

California Turfgrass Culture

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Interpreting Turfgrass Irrigation Water Test Results

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The notion that water quality problems caused by soluble salts arise only-or even primarily-in regions with arid climates is far from the truth. For example, the excessive pumping of fresh water from wells in coastal areas can lead to saltwater intrusion problems. Even in high-rainfall areas the groundwater may contain significant levels of soluble salts derived from underground rock formations of marine origin. Moreover, increasing numbers of golf courses, parks, cemeteries, school campuses, industrial, and commercial turfed sites use potentially saline recycled municipal water for irrigation. The result of this breadth of use is that the effects of excess soluble salts are visible on turfgrass plantings in a wide range of climates. Water analysis and periodic monitoring have thus become key components of sound irrigation management.

Water analysis by a commercial laboratory provides data on many parameters, some of which are of little significance for turfgrass irrigation. The most important parameters for turfgrass management are total concentration of soluble salts (salinity); sodium (Na) content; relative proportion of sodium to calcium (Ca) and magnesium (Mg) (Sodium Adsorption Ratio or SAR); chloride (Cl), boron (B), bicarbonate (HCO₃), and carbonate (CO₃) content; and pH. Other parameters that you are likely to find on a water test report and that you should review are nutrient content (nitrogen, phosphorus, and potassium), chlorine content, suspended solids, and turbidity, though none of these by itself plays a major role in determining the suitability of water for irrigation.

IMPORTANT TEST PARAMETERS

Salinity. All irrigation waters contain some dissolved mineral

salts and chemicals. Some soluble salts are identified as nutrients and are beneficial to turfgrass growth; others may be phytotoxic or may become so when present in high concentrations. The rate at which salts accumulate to undesirable levels in a soil depends on their concentration in the irrigation water, the amount of water applied annually, annual precipitation (rain plus snow), and the soil's physical and chemical characteristics.

Different laboratories report water salinity in different ways: as Total Dissolved Solids (TDS) measured in parts per million (ppm) or milligrams per liter (mg/L), or as electrical conductivity (EC_w) measured in millimhos per centimeter (mmhos/cm), micromhos per centimeter (ymhos/cm), decisiemens per meter (dS/m), or siemens per meter (S/m). Some labs may also report the individual components of salinity (e.g., sodium) in milliequivalents per liter (meq/L). You can use the following equations to convert results from one set of units to another, and so compare data from differently formatted reports:

- (1) 1 ppm = 1 mg/L
- (2) 1 mg/L = meq/L X Equivalent Weight (see Table 1)
- (3) 1 mmho/cm = 1 dS/m = 1,000 μmhos/cm = 0.1 S/m

Historically, laboratories determine TDS in water by evaporating a known volume and then weighing any precipitate. Results of this method were reported as ppm or mg/L. This process is time-consuming, and today the preferred method for assessment of soluble salt content is the measurement of electrical conductivity (EC_w), which is directly related to the

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Table 1. Conversion factors for mg/L and meq/L.

Constituent	To convert mg/L to meq/L multiply by	To convert meq/L to mg/L multiply by
Sodium (Na)	0.043	23
Calcium (Ca)	0.050	20
Magnesium (Mg)	0.083	12
Bicarbonate (HCO ₃)	0.016	61
Carbonate (CO ₃)	0.033	30
Chloride (Cl)	0.029	35

salt content of the water. Regardless of how salinity is reported, the relationship between EC_w and TDS is approximately:

$$(4) \text{ EC}_w (\text{mmhos/cm or dS/m}) \times 640 = \text{TDS (ppm or mg/L)}$$

Note that the 640 value is a general average factor and may require adjustment in special circumstances. For example, waters containing substantial amounts of sulfate require a higher conversion factor. Many low-salinity groundwater supplies along coastal valleys of California have water that would fall within this category. Sometimes the appropriate conversion factor can be as high as 700. If you are unsure about which conversion factor to use, consult the testing laboratory.

