Adding inorganic amendments to a poorly performing green

The addition of inorganic amendments did not solve a putting green's infiltration problems.

In the last decade, considerable research has focused on the use of inorganic amendments in putting green construction. Reasons for the incorporation of the amendments vary, ranging from improvement in the holding capacity of plant-available water to increases in nutrient retention. Typically some type of clay, diatomaceous earth or other porous ceramic, the materials may also be kiln-fired to increase their hardness and resistance to wear. Using inorganic amendments as a substitute for peat in putting green construction has become so common in the industry that their use is now discussed in the USGA's guide to putting green construction (9).

However, the inclusion of such amendments has largely been evaluated as part of the construction process, with the amendments incorporated throughout the final greens mix. A great deal of research has been expended in this area, with mixed results as to the effectiveness of inorganic amendments. When 90% sand/10% amendment greens mixes were compared to a 100% sand greens mix, the inclusion of amendments such as clinoptilolite zeolite reduced nutrient loss (3,6,7), improved turf quality and establishment (2,7) and increased cation exchange capacity (CEC) (5) in the putting greens.

The test site was a practice putting green at Saugahactee CC, Opelika, Ala. **Photos by E. Guertal**

When compared to a sand/sphagnum peat greens mix, however, inorganic amendments were less likely to provide highly significant benefits. For example, when greens mixes were ranked according to the quality of turfgrass establishment from best to worst, the results were: sand/peat greens mix > clinoptilolite zeolite (Ecolite) = porous ceramic (Profile) ≥ porous ceramic (Greenschoice) = 100% sand (2). When water retention was studied, mixtures with peat often had better water retention than greens mixes containing inorganic amendments (1,10). Results did vary with sand size, indicating that sand selection was important.

In brief, constructed greens mixes that contain inorganic amendments (typically about 10% by volume) have been shown to increase the cation exchange capacity of the green and increase retention of some nutrients, especially ammonium and potassium. Benefits are most pronounced when the inorganic greens mixes are compared to 100% sand systems. Including inorganic amendments in the greens mix has caused differences in water retention, with wide variation in water-holding capacity because of sand size, amendment type and percent of inorganic amendment included.

The research briefly summarized above has two common characteristics: the inorganic amendments were added at initial greens construction, and, therefore, most of the research focused on the first two to three years after construction with long-term effects yet to be evaluated. Many of the inorganic amendments discussed above are mar-

Environmental Institute for Golf

This research was funded by The Environmental Institute for Golf.

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keted and used in greens renovation or "drill and fill" programs, yet very little research has looked at their use in putting green renovation. Thus, the objective of this research project was to examine the impact of common inorganic amendments on bermudagrass putting green performance when the amendments were used as a part of a drill-and-fill greens renovation project.

Materials and methods

The research area was the practice putting green at the Saugahactee Country Club, Opelika, Ala., which was initially constructed as a push-up green and renovated with Tifdwarf bermudagrass in 2002. However, the green was not rebuilt to USGA recommendations and suffered from poor infiltration.

The superintendent was responsible for all fertilizer and pesticide application, and records of all applied materials were kept. The green was overseeded with perennial ryegrass each fall (September) and was allowed to transition naturally back to bermudagrass each spring.

Treatments

On June 28, 2004; June 30, 2005; and June 13, 2006, eight treatments (Table 1) were installed on the Saugahactee CC practice green. Treatments included Profile, a porous ceramic created from illite clay (CEC: 13 centimoles of charge (cmolc)/kilogram); Clinolite, clinoptilolite zeolite clay (CEC: 58 cmolc /kilogram); and Axis, diatomaceous earth (CEC: 6 cmolc/kilogram). The same treatments were applied to the same plots over the three-year period.

Amendments were applied using a commercial drilling and injection machine, which drilled holes ⅞ inch (2.2 centimeters) in diameter (approximately 6 inches [15.2 centimeters] deep) into the Tifdwarf bermudagrass putting green. The soil was removed, and the various amendment mixes were poured into the holes.

