Improved overseeding programs 1. The role of weather

A mathematical model helps explain the role of weather in the outcome of overseeding programs.

Wendy Gelernter, Ph.D., and Larry Stowell, Ph.D.

Superintendents who overseed are well acquainted with the influence of weather on the success or failure of overseeding and transition programs. Although many other factors — including soil and water quality, turf species, previous management practices and the specific expectations at each golf course — play important roles in the success of overseeding and transition programs, weather is always the driving force (Figure 1).

Agronomists have produced models that can help superintendents to deal with weather-driven phenomena such as the timing of insect infestations, disease epidemics and weed invasions. In this article, we present a turf growth model that illustrates the role of weather in the growth of both warm-season and cool-season turf and helps superintendents cope with the effects of weather on their overseeding management plans.

Photo by Seth Jones

Figure 1. Weather is always the driving force that determines the success or failure of overseeding and transition programs.

The concept of turf growth potential

To understand why overseeding results can vary so much from year to year and from location to location, it is useful to review the scientific literature (1,2) for information on the growth requirements for warm-season and cool-season turf (Table 1). Using this information, we were able to develop a turf growth model that makes it easier to understand and to explain the variable nature of overseeding programs.

The model is based on *turf growth potential,* a concept that we have developed to help illustrate the interaction between weather and turf performance. When the growth potential of either cool-season or warm-season turf is 100%, the turf has reached its optimal growth because temperatures are ideal for that particular turf species (Figure 2). Turf growth is still good below the 100% level, however, and as long as the growth potential is above 50%, turf is generally doing well, with minimal stress. However, as the weather becomes less conducive to turf growth (either too hot or too cold), the growth potential falls below 50%, and turf will become progressively more stressed and weakened. As the growth potential reaches 10% or lower, growth is extremely limited, and, at 0%, growth has completely halted.

In Figure 2, note that for cool-season turf, 100% of the plant's growth potential is reached when average air temperatures are 68 F (20 C). When the temperature is cooler or warmer than 68 F (20 C), the growth potential decreases. Warm-season turf growth follows a similar pattern, but its optimal temperature for growth is much higher, at 88 F (31 C). When it is either cooler than 88 F (31 C) or warmer, the warm-season turf growth potential decreases.

The equation for the growth potential model is:

$$GP = 100\left[\frac{1}{e^{\left[\frac{1}{2}\left[\frac{(obsT - optT)}{sd}\right]^2\right]}}\right],$$

where GP = growth potential; obsT = observed temperature (F); optT = optimal turf growth temperature (F); sd = standard deviation of the distribution (sd warm-season turf = 12; sd cool-season turf = 10), and e = natural logarithm base 2.718282... .

Putting the turf growth model to work

The turf growth potential for various locations is shown in Figure 3 and Table 2.

The ideal overseeding environment?

If there is an ideal overseeding environment in the United States, it can be found in the desert Southwest. The growth potential chart for Phoenix in Figure 3A shows why the area is such a good environment for overseeding.

