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Natural Versus Artificial Turf- an Economical Alternative*

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Given this topic, writers with different backgrounds and interests would, understandably, present different points of view. As a horticulturist who has spent the past 20 years doing applied field research in the development and management of high-use athletic areas, you might well expect that I am biased in favor of natural turf. I also believe that inclement weather is just part of the game for outdoor sports, such as football, baseball, soccer, rugby, and golf.

If our concern is primarily a high profit business, then there may be little argument that artificial turf is the most economical surface. If we require almost continuous use of the turf for a variety of activities, in order to pay the high cost of building and maintaining a multipurpose stadium, nothing short of artificial turf is the answer. Such is not the case for many athletic fields or stadiums where artificial turf has been sold and installed, mainly because their turf managers could not maintain an acceptable natural turf. As horticulturists, agronomists, and managers of athletic areas, we have failed. Basically, we do the best we can with what we are given to maintain, and there are limits to what can be done. Professionally, the extent to which we play a major role in the decision-making process concerning development, use frequency, or budget needs to establish and maintain acceptable natural turf has not been recognized. Coaches, players, and businessmen (former players) control these major decisions, and, because they are people-oriented and have limited plant knowledge, they tend to respond to alternative solutions for high-use athletic areas differently than do plant-oriented turf managers.

Artificial turf is the best single thing that could have happened to the natural turf manager. We now have a very high cost alternative to natural turf which has given us the opportunity to say: "For that kind of money, we too can produce high-use, natural, athletic turf areas." Before the introduction of artificial turf, few decision makers would even consider the possible alternatives we have available for natural turf.

Several years ago an athletic director of a major university asked me to solve the problem of its soil-based football field. He offered a budget of $20,000 and 3 months' open time to produce a new natural turf field, one which would give the university excellent playing conditions and high aesthetics for national television. The field also had to be in excellent condition through late November so that if it rained before or during the final football game, it would not be played in the mud. Within this time limit and budget, the task was impossible. Before our meeting, the university had seriously considered another alternative: for $650,000 and 6 months' construction lead time, an artificial turf could be installed that would be guaranteed for 5 years. Now, the university's athletic director was willing to listen to my alternative – a special sand growing medium for a natural turf field at a cost of $200,000, complete with automated irrigation system and 5 months' construction lead time to grow a bluegrass and ryegrass turf.

Throughout the United States, many of our major league sports stadiums have switched to artificial turf. Monsanto's "Astroturf" is the most popular one. Some of these stadiums are completely indoors like the Astrodome in Houston, Texas; others are partly covered, which makes artificial turf the only choice. Several major stadiums are now returning to natural turf with various modifications of a sand-base growing medium. The reasons for returning to natural turf vary. Now that we have several years of experience with both artificial and the new sand concept for natural turf, we can better

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judge the pros and cons of each system.

Artificial turf has two major advantages:

(1) The field can be extensively used, moving from one sport or activity to another, with a minimum chance of reducing its useful life over a 5- to 7-year period.

(2) Annual maintenance costs are lower, and it requires a less technically trained management team. (Its management, however, can not be considered "low maintenance," particularly when compared with the type of average to low maintenance budgets many natural turf managers have worked with in the past.)

Several arguments favor the newer, sand-based natural turf athletic areas:

(1) Construction cost of a sand-based field, even if it includes a closed cell system, ranges between one-third to one-half that of an artificial turf. For many fields where noncelled systems have been used, the difference in costs is even greater.

(2) Serious vandalism to natural turf, particularly the new sand-base fields, can be repaired at considerably less cost than for artificial turf.

(3) Total football injuries, both minor and serious, are 32 percent less on natural turf. When you look at only the very serious types of injuries, it makes little difference what type of surface football is played on.

(4) Survey results show that 84 percent of the professional football players prefer natural turf.

(5) Natural turf does not generate uncomfortable amounts of heat. In one study made in October at noon when the ambient air temperature was 78° F, the surface temperatures of blue grass and artificial turf were as follows:

Artificial turf. .125° F
(+ 46° F above air temperature)
Bluegrass (1/2-inch tall). . . . . 83° F
(+ 15° F above air temperature)
Bluegrass (1 '/-inches tall) . . . . , .79° F
(+ 1° F above air temperature)
Bluegrass (6inches tall) . . . . .67° F
(- 11° F below air temperature)

In most of California, it is this heat problem which makes natural turf the first choice even when old soil construction methods are used.

In 1978, the only major stadium in California with an artificial turf, Candlestick Park in San Francisco, was converted back to a natural field. A type of cell system was chosen for this park in which the extensive drainage system overlaying a plastic barrier can double as a subirrigation system. The growing medium was a uniform, fine sand surface amended with fir bark. The field was open for professional baseball before the contractor had completed the job. The baseball players were not well pleased during the first season, which was to be expected, but the field was well received by football players. Once a proper management program has been developed, this field could establish natural turf over artificial as the best answer for California's high traffic athletic areas.