Treatment 1 (Table 1) was cored, and the holes were filled with 100% sand. For treatments 2 through 7, the remaining volume of fill material consisted of sand. For example, treatment 2 was a fill material consisting of 25% Profile (by volume) and 75% sand. Treatment 8, the control, received nothing — no drilled holes and no amendment.

The sand was purchased from Red Bay sand in Florida and met all USGA recommendations for putting green sand. The sand was stockpiled and used in all three years of the study.

Data collection

Throughout the three years of the study, data collected included: quarterly removal of 0–3-inch-deep soil samples, with samples analyzed for plant-available phosphorus, potassium, calcium, and magnesium and soil pH; twice yearly shoot-density determination (including overseed density); once yearly root-length determinations; twice yearly in situ double-ring infiltrometer readings; and once yearly laboratory determination of

A drill-and-fill method was used to incorporate amendments into the putting green.

After the holes were drilled and the cores removed, the holes were filled with the amendment mixture. A mixture of 25% Profile and 75% sand (by volume) is shown here.

Treatments

Treatment no.	Amendment	% amendment/sand (by volume)
1	Sand	0/100
2	Profile	50/50
3	Profile	25/75
4	Clinolite	50/50
5	Clinolite	25/75
6	Axis	50/50
7	Axis	25/75
8	None	

Table 1. Amendments incorporated (v/v) via a "drill and fill" process in a Tifdwarf hybrid bermudagrass putting green.

saturated hydraulic conductivity (2004 and 2005 only).

Results and discussion

Soil-test results

In the first year of work, there were few differences in nutrient status attributable to the volume or type of amendment. After two years of amendment incorporation (amendments incorporated in June 2004 and 2005), there were differences in soil nutrient status as a result of amendments. Table 2 shows differences in extractable phosphorus, potassium, calcium, magnesium and pH as affected by the volume and type of amendment after the third year of incorporation. Soil-test phosphorus and magnesium and soil pH were unaffected by amendment (this was the case in all soil tests in all years), indicating that the superintendent's fertilization program was frequent enough and sufficient to fulfill fertilization recommendations for these nutrients.

Potassium

The nutrient most affected by the inclusion of various amendments was potassium, with plots that contained any amount of Clinolite holding significantly more potassium than any other treatment. This effect was first observed in the second year of the study, when Clinolite-amended plots had a higher potassium content than any other plots. Table 2 shows that the extractable potassium content in the Clinolite plots averaged 109 pounds potassium/acre, significantly more than that in any other treatments. Of the incorporated amendments, Clinolite had the highest cation exchange capacity, and therefore should be better able than other treatments to hold cations such as potassium.

Soil test characteristics

Treatment	Phosphorus	Potassium	Calcium	Magnesium	pH
			pounds/acre		
Sand	70 a	50 c	602 ab	68 a	6.0 a
Profile (50%)	77 a	70 bc	623 ab	77 a	5.9 a
Profile (25%)	70 a	60 bc	613 ab	71 a	6.0 a
Clinolite (50%)	76 a	100 a	774 a	77 a	6.1 a
Clinolite (25%)	80 a	118 a	628 ab	76 a	6.1 a
Axis (50%)	74 a	56 c	545 b	63 a	5.8 a
Axis (25%)	77 a	62 bc	593 ab	68 a	5.9 a
None	79 a	70 bc	714 ab	81 a	6.0 a

Within each soil-test characteristic (column), differences followed by the same letter are not significantly different.

Table 2. Mehlich extractable soil phosphorus, potassium, calcium and magnesium, and soil pH at 10 months after third incorporation of amendments (April 2007).