Most water that is acceptable for turfgrass irrigation contains from 200 to 800 ppm soluble salts. Soluble salt levels greater than 2,000 ppm may injure turfgrass; salt levels up to 2,000 ppm may be tolerated by some turfgrass species (Table 2) but only on soils with exceptional permeability and subsoil drainage. Good permeability and drainage allow a turfgrass manager to leach excessive salts from the root zone by periodically applying heavy irrigations. Sand-based sport fields and golf greens have the proper soil structure for this form of salinity management. (It should be noted that irrigation water with a very low salt content [i.e., below 0.2 dS/m] can actually reduce the permeability of a soil. Such water can disperse clay particles, which then clog large soil pores that are important for good permeability.)

Table 3 lists the parameters a turfgrass manager should consider in evaluating irrigation water quality. As indicated, waters with EC_w values greater than 0.7 dS/m (450 mg/L) present increased salinity problems. Only careful management will prevent the accumulation of deleterious amounts of salts in the soil if water with a high EC_w is used for irrigation. Avoid using any water with an EC_w above 3 dS/m.

The salt tolerance of turfgrass and other plants is expressed in terms of the salt content of the soil root zone. For example, as indicated in Table 2, Kentucky bluegrass will tolerate a soil salinity (EC_e, the electrical conductivity of the soil water extract) of up to 3 dS/m. You must therefore consider soil physical characteristics and drainage, both of them important factors in determining root zone salinity, when you decide about the suitability of a given irrigation water. Water with an EC_w of 1.5 dS/m may be suitable for grass grown on sandy soil with good drainage (and thus high natural leaching), but the same water may prove injurious within a very short period if used to irrigate the same grass grown on a clay soil or a soil with limited drainage resulting from salt buildup in the root zone.

The figures in Table 2 give a general guide to the salt tolerance of individual turfgrasses. As indicated, soils with EC_e values below 3 dS/m are considered satisfactory for most turfgrasses. EC_e values above 10 dS/m indicate soils in which only a few salt-tolerant turfgrass species can survive.

Sodium. Sodium content is another important factor in irrigation water quality evaluation. Plant roots absorb sodium and transport it to leaves where it can accumulate and cause injury. The leaf symptoms of sodium toxicity resemble those of salt burn. Because salts can be absorbed directly by leaves, irrigation water with a high level of sodium salts can be particularly toxic if applied to plant leaves via overhead sprinklers. Sodium toxicity is often of more concern on plants other than turfgrasses, primarily because accumulated sodium is removed every time grass is mowed. Among grasses grown on golf courses, annual bluegrass and bentgrass are the most susceptible to sodium phytotoxicity. In these cases, mowing

Table 2. Relative tolerances of California turfgrass species to soil salinity (EC_e).

Sensitive (<3 dS/m)	Moderately sensitive (3 to 6 dS/m)	Moderately tolerant (6 to 10 dS/m)	Tolerant (>10 dS/m)
Annual bluegrass	Annual ryegrass	Perennial ryegrass	Alkaligrass
Colonial bentgrass	Creeping bentgrass	Tall fescue	Bermudagrasses
Kentucky bluegrass	Fine-leaf fescues	Zoysiagrasses	Seashore paspalum
Rough bluegrass	Buffalograss		St. Augustinegrass

From: M. A. Harivandi, J. D. Butler, and L. Wu. 1992. Salinity and turfgrass culture. In D. V. Waddington, R. N. Carrow, and R. C. Shearman (eds.) *Turfgrass*, pp.201-229. Series No. 32. Madison: American Society of Agronomy.

Table 3. Guidelines for the interpretation of water quality for irrigation.

