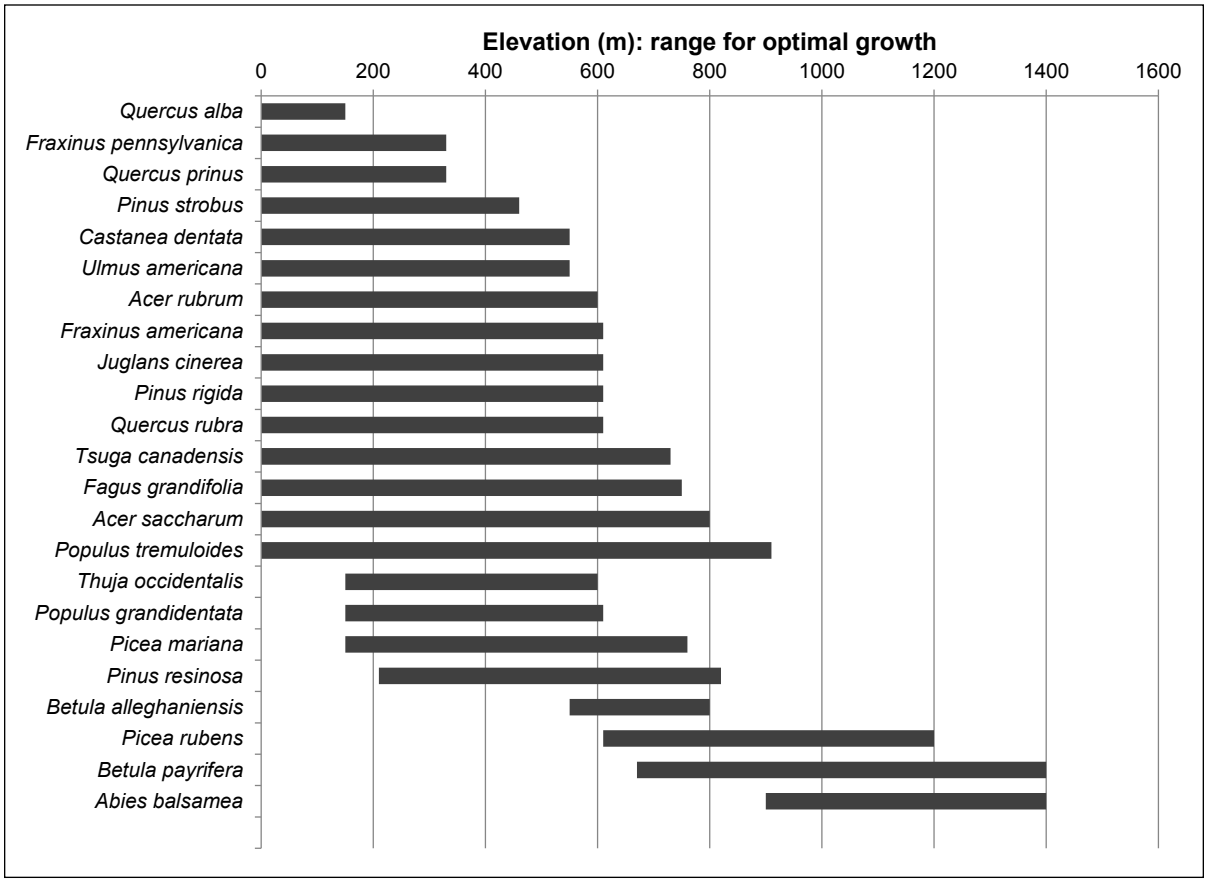
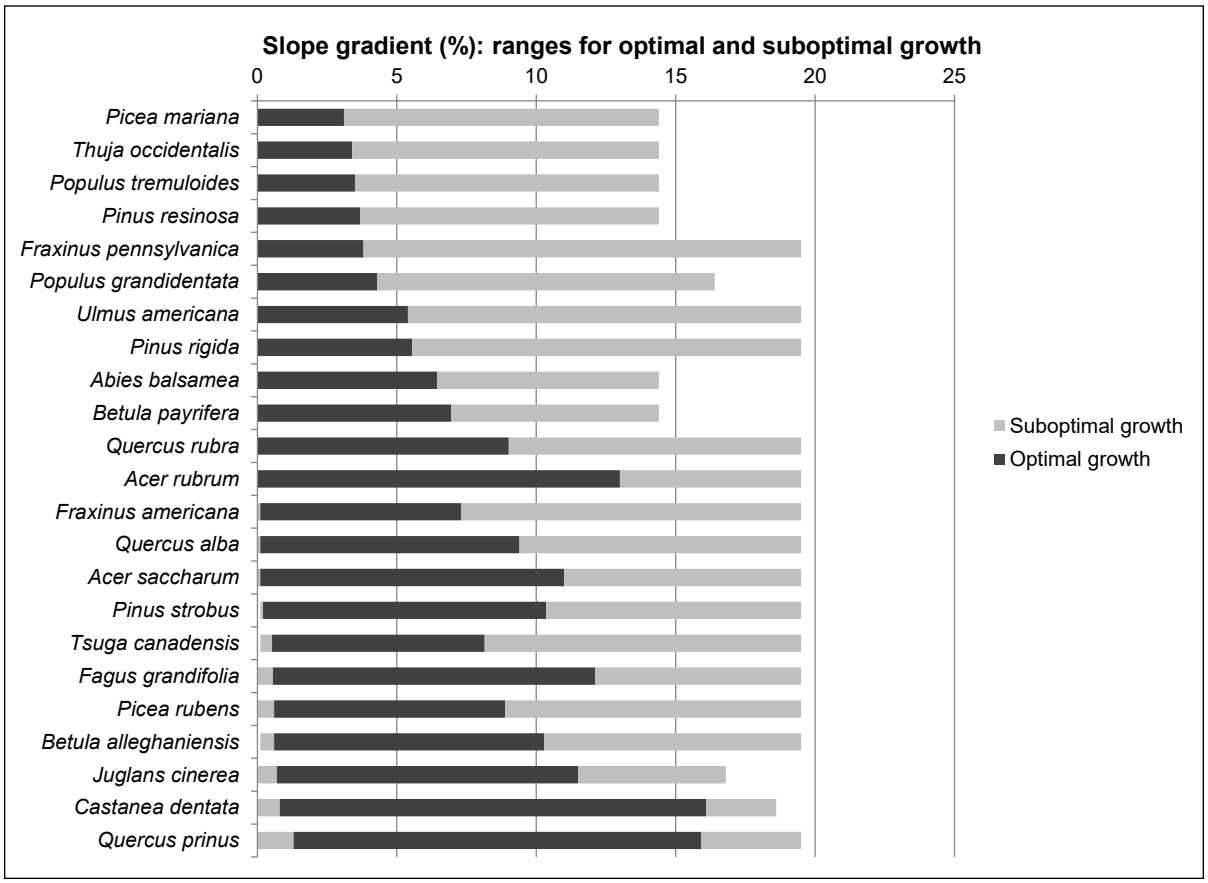
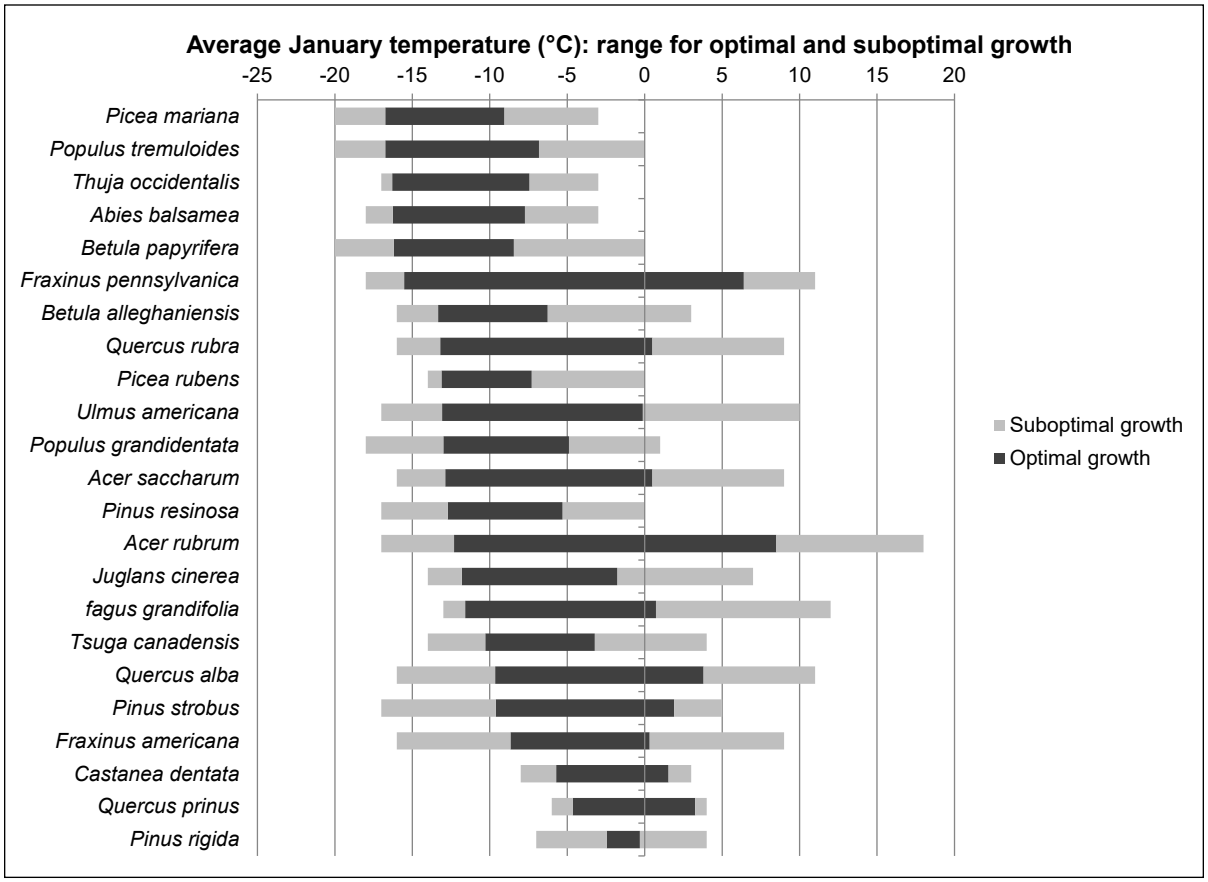
APPENDIX 2