COOL- VS. WARM-SEASON TURF

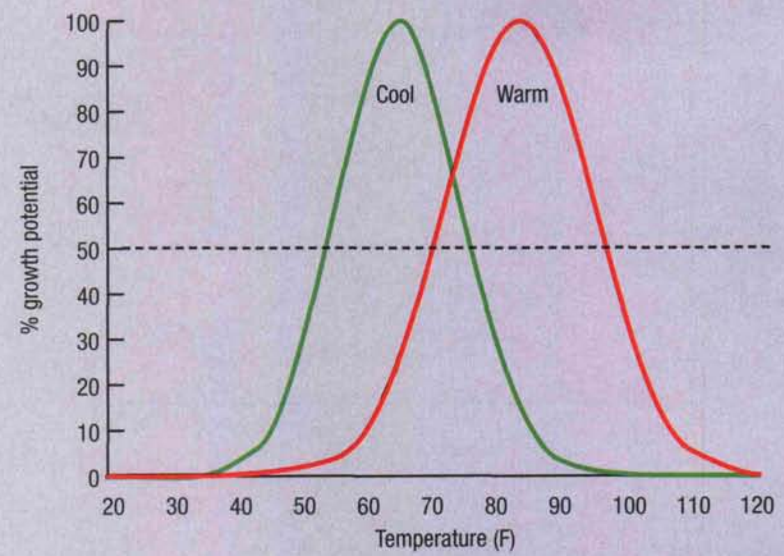

Figure 2. Percent growth of cool-season turf (green curve) versus warm-season turf (red curve) at different average air temperatures. The best turf growth (100% growth potential) occurs at 68 F (20 C) for cool-season turf and 88 F (31.1 C) for warm-season turf. Increasingly vigorous growth occurs at 50% growth potential (horizontal dotted line) and higher, while turf growth becomes slower and slower as the growth potential decreases below 50%.

COOL- VS. WARM-SEASON TURF

Cool-season turf	Warm-season turf*
Examples: creeping bentgrass, Kentucky bluegrass, perennial ryegrass, tall fescue	Examples: bermudagrass, buffalograss, seashore paspalum, zoysiagrass
Grows best 60-75 F (15.5-23.8 C)	Grows best 80-95 F (26.6-35 C)
Growth decreased higher than 80 F (26.6 C) and lower than 50 F (10 C)	Growth decreased (dormancy) when less than 55 F (12.7 C)
Solar radiation optimum: 242-485 langleys/day (116-233 watts/square meter/day)	Solar radiation optimum: 812-969 langleys/day (390-465 watts/square meter/day)
Sensitive to heat, drought and salts	Tolerant to heat, drought and salts
C_3 carbon-fixing cycle in photosynthesis	C_4 carbon fixing: helps plant deal with high temperature and high solar radiation

*Kikuyugrass is classified as a warm-season variety but shares many features with cool-season turf. As a result, it straddles these two categories, with values that are intermediate for salinity tolerance, solar radiation and heat requirements.

Table 1. Growth requirements for cool- and warm-season turf varieties. Temperatures listed are average air temperatures.

- Warm-season turf clearly dominates cool-season turf more than four months of the year (May–October). During these months, it is much too hot for growth of cool-season turf, which usually dies or slows its growth significantly.
- In about six months each year (November–April), cool-season turf clearly dominates. During these months, it is too cool for warm-season turf (it goes dormant), but it is perfect weather for growth of perennial ryegrass (*Lolium perenne*), *Poa trivialis,* creeping bentgrass (*Agrostis palustris*) and other cool-season overseeded species.
- The large differences in growth potential between cool-season and warm-season turf in this location are reflected in the graph (Figure 3A). When warm-season turf growth is at 100%, cool-season turf growth is very close to zero, and vice versa. In other words, competition between these two turf types is limited for most of the year.

Even in this ideal environment, problems can occur. In Figure 3A, the cool-season growth potential line crosses the warm-season line roughly in mid-April and again in late September–early October. During these crit-

