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EARLY GROWTH TOLERANCES OF GRASSES, SHRUBS, AND TREES TO BORON IN TUNNEL SPOIL

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ABSTRACT: The effects of boron and salts in spoil material on survival and growth of 44 grass, shrub, and tree species were tested under greenhouse conditions. The spoil used was from the Angeles Tunnel of the California Aqueduct's West Branch now being built. Several species within each plant group apparently can tolerate boron, but field tests will be needed before most of them can be recommended for widespread planting.

OXFORD: 114.449.8:114.53[–114.263B + 175.2 monocotyledons + 176.1 dicotyledons + 114.263B]. *RETRIEVAL TERMS:* spoil mounds; soil toxicity; boron; monocotyledons; dicotyledons.

Establishing vegetative cover to heal seriously-disturbed areas created by construction activity requires special methods and plants because conditions are quite unlike most natural planting sites. Excavated spoil or exposed materials may include substances toxic to plants.

The Angeles Tunnel is a segment of the West Branch Division of California Aqueduct now being constructed through a mountain on the Angeles National Forest. The Aqueduct will carry additional water from northern California for use in southern California communities. Spoil removed from the 7-mile tunnel has relatively high amounts of boron—enough to affect adversely the growth of many plants.

Injury to plants by boron is distinctive in its effects on plant foliage. Symptoms of boron toxicity are clearly distinguishable from normal maturation processes in the plant or symptoms resulting from excesses of other elements of soil nutrition.[1] Leaves of plants injured by boron usually turn yellow—beginning at the apical margins and then extending toward the midveins. As yellowing advances, dead tissue develops on the leaves. In some plants, it is confined to margins of leaves; in others, dead spots develop between the lateral veins—either with or without notable yellowing in advance. Older leaves are the first to show injury, and they abscise sooner than leaves of similar age on uninjured plants.

Laskowski and LaValle[2] reported that the Castaic Valley and surrounding hills, in which the Angeles Tunnel is situated, are known to be plagued by a variety of soil toxicity problems. Excessive amounts of boron, chlorine, sodium, sulfates, and zinc in the soils seriously restrict planting and revegetation in much of the Valley for agricultural or outdoor recreational uses. A few studies on boron tolerance have been made on forage and turfgrasses and other agricultural crops.[1,3,4] Except for studies by Chatterton *et al.*,[5] we know of no studies on tolerances of shrubs or trees that may be suitable for planting on arid sites where boron may be a problem.

This study was done to identify grass, shrub, and tree species that would tolerate boron and might also survive high summer temperatures and other unfavorable site conditions. We assumed, in selecting plants for testing, that supplementary irrigation could be applied only during the first year or two after planting. Among the 44 species tested under greenhouse conditions, we found six grass, eight shrub, and four tree species that tolerated boron in spoil from the Angeles Tunnel. Additional field trials should be made before most of these plants can be recommended for widespread use where boron may be a problem.

MATERIALS

Spoil material tested consisted mainly of air-dried soft shale crushed to pass through quarter-inch diameter sieve openings. The saturation extract of this material had 5 ppm soluble boron, an electrical conductivity of 10 mmhos per cm at 25°C, and a sodium saturation of 30 percent. The gypsum required to reduce exchangeable sodium to a satisfactory level, as determined by equilibrium with saturated calcium sulfate solution, was 5.2 meq per 100 g spoil. Sulfates were the main soluble salts in the saturation extract. Analysis of ammonium nitrate extracts showed relatively high levels of available potassium and magnesium, and spectrographic analysis indicated adequate amounts of trace elements available for plant growth.

Treating spoil material with acidifying soil amendments and fertilizers with acid residues showed that any acidification of the spoil material increased boron solubility. Some acidifying materials almost doubled the amount of boron in the saturation extract. Thus, calcium nitrate and pulverized dicalcium phosphate were used as nitrogen and phosphorus sources because they do not leave acid residues which may actually aggravate boron toxicity to plants.

Plants tested were selected because we had information about them from published reports[5-9] or were recommended by specialists who felt that they might grow in southern California wildlands. Plant materials came from several sources, generally wherever they were available—either from commercial dealers,[10] county, State and Federal agencies, or educational institutions.