During the past 15 years, our work with high-use athletic areas has centered on the use of special sands overlaying a tile system. Because of our climatic conditions, we have not felt that we could justify a closed cell system for drainage and subirrigation. We have worked closely with architects, contractors, and developers in the planning and construction of 15 football fields and seven multi-use part sites in northern California. We also have tested and supplied information for many projects both within California and throughout the U.S. We believe the key to these high-use areas is in the selection of a relatively fine particle size range of sand placed at a depth of 12 to 14 inches. This sand must accept and drain excess water rapidly and, once drained, still retain sufficient water in the grass root zone so that irrigation need be no more frequent than every 2 to 3 days during the normal summer weather. These are the same sands and the same horticultural concepts that we recommend for golf and bowling greens. The only real differences are these: we use different grass species, we can tolerate sand nearer the outer limits of our recommendation, and their management is less demanding. The table shows the particle-size range of sand used at different sites in northern California

We do not recommend amending these sands with organic or inorganic materials, because our research and field experience have shown amendments to have a poor cost-benefit ratio. The benefits commonly attributed to amendments are improved nutrient and water-holding capacity. With the "right" sand, the advantages of amendments are small compared to the cost of the amendment and the special mixing requirements. All too often the mixing is so poorly done on large jobs that more problems are created than solved. Grass also is a very high producer of organic matter, and, once a turf is well established and properly managed, the cation exchange in the root zone is that of a sandy loam soil.

Each field varies in the extent and design of the drainage system according to its climate and use. Water moves rapidly through the 12 inches of sand to the subbase soil, at which point extra water will create a perched water table. A tile system at this interface functions to drain off this perched water table. The best systems make use of a sloping subbase to the tile lines. One such system is illustrated on page 27, but this system may be modified in many ways and still achieve its purpose.

The sand-based field is no panacea. Overuse still will wear out the turf. Mismanagement can still reduce the quality and playability of the turf. The advantage of the

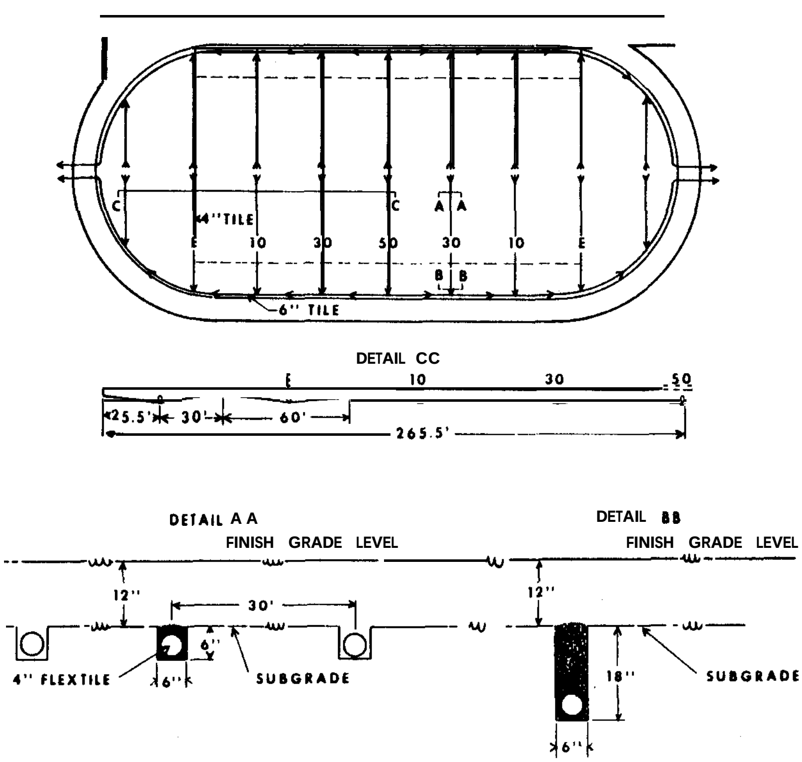
Analysis of Representative Sand Samples According to Particle Diameter (mm) from Various Sportsfields In Californls (and Recommended Proportions)

Location	Use	Fine gravel (2.0-2.0)	Very coarse sand (2.0-l .O)	Coarse sand (1 .O-0.5)	Medium sand (0.5-0.25)	Fine sand (0.25-O.l)	Very fine sand (O.l-0.05)	Silt	Clay	Key fraction	Compacted Infiltration inch/hour
					Percent						
Fortuna	Football Soccer	6.0	0.0	0.5	74.5	23.5	0.5	1.0	0.0	98.5	26
Eureka	Football	0.2	0.2	0.8	60.5	35.0	0.9	1.4	1.0	96.3	29
[illegible]	Football	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	49 (?)
Delta	Baseball	0.2	2.2	19.0	44.5	28.0	3.5	1.7	0.9	91.5	21
Petaluma	Soccer	0.0	0.6	3.1	83.2	11.0	1.4	0.0	0.7	97.3	51
Salinas	Football	0.0	0.0	26.0	68.0	4.7	0.1	0.5	0.7	98.7	>70
Cabrillo	Football	0.0	0.3	1.0	65.4	27.5	2.3	1.7	.08	94.9	27
Peralta	Soccer	0.1	3.0	42.5	45.5	4.9	0.6	1.2	3.2	91.9	37
Gilroy	Football	0.3	6.9	60.9	25.6	5.1	6.3	0.0	0.0	90.5	36

Recommended proportions for construction

Acceptable = [1.0 to 2.0 mm (0 to 10%)] + [0.1 to 1.0 mm (80 to 90%)] + [clay to 0.1 mm (5 to 10%)]

Desirable = [1.0 to 0.5 mm (0 to 15%)] + [0.1 to 0.5 mm (80 to 90%)] + [clay to 0.1 mm (4 to 8%)]



