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Managing Turfgrasses During Drought

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Turfgrass directly affects the way most Californians live. It provides the play medium on many recreational facilities; it modifies our environment to make life easier and more pleasant; it provides opportunity for a pleasing and functional home landscape; and, in turn, the turfgrass industry has a significant direct economic impact on our economy and indirect impact on our tourist economy.

Turfgrasses need water for growth and development. There is not enough precipitation and it is not adequately spaced throughout the year to sustain turfgrasses or other landscape plants. Therefore, supplemental water supplied as irrigation is needed.

Many California turfgrass and landscape facilities are facing, or will face, a serious water deficit this summer. Several California water districts have already enacted mandatory water rationing and many others are strongly encouraging water conservation. It is therefore essential for turfgrass managers and lawn owners to take preventive drought measures, especially in areas where turfgrass irrigation has been severely reduced or entirely eliminated.

It is important to remember that a brown-dormant turf possessing a healthy lateral stem system may not be dead; such a turf often has the recuperative potential to initiate new growth within a few days after the first significant fall rain. This said, several cultural practices may help turf plants survive drought.

IRRIGATION

— Repair leaky pipes, heads and valves immediately. Correct irrigation systems that have a poor uniformity of water distribution.

— Irrigate when first signs of wilt occur. Spots in the lawn that turn bluish gray color, footprints that remain in the grass long after being made, and many leaf blades folded or rolled lengthwise are signs of wilt.

— Irrigate infrequently and deeply. Stretch the time interval between irrigations as much as possible.

— Avoid runoff by matching water application rates to soil infiltration rates. If runoff occurs, apply water in several short repeat cycles, instead of one single long irrigation.

— irrigate late at night or in early morning when wind and evaporation losses are lowest.

— Reduce irrigation of shaded relative to unshaded areas.

— Large turf areas should investigate the possible availability of effluent water, if state and local regulations permit its use.

FERTILIZATION

— If nitrogen must be applied because of play or other special use, then very light nitrogen rates applied infrequently should be considered. Moderate or heavy spring and summer nitrogen applications lead to higher water use due to stimulated top growth. Certainly, lush growth is to be avoided where low water use rates and drought resistance is desired.

— Apply potassium if deficiencies are suspected. Potassium promotes increased root growth and thicker cell walls, thus enhancing drought tolerance.

MOWING

— Increase mowing height to the highest allowable height for the turfgrass species grown. Following are the recommended mowing height ranges.

Turfgrass Species	Cutting Height Range Inches
I. Cool Season Turfgrasses	
Creeping bentgrass	0.2 - 0.5
Colonial bentgrass	0.5 - 1.0
Red fescue	1.0 - 2.0
Kentucky bluegrass	1.5 - 2.5
Perennial ryegrass	1.5 - 2.5
Tall fescue	1.5 - 3.0
II. Warm Season Turfgrasses	
Bermudagrass	0.5 - 1.0
Zoysiagrass	0.5 - 1.0
Seashore Paspalum	0.5 - 1.0
St. Augustinegrass	0.5 - 1.5
Kikuyugrass	0.5 - 1.0

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By increasing the height of cut, turfgrass leaf area and thus photosynthesis are increased. This results in more carbohydrates for plant growth, especially root growth. In general, the higher the height of cut on turf,the deeper and more extensive will be the root system.

— Do not allow grass to grow more than 1 1/2 times its mowing height. (e.g., if the mower is set for 2-inch cut, mow before the turfgrass reaches an overall height of 3 inches.)
— Keep mower blades sharp and properly balanced. A leaf blade cut by a sharp blade will heal more quickly, losing less water than a leaf shredded by a dull mower.

AERIFICATION

— Aerify (by coring or slicing) slopes and compacted soils to permit efficient water penetration into the soil. Compaction can reduce water entry into the soil, resulting in wasted water from runoff or evaporation.

WATER USE PRIORITIES

— Make a list of priorities for water use. For example, on a golf course, greens are usually at the top and rough areas at the bottom of such a list. Under 30-40 percent water restrictions it may be possible to cut back or even shut off irrigation on rough area and fairway approaches and still provide normal amounts of water to the rest of the course. A similar method may be employed in many other turf areas. Allowing the lawn in front of a home to turn brown from no irrigation may not be a bad trade off for a green back yard!

— Often, several turfgrasses are separately found in a turfed site. More drought resistance and deeper rooted turfgrasses can withstand a longer drought period by going dormant and resuming growth once water is available. Less drought-resistant species may actually die in a prolonged drought period.
— Ranked drought resistance for California turfgrasses, based on root depth and recuperative potential, would be as follows: kikuyugrass, bermudagrass, Seashore Paspalum, St. Augustinegrass, zoysiagrass, tall fescue, red fescue, Kentucky bluegrass, perennial ryegrass, colonial bentgrass, and creeping bentgrass.

DORMANT TURF

— In some cases, a brown, dormant turf resulting from lack of irrigation may not be objectionable. There is always, however, the option of turning a brown lawn “green” by applying turf colorant (synthetic turf dyes) to dead or dormant grass. Some colorants may provide acceptable appearance for up to 10 weeks. Turf colorants are available from turfgrass suppliers or garden centers. If using colorants, be sure to follow manufacturer’s label instructions for rates and volume.

In summary, each turfgrass manager or lawn owner has special, specific problems and opportunities on his/her facility. To deal with a drought condition effectively, the user must know local water availability, be aware of turfgrass management practices that lead to water conservation and implement them.

Buffalograss Turf Performance and Management in Shade

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Buffalograss (Buchloe dactyloides Nutt.) is a warm-season perennial grass species native to the North American Great Plains. Its potential for use as low maintenance and drought-tolerant turfgrass is gaining increasing attention from both the public and turfgrass industry. In arid and semiarid, highly populated metropolitan areas, water has become a limited natural resource. In California, drought problems have caused municipal governments to implement restrictions on the amount of water that may be used on home lawns, golf courses, and in the landscape. Water shortages and changes in philosophy by many turfgrass “consumers” have led to increased use of drought-tolerant grasses on sod farms, golf courses, industrial and public parks and similar locations. Buffalograss is one of the most drought-tolerant grasses among turfgrass species. However, its use is limited because of its remarkably long period of winter dormancy, undesirable turf quality, and shade intolerance.

Genetic variation in winter turf color and cold resistance has been found among buffalograss collections, and turf quality has been improved through selection and breeding conducted at the University of California, Davis. However, there is no information available about shade adaptation in buffalograss.

Most shade-related problems to turfgrass are a result of blocking out direct sunlight by tree canopies, large buildings, and other kinds of structures. Extensive acreage of shaded turf exists in the United States. It has been estimated that in the United States, 20 to 25 percent of turfed areas are under some degree of shade. Nearly all parks, golf courses, cemeteries, schools, and lawns, either commercial or residential, have unique areas where turf is difficult to grow to shade conditions. There is no simple solution or single recommendation available. One reason is that the problem itself is very complex. The conditions found in a shaded site can vary significantly not only between climatic regions but with a relatively small geographic area. For example, the shade cast from a building can be very different from the shade cast by trees. In addition, different tree species may affect the performance of a particular turfgrass growing beneath them.