Potential irrigation problem	Unit of measure	Degree of restriction on use		
		None	Slight to moderate	Severe
Salinity				
ECw	dS/m	<0.7	0.7 to 3.0	>3.0
TDS	mg/L	<450	450 to 2,000	>2,000
Soil water infiltration (evaluate using ECw [dS/m] and SAR together)				
if SAR=0 to 3 & ECw		>0.7	0.7 to 0.2	<0.2
if SAR=3 to 6 & ECw=		>1.2	1.2 to 0.3	<0.3
if SAR=6 to 12 & ECw=		>1.9	1.9 to 0.5	<0.5
if SAR=12 to 20 & ECw=		>2.9	2.9 to 1.3	<1.3
if SAR=20 to 40 & ECw=		>5.0	5.0 to 2.9	<2.9
Specific ion toxicity				
Sodium (Na)				
root absorption	SAR	<3	3 to 9	>9
foliar absorption	meq/L	<3	>3	-
	mg/L	<70	>70	
Chloride (Cl)				
root absorption	meq/L	<2	2 to 10	>10
	mg/L	<70	70 to 355	>355
foliar absorption	meq/L	<3	>3	
	mg/L	<100	>100	
Boron (B)	mg/L	<1.0	1.0 to 2.0	>2.0
Miscellaneous effects				
Bicarbonate (HCO ₃)	meq/L	<1.5	1.5 to 8.5	>8.5
(unsightly foliar deposits)	mg/L	<90	90 to 500	>500
pH		normal range	6.5 to 8.4	
Residual chlorine (Cl ₂)	mg/L	<1.0	1 to 5	>5

Adapted from D. W. Westcot and R. S. Ayers. 1984. Irrigation water quality criteria. In G. S. Pettygrove and T. Asano (eds.) Irrigation with Reclaimed Municipal Wastewater - A guidance manual. Report No. 841 -1 wr. California State Water Resources Control Board, Sacramento, CA; and from D. S. Farnham et al. 1985. Water Quality: Its Effects on Ornamental Plants. University of California Division of Agriculture and Natural Resources Publication 2995.

may not provide protection since these grasses are generally cut very short (a stress in itself), and any sodium accumulation will then make up a large proportion of the small remaining quantity of leaf tissue.

The data in Table 3 provide general guidelines for assessing the effect of sodium in irrigation water. As indicated in the table, the level of sodium tolerated by non-turf plants varies with irrigation application method. Most landscape plants will

tolerate as much as 70 ppm (mg/L) sodium when irrigated by overhead sprinkler.

SAR (Sodium Adsorption Ratio). Although sodium in the irrigation water can be toxic to plants, a more common deleterious effect of sodium results from its effect on soil structure. This effect generally is of more concern to golf course superintendents and other professional managers of intensely used turfgrassess.

When irrigation is applied to the soil, the best indicator of sodium effect is a water's Sodium Adsorption Ratio (SAR), a value which should be provided in all laboratory water analyses. As a general rule, water with an SAR value below 3 is considered safe for turf and other ornamental plants (Table 3). Because SAR is such an important factor in water evaluation, however, it merits a thorough understanding.

The high sodium content common to recycled water can cause deflocculation (breakdown) of soil clay particles, severely reducing soil aeration and water infiltration and percolation. In other words, a soil's permeability is reduced by irrigation with water high in sodium. The best measure of a water's likely effect on soil permeability is the water's SAR considered together with its EC_w. SAR is the ratio of the concentration of sodium ions to the concentration of calcium plus magnesium. You can use the formula below to calculate SAR if a laboratory report does not provide it but does provide values for sodium, calcium, and magnesium in meq/L. If values are provided as mg/L or ppm, convert them to meq/L using the conversion factors in Table 1 before you use the formula.

$$(5) \text{ SAR} = \frac{\text{Na}}{\sqrt{(\text{Ca} + \text{Mg}) + 2}}$$

Generally, water with an SAR greater than 9 can cause severe permeability problems when applied to fine-textured (clay) soils over a period of time. Coarse-textured (sandy) soils have fewer permeability problems and can tolerate an SAR of this magnitude. For example, you can successfully irrigate golf greens and sports fields constructed with high-sand-content root zone mixes using high-SAR water because of their good drainage.

For waters high in bicarbonate, some laboratories adjust the calculation of SAR (yielding an "adjusted SAR" or "Adj. SAR") because soil calcium and magnesium concentrations are affected by the water's bicarbonate. In simplest terms, Adj. SAR reflects the water's calcium, magnesium, sodium, and bicarbonate content as well as its total salinity. Other labs use a newer method to adjust the SAR value and report the adjusted value as Adj. R_{Na}. Not all labs have adopted this new method, which adjusts the SAR to account for either the precipitation or dissolution of calcium carbonate, but the unadjusted SAR value is sufficient for our purposes.