Growth potential

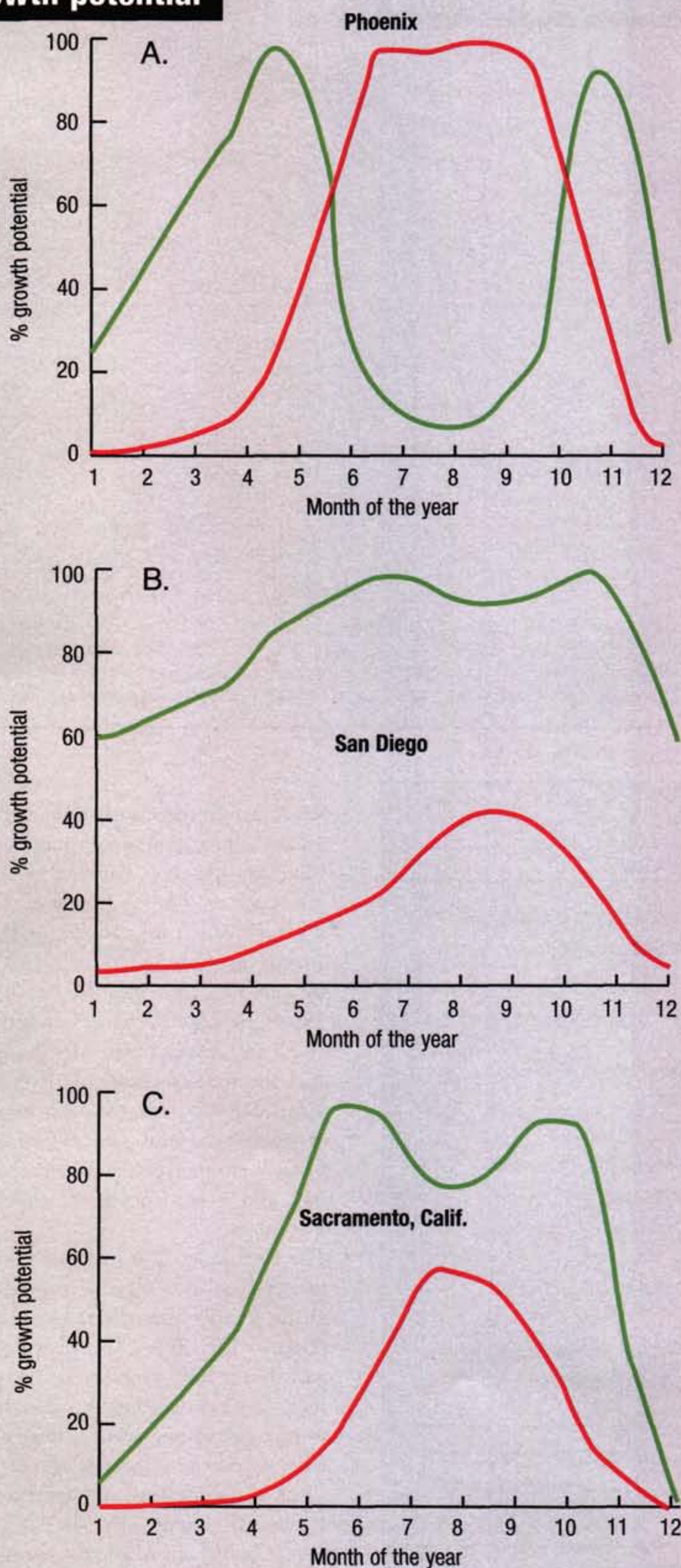

Figure 3. Percent growth potential of cool- (green line) and warm-season turf (red line) at selected locations in the United States. The temperatures used to generate these graphs are the 30-year normal monthly air temperatures (the monthly air temperatures averaged over a 30-year period). For this reason, in any given year, turf performance may vary slightly, depending on current weather conditions.

ical periods, the spring and fall transitions, both turf types can grow vigorously. When the growth potential is simultaneously high for cool- and warm-season turf, competition between them is heavy, and it is difficult to manage the system to favor one over the other.

Contradictions on the coast

The effects of the mild climate of coastal California are illustrated in the San Diego graph in Figure 3B, where the climate dramatically favors cool-season turf over warm-season turf all year long. In this environment, warm-season turf grows moderately (but never vigorously) for five to six months of each year; for the remainder of the year, its growth is stagnant. Looking at this graph, most people would choose cool-season turf based on the climate alone. And yet, the majority of golf courses in San Diego do *not* have cool-season fairways and roughs, but are overwhelmingly bermudagrass (*Cynodon* species) or occasionally seashore paspalum (*Paspalum vaginatum* Swartz) — overseeded or not overseeded. These courses choose to grow warm-season turf in a cool-season environment because lack of rainfall and poor-quality irrigation water have resulted in very high soil salinity, a condition that is too stressful for many salt-sensitive cool-season turf species. Increasing restrictions on water use also favor the use of the more drought-tolerant warm-season species.