A suggested drainage system for a football field inside a quarter-mile running track sand-based field as compared to a natural soil-based turf field is that the "right" sands are not compactable. Water moves into and through the medium. The more optimal growing condition produces a healthy, strong, growing turf. Even a badly worn field is not muddy. The field is playable even if it is raining. We can mow, overseed, aerate, and/or practice other management programs without waiting for the field to dry out. Fields can be flat, because we don't depend on any surface drainage to remove excess water. Disease problems are reduced because we have a better soil-to-air water relationship in a root zone. Fertility management is important and does require careful attention during the first 6 to 12 months. Once established, we have not found that sand-based fields require any more special attention than a properly managed soil-based field. We can overleach sand-based fields by applying water too frequently and in greater amounts than are necessary. The sand-based field must have a well-designed irrigation system to supply uniform coverage. All too often we tend to flood-irrigate with a sprinkler system. This will not work on a sand field.

As turf managers, we do have alternatives. Where traffic is high and we must use our field during periods of wet weather, the sand-based field can be an answer. We must use the right type of sands, and, therefore, construction costs will generally be higher than for a typical soil-based field. Even if properly constructed, sand-based fields will not measure up to their potential with a minimum management program. Their real asset is the fact that they can be managed. They never need to be rebuilt and can always be managed back to a perfect natural turf field. For the vast majority of outdoor sports areas, there are few situations where an artificial turf would be needed or, over time, be a greater economical benefit than a sand-based natural turf.

Sand Green Construction[1]

William B. Davis[2]

Few landscape areas present the complexity of problems that are found on a golf green. In order to produce a living grass carpet of putting quality, we must mow it too frequently and too short for the best health of the grass. We stimulate the grass with excessive fertilization and frequent irrigation and then subject this grass to excessive use. To insure the greatest abuse of our putting greens, we have designed special shoes with small cleats to compound our problems. We require that there be 18 of these special turf areas on a golf course and that they be strategically located in an area of 75 to 125 acres (30.4 to 41.6 hectares). All of these areas must be uniform in their putting quality, even though the sites vary as to exposure to wind, sun, and possible shade from trees.

For many years, man has tried to duplicate the sandy links of Scotland where golf originated. We have made all manner of mixtures using every natural and man-made waste product to produce a putting green growing medium which could give the desired results. In California, every conceivable organic and inorganic amendment has been mixed with whatever sand or sandy loam was readily available. Following World War II, the golf boom got under way, and everyone was an expert. Between 1890 and 1950, only 183 golf courses had been constructed in California. From 1950 to 1968, 522 new courses were completed and open for play. Since 1968, construction of new golf courses has leveled off; only about 100 new courses have been developed during the past 12 years. Use of our courses also has changed during the past two decades. Typically, private clubs had annual play of 7,000 to 20,000 rounds per year; they now have 20,000 to 40,000 rounds per year. City, county, and fee courses went from 20,000 to 30,000 up to 65,000 and 100,000 rounds per year.

During the mid 1960s, Dr. John Madison' and I began to look at the problems resulting from the high use of golf greens and the failure of these greens, due primarily to the compaction of their growing media. We studied all types of amendments with various sand graduation and concluded that the "right" sand unamended would produce the type of green we need. In 1965, G. B. Bodman and G. K. Constantin, then soil physicists at U.C., Berkeley, completed an extensive laboratory study on the influence of particle size distribution in soil compaction. This study gave us added assurance to continue our field work which has resulted in our present

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sand green construction recommendation.

There are two major problems of the pure sand-green concept which must be overcome before superintendents and golf course architects are willing to accept it. Everyone knows sands are droughty and will not hold sufficient water to make them suitable as a field-growing medium. Secondly, sands have a very poor cation exchange and, therefore, will not hold nutrients needed for plant growth. These two objections to the concept are found in every agricultural soil text book and are valid for sands as a general soil medium. But we are not talking about just any sand, and we are not growing an agricultural crop. We are talking about a special sand that under conditions of extensive use, will not compact: uniform sand on the fine side which retains sufficient moisture in the rooting zone to carry turf for 2 to 3 days between irrigation at normal summer evapotranspiration rates. We mean sand that drains its excess water from the surface root zone in less than 15 minutes, no matter how much water it receives in a short period of time. As for nutrients, problems of fertility management are no greater for our pure-sand greens than they are for other putting-green media. But, during the establishment period, greater attention to holding a good balanced nitrogen program is required.

Sands that meet our specification may or may not be readily available at the closest sand and gravel company. We are not constructing a concrete foundation, road, walk, or plastering a building; we are building a growing medium for an extensively used and managed recreational outlet. Being in a coastal state, we are blessed with many natural deposits of sands quite suitable for golf green construction that don't have to be screened or washed. We also have many river sands that can be processed to meet our requirements. Because of where the sand deposits are located or processed, they are relatively weed-free, so sterilization is rarely recommended before sowing the green to a creeping bentgrass.