METHODS

The study consisted of growing plants in greenhouse pots filled with about one-half cubic foot crushed spoil and testing their response to boron and salts in the spoil. The material in half the pots was treated with 5.2 meq of calcium chloride per 100 g to meet the equivalent gypsum requirement, and then leached with sufficient water to obtain a volume of drainage equal to the volume of the spoil. After the leached material was dry enough to manipulate, the material was treated with pulverized dicalcium phosphate at a rate of 100 ppm phosphorus and calcium nitrate at a rate of 100 ppm nitrogen. If the bulk density of the spoil was assumed to be 1.3 gm/cm^3 and if the fertilizer was mixed in a 12-inch depth, this rate would be about 350 pounds nitrogen or phosphorus per acre. To avoid excessive drying or waterlogging, we placed tensiometers in each pot to measure soil moisture and to gauge the need for irrigation.

The first experiment, started on July 3, 1968, consisted of grasses, saltbushes, cliffrose, and bitterbrush grown from seeds. Seeds were covered with a thin layer of peat above the spoil mixture to maintain better moisture conditions for germination. Each of the two treatments—leached and unleached spoil material—was replicated twice for each species.

No soil other than the spoil material was used because we anticipated that seedlings of tolerant species would germinate and grow quickly and that no problems in the evaluation of toxicity or performance would be found.[4,5] Sufficient seedlings developed for all species except for California buckwheat *(Eriogonum fasciculatum)*, which failed to germinate, and was subsequently tested by using young transplants. Growth ratings and symptoms of toxicity were evaluated on August 14, 1968.

The second experiment included only young nursery-grown or wildling plants of shrub and tree species that were transplanted into greenhouse pots. Because of the diverse nature of the plant material available, a nonsaline low boron gravelly loam soil was included as a control treatment. Extending from September to March 1968, this experiment, had two replications for each of the three treatments: a check soil (gravelly loam), unleached, and leached spoil material.

Tolerance of plants to boron in the spoil medium was rated according to classes used by Eaton[1] and Oertli *et al.*[4] This classification of tolerant, moderately tolerant, and intolerant took into account the growth and survival of the plants and the degree of tip burn that developed on the leaves.

Four species that were tested failed to survive: gold carpet *(Eremophylla glabra*-cultivar*)*, Coulter pine *(Pinus coulteri)*, Italian stone pine *(P. pinea)*, and big-cone spruce *(Pseudotsuga macrocarpa)*. Needles of Coulter and Italian stone pines had severe tip burn on plants that were in the spoil material, but there was no evidence of toxicity on plants in the control soil.

RESULTS

The relative tolerance of plants[11] tested to spoil material with boron was:

Tolerant (slight tip burn)

GRASSES

Agropyron elongatum	tall wheatgrass
Cynodon dactylon	giant (N-K No. 37) Bermuda
Cynodon dactylon	Bermuda-hulled seed
Elymus cinereus	Great Basin wildrye
Festuca arundinacea "goers"	Goer's tall fescue
Lolium rigidum x *L. multiflorum*	Wimmera annual ryegrass[8]

SHRUBS

Atriplex canescens	fourwing saltbush
Atriplex lentiformis	quailbush saltbush
Atriplex polycarpa	allscale or desert saltbush
Baccharis viminea	mulefat baccharis
Eriogonum fasciculatum	California buckwheat
Isomeris arborea	bladderpod
Myoporum parvifolium (cultivar)	horshum
Spartinum junceum	Spanish broom

TREES

Acacia graffiana	"Graffiana" acacia
Parkinsonia aculeata	Jerusalem-thorn, palo verde
Pinus halepensis	aleppo pine
Schinus molle	California or Peruvian pepper

Moderately tolerant (slight-to-moderate tip burn)

GRASSES

Eragrostis curvula	weeping lovegrass
Eragrostis lehmanniana	Lehmann lovegrass
Eragrostis spp.	Wilman lovegrass
Festuca arundinacea	Alta fescue
Hordeum vulgare	barley
Oryzopsis miliacea	smilo
Phalaris tuberosa	hardinggrass

SHRUBS

Cowania mexicana var. *stansburiana*	Stansbury cliffrose

TREES

Cupressus arizonica	Arizona cypress

Intolerant (severe tip burn)