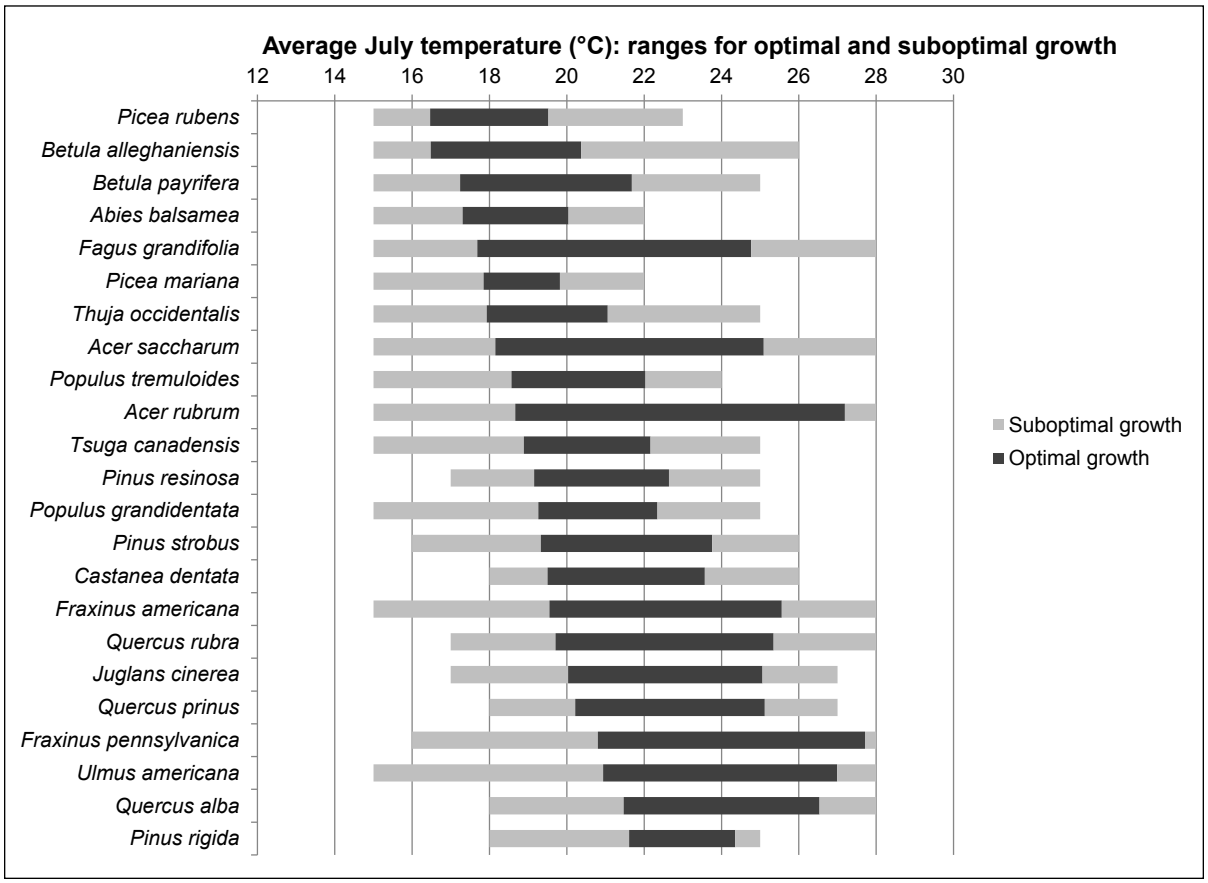
Ranges for Optimal and Suboptimal Growth for Site, Climate, and Soil Variables