Analysis of Representative Sand Samples According to Particle Diameter (mm) from Northern Californian Puttlng Greens (and Recommended Proportions)

Source	Fine gravel (2.0-2.0)	Very coarse sand (2.0-1.0)	Coarse sand (1.0-0.5)	Medium sand (0.5-0.25)	Fine sand (0.25-0.1)	Very fine sand (0.1-0.05)	Silt	Clay	Key fraction	Compacted infiltration (inch/hour)
					Percent					
Dillon Beach*	0.0	0.0	29.9	52.4	13.6	0.3	1.7	1.1	95.2	32.5
Presidio Shoals	1.0	1.6	7.0	74.0	15.0	0.3	0.4	0.0	97.8	55.5
Santa Cruz 1070	0.0	0.0	11.7	62.7	23.6	1.0	1.5	0.5	97.0	27.8
Olympic Club*	0.0	0.0	1.5	58.0	35.5	2.0	1.5	2.0	95.0	13.5
Pacific Grove"	0.0	0.5	34.0	62.0	2.2	0.1	0.4	0.8	98.2	94.5
Monterey Dune	0.0	0.4	22.1	61.2	15.1	0.2	0.8	0.2	98.4	66.7
Manteca	0.0	1.4	18.4	49.0	27.7	1.6	1.1	0.6	95.1	27.5
Fortuna*	0.0	0.0	0.5	74.5	23.3	0.1	1.0	0.0	98.9	26.3
Mendocino'	0.0	0.0	0.0	49.2	49.0	0.5	0.5	0.8	98.2	37.5
Gordon	0.0	0.0	0.7	88.5	6.9	0.3	0.5	3.1	96.1	71.4

Recommended proportions for construction

Acceptable = [1.0 to 2.0 mm (0 to 10%)] + [0.1 to 1.0 mm (80 to 90%)] + [clay to 0.1 mm (5 to 10%)]

Desirable = [1.0 to 0.5 mm (0 to 15%)] + [0.1 to 0.5 mm (80 to 95%)] + [clay to 0.1 mm (4 to 8%)]

Recommended proportions for topdressing

Acceptable = [1.0 to 0.5 mm (0 to 15%)] + [0.1 to 0.5 (75%)] + [clay to 0.1 mm (0 to 8%)]

Desirable = [0.1 to 0.5 mm (100%)]

*Natural deposits which were used as dug-without any washing or screening.

We first encountered the “right” sand being used and sold as a top soil or fill sand, because it was too uniform in its particle size distribution to grade economically for use in the building trade. Typical particle size distribution of a washed plaster sand differs from the narrow particle size range of the sands we recommend. The table shows 10 sands which have been used for construction of golf greens in northern California over the past 10 years, as well as our general recommended particle size range. The real key to selection of the “right” sand is to first look for a particle size range that has 90 to 100 percent no larger than 1 mm in diameter and no finer than 0.1 mm, with the dominant faction between 0.5 mm and 0.25 mm.

Construction of an actual putting surface is quite simple. The contouring or raised area around the green is of the parent soil. Only the apron and the green proper have a 12-inch (30.5 cm) depth of sand. Most greens are graded evenly at the subbase so that they have a 2- to 4-percent slope from the back to the front. No subsurface contouring is necessary. The surface sand can have added contour if the raised areas do not change the total depth of the sand at the highest point more than 3 inches (7.6 cm). We do not need to establish surface drainage in different directions because all water reaching the green will readily move into the green. See typical cross sectional view through center of green (figure 1).

At most construction sites, the parent soil has a very low water infiltration rate of from 0.1 inch to 1.O inch per hour. The infiltration rate of the sand we use can vary from 10 inches to 50 inches or more per hour when compacted with a soil-kneading compactor in the laboratory. At the interface between the sand and the subbase soil, a perched water table can be produced during heavy rains or by excessive irrigation. Therefore, a tile system is recommended to remove this excess water. Many typical tile systems don’t really function as planned, and this is an area in which we are now doing basic studies. The most important tiling of the green is the lowest area, which is generally the front of the green. This water must be removed so that it does not produce a soft approach area into the green. The spacing and need for additional tile up through the green depend on the size of the green, the slope of soil around the green, and the rate of excess water falling on the green. The sand green does not depend on any surface drainage to remove water. All water reaching the green will move into and through the green, and, if in excess, a perched water table will be created; hence, the need for a removal tile system. Each green is different, but figure 2 shows the most important element of the drainage system in solid lines and possible additional system in broken lines. Surface water draining off soil that slopes onto the green may require a tile line ringing the green. Excess rates of water moving along the interface from the back to the front of the green may need to be intercepted in order to drain the perched water table more rapidly.

Most tile lines fail when they are first installed due to poor workmanship and failure to use a transit to check for proper fall in the tile line. Once a tile line leaves the green, it must go someplace where the water can be discharged into a storm sewer or surface drainage outlet. Installation of the tile first requires that all loose soil be removed. Secondly, the width and depth of the trench should fit the tile size used and be no larger than necessary to properly incase the line in 1/4-inch pea gravel. (See fig. 2 for cross section view.) A 3-inch tile line needs only a 6- by 6-inch trench, while a 4-inch tile line needs a 6- by 8-inch trench. There should be 1 inch of pea gravel under the tile, 1 to 2 inches on the side and 2 to 3 inches covering the top of the tile. Most tile lines used today are a corrugated flexible plastic with two to four slits running the length of the line for water entry. Sometimes these tiles are incased in a fine mesh sleeve. Careful trenching and placement of 1/4-inch pea gravel will not allow movement of sand into the tile lines.