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Buffalograss turf performance in shade was studied at UC Davis. This report presents the information of improved turf quality and management practices of buffalograss under 30 and 50 percent full sunlight, and the findings may serve as references for buffalograss management in shade.

MATERIALS AND DISCUSSION

Ten-foot by lo-foot plots of buffalograss turf were established during the summer of 1987 from a commercial seed variety Texoka and a vegetatively propagated experimental variety Highlight 24 selected at UC Davis. The plots were mowed at a 1 1/2-inch height, irrigated once a week through the summer months, and fertilized with 1 pound of nitrogen per 1,000 sq ft as ammonium sulfate in May, July and September of 1988. In the second week of May 1989, l-inch diameter turf plugs were collected from the Texoka and Highlight 24 turf and transplanted for the shade studies. For shade treatment, lo-foot by 20-foot field plots were shaded with black nylon screens which provided either 50 percent full sunlight (daily energy accumulation of about 1.5 mol photons $m^{-2}h^{-1}$ in July) or 30 percent sunlight (0.9 mol photons $m^{-2}h^{-1}$). Control plots were not shaded. Buffalograss plugs of each of the two varieties were transferred into a lo-foot by lo-foot area at 2-foot intervals, and the two varieties were planted in each half of the lo-foot by 20-foot plots. Duplicate plots were used for each shade treatment, and the plots and the treatments were completely randomized. The turf was mowed once every two weeks at a 2-inch height. Ammonium sulfate was applied at a rate of 1 pound of nitrogen per 1,000 sq ft on May 15, 1989. The following turf characters were measured:

1. Growth rate of the buffalograss was measured by the rate of stolon elongation. Length of the longest stolon of each of three turf plugs for both buffalograss varieties in each turf plot was measured at an interval of 6 days in the second week of July 1988. These data are presented as inches of growth per day.
2. Turf dry weight was measured by collecting 1 square foot of turf above the soil surface on September 30, 1989.
3. Percentage of ground covered by buffalograss turf in each turf plot was visually estimated on September 28, 1989.

RESULTS AND DISCUSSION

Figure 1 shows that Highlight 24 had a greater turf establishment rate than Texoka. Highlight 24 produced a full turf cover by August 15 three months after transplanting. Buffalograss did not reach its maximum growth rate until July. Texoka had a slower growth rate and produced only 70 percent turf cover by the end of September.

The greater turf spreading rate of Highlight 24 is attributable to its greater stolon elongation rate. Table 1 shows that Highlight 24 had a stolon elongation rate of 0.44 inch per day under full sun, and 0.24 and 0.13 inch per day under 50 and 30 percent sunlight, respectively. Texoka had only half of the stolon elongation rate of Highlight 24. Under 50 percent sunlight, it produced less than 50 percent ground cover by September 1989. By the second week of September, Highlight 24 had produced 100 and 95 percent ground cover under 50 and 30 percent sunlight, respectively. In contrast, Texoka only developed 50 percent ground cover under 50 percent light and 40 percent cover under 30 percent light.

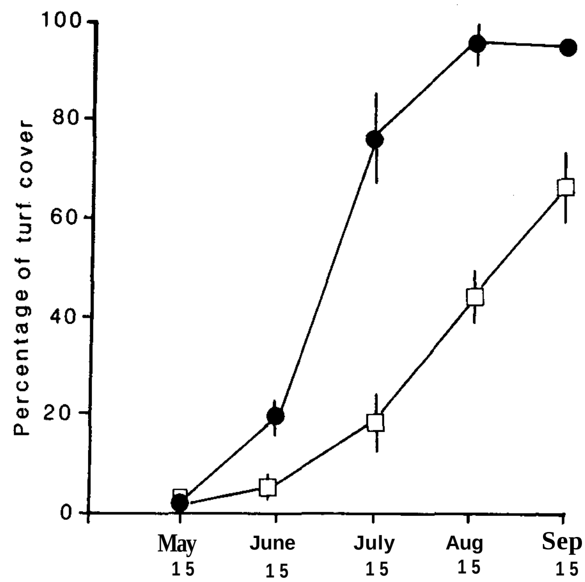

Fig. 1. Turf development rates from 1 inch diameter plugs of Highlight 24 (●) and Texoka (□) buffalograss varieties grown under full sun.

Table 1. Rate of stolon elongation of two buffalograss varieties established from l-inch plugs.

	Rate of stolon elongation (inches per day)		
Varieties	Full sun	50% light	30% light
Texoka	0.24±0.05	0.13t0.04	0.04±0.01
Highlight 24	0.44±0.10	0.24f0.05	0.13±0.03

Buffalograss turf grown under shade was thinner and more open than that grown under full sun. Therefore, the turf dry weight was severely reduced. Figure 2 shows that Highlight 24 and Texoka produced 50 gram and 30 gram dry weight per square foot of turf, respectively, under full sun. Under 50 percent sunlight, both Highlight 24 and Texoka produced about 20 grams of turf dry weight per square foot. The turf dry weight was further reduced to about 10 gram per square foot for both buffalograss varieties under 30 percent sunlight.

The results of the shade studies indicate that buffalograss basically is intolerant of shade. However, turf quality differences in shade exist between buffalograss varieties. Highlight 24 is a recently selected and vegetatively propagated buffalograss line. Its superior turf performance under shade is attributable to its greater intrinsic growth rate. This character in buffalograss not only improves turf quality in shade but also is of importance in turf establishment and recovery from traffic damage. A buffalograss variety that is able to produce 100 percent ground cover under moderate shade may be used in parks, cemeteries, and golf courses where turf is under minimum maintenance.

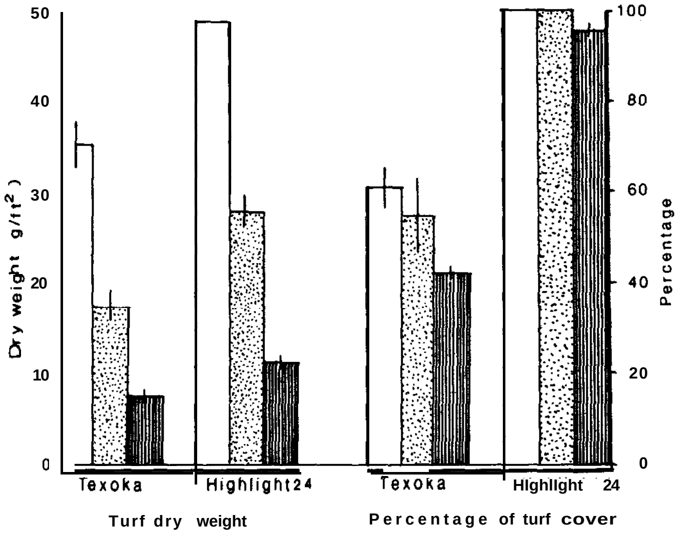

Fig. 2. Dry weight production and percentage of turf cover Of buffalograss after one season Of growth under three different light conditions: **full sun** ( ), 50% sunlight ( ), and 30% **sunlight** ( ).