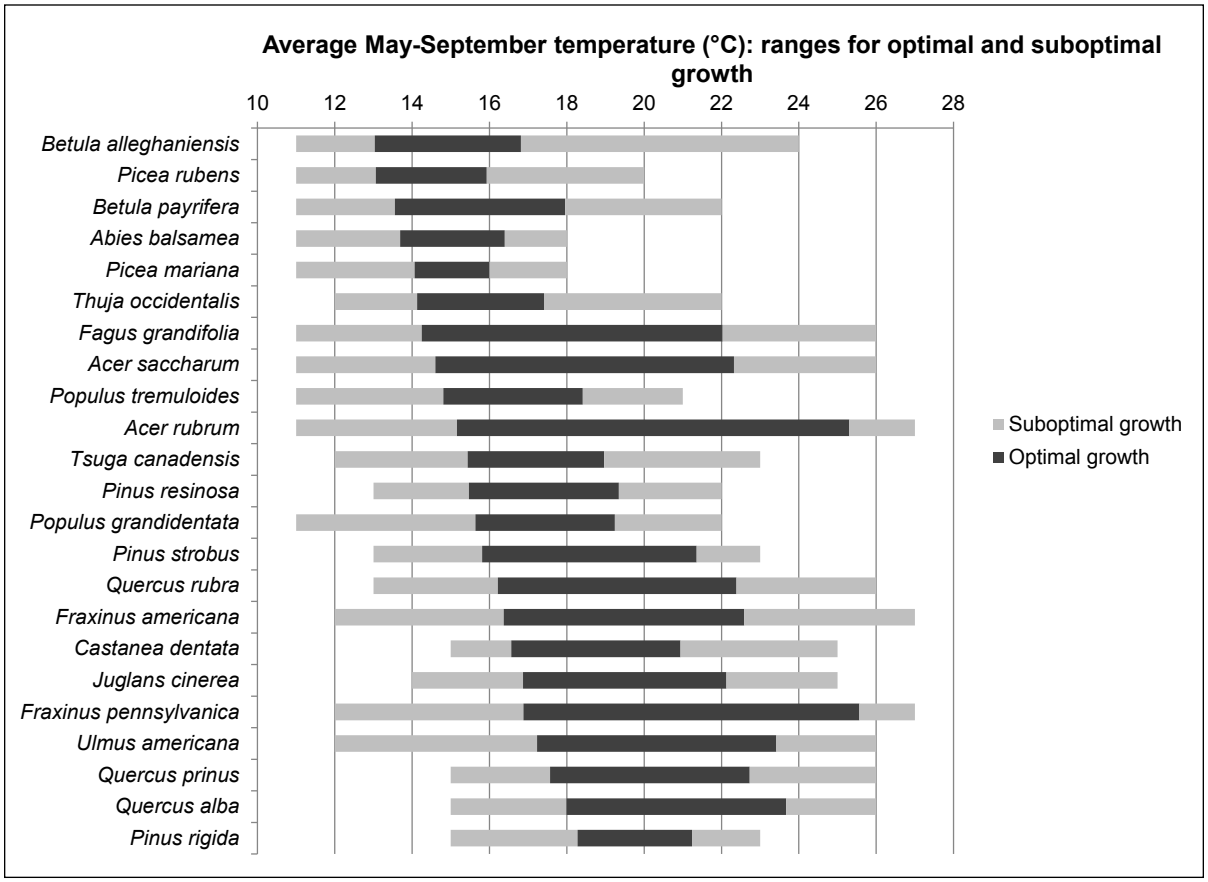
Climate and soil data in these figures were provided by the Landscape Change Research Group (U.S. Forest Service, n.d.). Current climate parameter data are from Hayhoe et al. (2007) and are based on United States Historical Climatology network data from 1961-1990. Soil and topographic parameter data are from STATSGO data (Soil Conservation Service 1991). For further information, see the Climate Change Atlas website: https://www.fs.fed.us/nrs/atlas/. Optimal elevation ranges were derived from information in "Silvics of North America" (Burns and Honkala 1990), Leak and Graber (1974), Beckage et al. (2008), and other sources. Depth to bedrock (minimum rooting depth) values come from the PLANTS database (NRCS 2014). Because optimal and suboptimal ranges are not known for minimum rooting depth, arrows indicate the beginning of the range.