Nutrients available in sands vary depending on whether or not they contain any secondary minerals or are pure quartz. We have tested 35 suitable sands for golf green construction by the pot test method, where one element was removed from each sample. All sands were deficient in nitrogen, and turf would die shortly after germination in it. The same was true of sulfur. The seedling growth was stunted and yellow, dying within the first 2 weeks. As for phosphorus, 50 percent of the sands were well supplied with available phosphorus, and only 9 percent of the sands had a severe deficiency. Fifty-three percent of the sand had an adequate supply of potassium, 38 percent showed moderate deficiency, and only 3 percent was severely deficient. Even though many of our sands may appear to need only nitrogen and sulfur, we recommend a starter fertilization of 20 pounds of single superphosphate and 5 pounds K20 per 1,000 square feet. Nitrogen and sulfur are supplied by 5 pounds of ammonium sulfate followed by 2 1/2-pound applications every 2 to 3 weeks until the green is well established. On one of our experimental greens, we produced excellent growth and putting quality over an 8-year period using only 8 to 10 pounds of nitrogen annually with ammonium sulfate after our starter P and K fertilization. Most of our irrigation water ranges in a pH of 7.0 to 8.0, and the soil solution pH over this 8-year period has ranged between 6.5 in the winter to 6.8 in the summer.

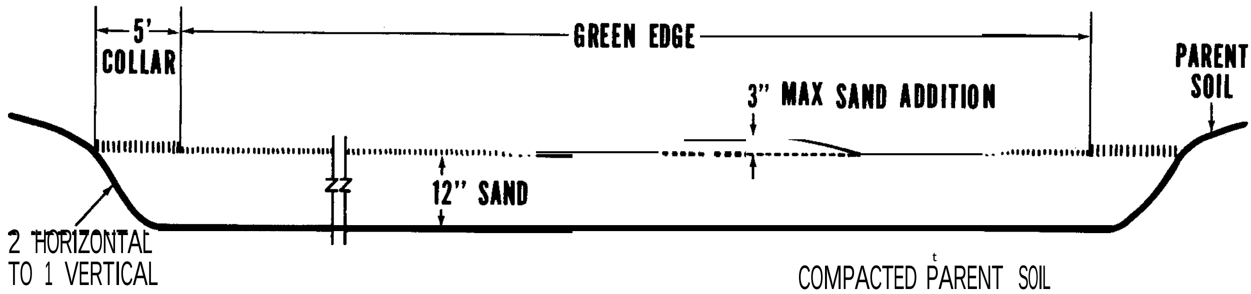

Fig. 1 Typical center cross-sectional view of the sand green.

After 15 years of continuous study with sand greens, we believe they are the best solution to date in solving our problems associated with high-use putting greens, particularly when coupled with our light, frequent top-dressing management program. Like any green, a sand green can be mismanaged by daily irrigation during periods of low evapotranspiration and excess leaching of nitrogen and potassium. Overuse of all nutrients will produce excess thatch. Use of organic fertilizers (particularly sewage sludges) can seriously reduce infiltration, and overuse of herbicides and fungicides can be toxic to roots. Diseases are greatly reduced due to the excellent drainage characteristics of the sand green. Typical application rates of fungicides for poorly drained greens with high clay and organic content may be too high for the sand green.

Properly managed sand greens are firm, fast greens at normal cutting height and cutting frequency. Tournament golf is possible every day. Golfers who expect to hold a 2-iron shot into the green which is soft and mushy will be greatly disappointed. For the golfer, be he of great or little skill, the sand green can be managed even under high use to give him a quality putting surface 365 days per year.