MANAGEMENT OF BUFFALOGRASS IN SHADE

Buffalograss turf management in shade has rarely been studied and reported. The information of buffalograss management in shade generated from the buffalograss research program conducted at UC Davis may serve as a reference for buffalograss management.

TURF ESTABLISHMENT

Buffalograss can be established either by seed or by vegetative plant materials. Texoka and Texas Native are commercially available seed varieties. Five to 6 pounds of seed per 1,000 sq ft seeding rate (seed burrs) is recommended. For vegetative establishment, 1- to 2-inch diameter buffalograss plugs are used and transplanted at a 2-inch depth and at 1- or 2-foot intervals. June through August is the best season for buffalograss turf establishment. For seeded turf, four to six months are required for establishment, and it takes two summers to become mature. Turf established from the vegetatively propagated Highlight buffalograss lines (fast growth rate) during July takes 6 to 7 weeks to make a 100 percent ground cover. Buffalograss lines having high turf density have been selected, and it is possible to establish buffalograss by sod.

FERTILIZATION

Buffalograss requires relatively little fertilizer for its normal growth. Application of 1 pound of nitrogen per 1,000 sq ft in the first week of May for stimulating new growth is recommended. The second application in mid July is important for maintaining a healthy growth through the growing season. The third 1 pound of nitrogen may be applied at the end of August or the first week of September to stimulate a late season flush of growth for prolonging winter turf color and to enhance early spring regrowth from winter dormancy.

MOWING

Buffalograss has a low growth stature and only requires infrequent mowing. Under full sun it should be mowed below 1 inch. However, in shade, buffalograss tends to grow more erect than its counterparts in sunny areas. Therefore, a higher mowing height of 1 1/2 inches is recommended in order to leave sufficient amounts of leaf area for photosynthesis and carbohydrate production: Through the growing season, from May to October, turf may be mowed once a week or once every two weeks. No mowing is needed from late October to April of the following year during the cool winter months, while the growth slows down or the turf is dormant.

IRRIGATION

Buffalograss is drought-tolerant. In shade, especially, it requires a minimum amount of irrigation to maintain an acceptable turf quality.

ACKNOWLEDGEMENT

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Hard Fescue - Characteristics and Herbicide Tolerance

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Hard fescue (Festuca longifolia), a native of Europe, is a medium-tall, semi-erect, long-lived, densely tufted, noncreeping bunch-type grass. Its leaf texture is very fine. The plant is a heavy root producer and has a high root-to-shoot ratio. Its root system enables the plant to draw water from deep within the soil profile; this characteristic contributes considerably to the grass's high drought resistance. A heavy root system, abundant, dense leaves, and a low crown make hard fescue an excellent grass for erosion control.

Hard fescue is adapted to mowing; however, it is not recommended for mowed turf in areas with hot summers. Nonmowed hard fescue makes an attractive ground cover with a natural, meadow-like appearance.

Although hard fescue is adapted to a wide range of soil conditions, its performance is best on well-drained soil with a pH range of 5-6. The species does not tolerate "water-logged" conditions on saline or alkali soils, but it does well on low-fertility soils and in shaded areas.

The recent increase in demand for low-maintenance turf and landscape plants makes hard fescue a prime candidate for a minimum maintenance "grassy" ground cover. Slopes, median strips, golf course roughs, cemeteries and nonused areas of parks are among the many potential sites for this grass.

A four-year-old hard fescue plot at the UC Field Station in Santa Clara has proven itself as a low-maintenance nonmowed turf for California's central coast region. This plot, half of which was mowed to 1 1/2 inches and the other half nonmowed, received not more than 2 pounds of nitrogen per 1,000 sq ft per year. The mowed section thinned out considerably and was infested heavily with weeds. The nonmowed half, however, consistently rated high for color and quality. With drooping leaves attaining not more than 12 inches in length, and thinned seed heads, it appeared natural and attractive. Since leaves stay green throughout the year, stands should not be a fire hazard.

Hard fescue clearly qualifies as a low-maintenance grass sward. It can be left unmowed, and requires no more than 2 pounds N/1,000 sq ft/year. Note, however, that summer irrigation is essential if hard fescue is grown as turf or ground cover and green color is desired.

Commonly used hard fescue cultivars are 'Scaldis,' 'Tournament,' 'Spartan,' and SR 3000.

Due to the rising popularity of this species, lack of information regarding its tolerance to various herbicides has become an increasing concern. To evaluate hard fescue's reaction to commonly used herbicides, the following two studies were conducted.

POSTEMERGENCE HERBICIDES STUDY

This study evaluated turf tolerance to commonly used post-emergent herbicides. The herbicides listed in Table 1 were applied on July 15, 1988 to an established stand of 'Spartan' hard fescue and reapplied on August 2, 1988. The stand was mowed at 2.5 inches during the term of the study. It was irrigated as needed and received 2 pounds of nitrogen per N/1,000 sq ft as ammonium nitrate. Herbicides were applied with a CO_2 backpack sprayer using flatfan nozzles at 37 psi and 50 gallons of water per acre. Treatments were replicated four times on 5' x 5' plots in a randomized complete block design. Air temperatures at the time of first and second applications were 72 F and 68 F, respectively. Plots were visually rated for phytoxicity after the first and second herbicide applications. No weed species were present. Table 1 summarizes the phytotoxicity data from this trial. Climatological data for the duration of the study are summarized in Table 2.

Table 1. Effects of postemergence herbicides on hard fescue.

		Visual Ratings					
		Phytotoxicity**			% Green Grass Cover***		
Treatment*	Rate lb ai/acre	7/22/88	7/29/88	8/17/88	10/5/88	10/25/88	12/1/88
2,4-D oil soluble amine (3E)	0.5	1.2	1.5	1.2	99.5	99.5	100
2,4-D oil soluble amine	1.0	1.5	1.2	1.2	98.7	100	100
triclopyr (4E)	0.25	1.5	1.5	1.2	100	100	100
triclopyr	0.5	1.2	1.7	1.0	100	100	100
MSMA (6S)	1.5	4.5	5.2	6.5	82.5	95.0	100
MSMA	3.0	6.0	7.5	8.0	78.7	88.7	100
bromoxynil (4E)	0.5	1.2	1.2	1.5	96.2	98.7	100
bromoxynil	1.0	1.2	1.0	1.0	100	100	100
Trimec (2.2E)	1.0	1.2	1.0	1.0	100	100	100
Quadmec (1.8E)	1.8	4.0	5.5	6.2	82.5	96.2	100
Super Trimec (ester) (2.0E)	0.75	1.7	1.2	1.5	93.7	98.7	100
triclopyr + clopyralid	0.25 + 0.0825	1.2	1.0	1.0	100	100	100
triclopyr + clopyralid	0.5 + 0.165	1.0	1.0	1.2	100	100	100
triclopyr + trimec	0.5 + 1.0	1.7	1.7	2.0	92.0	97.0	100
control	---	1.2	1.2	1.2	100	100	100
LSD (0.01)****	---	1.4	1.4	1.1	10.8	6.8	---

*First application: 7/15/88. Second application: 8/2/88.