Interaction of salinity and SAR. Salts and sodium do not act independently in the plant environment. The effects of sodium on soil particle dispersion (and therefore permeability) are counteracted by a high electrolyte (soluble salts) concentration; therefore, one cannot assess a water's sodium hazard independent of its salinity. The combined effect of water EC_w and SAR on soil permeability is given in Table 3. Note that the table provides general guidelines only. Soil properties,

irrigation management, climate, a given plant's salt tolerance, and cultural practices all interact significantly with water quality in the actual behavior of soils and plant growth.

Bicarbonate and carbonate. The bicarbonate content and, to a lesser degree, the carbonate content of irrigation water also deserve careful evaluation. Recycled waters and well waters are especially likely to contain excessive bicarbonate levels. Substantial bicarbonate levels in irrigation water can increase soil pH, and in combination with carbonate they may affect soil permeability. In addition, bicarbonate content may make itself obvious during hot, dry periods, when evaporation may cause white lime (CaCO₃) deposits to appear on leaves of plants irrigated by overhead sprinklers.

Although high levels of bicarbonate in water can raise soil pH to undesirable levels, bicarbonate's negative impact on soil permeability is often of greater concern. As mentioned above, the bicarbonate ion may combine with calcium or magnesium and precipitate as calcium carbonate or magnesium carbonate. This precipitation increases the SAR in the soil solution because it lowers the dissolved calcium concentration.

Table 3 indicates tolerable levels of bicarbonate in irrigation waters. The bicarbonate hazard of water may be expressed as Residual Sodium Carbonate (RSC), calculated thus:

$$(6) \text{ RSC} = (\text{HCO}_3 + \text{CO}_3) - (\text{Ca} + \text{Mg})$$

where concentrations of ions are expressed in meq/L (see Equation 2 and Table 1 for conversions). Generally, water with an RSC value of 1.25 meq/L or lower is safe for irrigation, water with an RSC between 1.25 and 2.5 meq/L is marginal, and water with an RSC of 2.5 meq/L or more is probably not suitable for irrigation.

pH (hydrogen ion activity). The pH is a measure of water's acidity or alkalinity measured in pH units. The scale ranges from 0 to 14, with pH 7 representing neutral-water with a pH of 7 is neither acidic nor alkaline. As it progresses from pH 7 to pH 0, water becomes increasingly acidic; from pH 7 to pH 14, water becomes increasingly basic (alkaline). The pH units are on a logarithmic scale: there is a tenfold change between each whole pH number. Thus a water with pH 8 is 10 times more basic than a water with pH 7, and 100 times more basic than a water with pH 6. Water pH is easy to determine and provides useful information about the water's chemical properties. Although seldom a problem in itself, a very high or very low water pH can be a warning that you need to evaluate the water for other constituents. The desirable soil pH for most turfgrasses ranges from 5.5 to 7.0; most irrigation waters' pH values, however, range from 6.5 to 8.4. Depending on the properties of the soil where the grass is grown, an irrigation water pH range of 6.5 to 7 would be most desirable. Water

with a pH outside the desirable range must be carefully evaluated for other chemical constituents.

Chloride. Besides contributing to the total soluble salt concentration of irrigation water, chloride (Cl) may be directly toxic to plants grown on a golf course, park, or other landscape site. Although chloride is not particularly toxic to turfgrasses, many trees, shrubs, and ground covers are quite sensitive to it.

Chloride is absorbed by plant roots and translocated to leaves where it accumulates. In sensitive plants this accumulation leads to necrosis: leaf margin scorch in minor cases, total leaf kill and abscission in severe cases. Similar symptoms may occur on sensitive plants if high-chloride water is applied via overhead sprinklers, since chloride can be absorbed by leaves as well as roots. Turfgrasses tolerate all but extremely high levels of chloride as long as they are regularly mowed.