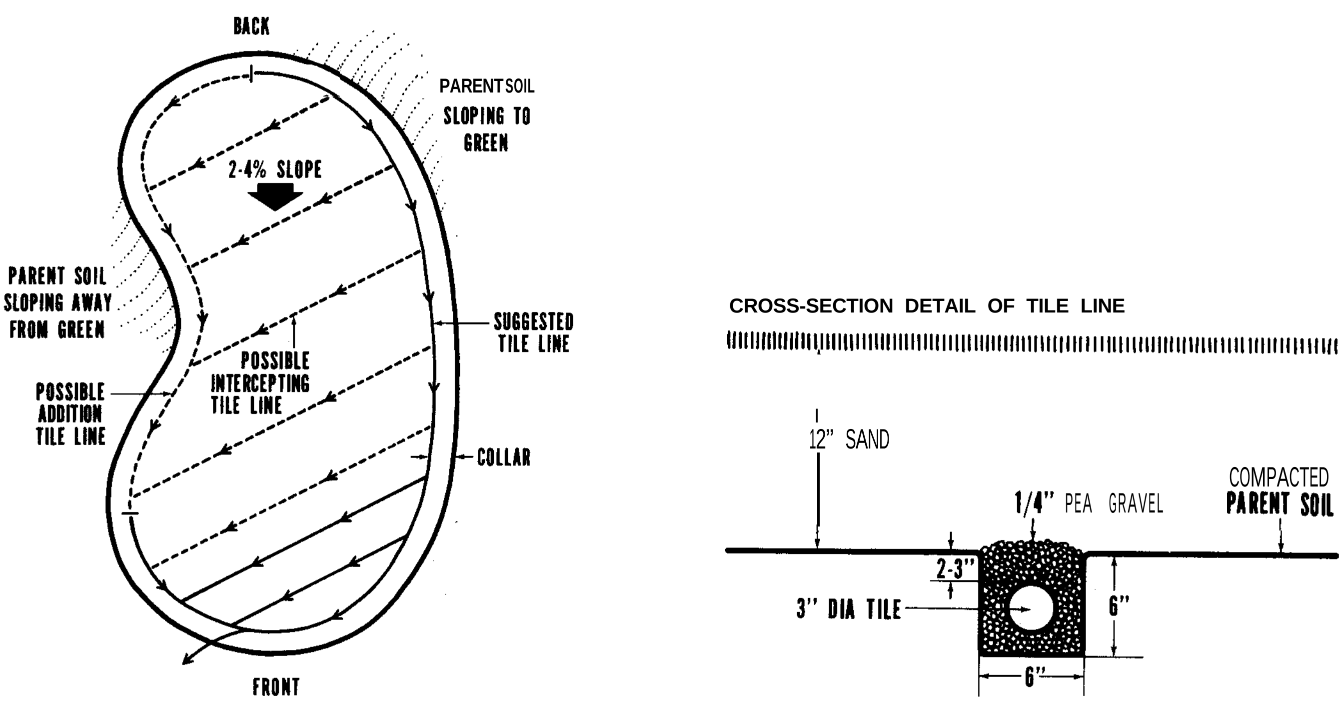

Fig. 2. Suggested tile line for sand green.

Fertility Assay of Sands

Jack A. Paul'

Use of sand as growing media either as a component in soil mixes or alone stems from desirable physical properties imparted by sands, not their fertility. Generally, sands are thought of as being poor nutritionally. Under those circumstances where sand is used in potting soil, the fertility of sand is not important since nutrition in container culture is easily effected with combinations of chemical amendment, liquid fertilization, controlled-release and dry fertilizers. Under conditions where sand is used as a sporting turf soil (putting green, football field) and will not receive the intense fertilizer management of a container soil, inherent fertility is important. If sand can provide some of the plant nutrients, management is easier. Fertility of sands, as a separate class of soil, has not been evaluated, yet it would be useful to have this information.

The purpose of this work was to assess fertility of sands suitable for horticultural purposes with particular references to sands used for turf. The present study evaluates nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) status of 35 sands using the pot testing method (Jenny, Vlamis, and Martin, 1950). Soil testing for estimating available P and K in sands is also presented.

Before discussing the results on fertility, it is worthwhile to review briefly the reason for using sand as a traffic soil. It is not necessary that all turf soils receiving traffic be constructed of sand. Under conditions of low to moderate traffic and with good management, soil other than sand can and will support good turf growth. Heavy traffic can cause extra demands on management to keep the soil permeable to water and air, and it is under such conditions that sands are most useful.

Soils containing silt and clay are more or less in a state of aggregation. Under a compactive force, moist soil aggregates deform and flatten, filling in the large air- and water-conditioning pores between the aggregates. The remaining pores are very small and conduct water slowly. Sands form rigid networks of grains that can withstand compaction. After compaction, there is little change in numbers of conducting pores between grains, and so permeability to air and water is preserved. This ability to withstand compaction is the principal reason for preferring sand rather than finer textured soils.

Particle size distribution

Since natural sands are generally unsorted sediments, particular attention should be given to the particle size distribution. Not all sands are ideal for growing plants or for managing. The particle size diameter of sands is given in the tables of the two preceding articles.)

Silt is 0.05 mm and clay is less than 0.002 mm. Fine gravel is greater than 2.00 mm. Sands having a broad particle size distribution, i.e., a fairly continuous particle size representation, are poor horticultural sands, because the finer grains fit into pores between larger grains, and if silt and clay are also present (8 to 10% by weight), the problem is further aggravated. The resulting mixture is a very dense (bulk densities of 1.9 g/cc), tough matrix with only fine pores. We seek uniform sands in horticulture, medium sands for sport turfs and medium-coarse sands for potting soils. Uniform medium and medium-fine sands are permeable after compaction (6 to 12 in./hr.) and contain adequate available water (1 1/4 to 1 1/2 in.) in the surface 4 inches of a 12-inch depth following drainage. Medium-coarse and coarse should probably be amended to increase plant-available water. For a review of sands recommended for putting greens see Davis (1973 a, b) and articles in this issue.

In selecting sand to meet the physical requirements for a traffic soil, to what extent is fertility sacrificed? Sands have little or no cation exchange capacity; sands taken from below the surface foot have no organic matter and probably a small microbial population. Visual inspection of some sands suggests that they consist primarily of quartz. Such sands would require careful and complete fertilization. Other sands appear to be rich in primary minerals, such as mica, feldspars and ferro-magnesium minerals. Thus, some sands appear to have no plant nutrient-bearing minerals, while others seem to have a full complement of such minerals.

Fertility of sands

The pot test method was used to assess fertilizer requirements of 35 sands obtained from various commercial sources in central California. It consists of treatments with elements in various combinations with elements subtracted one by one - e.g. PKS minus N(N_O). Treatments consisted of: NPKS: full; PKS: N_O; NKS: P_O; NPS: K_O; NPK: S_O; -: Check.

Plants were grown in 4-inch plastic pots containing 650 grams of sand. The fertilizers were applied as chemically pure salts at the following rates:

Element	Fertilizer salt	grams/pot	Pounds/acre Element	Pounds/acre Oxide
N	NH_4NO_3	0.261	300	—
P	$Ca(H_2PO_4)_2{*}H_2O$	0.115	66	200
K	KCl	0.103	166	200
S	Na_2SO_4	0.144	100	—

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Nitrogen was applied as a split application with one-half applied 45 days after planting.