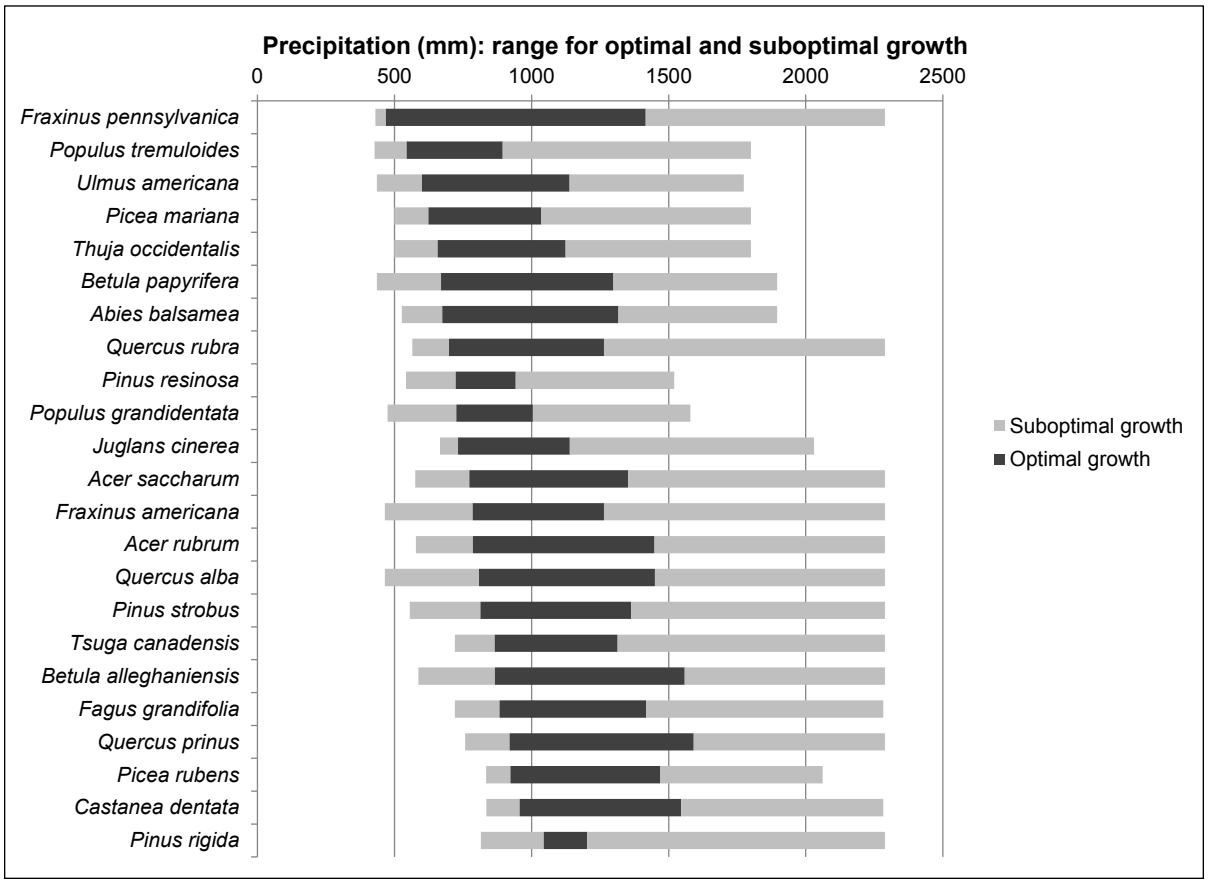

Elevation (m): range for optimal growth
0
200
400
600
800
1000
1200
1400
1600
Quercus alba
Fraxinus pennsylvanica
Quercus prinus
Pinus strobus
Castanea dentata
Ulmus americana
Acer rubrum
Fraxinus americana
Juglans cinerea
Pinus rigida
Quercus rubra
Tsuga canadensis
Fagus grandifolia
Acer saccharum
Populus tremuloides
Thuja occidentalis
Populus grandidentata
Picea mariana
Pinus resinosa
Betula alleghaniensis
Picea rubens
Betula payrifera
Abies balsamea