**Phytotoxicity visual ratings are on a scale of 1-10, with 10 being complete kill of hard fescue.

***% green grass cover visual ratings are percentage of each plot covered by uninjured green grass.

****LSD (Least Significant Difference) for a characteristic exists between two treatments when differences in their rating for that character exceeds the LSD listed.

[1] Area Turf AdVisor, Alameda, Contra Costa and Santa Clara counties, and Weed Scientist, Cooperative Extension. UC Davis.

Table 2. Average monthly air and soil temperatures at Santa Clara Field Station, Santa Clara, California *1988-89)

Month	Air Temperature F			Soil' Temperature F		
1988	Ave Max	Ave Min	Mean	Max	Min	Mean
June	79.3	56.6	67.95	72	64	68
July	85.2	60.1	72.65	76	70	73
Aug	82.4	59.3	70.85	76	70	73
Sep	80.9	55.6	68.25	74	66	70
Oct	74.3	55.1	64.70	70	60	65
NO"	64.9	49.4	57.15	64	51	57.5
Dec	56.7	41.3	49.00	54	43	48.5
1989						
Jan	58.3	39.6	48.95	49	42	45
Feb	58.1	40.5	49.30	54	40	47
Mar	65.5	45.1	55.30	61	50	55.5
Apr	75.3	53.3	64.30	69	61	65
May	70.6	53.0	61.80	71	62	66.5
Jun	77.0	56.7	66.85	70	65	67.5
Jul	82.0	55.6	68.80	72	68	70

' Soil temperature measured 4 inches below surface. Maximum and minimum are highest and lowest figures for the month.

Table 3. Effects of preemergent and selected herbicides on hard fescue.

Treatment'	Rate lb ai/acre	Visual Ratings Phytotoxicity*' 5/4/89	S/19/89	7/19/89
DCPA (Dachtal 75 WP)	I0	1	1	1
bensulide (Betasan 4E)	I0	1	1	1
pendimenthalin (Pre M 60 WDG)	3	1	1	1
dithiopyr (Dimension 1E)	0.5	1	1	1
oxadiazon (Ronstar 50 WP)	2	5	5.5	1
prodiamine (Endurance 65 WDC)	1	1	1	1
benefin + trifluralin (Team 2G)	2	1	1	1
isoxaben + trifluralin (Snapshot 2.5 G)	2.5	1	1	1
benefin (Balan 60 WDG)	3	1	1	1
trifluralin (Treflan 4 E)	0.5	1	1	1
isoxaben (Gallery 75 DF)	2	1	1	1
sethoxydim (Poast 1.5)	0.5	1	1	1
flusifop-p-butyl (Fusilade 1)	0.5	1	1	1
control	---	1	1	1
LSD (0.0l)***	---	0.4	0.3	---

' Herbicide application date: 3/31/89.

t. Phytotoxicity visual ratings are on a scale of l-10, with 10 being complete kill of hard fescue

''' LSD (Least Significant Difference) for a characteristic exists between two treatments when differences in theirrating for that character exceeds the LSD listed.

Data from Table 1 indicate that the treatments containing MSMA alone or in combination with broadleaf herbicides (i.e., Quadmec) injured hard fescue after the first application in July. This injury was again observed after the second application. The ester formulation of Trimec (Super Trimec) was injurious after the second application. Other herbicides did not injure the turf above a rating of 3 on a scale of l-10. This test, with two applications of postemergence herbicides, identifies herbicides that can be safely used for post-emergence broadleaf weed control in hard fescue turf. MSMA, a material intended for postemergence grass control, should not be used on hard fescue turf.

A second trial evaluated several preemergent herbicides and their phytotoxicity effects on hard fescue. Two postemergent herbicides, effective on grass weeds, were also included in this trial. All the herbicides used in this study and their rates of application are listed in Table 3. The herbicides were applied on March 13, 1989 to the hard fescue stand used for the postemergence herbicide study described above. All maintenance practices for the turf were as described above. Each treatment and check plot were replicated 4 times on 5' x 5' plots in a randomized complete block design. Air temperature at the time of application was 55 F. Plots were visually rated several times for a period of four months after application for herbicide phytotoxicity effects. No weeds were present. Table 3 summarizes the phytotoxicity data from this trial. Climatological data for the duration of this study are summarized in Table 2.

Data from Table 2 indicate that none of the herbicides caused injury to hard fescue with the exception of oxadiazon (Ronstar). Even the two postemergent herbicides, flusifop-p-butyl (Fusilade) and sethoxydim (Poast) did not injure hard fescue. The phytotoxicity of oxadiazon lasted for only three months and the grass eventually recovered. However, since other preemergent herbicides had no injurious effect on hard fescue, use of oxadiazon is not recommended.

Similarly, flusifop-p-butyl and sethoxydim, both grass post-emergent herbicides, cause no injury to hard fescue, when, per the previous study, MSMA cannot be used. It is important to note, however, that neither flusifop-p-butyl nor sethoxydim are currently registered for use on any species of turfgrasses and should not be used until they are.

Note. Data in this report do not constitute a recommendation for use. Until the chemicals with their uses appear on a registered pesticide label or other legal form of instructions, it is illegal to use them as described herein. References to commercial names do not constitute a University of California recommendation or discrimination, implied or otherwise.

Acknowledgement

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Fine-Leaf Fescue Performance for California Central Coast

M. Ali Harivandi and Lin Wu[1]

Although fine-leaved fescues have been available for turf purposes since the 1930s and '4Os, most of them did not come to the market until 20 years later. Several improved cultivars were introduced after 1970.

The most common botanical categorization of fine-leaved fescues, all of which are perennial, cool-season grasses, recognizes four distinct grasses: creeping red fescue (Festuca rubra ssp. rubra); Chewings fescue (F. rubra ssp. comutata); sheep fescue (F. ouina ssp. ovina); and hard fescue (F. longifolia). Of these four, creeping red fescue, a native of Europe, is the most widely used for turf purposes. It is comprised of two distinct types, both of prime importance to turf breeders. One of the creeping red fescue types includes fine-leaved, low-growing grasses with short, thin rhizomes. These grasses are weak creepers and are therefore slow to fill in bare areas. Commonly known as slender creeping red fescue, this type is well-represented by the cultivars 'Dawson' and 'Logro.'

The second type of creeping red fescue is a strong creeper with long, spreading rhizomes and wider leaves. This type is not so tolerant of close mowing and grows less densely than the first type. However, excellent seedling vigor makes grasses of this type particularly valuable as companion grasses during turf establishment. The cultivars 'Ensylva,' 'Fortress,' ' Ruby' and 'Pennlawn' are good examples of this group.

Both types of creeping red fescue are adapted to well-drained, dry and moderately shaded sites; they are especially intolerant of wet conditions. Most require minimal levels of nitrogen and a pH of 5.5 to 6.5. Cutting heights of 1 to 2.5 inches are common, with higher heights preferred under shady conditions.

