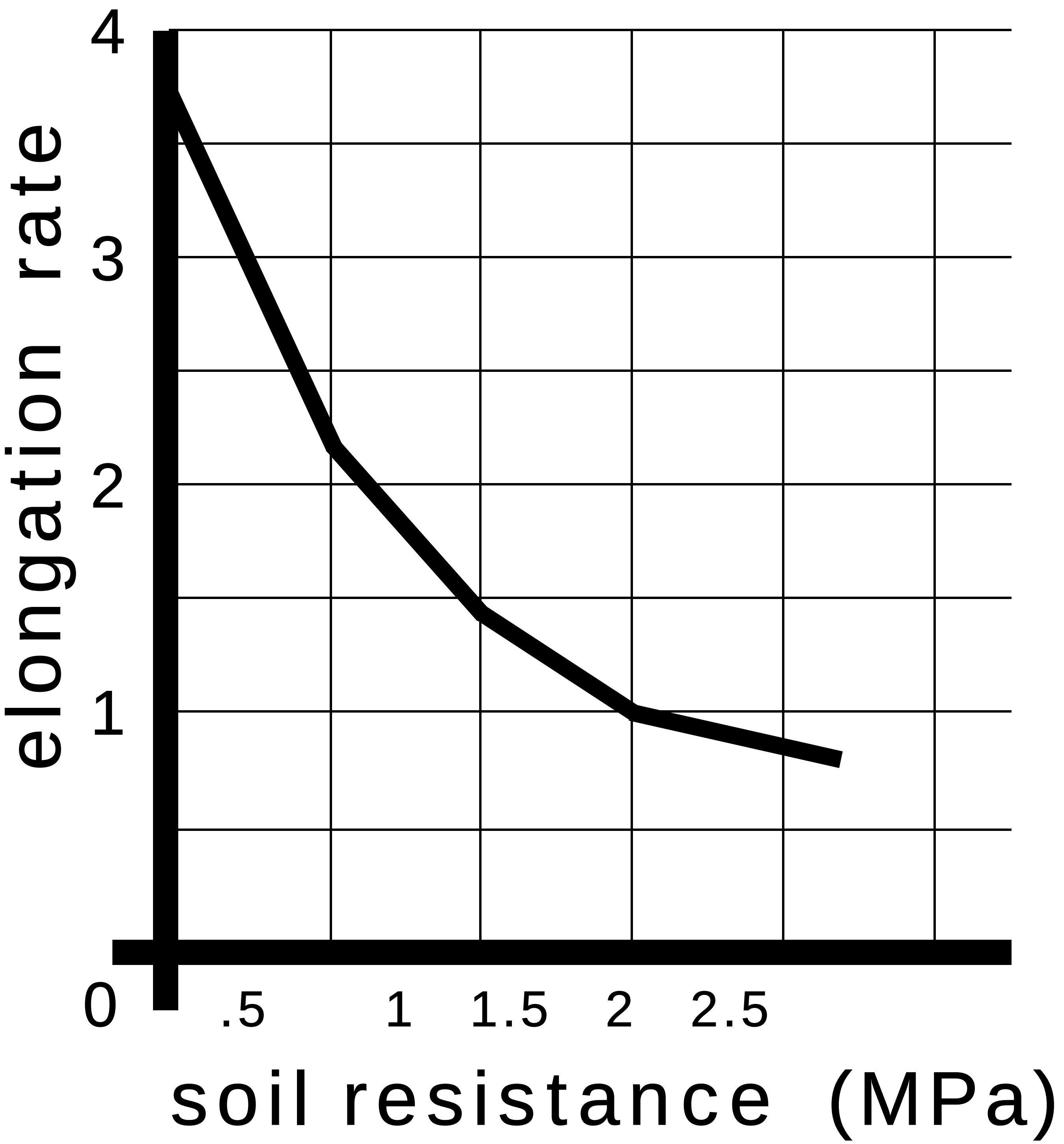

Figure 4: Soil penetration resistance and root elongation rate. (42)

(1 MPa =100 kPa ≈ 1 bar)