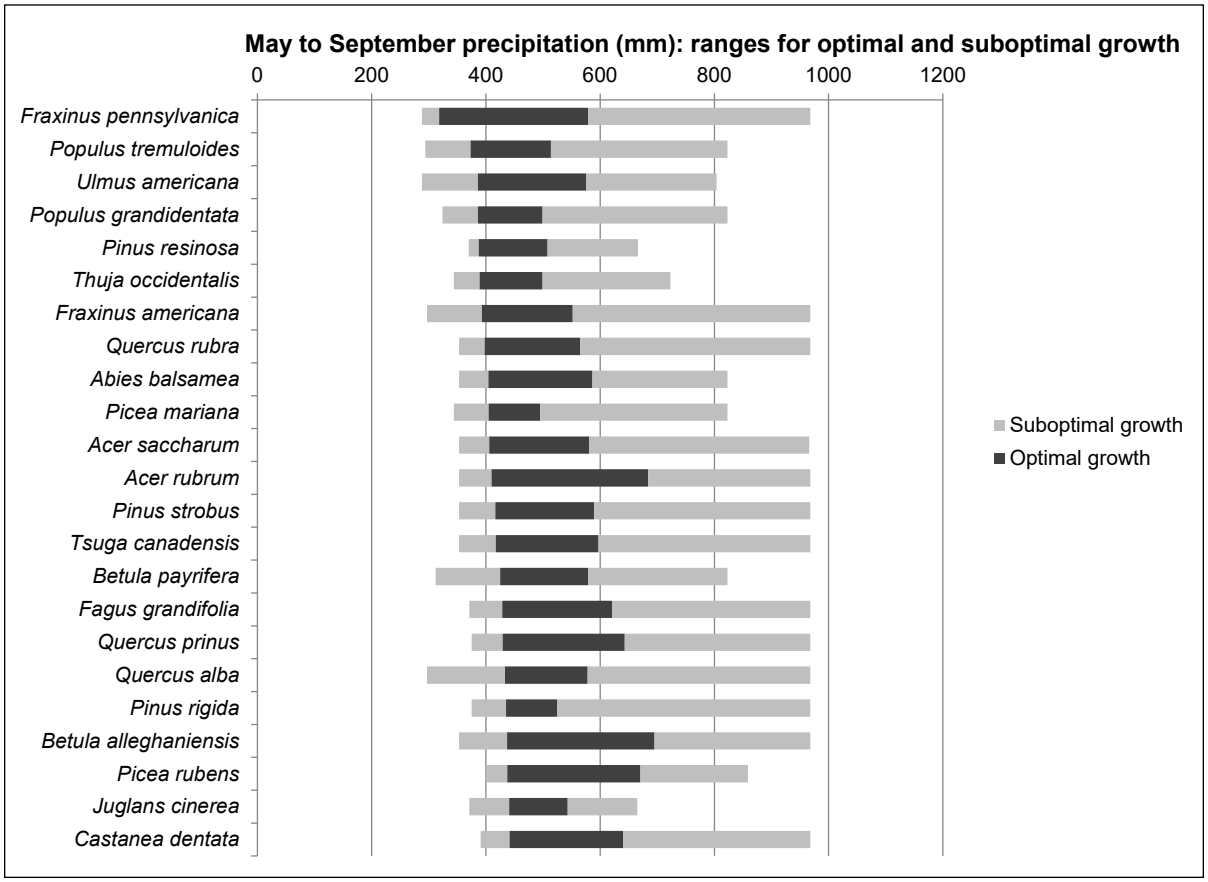

Slope gradient (%): ranges for optimal and suboptimal growth
0
5
10
15
20
25
Picea mariana
Thuja occidentalis
Populus tremuloides
Pinus resinosa
Fraxinus pennsylvanica
Populus grandidentata
Ulmus americana
Pinus rigida
Abies balsamea
Betula payrifera
Quercus rubra
Acer rubrum
Fraxinus americana
Quercus alba
Acer saccharum
Pinus strobus
Tsuga canadensis
Fagus grandifolia
Picea rubens
Betula alleghaniensis
Juglans cinerea
Castanea dentata
Quercus prinus
Suboptimal growth
Optimal growth

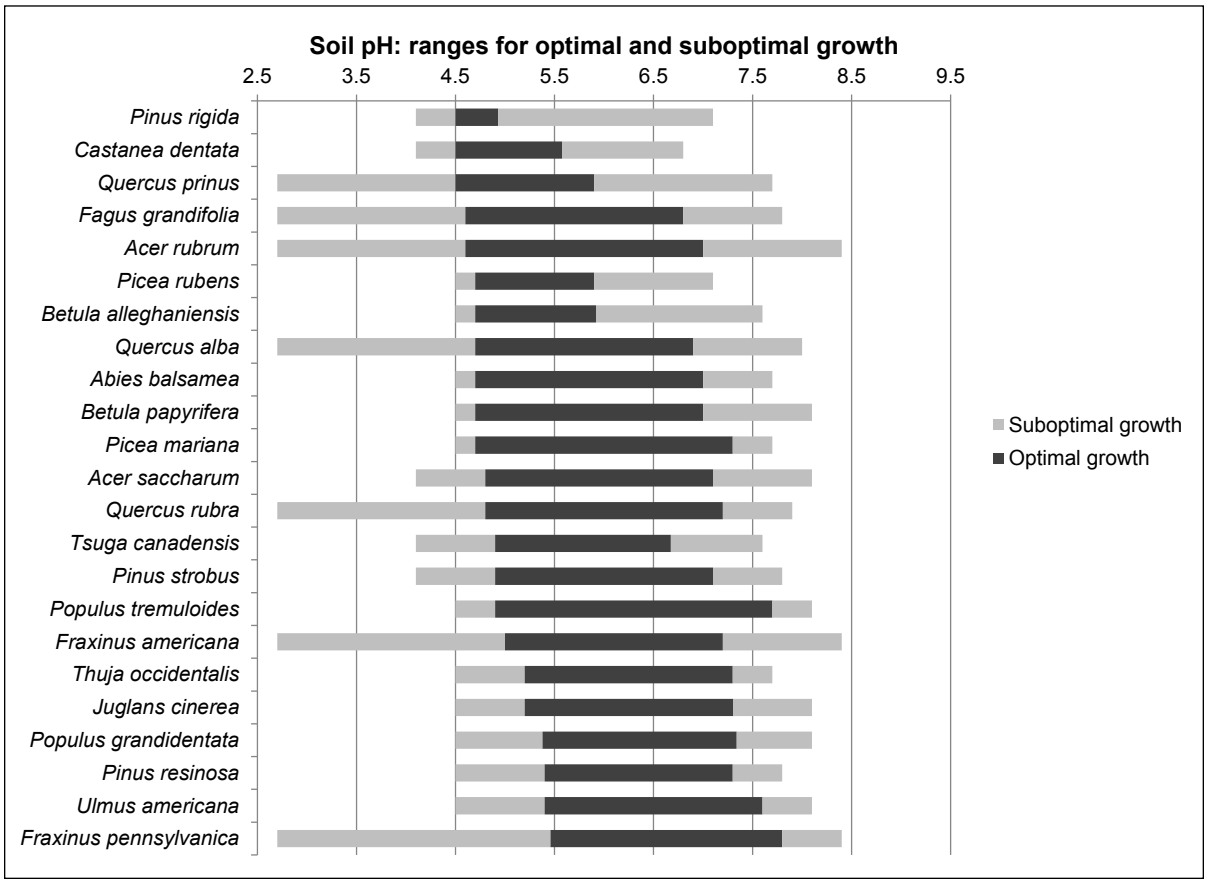

Average January temperature (°C): range for optimal and suboptimal growth
-25
-20
-15
-10
-5
0
5
10
15
20
Picea mariana
Populus tremuloides
Thuja occidentalis
Abies balsamea
Betula papyrifera
Fraxinus pennsylvanica
Betula alleghaniensis
Quercus rubra
Picea rubens
Ulmus americana
Populus grandidentata
Acer saccharum
Pinus resinosa
Acer rubrum
Juglans cinerea
fagus grandifolia
Tsuga canadensis
Quercus alba
Pinus strobus
Fraxinus americana
Castanea dentata
Quercus prinus
Pinus rigida
Suboptimal growth
Optimal growth