Root-length density

Treatment	Mar 2006		June 2006		Sept 2006	
	feet	meters	feet	meters	feet	meters
Sand	21.0 cd	6.4 cd	15.1 ab	4.6 ab	13.5 a	4.1 a
Profile (50%)	33.1 ab	10.1 ab	19.7 ab	6.0 ab	10.5 a	3.2 a
Profile (25%)	24.6 bcd	7.5 bcd	13.1 b	4.0 b	13.1 a	4.0 a
Clinolite (50%)	18.4 d	5.6 d	25.3 a	7.7 a	15.1 a	4.6 a
Clinolite (25%)	24.6 bcd	7.5 bcd	17.7 ab	5.4 ab	12.1 a	3.7 a
Axis (50%)	28.2 bc	8.6 bc	22.6 ab	6.9 ab	11.8 a	3.6 a
Axis (25%)	37.7 a	11.5 a	19.7 ab	6.0 ab	9.8 b	3.0 b
None	26.6 bcd	8.1 bcd	16.4 ab	5.0 ab	9.8 b	3.0 b

Within each sampling date (column), differences followed by the same letter are not significantly different.

Table 3. Root-length density (in feet and meters) of Tifdwarf hybrid bermudagrass in March, June and September 2006.

Plant variables

Shoot density

Over the course of the study, bermudagrass and perennial ryegrass shoot density were rarely affected by the amendment treatments. In November 2005, any plot that had been aerified by drilling had a higher bermudagrass shoot count than the non-aerified control plot. Thus, the increase in shoot density had nothing to do with amendments and simply illustrated the benefit of aerifying the green.

On two sampling dates, one in September 2006 and one in April 2007, the Profile (50%) plots had a greater shoot density than some of the other treatments. Shoot density was not affected by amendments on any other sampling date (November, March, June or January of any year).

Because shoot data taken in late fall and winter measured dormant bermudagrass, the shoot density of the perennial ryegrass overseed also was measured. Amendments did cause some differences in perennial ryegrass density, but no consistent trend in differences was seen throughout the three years of sampling. For example, in November 2005 (after one year of amendment incorporation), there was no significant difference in perennial ryegrass shoot density. In March 2006, the Clinolite (50%) plots contained significantly more perennial ryegrass than the untreated control and Profile (50% or 25%) plots. However, in January 2007, the Clinolite (50%) and Profile (25%) plots had higher perennial ryegrass density than the Axis (50% and 25%), sand-only, and untreated control plots. By April 2007, such differences had disappeared, with no significant differences in perennial ryegrass population resulting from the treatments.

Root length

Root-length data also were highly variable from sampling to sampling. Table 3 shows data from the 2006 root-length samplings, with the March 2006 data collected before the third incorporation of amendments, the June data collected two weeks after the third incorporation, and the September data collected four months after the third incorporation. In March 2006, only the Axis (25%) treatment showed greater root growth than the sand-amended control and the non-aerified control. In June 2006, bermudagrass growing in the Clinolite (50%) treatment had the greatest root length, which was not significantly better than root length in control plots. In September 2006, the addition of any amendment (except Axis 25%) improved bermudagrass root length, when compared to the non-aerified control.

Double-ring infiltration data, 2005

Treatment	Inches/hour
Sand	3.0 a
Profile (50%)	2.4 a
Profile (25%)	2.8 a
Clinolite (50%)	2.2 a
Clinolite (25%)	3.4 a
Axis (50%)	3.4 a
Axis (25%)	2.2 a
None	3.4 a

Table 4. Double-ring infiltration data collected on Aug. 30, 2005, two months after the second application of amendments.

Saturated hydraulic conductivity

	Saturated hydraulic conductivity (inches/hour)		
Treatment	Sept 2004	Nov 2005	Mar 2006
Sand	16 a	18 ab	10 ab
Profile (50%)	13 a	14 ab	11 ab
Profile (25%)	11 a	11 b	7 ab
Clinolite (50%)	12 a	23 ab	12 ab
Clinolite (25%)	14 a	12 b	14 a
Axis (50%)	14 a	24 a	13 ab
Axis (25%)	10 a	15 ab	6 b
None	11 a	14 ab	8 ab

Within each sampling date (column), differences followed by the same letter are not significantly different.

Table 5. Laboratory determination of saturated hydraulic conductivity as affected by amendments. Cores were collected after first amendment incorporation (September 2004) and second amendment incorporation (November 2005 and March 2006).