Chloride salts are quite soluble, so they can be leached from well-drained soils with good subsurface drainage. As indicated in Table 3, irrigation water with a chloride content greater than 355 mg/L is toxic when absorbed by roots, while a chloride content greater than 100 mg/L can damage sensitive ornamental plants if applied to foliage.

Boron. Boron (B) is an essential micronutrient for plant growth, though it is required in very small amounts. Even at concentrations as low as 1 to 2 mg/L in irrigation water, it is phytotoxic to most ornamental plants and capable of causing leaf burn (Table 3). The most obvious symptoms appear as a dark necrosis on the margins of older leaves. Turfgrasses generally tolerate boron better than any other plants grown in a landscape, but they are more sensitive to boron toxicity than to either sodium or chloride. Most turfgrasses will grow in soils with boron levels as high as 10 ppm.

OTHER PARAMETERS

Chlorine. Irrigation water originating from municipal recycled water may contain excessive residual chlorine (Cl₂), a potential plant toxin. Chlorine toxicity is almost always associated only with recycled water sources, which are routinely disinfected with chlorine-containing compounds. Chlorine toxicity occurs only if high levels of chlorine are sprayed directly onto foliage, a situation likely to occur only if the recycled water goes straight from the treatment plant to an overhead irrigation system. Free chlorine is very unstable in water, and it will dissipate quickly if the water is stored for even a short period of time between treatment and application to plants. As indicated in Table 3, residual chlorine is of concern at levels above 5 mg/L.

Nutrients. With the exception of municipal recycled water,

the nutrient value of most irrigation waters is negligible. Recycled waters, however, always contain a range of micro (trace) elements sufficient to satisfy the needs of most turfgrasses. They may also contain enough macro (major) nutrients (nitrogen, phosphorus, and potassium) to figure significantly in the fertilization program of a large turfed area.

Most laboratories test recycled water for nutrient content, and many report nutrients in terms of "lb/acre-ft of water applied." The economic value of these nutrients can be substantial. Even where the quantities of nutrients are low, the nutrients can be used very efficiently by plants because they are applied on a regular basis. If the laboratory report does not include the lb/acre-ft of nutrients, you can use the following conversion formula to determine this value for any nutrient contained in the irrigation water:

$$(7) \text{ lb/acre-ft of nutrient} = \text{nutrient content (mg/L or ppm)} \times 2.72$$

Suspended solids. The suspended solids (SS) in irrigation water are the inorganic particles such as clay, silt, and other soil constituents, as well as organic matter such as plant material, algae, and bacteria. These materials do not dissolve in water and can thus be removed only by filtration, an essential step for most irrigation systems in which plugged sprinkler head openings or plugged valves can reduce a system's efficiency and life span.

The suspended solids in domestic municipal water sources are negligible and not a cause for concern. However, you should monitor suspended solids in well, lake, pond, canal, or recycled waters used for irrigation. Besides the mechanical problems they present for irrigation systems, suspended solids can seal a soil surface, especially on sand-based golf greens, sports fields, and other sandy media. Solids can fill in air spaces between sand particles, reducing infiltration and drainage and increasing compaction. Since these effects vary considerably with the type of suspended solid, the irrigation system, and the turfgrass soil, it is difficult to formulate general acceptable values for suspended solids in irrigation water. General consensus says that an SS level below 50 mg/L is safe for a drip irrigation system while values above 100 mg/L will cause plugging, but the complexity and variability of irrigation waters and systems make effective filtration the most sensible approach to controlling hazards posed by suspended solids.

Turbidity. Another factor, turbidity, measures the transmission of light through water with respect to matter suspended in the water. This measurement frequently appears in laboratory results, especially in analyses of recycled water, and it is an important tool in determining the quality of domestic and recycled water. It is not a useful tool for evaluating irrigation water, primarily because there are no uniform guidelines for

acceptable turbidity values for irrigation water.