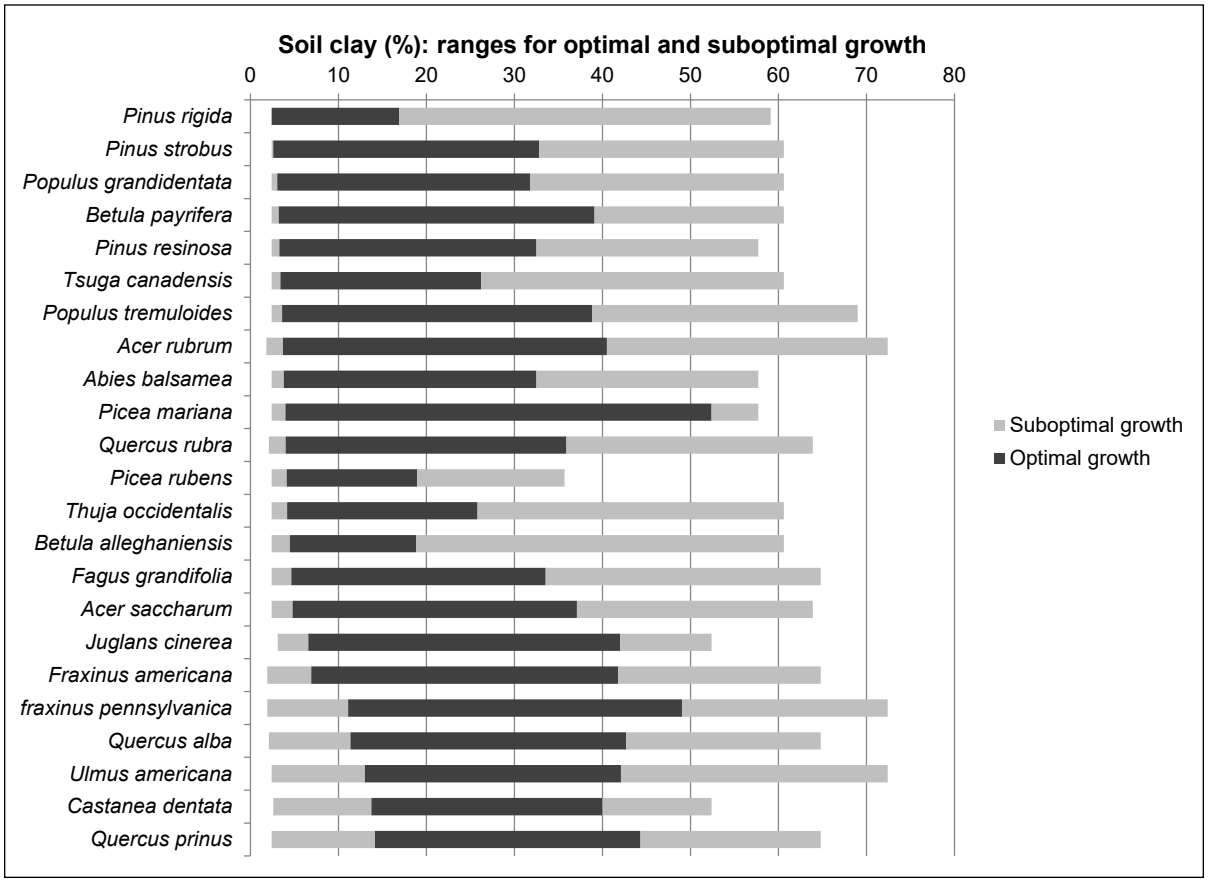

Average July temperature (°C): ranges for optimal and suboptimal growth
12
14
16
18
20
22
24
26
28
30
Picea rubens
Betula alleghaniensis
Betula payrifera
Abies balsamea
Fagus grandifolia
Picea mariana
Thuja occidentalis
Acer saccharum
Populus tremuloides
Acer rubrum
Tsuga canadensis
Pinus resinosa
Populus grandidentata
Pinus strobus
Castanea dentata
Fraxinus americana
Quercus rubra
Juglans cinerea
Quercus prinus
Fraxinus pennsylvanica
Ulmus americana
Quercus alba
Pinus rigida
Suboptimal growth
Optimal growth