Many superintendents successfully grow warm-season turf in this coastal cool-season environment, but it requires careful programs for traffic management, specialized fertility and cultivation and shade management. If overseeding is demanded by the clientele at the golf course, this is an additional stress on already weakened warm-season turf that is surviving at below 50% growth potential — a stress that must be dealt with very carefully. The recent introduction of more salt-tolerant varieties of perennial ryegrass, fescue (*Festuca*) species and bluegrass (*Poa*) species is now allowing some superintendents at coastal courses to manage cool-season turf on their fairways and roughs with some success. Although the inputs are higher than for warm-season turf (see below), these new cool-season varieties have much higher growth potential on the coast and are therefore generally less stressed and grow more vigorously than warm-season species.

A dilemma in Sacramento

In Sacramento, Calif., as in many of the West's inland areas, some golf courses cultivate only cool-season turf, while others cultivate primarily warm-season turf. Some courses overseed, and others do not. To determine which turf species and overseeding strategies would make the most sense for Sacramento, note the trends in the graph in Figure 3C.

- Cool-season turf dominates warm-season turf for the entire year, and its growth potential is well over 50% for two-thirds of the year. However,it is heavily stressed by hot temperatures during the summer, as the drop in growth potential indicates.
- Warm-season turf barely makes it over 50% growth potential, and when it does, it is only for one or two months.

A choice to grow only cool-season turf appears to make the most agronomic sense. However, the summer months will be tough because during this time, the cool-season growth potential actually decreases (because of the very high temperatures), which stresses the turf. Cool-season turf is also more susceptible to damage by white grubs and by diseases such as gray leaf spot; for this reason, a greater investment in pesticides and water is required. But if the budget and commitment are there, a cool-season turf strategy will deliver the highest-quality turf on a year-round basis.

The second-most desirable choice would be to cultivate warm-season fairways and/or roughs that are not overseeded. Although the turf will perform adequately during the sum-