GRASSES

Adenostoma fasciculatum	chamise
Baccharis pilularis	kidneywort baccharis (dwarf baccharis, dwarf chaparral broom)
Ceanothus cyaneus	mountain lilac
Cistus villosus	purple rockrose
Purshia glandulosa	desert bitterbrush
Salvia sonomensis	Sonoma (creeping) sage

SHRUBS

Agropyron trichophorum	pubescent wheatgrass
Dactylis glomerata palestine	Palestine grass
Ehrharta calycina	perennial (Mission) veldtgrass
Lolium spp. (N-K No. 333)	tetrablend 333
Paspalum notatum saurae	Pensacola Bahiá grass

TREES

Cedrus deodora	Deodor cedar
Libocedrus decurrens	incense cedar
Populus fremontii	Fremont cottonwood
Quercus wislizenii	interior live oak
Robinia pseudoacacia	black locust

All grasses showed some symptoms of boron toxicity, but this is not an unusual condition. Oertli *et al.*[4] found effects of boron in all grasses they tested; however, slight tip burn did not seriously reduce growth or adversely affect condition of the grasses. Grasses we tested that grew satisfactorily and appeared normal in all other respects except for slight tip burn on the leaves were considered tolerant of boron. On the other hand, if a plant had severe tip burn, it usually stopped growing. And in most instances, these grasses either died or were in very weakened condition by the end of the test. Between these extremes were seven grasses that showed intermediate symptoms of boron toxicity. Although these seven grasses which had slight-to-moderate tip burn survived, they grew only slightly and lacked vigor.

Most of the woody species tested showed either no evidence of boron toxicity or developed severe tip burn when growing in the tunnel spoil. There were only two exceptions: Stansbury cliffrose and Arizona cypress showed intermediate symptoms of toxicity, but these plants did not appear to be otherwise affected—probably a sign of moderate tolerance.

Shrubs and trees showing no evidence of toxicity when growing in the tunnel spoil were considered to be tolerant of boron. These plants were generally equal in growth, vigor, and survival to control plants of the same species growing in the nonsaline, low boron soil. Shrubs and trees which developed severe tip burn when growing in the spoil usually died, or plants were in such weakened condition by the end of the test that they could not survive, if the experiment were to have been continued. In marked contrast, these same species growing in the check soil developed normally throughout the test period.

Adding gypsum to the spoil material and then leaching to remove soluble salts failed to help reduce toxicity of boron and salts or to aid growth and survival of the plants. Apparently the weakly-cemented shale particles that held entrapped salts and boron disintegrated quickly enough to replenish the boron and salts removed by leaching.

DISCUSSION

Enough species within each plant group were tolerant to boron in these greenhouse tests to suggest that production of a vegetative cover for the spoil material is feasible. A few species within each group are known to be climatically adapted to southern California wildland conditions. Tall wheatgrass and Wimmera annual ryegrass are good candidates for use on the tunnel spoil because they can resist drought and can grow under adverse conditions.[7-9] The other boron-tolerant grasses also may be suitable, but they would probably require supplementary irrigation and fertilization not only to become established but to survive and grow satisfactorily thereafter on most sites in southern California.

Among the shrubs which showed tolerance to boron, at least five species have been successfully established by direct seeding and can provide good cover on seriously disturbed sites in southern California. The three saltbushes we tested, along with California buckwheat and bladderpod, are often seeded with mixtures of other plants along many roadcut and fill slopes to stabilize the soil and enhance the landscape. Although our tests did not indicate the amount of boron these species will tolerate, Chatterton *et al.*[5] found that germination of allscale (or desert) saltbush was not affected by boron and that plants were highly tolerant to high concentrations of boron. This same condition probably applies in some degree to the other species rated as boron tolerant, but especially to shrub and tree species native to arid regions where boron may be in the soil. Methods for improving germination and for establishing some of these saltbushes have been developed. Such methods would have direct application to plantings of these species in southern California.[12,13]

Mulefat baccharis and Spanish broom have also demonstrated their adaptability for roadside plantings on arid sites[6] but are not readily established by direct seeding on the site. Baccharis can be established from cuttings which sprout and may grow prodigously in one season on favorable sites.[14] Spanish broom generally requires nursery-grown stock for plantings to succeed. In most instances, supplementary irrigation is needed for one or more years for these plants to survive and grow satisfactorily.