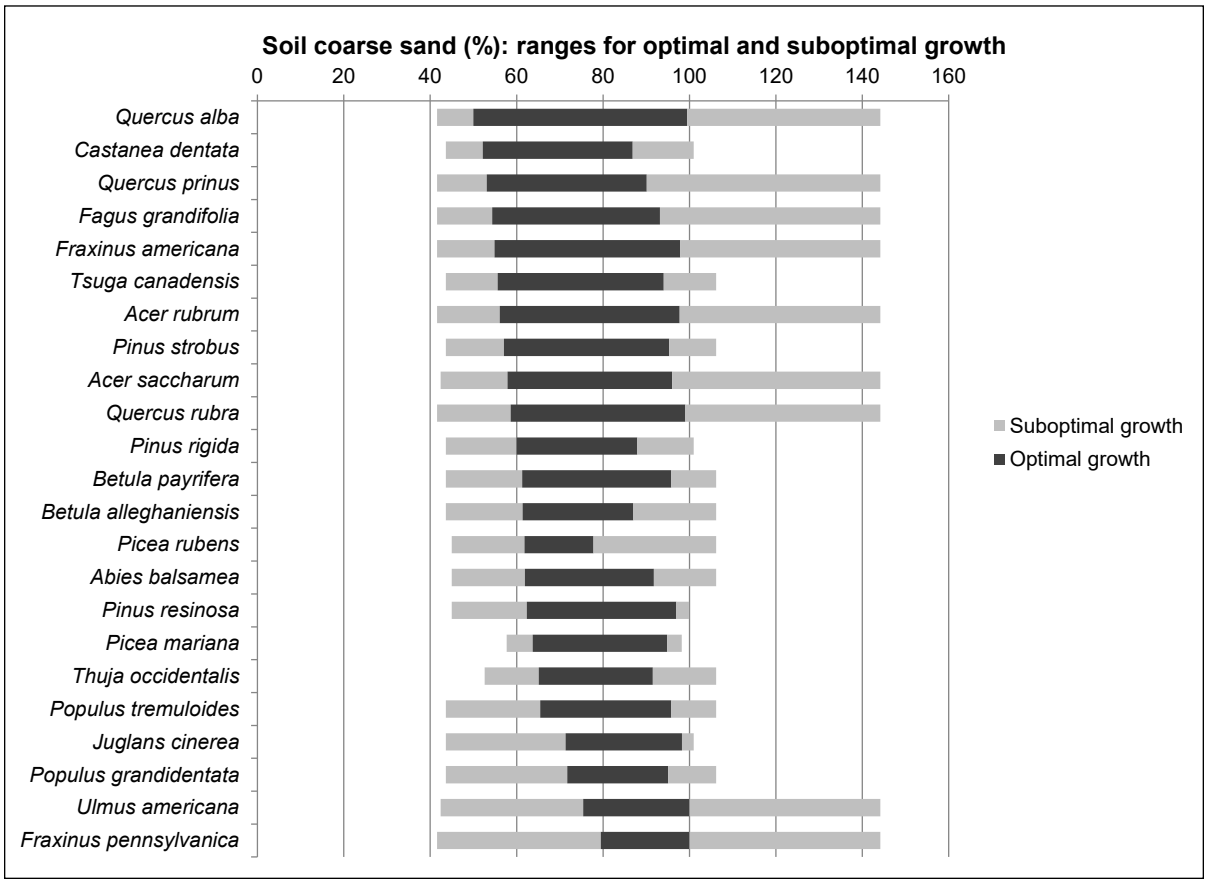

Average May-September temperature (°C): ranges for optimal and suboptimal growth
10
12
14
16
18
20
22
24
26
28
Betula alleghaniensis
Picea rubens
Betula payrifera
Abies balsamea
Picea mariana
Thuja occidentalis
Fagus grandifolia
Acer saccharum
Populus tremuloides
Acer rubrum
Tsuga canadensis
Pinus resinosa
Populus grandidentata
Pinus strobus
Quercus rubra
Fraxinus americana
Castanea dentata
Juglans cinerea
Fraxinus pennsylvanica
Ulmus americana
Quercus prinus
Quercus alba
Pinus rigida
Suboptimal growth
Optimal growth

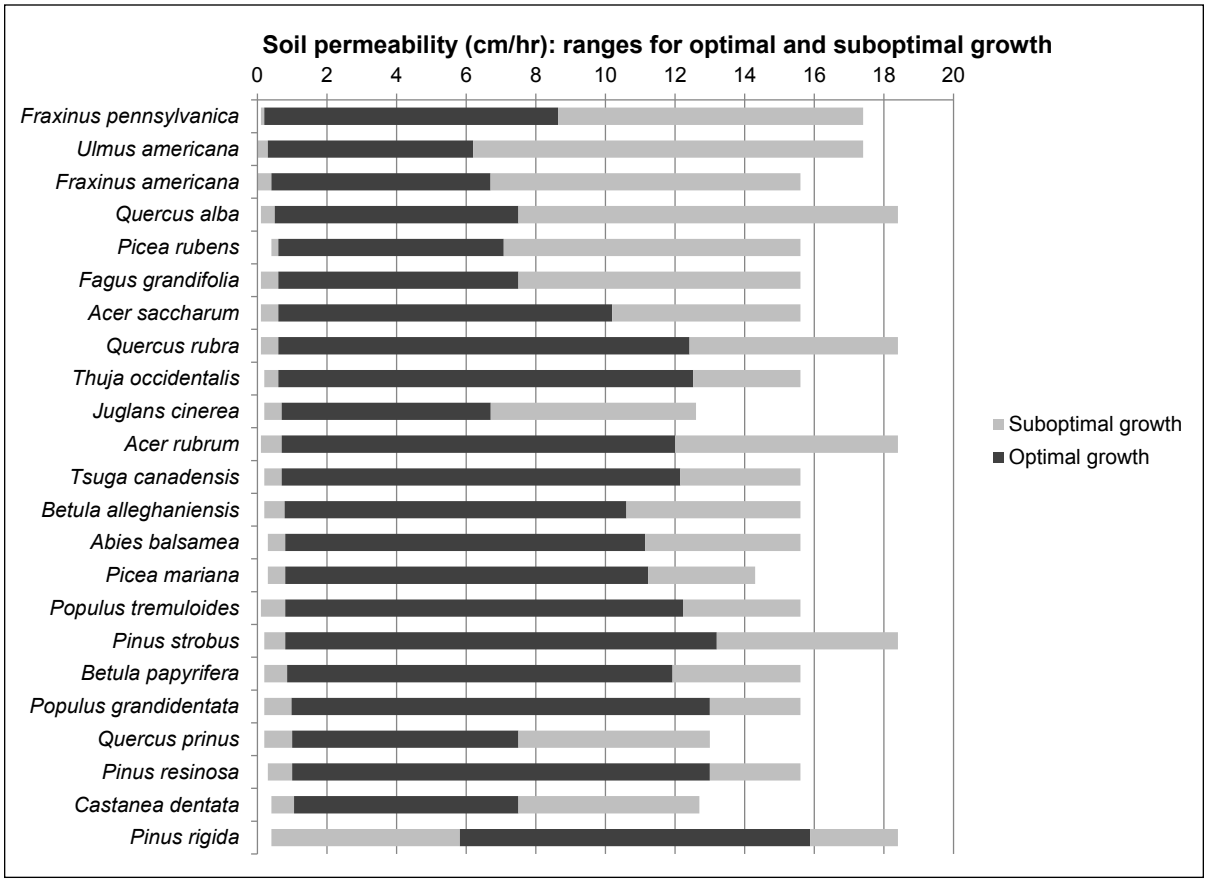

Precipitation (mm): range for optimal and suboptimal growth
0
500
1000
1500
2000
2500
Fraxinus pennsylvanica
Populus tremuloides
Ulmus americana
Picea mariana
Thuja occidentalis
Betula papyrifera
Abies balsamea
Quercus rubra
Pinus resinosa
Populus grandidentata
Juglans cinerea
Acer saccharum
Fraxinus americana
Acer rubrum
Quercus alba
Pinus strobus
Tsuga canadensis
Betula alleghaniensis
Fagus grandifolia
Quercus prinus
Picea rubens
Castanea dentata
Pinus rigida
Suboptimal growth
Optimal growth