SAMPLING IRRIGATION WATER

The results of a laboratory water test are only as good-and therefore only as useful-as the water sample tested. Thus, a tested sample must be truly representative of the irrigation water applied. Poor or contaminated samples result in misleading evaluations. Since the few ounces of water finally tested represent a tiny fraction of the millions of gallons of water eventually used to irrigate a golf course, cemetery, or park, getting a good sample can be trickier than it may at first appear.

There are no strict rules for sampling water. Equal attention is due, however, to the sampling equipment, timing, location, and handling of the sample. Some laboratories provide instructions on what type of containers to use for sampling and the amount of water needed for a sample. If no instructions are available from the lab, use clean plastic bottles rather than glass since some glass bottles may be a source of boron. Also, plastic bottles reduce the chance of breakage during transfer. Always use a clean bottle; if unsure of its cleanliness, wash the bottle thoroughly first, using the water to be sampled.

Label the bottles immediately after sampling. Use permanent ink and good quality labels. Record the time, date, and location of sampling. Make sure each sample bottle is tightly closed.

A water sample should represent the water actually applied to

plants. Thus, for example, you should collect water from sprinklers while they are operating. Similarly, the quality of water stored in ponds or lakes may change over time, particularly if the water has been recycled or if it is held for an extended period during hot weather, so sampling must take this into account. Water quality may also vary from season to season, so it may be appropriate to take samples for analysis at different times of year.

INTERPRETING WATER QUALITY HAZARDS

Clearly, water quality involves a complex set of factors and each irrigation water must be analyzed on an individual basis. Very few water sources are absolutely unsuitable for turfgrass irrigation. While you can use the discussion in this publication as a general guide to help you determine whether you have a turfgrass water quality problem, any determination of the precise nature and magnitude of that problem may require more than just water analysis. Climate, soil chemistry and physics, use patterns, and turf quality expectations all contribute both to any problem and to any potential remedies in turfgrass water quality.

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Drought and Heat Stress on Sportsfields

Stephen T. Cockerham¹

Turfgrasses on sportsfields are subject to many stresses and each induces a strain or injury to the plant. The most common stress on sportsfields is traffic. In the summer when sports traffic is often at the maximum, drought and high temperature stresses are also occurring. Heat stress on sports fields rarely occurs without drought stress.

Traffic Stress

Cleated-shoe sports traffic causes injury to turfgrasses by (1) soil compaction, (2) the abrading and crushing of tissue, and (3) the tearing of roots and shoots with turf displacement. Soil compaction has been called a hidden stress due to the indirect impact on the plant through the affect on aeration, soil strength,

plant and soil moisture relationships, and soil temperature. A more direct and sudden impact by traffic is the sudden water and solute loss from the tissue injury. Physiological shock is imposed on the turf and growth is reduced or stopped. As a result, the plant becomes more susceptible to such environmental pressures as drought and high temperature.

Drought Stress

Water enters the turfgrass plant through the root hairs near the root tip and diffuses into the water-conducting cells moves upward through the roots, stem, and blades then into the atmosphere. The plant process by which water moves through the plant for solute transport and for temperature regulation is

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called transpiration. The water leaves the plant through pores, in the surface of the grass blades, called *stomates*.

When the amount of water leaving the plant in transpiration is greater than that entering the roots a water deficit occurs, creating drought stress. On bright sunny days, transpiration can be faster than water absorption, even in moist soil, and wilt occurs. Wilt is the first visual expression of drought stress as the turf shows a patina of gray-blue color. The grass blades do not spring back when stepped on and they appear dry and limp. In the early stages, an application of water leads to satisfactory recovery. If the permanent wilting point is reached, the turf will not recover and the plants die.

An early response of the grass plant to water deficit is to close the stomata pores to reduce water loss; when the stress abates, the stomata may reopen. As a result of the closure, growth slows. Continued water stress also results in reduced tillering and, in time, a loss of turf density. Shorter rhizomes and stolons with shorter internodes will also be produced. Root growth will not be as readily affected, leading to an increase in the root:shoot ratio. Moderate water stress may actually stimulate deeper rooting. Sports turf managers can produce turf better able to withstand drought by gradually lengthening the intervals between irrigations to create gradual water stress for deeper rooting.