One-hundred mg of seed of bentgrass (Agrostis tenuis cv. 'Penncross') were planted per pot. The grass was grown for 60 days, and three harvests were made by taking clippings 30, 45, and 60 days after planting. Total dry weight yield per pot was obtained by summing the three harvests. There were four replicates per treatment. Relative yield (yield of subtractive treatment per yield of full treatment, x 100) is used to compare fertilizer responses between sands.

All experiments were performed in a cool greenhouse (night temperature 55° F and day temperature 80° F) from April through October.

Results

The following table summarizes the extent and frequency of fertilizer responses obtained for 35 sands.

Relative yield (percent)	Percent of sands deficient in			
	N_o	P_o	S_o	K_o
0-20	100	3.1	6.2	0
20-40	-	6.2	18.8	3.1
40-60	-	25.0	31.3	6.2
60-80	-	15.6	25.0	37.6
80-100+	-	50.0	18.7	53.1

Nitrogen

The N_o treatment for all sands had relative yields (RY) of 0 to 20 percent. Yields of this treatment were no better than the check, which suggests that the sands were absolutely deficient in available nitrogen. This is not too surprising if the source of sand is considered. All came from subsurface deposits. Nitrogen-deficient grass was stunted and light yellow.

Phosphorus

Fifty percent of the sands tested were well supplied with available phosphorus (RY, 80 to 100 percent) and 9 percent were severely deficient. It is interesting to note that, in the P_o treatments for some sands, growth rate increased after the first clipping. This suggests that, with time, more phosphorus became available. Moderately phosphorus-deficient grass is stunted and dark green with narrow blades.

Sulfur

Sulfur-deficient sands appeared to be more or less represented in all RY categories. It is speculated that S compounds originally present in these sands were leached with low sulfate waters, and since no organic matter is present, there is no mineralization from organic sources. Sulfur-deficient grass is very similar to N deficiency.

Potassium

Fifty-three percent of the sands were adequately supplied with available K. Three percent were severely deficient, and 38 percent were moderately deficient. Potassium-bearing minerals, such as mica and the feldspars (microline and orthoclase), would be the main sources of K; clay-derived K would be minor, since clay was generally less than 3 percent of the sand sample.

Micro-nutrient treatments were included in many of the sands, but no significant yield increment was obtained in these treatments. None of the sands tested indicated a need for lime, and no calcium (Ca) or magnesium (Mg) deficiency symptoms were noted, but this does not rule out the possibility that some sands will be deficient in these nutrients. Since only 35 sands were evaluated, no generalizations can be made regarding micro-nutrient and lime requirements.

Chemical analyses

The pot testing method provides a reliable means for assessing the fertility status of soils, but it requires proper facilities and time. Soil tests are not as reliable, but if they are well correlated with fertilizer requirements, they are very useful. They are also less expensive. Soil analyses for phosphorus and potassium were performed on all sands and were correlated with appropriate subtractive treatments. The test for sulfur has not yet been done for these sands. Nitrogen need not be considered for obvious reasons.

Phosphorus

Available phosphorus was estimated on untreated sand samples by two methods: 0.5M $NaHCO_3$ extractable P and water soluble P (Rible and Quick, 1960). For the $NaHCO_3$ method, extractable P is reported as ppm P on a soil basis, while water soluble P is expressed as ppm P in the extract. Both values are plotted against the RY of the P_o treatment.

The correlation between P_o RY and $NaHCO_3$ extractable P suggests that this procedure could be useful in predicting phosphorus fertilizer requirements. While the correlation is not excellent, a value of 3 ppm P appears to be near the critical level. This value is lower than is recommended for soil (6 ppm). The relation between P_o RY and water soluble P provides a better correlation. The critical level is about 0.15 ppm P. This value is the same as that cited by Bingham (1962) for soil, with cereals as the indicator plant. Both methods are useful in estimating phosphorus fertilizer requirements in sands.

Potassium

Available K was estimated by extracting with neutral normal NH_4OAc (ammonium acetate). Sands have a very low cation exchange capacity, and extractable K is expected to be low even in sands well supplied with K. Beyond 20 ppm, there is no response to K fertilization. This critical value is considerably lower than for soils containing clay, but it is in keeping with the critical level found for sands in Australia.'

In addition to P and K analysis, salt and pH should be determined. Salt should not present a problem since it is easily leached if the sand is a permeable one. Sands having a very low pH (4 to 5) indicate a need for lime or dolomite, while sand having a pH≥8 may have lime present.

Conclusions

The results of the pot test for a limited number of sands indicate that they behave as might be anticipated for sub-soil. The extent and frequency of P deficiency is similar to surface soils which have been tested (Vlamis, 1966). Nitrogen is completely lacking. Occurrence of S and K deficiencies is probably more frequent in pot tests than in valley soils in California.

It is apparent that all sands will require N to start grass, and many will also require S. Soil tests can help decide whether P and K should be added also, but sand well supplied with P and/or K initially may eventually become deficient in these nutrients as clippings are removed. Soil and tissue tests may be useful to indicate when these nutrients should be applied.

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UC TURF CORNER

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UC Turf Corner contains summaries of recently reported research results, abstracts of certain conference presentations, and announcements of new turf management publications. The source of each summary is given for the purpose of further reference.