GROWTH POTENTIAL IN U.S. LOCATIONS

	% warm-season turfgrass growth potential												% cool-season turfgrass growth potential											
Location	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Phoenix	2	5	11	34	77	100	88	95	99	56	10	2	38	62	87	97	53	12	3	6	19	78	85	41
Little Rock, Ark.	0	0	2	11	35	75	90	85	54	12	1	0	2	6	35	86	96	55	35	42	80	90	31	5
Fresno, Calif.	0	1	3	9	30	66	90	84	56	18	2	0	9	26	46	82	99	66	35	44	78	97	38	9
Los Angeles (airport)	5	7	8	13	19	33	55	59	52	33	12	5	56	61	64	76	89	98	99	96	97	100	84	57
Palm Springs, Calif.	3	7	13	31	65	97	94	98	97	58	12	3	46	73	91	99	67	24	5	8	23	75	90	50
Riverside, Calif.	2	3	4	8	18	39	69	68	53	22	5	2	34	46	56	78	98	94	62	64	81	100	65	36
Denver	0	0	0	0	4	23	51	41	11	1	0	0	0	0	2	16	59	100	84	93	87	27	2	0
Jacksonville, Fla.	1	3	9	23	50	78	89	87	74	34	10	3	32	47	81	100	84	51	37	39	57	97	85	46
Tampa, Fla.	7	10	22	40	70	88	91	91	86	57	25	11	75	84	100	93	61	39	33	33	41	77	100	87
Atlanta	0	0	2	10	31	63	77	74	47	11	2	0	3	8	38	84	99	70	53	57	87	87	35	7
Macon, Ga.	0	1	4	15	43	75	87	84	60	17	3	1	9	17	57	95	91	55	39	44	74	96	52	17
Honolulu	48	48	55	62	71	80	84	88	86	81	69	54	86	86	79	71	61	49	43	38	40	48	62	80
Chicago	0	0	0	1	6	29	49	42	16	2	0	0	0	0	1	17	69	99	85	92	95	34	2	0
Indianapolis	0	0	0	1	12	43	60	49	22	2	0	0	0	0	3	32	90	91	73	85	100	44	5	0
Des Moines, Iowa	0	0	0	1	11	42	66	53	18	2	0	0	0	0	1	25	87	91	66	81	97	38	2	0
Wichita, Kan.	0	0	0	3	19	62	88	79	36	6	0	0	0	0	9	54	98	71	38	50	96	67	7	0
Shreveport, La.	0	1	4	19	46	80	92	91	67	22	4	0	8	19	61	98	88	49	31	34	65	100	56	15
Boston	0	0	0	0	5	26	51	43	17	2	0	0	0	0	2	15	65	100	84	91	96	45	9	0
Detroit	0	0	0	0	5	25	45	37	13	1	0	0	0	0	1	13	66	100	89	96	91	26	2	0
Minneapolis	0	0	0	0	5	27	51	37	8	1	0	0	0	0	0	11	67	100	83	96	78	17	0	0
Jackson, Miss.	0	0	4	16	43	77	88	86	63	16	3	0	6	15	56	96	90	53	38	41	70	96	50	14
St. Louis	0	0	0	4	20	60	81	71	35	5	0	0	0	0	8	56	99	73	47	60	96	66	10	0
Las Vegas	0	1	3	15	53	98	96	100	84	28	3	0	9	26	53	94	81	22	6	11	43	100	46	9
Reno, Nev.	0	0	0	1	4	18	42	33	8	1	0	0	0	1	5	17	55	97	92	98	78	25	2	0
New York (JFK airport)	0	0	0	1	7	32	61	57	25	4	0	0	0	0	3	24	75	98	73	77	100	58	13	1
Raleigh, N.C.	0	0	1	6	23	55	74	69	39	7	1	0	2	4	23	70	100	79	57	63	94	76	26	5
Akron, Ohio	0	0	0	1	6	26	43	36	14	1	0	0	0	0	1	16	70	100	91	96	93	32	4	0
Oklahoma City	0	0	1	8	28	67	90	87	48	10	1	0	1	3	23	78	100	65	35	40	86	86	20	2
Guam	70	69	72	78	81	82	80	78	79	78	79	75	62	62	59	52	48	46	49	51	50	51	50	55
Pittsburgh	0	0	0	1	7	26	44	37	14	1	0	0	0	0	2	20	73	100	90	96	94	32	4	0
Charleston, S.C. (airport)	0	1	5	17	47	75	88	85	65	23	5	1	14	24	64	97	87	56	38	42	67	100	66	26
Knoxville, Tenn.	0	0	1	4	18	49	66	63	35	5	1	0	1	2	18	61	98	85	66	70	97	66	17	2
Austin, Texas	1	2	10	33	61	88	97	98	83	39	9	1	17	34	84	98	72	39	24	22	45	94	80	28
Corpus Christi, Texas	3	5	19	46	73	90	96	96	86	53	19	5	46	67	98	88	58	35	25	25	40	81	98	65
Houston	1	2	8	28	56	84	92	91	74	33	9	2	23	40	79	100	78	44	32	33	56	98	81	38
San Antonio	1	2	10	32	61	91	98	98	79	35	8	1	19	38	85	98	73	34	22	22	50	96	78	31
Richmond, Va.	0	0	0	4	20	53	73	67	35	6	1	0	1	2	15	59	99	81	58	65	97	67	20	2

Table 2. Percent warm-season and cool-season turfgrass growth potential in selected U.S. locations. Months with 50% or more warm-season turf growth potential are highlighted in dark blue; months with 50% or more cool-season turf growth potential are highlighted in light blue. Growth potentials are based on 30-year normal average monthly air temperatures obtained from the National Oceanic and Atmospheric Administration (NOAA).

mer, it will be dormant (with all of the problems that dormancy engenders) for several months each year.