Turf color and quality/plant response

Bermudagrass color and quality were rated monthly on a scale of 1 to 9, where 1 is completely brown or dead turf, and 9 is lush, dark green turf. We also rated spring green-up (1-9 scale) and fall color retention. In any rating month, turf color or quality was unaffected by treatment (data not shown). Additionally, spring green-up and fall color retention were unaffected by treatment.

Infiltration data

Two different types of infiltration data were collected. The first type — double-ring infiltration measurements — was collected in the field (in situ). To collect these data, two rings were inserted into the green, one with an outside diameter of 12 inches (30.5 centimeters) and an inner diameter of 6 inches (15.2 centimeters). Water was allowed to fill the inner and outer rings, and flow was maintained until a standing head was obtained in the inner ring. The drop in the depth of water over a given period of time was then measured, providing an assessment of the green's infiltration rate. This type of data collection is tedious, exacting and prone to variation, but it helps provide a "real-life" infiltration number.

The second type of infiltration data collected was saturated hydraulic conductivity (K_{sat}). To collect these data, cores are removed from the green and taken to the lab, where the rate of water movement through the saturated core is determined. We took K_{sat} data in the first two years of the study, but not in the third year.

Table 4 shows an example of the type of double-ring infiltration data collected from this experiment. Over the three years of data collection, we did not see a dramatic increase in the infiltration rate in this green as a result of the incorporation of amendments, and infiltration rates did not increase because of either aerification or amendment incorporation. As shown in this data set, infiltration rarely increased above 3.5 inches (8.9 centimeters) per hour, a relatively low rate of water entry into the green.

The data in Table 5 indicate that the cores of removed greens mixes had relatively high saturated hydraulic conductivity, with rates at or near the USGA recommendation of 6-12 inches (15.2-30.5 centimeters)/hour. However, in three different sample sets, the addition of amendments never improved the saturated hydraulic conductivity above that of the non-aerified plots. It may be that the greens mix of this particular putting green was suitable and that poor (or non-existent) underlying drainage was possibly the prime culprit behind its low rates of field infiltration.

Lack of treatment differences in the laboratory and field infiltration measurements was not surprising. Such data are highly variable, especially because the random core-removal process would also randomly sample holes in which amendment was placed. Thus, the actual amount of amendment in each core could vary, and measurements would therefore be highly variable as well. Replication and intense sampling per plot (we took two cores per plot and averaged our results) are always used to limit variability, but infiltration data are still prone to great variability (4,8).

Some conclusions

- Clinolite increased potassium retention in the green in the second and third years of the study.
- Shoot density of perennial ryegrass was sometimes greater when grown in Clinolite (50%) plots.
- In situ (double-ring) infiltration was unaffected by amendment and was low for this particular putting green.
- Differences in saturated hydraulic conductivity (laboratory measurement) as a result of amendment incorporation were never consistent.
- After three years of cumulative amendment incorporation, we did not see a substantial improvement in infiltration, nutrient-holding capacity, or turf performance (shoot density, root mass).
- Turf quality, turf color, spring green-up and fall color retention were not affected by the addition of amendments.
- Although previous research literature shows benefits from these amendments when used as part of a new construction, our research examined these amendments for remediation. In this study, incorporation of amendments in aerification holes showed no benefits, and reconstruction of the green (with proper drainage) would have been a better option.

Other thoughts

- Consider underlying drainage — in our case, was the bigger problem a poorly performing greens mix, or lack of drainage?
- Keep track of fertilization needs. How much fertility can you buy for the costs of an amendment?
- Don't forget the basics — aerification, vertical mowing, topdressing, thatch management.
- Research other than ours suggests that sand selection (what you mix your amendment with) is as important as the amendment itself.
- Amendment incorporation will likely be a very site-specific decision.

Funding

We thank The Environmental Institute for Golf for providing funding for this research.

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GCM

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The research says

→ Three years of cumulative amendment incorporation did not result in a substantial improvement in infiltration, nutrient-holding capacity or turf performance (shoot density, root mass).

→ Turf quality, turf color, spring green-up and fall color retention were not affected by the addition of amendments.

→ In this study, incorporation of amendments in aerification holes showed no benefits.