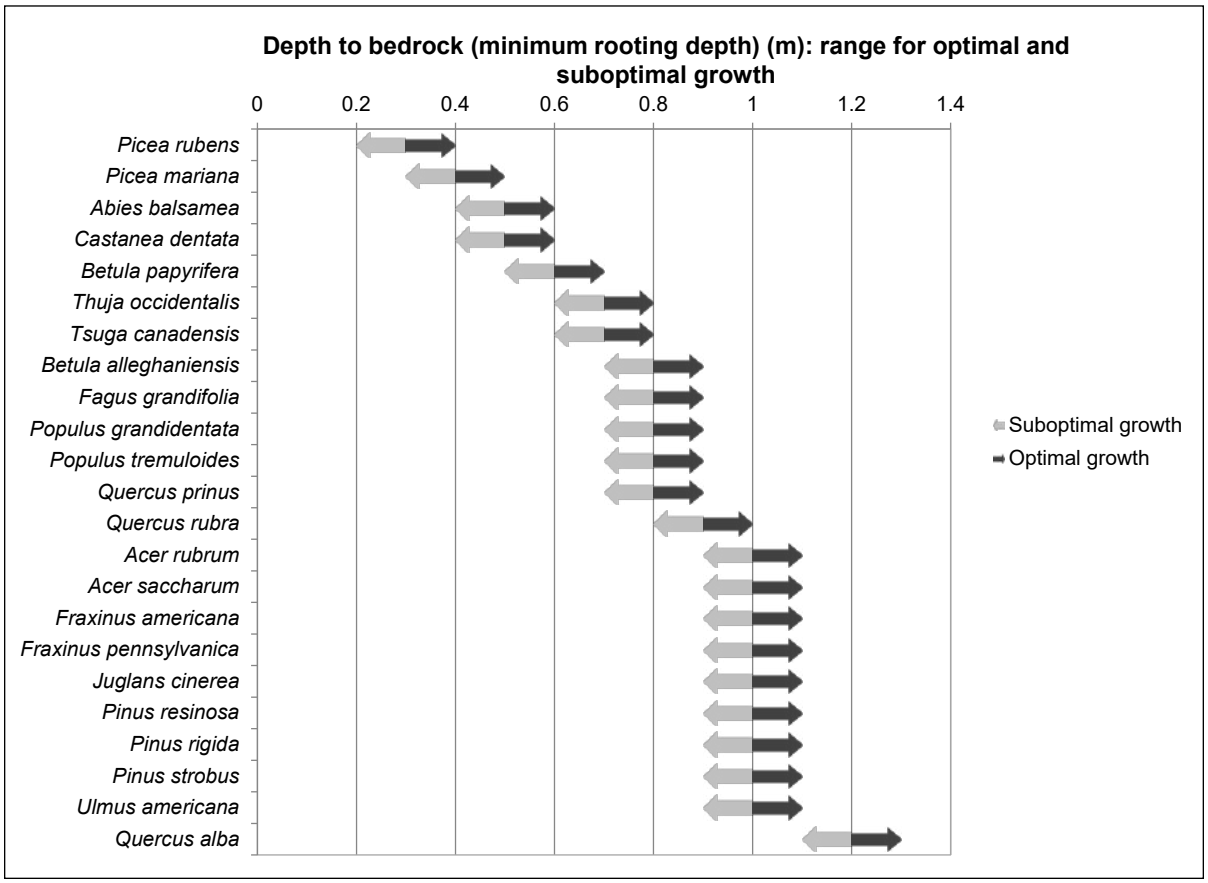

May to September precipitation (mm): ranges for optimal and suboptimal growth
0
200
400
600
800
1000
1200
Fraxinus pennsylvanica
Populus tremuloides
Ulmus americana
Populus grandidentata
Pinus resinosa
Thuja occidentalis
Fraxinus americana
Quercus rubra
Abies balsamea
Picea mariana
Acer saccharum
Acer rubrum
Pinus strobus
Tsuga canadensis
Betula payrifera
Fagus grandifolia
Quercus prinus
Quercus alba
Pinus rigida
Betula alleghaniensis
Picea rubens
Juglans cinerea
Castanea dentata
Suboptimal growth
Optimal growth


Soil pH: ranges for optimal and suboptimal growth
2.5
3.5
4.5
5.5
6.5
7.5
8.5
9.5
Pinus rigida
Castanea dentata
Quercus prinus
Fagus grandifolia
Acer rubrum
Picea rubens
Betula alleghaniensis
Quercus alba
Abies balsamea
Betula papyrifera
Picea mariana
Acer saccharum
Quercus rubra
Tsuga canadensis
Pinus strobus
Populus tremuloides
Fraxinus americana
Thuja occidentalis
Juglans cinerea
Populus grandidentata
Pinus resinosa
Ulmus americana
Fraxinus pennsylvanica
Suboptimal growth
Optimal growth


Soil clay (%): ranges for optimal and suboptimal growth
0
10
20
30
40
50
60
70
80
Pinus rigida
Pinus strobus
Populus grandidentata
Betula payrifera
Pinus resinosa
Tsuga canadensis
Populus tremuloides
Acer rubrum
Abies balsamea
Picea mariana
Quercus rubra
Picea rubens
Thuja occidentalis
Betula alleghaniensis
Fagus grandifolia
Acer saccharum
Juglans cinerea
Fraxinus americana
fraxinus pennsylvanica
Quercus alba
Ulmus americana
Castanea dentata
Quercus prinus
Suboptimal growth
Optimal growth


Soil coarse sand (%): ranges for optimal and suboptimal growth
0
20
40
60
80
100
120
140
160
Quercus alba
Castanea dentata
Quercus prinus
Fagus grandifolia
Fraxinus americana
Tsuga canadensis
Acer rubrum
Pinus strobus
Acer saccharum
Quercus rubra
Pinus rigida
Betula payrifera
Betula alleghaniensis
Picea rubens
Abies balsamea
Pinus resinosa
Picea mariana
Thuja occidentalis
Populus tremuloides
Juglans cinerea
Populus grandidentata
Ulmus americana
Fraxinus pennsylvanica
Suboptimal growth
Optimal growth


Soil permeability (cm/hr): ranges for optimal and suboptimal growth
0
2
4
6
8
10
12
14
16
18
20
Fraxinus pennsylvanica
Ulmus americana
Fraxinus americana
Quercus alba
Picea rubens
Fagus grandifolia
Acer saccharum
Quercus rubra
Thuja occidentalis
Juglans cinerea
Acer rubrum
Tsuga canadensis
Betula alleghaniensis
Abies balsamea
Picea mariana
Populus tremuloides
Pinus strobus
Betula papyrifera
Populus grandidentata
Quercus prinus
Pinus resinosa
Castanea dentata
Pinus rigida
Suboptimal growth
Optimal growth


Depth to bedrock (minimum rooting depth) (m): range for optimal and suboptimal growth
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Picea rubens
Picea mariana
Abies balsamea
Castanea dentata
Betula papyrifera
Thuja occidentalis
Tsuga canadensis
Betula alleghaniensis
Fagus grandifolia
Populus grandidentata
Populus tremuloides
Quercus prinus
Quercus rubra
Acer rubrum
Acer saccharum
Fraxinus americana
Fraxinus pennsylvanica
Juglans cinerea
Pinus resinosa
Pinus rigida
Pinus strobus
Ulmus americana
Quercus alba
Suboptimal growth
Optimal growth