The least desirable choice would be to overseed the warm-season turf. But because of the difficult transition-zone climate, successful spring or fall transitions will be problematic, and both the cool- and warm-season turf will struggle as they compete with each other. Mixtures of weakened stands of both turf types, rampant weed invasion and attack by insects and diseases are frequently the end result of overseeding in environments like this.

The role of nonagronomic factors

In Sacramento, therefore, there is no ideal strategy. Courses there and in similar environments are in that gray area where overseeding may or may not be beneficial. This is where the nonagronomic considerations come into play. What time of year are the most rounds played? Is it a resort or a private or a public course? What are the expectations of the membership? What are the influences of water and soil quality (if poor, warm-season turf would be favored) and shade and/or overcast conditions (if prevalent, cool-season turf would be favored)?

Got a light?

Another important issue can overshadow the complex interactions involved in overseeding performance — the quality of light. As indicated in Table 1, warm-season turf requires almost four times as much solar radiation as cool-season turf for optimal growth. Although most locations receive sufficient light to support cool-season growth (Figure 4), only a few in the United States receive enough light to support good growth of warm-season turf. Warm-season turf can therefore struggle even in hot locations (for example, Houston) if the weather is frequently rainy or overcast. In places like San Diego or Sacramento, where it is both cooler and more overcast than is ideal for warm-season turf, the situation becomes much more difficult. When warm-season turf is in an environment with less-than-optimal light, anything that shades the turf (from trees to overseeded turf) must be managed to decrease the impact of the shade as much as possible.

Using the turf growth model

The information supplied by the turf growth model can assist superintendents in communicating important points to both golfers and management.

• Demonstrate why cool-season and/or

% GP VS. AIR TEMPERATURES

Air temp (F)	% warm GP	% cool GP	Air temp (F)	% warm GP	% cool GP	Air temp (F)	% warm GP	% cool GP	Air temp (F)	% warm GP	% cool GP
38	0	1	60	7	75	82	90	35	104	39	0
39	0	2	61	9	81	83	93	30	105	35	0
40	0	2	62	10	86	84	96	26	106	30	0
41	0	3	63	12	90	85	98	22	107	27	0
42	0	4	64	15	94	86	99	18	108	23	0
43	0	5	65	17	97	87	100	15	109	20	0
44	0	6	66	20	99	88	100	12	110	17	0
45	0	8	67	23	100	89	99	10	111	15	0
46	0	10	68	27	100	90	98	8	112	12	0
47	0	12	69	30	99	91	96	6	113	10	0
48	0	15	70	35	97	92	93	5	114	9	0
49	1	18	71	39	94	93	90	4	115	7	0
50	1	22	72	43	90	94	86	3	116	6	0
51	1	26	73	48	86	95	82	2	117	5	0
52	1	30	74	53	81	96	78	2	118	4	0
53	2	35	75	58	75	97	73	1	119	3	0
54	2	40	76	63	70	98	68	1	120	3	0
55	3	46	77	68	64	99	63	1	121	2	0
56	3	52	78	73	58	100	58	1	122	2	0
57	4	58	79	78	52	101	53	0	123	1	0
58	5	64	80	82	46	102	48	0			
59	6	70	81	86	40	103	43	0			

Note. The growth potential (GP) values in the table were calculated using the equation for the growth potential model provided in the text.

Table 3. Percent growth potential (GP) of cool-season and warm-season turf at different average air temperatures.

warm-season turfgrasses perform the way they do at your location. Use the graphs in this article to show when cool-season and warm-season turf growth potential is above (and below) 50% at your location.

- Use the graphs and tables in this article to illustrate how unexpected weather patterns can influence turf growth and quality. The data in Table 2 and in Figure 3 are based on 30 years of historical data and therefore provide a rough idea of what to expect. What actually occurs in any given year can fluctuate quite a bit from this average, especially during periods of abnormal weather. To determine how your turf's growth potential is adding up under current weather conditions, see Table 3. How about growth potentials for yesterday or today? Scan Table 3 for the average air temperature on the day you're interested in. How is the turf likely to perform for the next five days? Take the average of the forecasted air temperatures for the next five days, and use Table 3 to find the predicted growth potentials.
- Explain why it is a good (or bad) idea to overseed at your location.