Plants under drought stress accumulate soluble carbohydrates in leaves, roots, and stem bases and there is frequently a surge of growth at the end of a droughty period. By controlling drought stress, the sports turf manager can time the growth surge to coincide with a particular need, such as an event from which quick recovery is important.

Evapotranspiration is the combined plant water loss from transpiration and from evaporation and is an important concept used in the development of turfgrass irrigation strategies. For turf management purposes, evapotranspiration is thought of as the water use rate of the turf. It is measurable and is reported for irrigation scheduling.

Warm-season grasses generally have lower water use rates than cool-season grasses. Bermudagrass and zoysiagrass, warm-season grasses used on sports fields, have mechanisms for drought avoidance, including extensive root systems and/or the ability to tolerate high concentrations of solutes in internal water.

Some cool-season turfgrasses, primarily the fescues, have leaf characteristics that are effective in limiting transpirational water loss. When water deficits occur, leaves of tall fescue, though not normally rolled will roll tightly lengthwise with stomata inside, enclosing the stomata in tiny chambers with high humidity and low transpiration. Tall fescue has a high water

use rate, but good drought tolerance results from the rolling of the leaves and an extensive root system.

Heat Stress

Warm-season turfgrasses possess excellent high temperature tolerance while heat stress is often a limiting factor in the use of cool-season turfgrasses. Increased transpiration due to rising temperature results in stomatal closure, thus reducing transpirational cooling and increasing leaf temperature. High temperature stress reduces grass shoot growth, tillering, root growth, stand density, and leaf size. Grasses with good drought tolerance tend to be more tolerant of high temperatures.

Heat stress injury begins to occur at temperatures between the optimum for cool-season turfgrass growth, about 75-85° F, and the upper limit for turfgrass plant growth, which is about 115-130°F measured in the canopy and surface soil. Reversible injury occurs slightly below the upper limit for growth and the irreversible injury occurs over the upper limit for growth. The range for killing temperature is 130-140°F with exposure time being critical as 2-3 hours for cool-season grasses and 8-10 hours for warm-season grasses. The temperature of the plant canopy may greatly exceed that of the ambient air.

MANAGING DROUGHT AND HEAT STRESS OF SPORTS TURF

Use drought/heat tolerant sportsturf grasses.

Increase root distribution and maximize carbohydrate reserves.
Moderate N fertility
Raise cutting heights.
Reduce mowing frequency.
Gradually increase intervals between irrigations

Relieve compaction by aerification.

Irrigate to replace losses to evapotranspiration.

Maintain adequate K levels to reduce turfgrass wilting.

Syringe during periods of high temperature stress to decrease wilting tendency.

WARNING ON THE USE OF CHEMICALS

Pesticides are poisonous. Always read and carefully follow all precautions and safety recommendations given on the container label. Store all chemicals in their original labeled containers in a locked cabinet or shed, away from food or feeds and out of the reach of children, unauthorized persons, pets, and livestock.

Recommendations are based on the best information currently available, and treatments based on them should not leave residues exceeding the tolerance established for any particular chemical. Confine chemicals to the area being treated. THE GROWER IS LEGALLY RESPONSIBLE for residues on his crops as well as for problems caused by drift from his property to other properties or crops.

Consult your County Agricultural Commissioner for correct methods of disposing of leftover spray material and empty containers. Never burn pesticide containers.

PHYTOTOXICITY: Certain Chemicals may cause plant injury if used at the wrong stage of plant development or when temperatures are too high. Injury may also result from excessive amounts of the wrong formulation or from mixing incompatible materials. Inert ingredients, such as wetters, spreaders, emulsifiers, diluents and solvents, can cause plant injury. Since formulations are often changed by manufacturers, it is possible that plant injury may occur, even though no injury was noted in previous seasons.

NOTE: Progress reports give experimental data that should not be considered as recommendations for use. Until the products and the uses given appear on a registered pesticide label or other legal, supplementary direction for use, it is illegal to use the chemicals as described.

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