Chewings fescue, also native to Europe, is fine-leaved, low-growing, and without rhizomes. It is a bunch-type grass which spreads, slowly even under mowing, by basal tillering. It tolerates mowing as close as 1 to 1.5 inches where summers are cool; in warmer areas, mowing heights of 2 to 3 inches are best. Chewings fescue forms a denser turf than creeping red fescue, especially under close mowing. It does not tolerate extremes in temperature but does tolerate shade and drought well. It is adapted to well-drained, coarse-textured, acidic, and infertile soils. A number of Chewings fescue cultivars exist; examples include 'Barfalla,' 'Cascade,' 'Jamestown,' 'Koket,' 'Wintergreen' and 'Shadow.'

Sheep fescue, a noncreeping bunch-type grass with tufted, stiff, bluish- green leaves, is indigenous to North America and Eurasia. It forms a relatively low quality turf and has not been widely used for turfgrass purposes. Its main use is stabilization of well-drained, droughty, coarse-textured, acid soils of low fertility. It is not adapted to either close mowing or intensive culture. Examples of sheep fescue cultivars are 'Covar,' 'Aries' and 'Azay.'

Hard fescue, a native of Europe, is also a noncreeping bunch-type grass similar to sheep fescue but with tougher, wider leaves. Its drought tolerance is less than that of sheep fescue but better than that of creeping red fescue. It is quite deep-rooted and has a high root-to-shoot ratio, a major reason for its drought tolerance. Hard fescue is shade tolerant but does not adapt to close mowing. Nonmowed hard fescue are attractive ground covers and often used for soil stabilization on roadsides and ditch banks, and for minimum maintenance, low quality, and nonuse areas. Commonly used cultivars of hard fescue are 'Biljart,' 'Durar,' 'Scaldis' and 'Tournament.'

Although fine fescues are used as mono-stands (i.e., fine fescues alone and not in a mixture with other turf species) of turf in several regions of the upper one-third of the United States, the use of them as mono-stand turf in California. especially the greater San Francisco Bay Area, has been a controversial issue. Fine fescues are shade tolerant and therefore are often used in seed mixtures (along with bluegrass and ryegrass) for shady or semi-shady sites. As mowed mono-stands of turf, they do not produce a quality stand year-round in most parts of California, especially along the Central Coast. A comprehensive variety trial was initiated in 1984 to study the suitability of fine fescues under Bay Area environmental conditions. The following report presents combined data from this four-year study at the University of California Santa Clara Field Station. This study was supported financially by the Northern California Turfgrass Council and University of California Cooperative Extension. Grass seed was supplied by the National Turfgrass Evaluation Program, sponsored jointly by U.S.D.A. and Maryland Turfgrass Council.

Forty-four cultivars (Table 1) were planted in October 1984 and were rated monthly through 1988 for overall quality (turfscore) as well as individual quality components: color, density, texture, uniformity and pest activity.

The study included several varieties of creeping red, Chewings and hard fescues. Rate of seeding for all varieties was 4.4 lb/l,000 sq ft.

Plots were in full sun and mowed at 2 inches, with clippings returned, and fertilized with 4 pounds of nitrogen per 1,000 sq ft per year. Irrigation was based on 100 percent ET measured from an aboveground class A evaporation pan. During the term of this study, plots were irregularly sprayed with herbicides to control heavy broadleaf weed infestations.

Table 1 presents overall results at the end of the fourth year. Ratings are the averages of the 4 years' monthly and quarterly ratings (1985 through 1988). Ratings fall on a scale of 1-9, with 9 representing the superior variety in terms of overall quality, texture, genetic color, winter color and density. Varieties are ranked in Table 1 from highest overall quality score received to lowest.

Review of the data reveals the following concerning the use of fine leaf fescues as mono-stand mowed turf grown in full sun under the San Francisco Bay Area climatological conditions (Table 2):

— Although some cultivars performed much better than others, none produced acceptable enough turf throughout the year to' warrant their use as mowed mono-stands.

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Table 1. Mean turfgrass quality and quality components ratings for fine leaf fescue cultivars grown in Santa Clara, California* (1985-88 data).

Cultivar** Name	Overall Quality	Leaf Texture	Color	Density			% Ground Cover		
				Spring	Summer	Fall	Spring	Summer	Fall
SCALDIS (H)	5.4	5.8	7.8	7.7	7.8	7.7	97.6	88.4	93.2
WALDINA (H)	5.3	5.8	8.6	8.1	7.7	7.7	97.2	87.1	94.0
ST-2 (SR 3000)(H)	5.1	5.3	7.7	7.8	7.3	7.8	97.2	90.0	94.5
CF-2 (VICTORY)(C)	5.0	4.9	7.7	7.7	7.1	7.3	99.0	92.1	94.0
430 (R)	4.9	4.8	6.7	7.7	7.3	6.4	99.0	88.1	85.7
LONGFELLOW (C)	4.8	5.1	8.0	7.6	6.8	7.3	97.1	86.2	94.3
BANNER (C)	4.7	5.0	7.6	7.6	7.0	7.0	98.3	92.5	91.9
BAR FO 81-225 (H)	4.7	5.8	7.8	7.4	7.4	6.8	97.1	84.8	88.3
ENJOY (C)	4.7	5.5	7.1	7.7	7.4	6.7	98.1	85.4	80.8
SHADOW (C)	4.7	4.8	7.7	7.4	6.8	6.6	99.0	90.8	91.9
FLYER (R)	4.6	4.8	7.7	7.4	6.9	6.7	96.0	79.8	84.6
IVALO (C)	4.6	5.4	6.1	6.9	7.2	7.3	98.0	90.9	95.9
PERNILLE (R)	4.6	5.2	6.7	7.4	6.6	6.3	99.0	80.2	81.5
AURORA (H)	4.5	5.3	7.0	7.6	6.9	7.0	97.1	82.4	87.9
LOVISA (R)	4.5	5.3	6.7	7.3	7.1	6.7	96.9	83.7	81.3
RELIANT (H)	4.5	5.5	7.4	7.2	7.1	6.9	97.6	81.4	89.3
WILMA (C)	4.5	4.9	7.6	7.6	7.0	7.2	98.1	84.5	87.3
BILJART (H)	4.4	5.4	7.3	7.3	7.3	6.8	95.1	78.6	84.8
MAGENTA (C)	4.4	5.3	8.0	7.0	7.3	7.2	98.1	86.0	92.3
MARY (C)	4.4	4.8	7.6	7.1	6.6	6.4	97.7	76.8	79.1
RUBY (R)	4.4	4.9	6.3	6.8	6.9	6.2	97.6	87.2	85.8
TAMARA (C)	4.4	5.4	6.6	7.3	6.8	6.2	98.1	88.0	84.8
BOREAL (R)	4.3	5.0	6.9	7.0	6.8	6.5	97.7	79.8	79.1
HIGHLIGHT (C)	4.3	4.8	6.6	7.2	6.8	6.2	98.6	76.1	72.3
JAMESTOWN (C)	4.3	4.9	7.1	6.9	7.0	6.7	97.1	87.1	87.9
ROBOT (R)	4.3	4.8	6.7	7.3	7.1	6.1	96.6	88.9	88.4
ATLANTA (C)	4.2	5.0	6.9	7.3	6.3	6.2	98.1	79.9	79.2
BEAUTY (C)	4.2	5.7	7.3	7.9	6.8	5.7	97.2	78.9	72.5
COMMODORE (R)	4.2	4.6	6.7	6.7	6.5	6.1	97.4	82.7	89.5
ENSYLVA (R)	4.2	5.2	6.1	6.6	6.7	6.5	98.1	81.6	86.6
KOKET (C)	4.2	5.4	7.0	7.2	7.1	6.0	98.1	81.0	78.8
PENNLAWN (R)	4.2	4.6	6.9	6.9	7.2	6.8	98.6	86.3	89.1
CERES (R)	4.1	4.5	6.3	7.3	6.3	6.4	97.7	89.3	87.6
EPSOM (C)	4.1	5.3	6.1	7.4	6.8	6.0	95.8	74.4	70.0
ESTICA (R)	4.1	5.5	6.6	7.6	6.2	5.7	97.1	68.7	62.7
TATJANA (C)	4.1	5.5	6.3	6.9	6.6	6.1	97.6	81.6	79.6
UNKNOWN (?)	4.1	4.5	6.8	6.3	7.0	6.5	95.2	85.9	91.2
HF9-3 (WEEKEND)(C)	4.0	5.1	7.1	7.2	6.8	5.9	96.6	75.7	69.8
WALDORF (C)	4.0	5.3	7.2	7.7	6.1	6.1	97.7	70.7	73.2
CHECKER (C)	3.9	5.2	6.6	7.2	6.7	5.9	97.6	82.4	73.5
FRI-FRT 83-1 (?)	3.9	4.8	6.8	7.1	6.5	5.2	97.2	70.3	63.1
VALDA (H)	3.9	5.8	8.0	7.2	6.8	6.6	93.6	65.3	79.8
WINTERGREEN (C)	3.8	5.5	6.1	1.9	6.4	5.8	96.1	74.8	69.0
CENTER (C)	3.5	5.2	6.8	6.9	6.5	5.9	93.7	66.4	77.2
LSD VALUE (0.05)	0.7	1.4	0.6	2.0	1.8	2.5	4.7	23.6	31.6