Effects of Air Pollution Oxidants on Cool- and Warm-season Grasses

Two experiments at the University of California, Riverside, show that common turfgrass species and cultivars vary markedly in susceptibility to air pollutant oxidants.

The experiments were conducted by Dr. Victor B. Youngner to determine the acute toxicity effects of ozone and peroxyacetyl nitrate (PAN) on cool- and warm-season grasses in a greenhouse and in fumigation chambers. One lot of each was fumigated with 0.5 parts per million (ppm) ozone and another with 50 parts per billion (ppb) PAN for 3 hours. A third lot was retained

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TABLE 1. Injury to Cool-season Turfgrasses Caused by 0.5 ppm Ozone or 50 ppb PAN (Peroxyacetyl Nitrate) for 3 Hours

Species and cultivar	Ozone'	PAN'
Perennial ryegrass *(Lolim perenne* L.)		
Lamora	4.75 a	3.25 bcdef
Pennfine	4.25 abc	2.75 defgh
Common	4.25 abc	3.75 abcd
Pelo	4.25 abc	4.50 a
Linn	4.25 abc	4.25 ab
Splendor	4.00 abcd	3.50 abcde
Manhattan	4.00 abcd	4.00 abc
NK-200	3.75 abcde	3.00 cdefg
Italian ryegrass *(Lolium multiflorum* Lam.)	4.50 ab	4.00 abc
Colonial bentgrass *(Agrosfis tennuis* Sibth.)		
Dryland	4.00 abcd	2.50 efghi
Astoria	4.25 bcdef	2.25 fghij
Highland	3.00 cdefg	1.75 hij
Creeping bentgrass *(Agrostis palustris* Huds.)		
Emerald	4.00 abcd	2.75 defgh
.Chewings fescue *(Festuca rubra* var. *commutata* Gaud.)		
Common	4.00 abcd	2.50 efghi
Jamestown	3.50 abcde	2.25 fghij
Creeping red fescue *(Festuca rubra* L.)	—	
Pennlawn	3.25 bcdef	2.50 efghi
Illahee	3.00 cdefg	3.00 cdefg
Kentucky bluegrass *(Poa pratensis* L.)		
A-34	3.75 abcde	2.50 efghi
Campus	3.50 abcde	2.50 efghi
Prato	3.50 abcde	1.50 ij
Merion	3.25 bcdef	2.50 efghi
Adelphi	3.00 cdefg	2.75 defgh
Windsor	2.75 defgh	2.00 ghij
Baron	2.75 defgh	3.50 abcde
Glade	2.75 defgh	3.00 cdefg
Park	2.50 efghi	1.25 j
P-142	2.50 efghi	1.75 hij
Cougar	2.00 fghi	1.50 ij
Pennstar	2.00 fghi	2.25 fghij
Newport	1.75 ghi	1.75 hij
Fylking	1.75 ghi	1.75 hij
Prim0	1.75 ghi	2.75 defgh
Common	1.75 ghi	2.00 ghij
Arista	1.50 hi	2.00 ghij
Nugget	1.25 i	1.25 j
LSD	1.49	0.95

*Rating of 1 = no injury to 5 = severe injury. Numbers in the same column with the same letter are not significantly different at the 5 percent probability level.

in the greenhouse as a control. Results are shown in tables 1 and 2.

"Significant variations in leaf injury were noted among the species and cultivars," Dr. Youngner reported. "Injuries to a cultivar from ozone and PAN were often of different magnitudes."

All perennial ryegrass cultivars showed severe injury, and Kentucky bluegrass cultivars ranged in sensitivity between the extremes for both pollutants. Colonial bentgrass and creeping red fescue had moderate injury. Generally, warm-season were less sensitive than cool-season grasses: only 'Emerald' zoysiagrass and 'Tif-green' bermudagrass were injured.

Foliar injury from ozone, Dr. Youngner explained, first appeared as water-soaked areas at or near the blade tips. Early injury symptoms from PAN were less obvious - usually a slight russeting or specking towards the midsection of the blades. After several days, areas injured by either ozone or PAN became bleached and dry; entire blades died if severely injured. Leaf necrosis appeared to be restricted to young blades or those just fully expanded, while the old, mature blades showed no injury.

"Although new growth quickly masked the effect of the single exposure to the pollutants," Dr. Younger concluded, "field observations have shown pronounced reduction in turf quality in areas subject to repeated pollutant exposure. In such places, use of one of the less sensitive species or cultivars may be advisable."

(See "Air Pollution Oxidant Effects on Cool-season and Warm-season Turfgrasses," by V. B. Youngner and F. J. Nudge, Agronomy Journal 72[1]: 169-170.)

TABLE 2. Injury to Warm-season Turfgrasses Caused by 0.5 ppm Ozone or 50 ppb PAN (Peroxyacetyl Nitrate) for 3 Hours

Species and cultlvar	Ozone'	PAN
Sermudagrass		
Tifgreen *(Cynodon* hyb.)	2.25	2.75
Santa Ana *(Cynodon* hyb.)	1.00	1.00
Common *(Cynodon dactylon)*	1.OO	1.00
Zoysiagrass		
Emerald *(Zoysia* hyb.)	1.75	1.00
Meyer *(Zoysia japonica)*	1.00	1.00
St. Augustinegrass *(Stenotophrum secundatum)*	1.00	1.00

*Rating of 1 = no injury to 5 = severe injury.

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