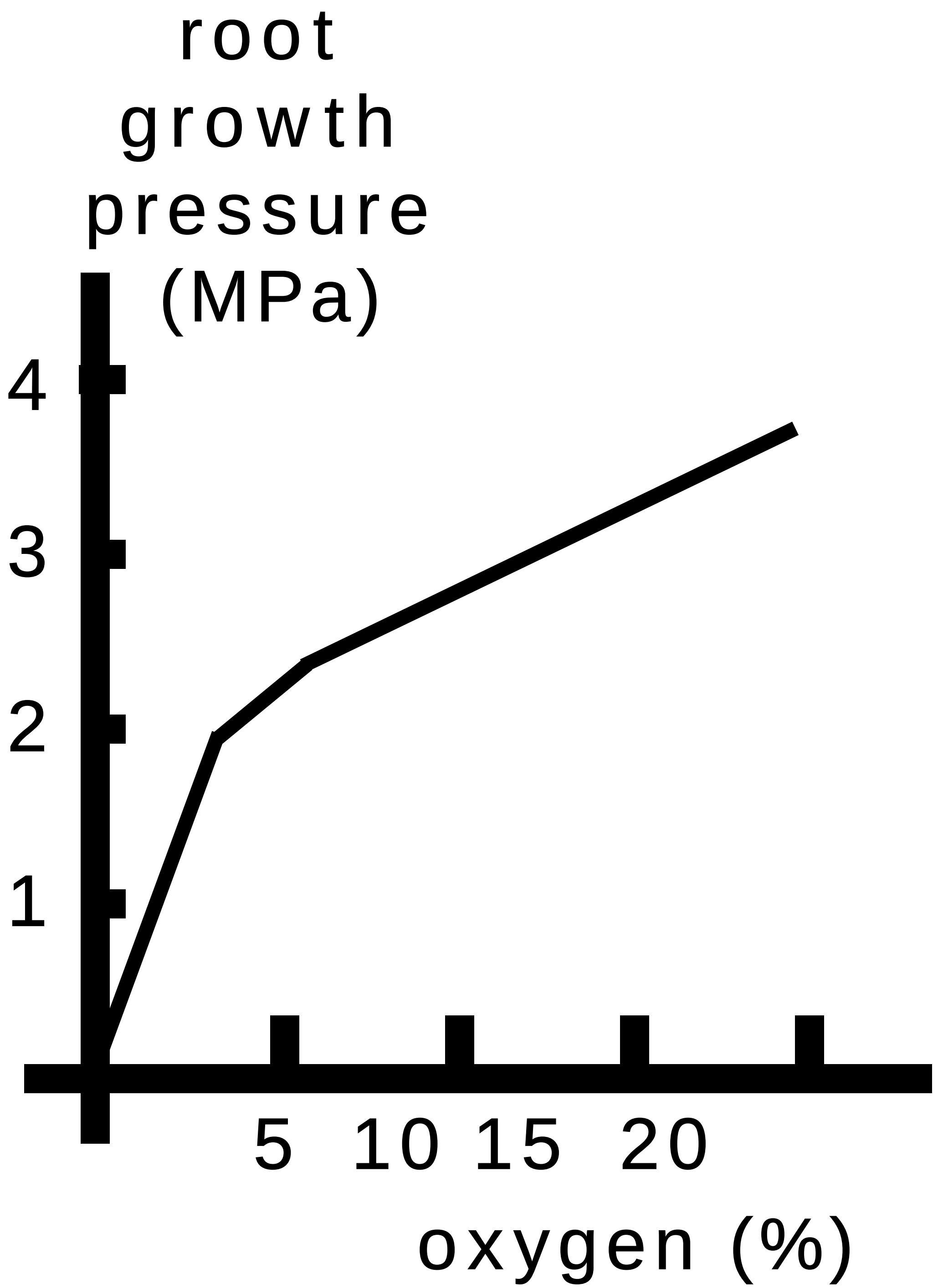

Figure 5: Root growth pressure by oxygen concentration. (48)