* The values are averages of monthly and quarterly ratings from 1985 through 1988. The rating scales are:

- Overall quality (turfscore): 1-9; 9 = Ideal turf.
- Leaf texture: 1-9; 9 = Finest texture (narrowest leaf blades).
- Color: 1-9; 9 = Darkest green color.
- Density: 1-9; 9 = The densest stand of turf in various seasons.
- % Ground cover: 0 - 99; 99 = Plots completely covered with the grass. This component evaluates pathogenic and/or environmental effects causing partial or complete death of turfgrass in a plot.

** Species designations of cultivars are:

H = Hard fescue
C = Chewings fescue
R = Creeping red fescue
? = Species unknown

LSD Value: To determine statistical difference among cultivars, subtract one cultivar's mean from another cultivar's mean. Statistical differences occur when this value is larger than the corresponding LSD value. If the difference between the mean values for two cultivars within the same column is not greater than the corresponding LSD, then the two cultivars are statistically the same for that specific quality component.

Table 2. Average monthly air and soil temperature at Santa Clara Field station, Santa Clara. California (1985-W).

Month	Air Temperature F			Soil* Temperature F		
	Ave Max	Ave Min	Mean	Max	Min	Mean
January	59	43	S1	52	45	49
February	66	46	56	57	47	52
March	68	47	58	60	52	56
April	74	51	63	65	5s	62
May	77	54	66	70	60	65
June	81	58	70	72	65	69
July	83	59	71	74	69	72
August	82	60	71	74	70	72
September	so	58	69	73	65	69
October	76	55	66	69	61	65
November	65	47	56	63	51	57
December	59	42	51	55	45	50

* Soil temperature measured 4 inches below surface. Maximum and minimum are highest and lowest for the months.

- Most of these cultivars performed very well mid-fall through mid-spring, but exhibited severe high temperature stress during the hot summer months and were prone to summer turf diseases common to the area (e.g., Pythium blight, Fusarium blight). The drastic summer reduction in percent ground cover shown for almost all the cultivars indicates this. No fungicides were used during this trial either as a preventative or cure. Preventing disease is presumably possible for these cultivars but would require several applications of fungicides during the year.
- There were no statistically significant differences among these cultivars in regard to texture (leaf blade width), spring and summer density, and spring percent ground cover. However, they were significantly different in terms of overall quality, color, fall density and summer and fall percent ground cover.
- All cultivars stayed green and performed well during the winter months. Fine fescues do not experience winter dormancy in Central Coastal California.
- Hard fescue cultivars appear to outperform both red and Chewings fescues.
- Although these grasses did not perform well in full sun, the possibility exists that they would provide acceptable stands if grown in shade. Also, their usefulness in general purpose turfgrass mixtures (i.e., in combination with bluegrasses and ryegrasses) is not affected by this study. Future trials will evaluate the suitability of these species for use as mono-stand turf in shade and as a component of general purpose turf mixtures.

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Sulfur, Soil pH and Turfgrass Management

Ali *Harivandi*[1]

Soil physical and chemical properties play an integral role in maintaining quality turfgrass stands. The balanced nutrition required for these stands depends in part on the availability of nutrients within the soil solution. Once adequate quantities of essential nutrients are present, their availability to plants depends on the soil's acidity or alkalinity (pH). Sulfur and sulfur-containing materials are the primary corrective compounds added to soil with high pH (alkalinity) problems.

SULFUR: THE ELEMENT

Plants need sulfur for tissue development, protein synthesis, chlorophyll production, and root development. The healthy growth of turfgrasses also depends on soil microorganisms, the growth and increase of which in alkaline soils are stimulated by sulfur. Quantitatively, turfgrasses generally require as much sulfur as they do phosphorous.

Sources of sulfur added to turfgrass soils vary. Previously, highly polluted air in metropolitan areas contributed significantly to the sulfur supply of plants. Sulfur deficiency in these areas increased as pollution was reduced. Many pesticides and low grade fertilizers contribute sulfur to the soil as does organic matter during decomposition. The primary sources of sulfur for turfgrasses, however, are sulfur-containing fertilizers and chemical amendments. Some fertilizers, such as ammonium sulfate, provide turfgrasses with a steady dose of sulfur, whereas many high analysis fertilizers (e.g., urea, conventional nitrogen solutions, triple superphosphate and muriate of potash) contain little or no sulfur. Elemental sulfur is the amendment most often used by turfgrass managers today. It ranges in purity from 99 percent to 20 percent or less in low grade deposits containing clay and other material. Pure elemental sulfur is a yellow, crystalline solid.