THE RESEARCH says . . .

- **The turf growth** model presented here takes into account the unique weather patterns at each location.
- **The model can** be used to: give the superintendent — and not the weather — more control over overseeding and transition programs; understand the role of weather on the growth of warm-season and cool-season turfgrasses at your location; educate golfers and management about the effect of the weather on overseeding and transition performance at your site; support decisions on overseeding, turf species selection and application timing for transition aid products.

- If new turf is being considered, determine whether warm-season or cool-season turf species are optimal for your site.
- Determine whether overseeding is appropriate for your location, and what the risks and benefits of your decision will be.
- Determine when the best overseeding date would most likely be at your location. This occurs when cool-season growth potential is significantly higher than warm-season growth potential. Several weeks of high growth potential for cool-season turf should occur after the overseeding date so that the overseed has time to establish before cold weather sets in.
- Determine the best time to apply chemical transition accelerating products in the spring. This is discussed further in part 2 of this series, "Managing the Spring Transition."

SOLAR RADIATION

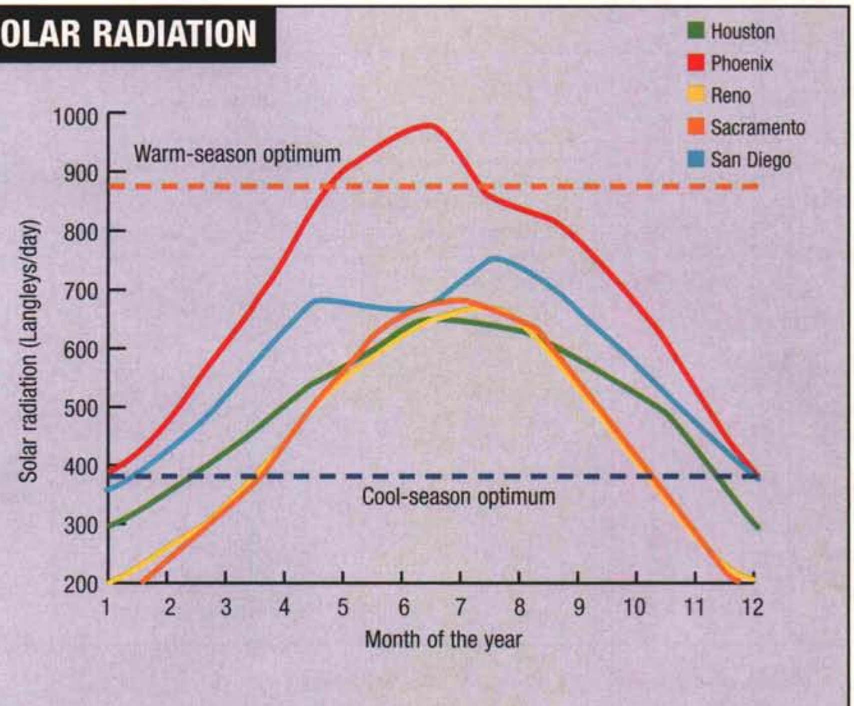

Figure 4. Average monthly solar radiation for five locations throughout the United States. Note that Phoenix is the only location of the five that has sufficient solar radiation to support good growth of warm-season turf. Values are 30-year averages of monthly solar radiation (1961-1990) provided by the U.S. Department of Energy at its Web site: http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/sum2/state.html.

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Wendy Gelernter, Ph.D. (gelernter@paceturf.org), and Larry Stowell, Ph.D. (stowell@paceturf.org), are the founders of Pace Turfgrass Research Institute, San Diego. Both authors were instructors at the 2005 GCSAA Education Conference in Orlando.