Three out of four tree species tested which showed tolerance to boron have been successfully used for roadside plantings on relatively harsh, arid conditions. Jerusalem-thorn, California pepper, and Aleppo pine have demonstrated adaptability on many sites in southern California in roadside plantings.[6] "Graffiana" acacia and horshum, a cultivar shrub, have been used in urban landscape plantings but have not been tested to determine their adaptability to other conditions.

Although Arizona cypress and Stansbury cliffrose showed some evidence of toxicity to boron, they could possibly be planted where the soil has a low concentration of boron. These plants, both native to the southwestern United States, are grown for various purposes, such as cover, shade, windbreaks, and game habitat, in many arid sites. They need little or no attention once they have become established.

NOTES

[1]Eaton, F. M. *Boron in soils and irrigation waters and its effects on plants with particular reference to the San Joaquin Valley of California.* U.S. Dep. Agr., Tech. Bull. 448, 131 p. 1935.

[2]Laskowski, E., and P. D. LaValle. *Aspects of soil toxicity in the Castaic Lake Region of California.* Yearbook, Ass. Pacific Coast Geographers 28:157-168. J. F. Gaines, ed. Corvallis, Ore: Oregon State University Press. 1966.

[3]Russel, D. A. *Boron and soil fertility.* U.S. Dep. Agr., Yearbook of Agriculture, p. 121-128. 1957.

[4]Oertli, J. J., O. R. Lunt, and V. B. Youngner. *Boron toxicity in several turfgrass species.* Agron. J. 55: 262-265. 1961.

[5]Chatterton, N. J., C. M. McKell, J. R. Goodin, and F. T. Bingham. *Atriplex polycarpa: II. Germination and growth in water cultures containing high levels of boron.* Agron. J. 61(3): 451-455. 1969.

[6]California Division of Highways. *California roadsides.* Sacramento, Calif. 36 p. 1961.

[7]Edmunson, G. C., and D. R. Cornelius. *Promising grasses for southern California fuel-breaks.* U.S. Forest Serv. Pacific SW. Forest & Range Exp. Sta. Misc. Paper 58, 13 p. 1961.

[8]Hanson, A. A. *Grass varieties in the United States.* U.S. Dep. Agr., Agr. Handb. 170, 72 p. 1959.

[9]Weintraub, F. C. *Grasses introduced into the United States.* U.S. Dep. Agr., Forest Sérv. Agr. Handb. 58, 79 p. 1953.

[10]Grass seeds used in tests were contributed by Northrup, King & Company, Fresno, Calif. Horshum plants were contributed by Pecoff Brothers Nursery, Escondido, Calif. Trade names and commercial enterprises or products are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.

[11]Sources for scientific and common names: **Grasses**–Hitchcock, A. W., and A. Chase. *Manual of the grasses of the United States.* U.S. Dep. Agr., Misc. Publ. 200, 1,051 p. 1950; Kelsey, H. P., and W. A. Dayton. *Standardized plant names.* 765 p. Harrisburg: J. Horace McFarlane Co. 1942; Weintraub *op. cit.* **Shrubs**–Munz, P. A., and D. D. Keck. *A California flora.* Berkeley: Univ. Calif. Press, 1,681 p. 1959; Kelsey and Dayton, *op. cit.* **Trees**–Little, E. L., Jr. *Check list of native and naturalized trees of the United States (including Alaska).* U.S. Dep. Agr., Handb. 41, 472 p. 1953.

[12]Nord, E. C., and J. E. Whitacre. *Germination of fourwing saltbush improved by scarification and grading.* U.S. Forest Serv. Calif. Forest & Range Exp. Sta. Res. Note 125, 5 p., 1957.

[13]Nord, E. C., P. F. Hartless, and W. D. Nettleton. *Effects of time, depth of seeding, and other factors on saltbush establishment in southern California.* J. Range Manage. 1971. (in press)

[14]Kraebel, C.J. *Erosion control on mountain roads.* U.S. Dep. Agr., Circ. 380, 45 p. 1936.

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