WHAT IS pH?

pH is a numerical designation of acidity and alkalinity in soils and other chemical systems. It is an expression used to indicate the hydrogen ion [H+] activity of a solution. pH is formulated as the negative logarithm of that ion activity and written:

$$pH = -\log [H']$$

where hydrogen ion activity, [H+], is in moles per liter.

A solution with hydrogen ion activity of .001 mole per liter has a pH of 3.0; one with a hydrogen ion activity of .000l mole per liter, a pH of 4.0 and so on. Values of pH range from 1 to 14, with pH 7.0 indicating neutrality. (The solution is neither acidic nor alkaline.) Higher values indicate increasing alkalinity, and lower values indicate increasing acidity. Since pH is a logarithmic value, each pH unit indicates alkalinity 10 times that of the next smallest unit. For example, a solution with pH 5 is 10 times more alkaline than a solution with pH 4 and 10 times more acidic than a solution with pH 6. A solution with pH 6 is 100 times more alkaline than a solution with pH 4.

As mentioned above, the acidity or alkalinity of a given soil is important to turfgrass management because it affects nutrient availability. It also affects the solubility of toxic substances such as aluminum, the rates of microbial activities and reactions, soil structure and tilth, and pesticide performance.

At a pH of 6.5 - 7.0 the primary nutrients N, P, and K, as well as most of the other essential elements, are most readily available. Alkaline soils may be deficient in phosphorus, iron, manganese, copper or zinc. Deficiencies of elements such as calcium, magnesium and phosphorus may occur at low pH levels. Generally, a turfgrass grown in soil with a pH below the grass's optimum range requires higher rates of fertilization to keep nutrients at an optimum level.

LOWERING SOIL pH

Where soil is inherently alkaline, or has been overlimed, pH may need to be reduced. The material most commonly used to acidify soil is elemental sulfur (S); however, iron (ferrous) sulfate ($FeSO_4$), aluminum sulfate ($AI_2[SO_4]_3$), sulfuric acid ($H2SO_4$), and similar acid-forming materials are sometimes employed. Repeated use of acidifying fertilizers such as ammonium sulfate, ammonium nitrate, ammonium phosphate and urea will also result in more acidic soils. [Note: nitrate sources of nitrogen, such as potassium nitrate (KNO_2) and calcium nitrate ($Ca[NO_3]_2$), decrease soil acidity]. Elemental sulfur, however, is the most commonly used material for soil acidification.

Elemental sulfur is useful for reclamation of both naturally alkaline (high pH) or overlimed soils and sodic (alkali) soils. One important advantage of elemental sulfur in this role is its low cost. Also, since it is relatively pure and thus has the highest equivalent sulfur concentration, its unit transportation cost is lowest. Unfortunately, application of powdered sulfur (the most effective form) is dusty and somewhat difficult. Once applied, finely ground elemental sulfur is oxidized by soil microorganisms and converted into sulfuric acid ($HeSO_4$). The general processes for the oxidation of elemental sulfur by these microorganisms are: sulfur(S) + oxygen (3/2 $0_,$) + water (H_2O) $\xrightarrow{\text{microorganisms}}$ sulfuric acid (H_2SO_4).

Theoretically, the sulfuric acid itself should reduce soil pH since it increases hydrogen ion activity. In calcareous soils (soils containing significant quantities of calcium carbonate ($CaCO_3$)) or in overlimed soils, however, sulfuric acid is neutralized by $CaCO_3$. The more calcium present, therefore, the more acid required to reduce pH and thus the more elemental sulfur which must be added to the soil. As long as $CaCO_3$ remains in the soil, pH cannot be permanently lowered, or very large quantities of sulfur are required to do so. This

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difficulty in changing the pH of a soil has to do with a property known as "buffering." The concept of "buffering" may be illustrated by visualizing two tires, both registering 40 pounds/sq in of pressure on a pressure gauge, but one belonging to a bicycle and the other to a truck. If air is released for 10 seconds from both tires, pressure in the bicycle tire will drop several pounds while pressure in the tire with greater volume will barely change. The truck's tire is "buffered" against pressure change.

Lowering the pH of less buffered soils, e.g., sandy soils with low lime content, is easier and faster. The amount of sulfur needed to lower the pH of a given soil is determined by chemical analysis for pH, cation exchange capacity, exchangeable sodium percentage, and lime content. Table 1 provides general guidelines from the Western Fertilizer Handbook. Note that the rates given in the table are for soil incorporation. Applied to established turf at these rates, sulfur would damage the grass.

Table 1. The approximate amounts of soil sulfur (99 percent) needed to increase the acidity of the plow-depth layer (7 inches) of a carbonate-free soil (Western Fertilizer Handbook).

Change in pH Desired	Pounds of Sulfur Per Acre		
	Sand	Loam	Clay
8.5 to 6.5	2,000	2,500	3,000
8.0 to 6.5	1,200	1,500	2,000
7.5 to 6.5	500	800	1,000
7.0 to 6.5	100	150	300

Applying elemental sulfur to sodic soils (soils with a high sodium content and often very high pH's) may help remove sodium from the root zone as well as lowering pH. Sodic soils, including saline-sodic soils, are "dispersed" or "deflocculated," terms referring to physical characteristics of the soil that make it particularly impermeable to water and air (and therefore fertilizer). Such soils are unsuitable for growth of most plants, including turf grasses. (By contrast, a soil high in soluble calcium rather than sodium is termed "flocculated," and generally exhibits good water and air permeability.) The primary amendment for sodic soil reclamation is gypsum ($CaSO_4$), the addition of which leads to replacement of soil sodium (Na) by calcium (Ca): Gypsum ($CaSO_4$ + soil sodium (Na+) $\longrightarrow$ soil calcium (Ca++) + sodium sulfate (Na_2SO_4).

The resulting salt, sodium sulfate, is soluble and easily leached from the root zone given sufficient water and adequate drainage. When sulfur is added to sodic soils containing $CaCO_3$, the acid produced by oxidation of sulfur reacts with the lime to form gypsum:

sulfur(S) + water (H_2O) + oxygen (O_2) $\xrightarrow{\text{microrganisms,}}$ sulfuric acid (H_2SO_4) $H_2SO_4 + CaCO_3 \longrightarrow$ gypsum ($CaSO_4$) + water (H_2O) + carbon dioxide (CO_2)

Gypsum then combines with soil sodium as in the previous scenario.

After sodium removal, soil pH is usually lowered, soil structure improved, and water penetration increased. The soil is thereby rendered more suitable for plant growth. Leaching after addition of sulfur to soil is essential to rid the root zone of sodium sulfate. If not leached, this salt can build to levels injurious to plants. On sodic soils where the chain of reactions that produce sodium sulfate may require several months, leaching can be delayed somewhat.

The rate at which elemental sulfur oxidizes to sulfuric acid depends largely on particle size. The smaller the particles applied the faster the reaction. Powdered sulfur, although not as convenient to use as larger granular forms, is therefore the fastest acting form. Several granular products (e.g., Disper-Sul and Agri-Sul) contain 90 percent or more elemental sulfur, are dust free, and disintegrate into finely divided particles in the presence of moisture. "Popcorn sulfur" is nearly pure sulfur that has been made porous by combining molten sulfur and water in a single combination nozzle. The resulting material is separated into classes of suitable particle size for soil application.

Available moisture, oxygen, nutrients, temperature, salinity and pH are all important in sulfur oxidation because they affect the soil microbes involved in the necessary chemical reactions. Temperature has one of the most pronounced effects on sulfur oxidation in soils. Oxidation begins at a soil temperature of approximately 40 F and its rate increases steadily with increasing temperature. A sharp increase in rate occurs above 70 F. In most climates, therefore, sulfur oxidation is relatively modest from midfall to midspring.

Soil moisture is probably the next most important environmental factor in sulfur oxidation, with either too much or too little moisture reducing oxidation rate. The activity of sulfur-oxidizing microorganisms is highest at, or slightly above, soil field capacity. These microorganisms require oxygen as well as moisture to function properly.

Elemental sulfur should be mixed thoroughly with the soil at the time of application. Immediately after, irrigation must begin and soil must be kept moist as long as oxidation is desired. If the soil is extremely sodic or contains very high amounts of lime, sufficient oxidation may require several months.

Sulfur is not water soluble and therefore cannot be applied in irrigation water. Suspensions of finely divided sulfur in water to which about 2 percent clay has been added may be available in some parts of the country as sulfur slurry. In some situations, sulfuric acid is applied either directly or through the irrigation system. Sulfuric acid (usually about 93 percent pure - i.e., containing 30 percent sulfur) is a heavy, corrosive liquid which, after entering the soil, reacts with lime to form gypsum. The reaction is much faster than that of elemental sulfur (which can take up to several months to oxidize under field conditions) because bacterial oxidation is not required. In sodic soil reclamation, for reasons not yet understood, addition of sulfuric acid often improves the soil more rapidly than does addition of gypsum. Unfortunately, sulfuric acid is difficult and dangerous to handle. It can be added to the soil by chiseling or drilling it in or by spraying it on the unplanted surface. It can also be added directly to irrigation water, if metal or concrete pipes are not used in the irrigation system. It will corrode concrete pipes, steel culverts, or check gates; therefore, experienced operators are usually hired to apply this chemical.

Other sulfur-containing materials used for soil reclamation include: polysulphide, calcium polysulphide, sulfur dioxide, ammonium thiosulfate, ammonium sulfate, ammonium bisulfate and iron and aluminum sulfate. Equivalent sulfur contents and other properties of several of these compounds are given in Table 2. These materials should be used according to their manufacturer's recommendation.

Table 2. Acid-forming, sulphur-containing materials (Stromberg and Tisdale, 1979)

Material	Formula	Nitrogen	Sulphur	Other	Sulphur Content (lb/ton)
Aluminum sulphate	Al_2SO_4 $18H_2O$	0	14.4	11.4(Al)	288
Ammonia-sulphur solution	$NH_3 + S$	74	10		200
Ammonium bisulphate solution	$NH_4HSO_3 = H_2O$	8.5	17		340
Ammonium polysulphate solution	NH_4S_X	20	40		800
Ammonium sulphate	$(NH_4)_2SO_4$	21	24.2		484
Ammonium thiosulphate solution	$(NH_4)_2S_2O_3 + H_2O$	12	26		520
Aqua-sulphur solution	$NH_3 + NH_3S_X = H_2O$	20	5		100
Ferrous ammonium sulphate	$Fe(NH_4)_2(SO_4)2$	6	16	16(Fe)	320
Ferrous sulphate (copperas)	$FeSO_4$ $7H_2O$	0	11.5	20(Fe)	230
Gypsum (hydrated)	$CaSO_4$ $2H_2O$	0	18.6	32.6(CaO)	372
Lime sulphur (dry)	CaS_X	0	57	43(Ca)	1140
Lime sulphur (solution)	$CaS_5 + Ca_2SO_3$ $5H_2O$ + $CaS_4 + CaSO_3$ $2H_2O$		23-24	99Ca)	480
Sulphuric acid (100%)	H_2SO_4	0	32.7		654
Sulphuric acid (66 Be + 93%)	H_2SO_4	0	30.4		608
Sulphur	S	0	100		2000
Sulphur dioxide	SO_2	0	50		1000

SULFUR APPLICATION TO ESTABLISHED TURF

The amount of sulfur required to acidify a particular soil is based on soil chemical and physical analyses. Application rate usually aims for alkalinity correction of the six-inch plow layers, assuming the sulfur will be spread uniformly over bare soil surface and then either plowed down or disked in. Repeated plowing or disking speeds acidification by increasing mixing of soil and sulfur. Preferably, this procedure is carried out long before turfgrass establishment to allow ample time for sulfur oxidation. However, in many cases the decision to acidify with sulfur is made after grass is established. Due to its insolubility, sulfur applied to already established turf creates only a thin zone of low pH soil near the soil surface. In such a condition, where soil at the turfgrass's crown level has a low pH, while soil in the root zone remains fairly alkaline, plants experience little or no benefit from acidification. In addition, extreme acidity at or immediately below the soil surface may actually injure the turf plant. When applying sulfur to established turf, therefore, considerable care must be exercised. It is always best to apply sulfur after coring. Core aerification before sulfur application helps downward movement, but even with this practice excessive amounts of sulfur should not be applied to the surface. Also, light and more frequent applications of sulfur are preferable to heavier, less frequent ones.

Sulfur (with 90 percent or above purity) applications to putting greens should be in 0.5 lb/l,000 sq ft increments or less (applied 3 to 4 weeks apart) not to exceed 10 lb sulfur per 1,000 sq ft per year, with application confined to the coolest period of the growing season (i.e., early spring, late fall or periods of winter dormancy). Since high temperatures (90 F and above) during fertilization of any turf are ill-advised, it is preferable not to apply sulfur in midsummer. After sulfur application, turf should be irrigated immediately to remove material from leaves and thereby prevent burning.

Higher cut grasses such as those of golf course fairways, in parks, athletic fields and home lawns, can tolerate applications of up to 5 lb sulfur (with 90 percent or above purity) per 1,000 sq ft per application. The timing and procedure of sulfur application given for greens applies to higher cut grasses as well.

Regular applications of acidifying fertilizers such as ammonium sulfate will produce essentially the same effects as application of elemental sulfur. Ammonium nitrate, ammonium phosphate, urea, sulfur-coated urea, ureaform, methylene urea, IBDU and activated sewage sludge also have acidifying effects. The lowering of pH by these nitrogen sources comes from release of hydrogen ions during the nitrification of ammonium nitrogen to nitrate nitrogen.

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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 she, away from food or feeds, and out of the reach of children, unauthorized persons, pets, and livestock.

Reommendations 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 you 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 Me wrong stage of plant development or when temperatures are too high. Injury may also result from excessive amounts or 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 directon for use. it is illegal to use the chemicals as described.

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