# RESEARCH UPDATE:
# Potential for Natural Zeolite Uses on Golf Courses

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THERE ARE MANY IMPORTANT characteristics of a desirable turfgrass root zone material, namely: minimum compaction tendency, good water infiltration and percolation rates, adequate aeration for deep rooting, high cation exchange capacity (CEC), and adequate moisture retention. However, due to the heavy traffic that putting greens and tees receive, sand is the major mix component. If properly chosen, it provides for good drainage, resistance to compaction, and good aeration. By itself, though, it generally lacks adequate cation exchange capacity and water-holding capacity, and it allows excessive percolation rates.

Typically, sands are amended with some form of organic matter to create a root zone mix, and peat is the most widely used organic amendment. In some situations, locally available organic matter sources are used. Rice hulls, sewage sludge, and lumber waste materials are all possibilities. The advantages of amending sand with organics include increased water retention, increased nutrient retention (cations), and some pesticide binding (reduced pesticide leaching). On the down side, organic amendments decompose with time and are of limited effectiveness in retaining nitrate from leaching. Though not routinely used, some inorganic amendments, including fired clay, colloidal phosphate, sintered fly ash, vermiculite, perlite, and calcined clay have received some attention. Inorganic amendments can increase moisture retention to a limited degree, but generally do not improve nutrient retention. Some break down over time as a result of weathering or traffic. Thus, there is a need for an amendment that will increase water-holding capacity and nutrient (especially nitrogen) and pesticide retention while still remaining stable over time. A natural zeolite like clinoptilolite may be such an amendment.

Zeolites are alumino-silicate minerals first discovered in 1756 by Swedish mineralogist Baron Axel F. Cronstedt, who named the porous mineral from the Greek words meaning "boiling stones." There are more than 40 natural zeolites. six of them in large deposits: anacline, chabazite, clinoptilolite, erionite, mordenite, and phillipsite. Clinoptilolite is of importance in agriculture because of its abundance and its chemical properties. Extensive deposits of clinoptilolite are found in the western United States, the former Soviet Union, Bulgaria, Hungary, Yugoslavia, and Japan. It has a crystalline structure with many minute internal pores that retain water and nutrients such as ammonium and potassium. It has a very high cation exchange capacity (from 100 to 230 cmol/kg). The pores are large enough to allow cations to pass in and out, but are too small for bacteria, especially bacteria that convert ammonium to nitrate. Water and nutrients held in the pores remain available. Thus, clinoptilolite amendment of sand acts as a mechanism for slowly releasing nutrients and water.

As seen in Figure 1, clinoptilolite is a rock that can be ground into sand-size particles. It can be mixed with sand, as shown in Figure 2, for the purpose of increasing both the efficiency of water uptake and nutrient utilization while reducing nitrate leaching.

## Other Research Findings

Several other researchers have studied the effects of clinoptilolite on creeping bentgrass growth and establishment. Research conducted at Washington State University (Nus and Brauen, 1991) studied the effects of various amendments (sawdust, sphagnum peat, and a gravel-sized clinoptilolite) at several amendment volumes on the establishment of creeping bentgrass on sand-based putting greens. They added sawdust at 5%, 10%, and 20% by volume; peat at 20% to 33% by volume; and clinoptilolite at 33%

*Figure 1. A piece of clinoptilolite zeolite before processing.*

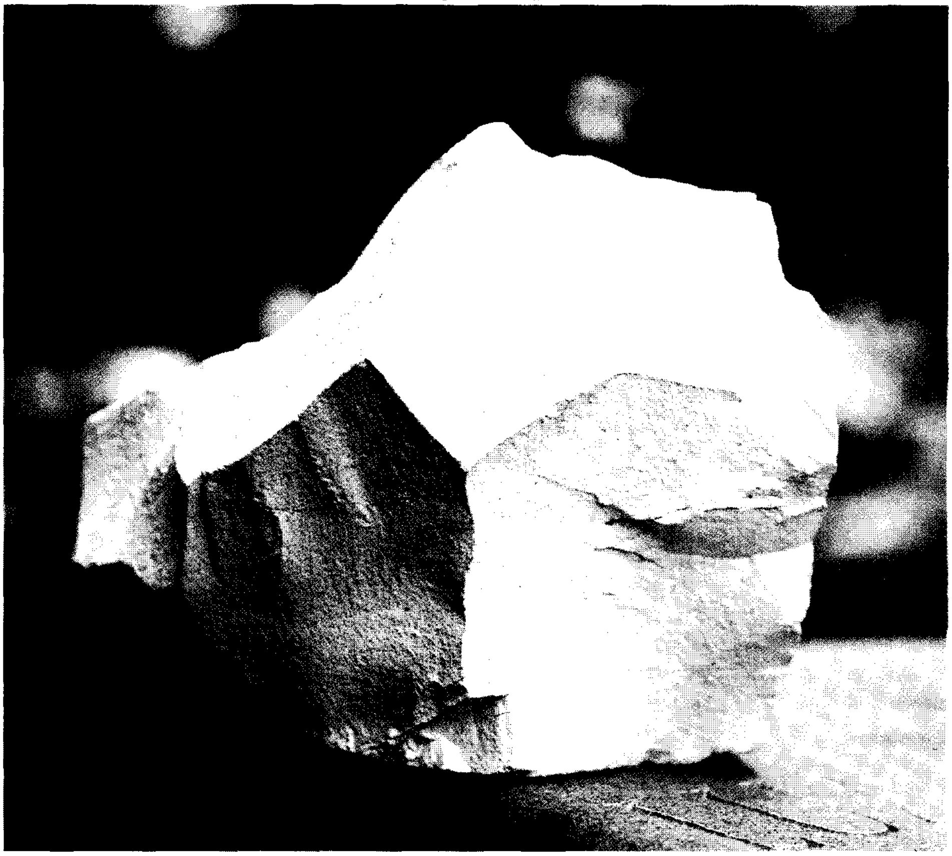


TABLE 1

Physical properties of clinoptilolite zeolite-amended sand (CZ-sand) and sand used in the greenhouse experiment

| Property | | CZ-sand* | Sand |
|---|---|---|---|
| Hydraulic conductivity, cm $hr^{-1}$ | | 40.53 | 39.58 |
| Total porosity, % (by v) | | 46.92 | 43.44 |
| Water availability, % (between -0.003 and -0.1 MPa) | | 12.60 | 6.37 |
| Aeration porosity, % (at -0.003 MPa) | | 34.11 | 36.53 |
| Bulk density, g $cm^{-3}$ | | 1.38 | 1.48 |
| Particle density g $cm^{-3}$ | | 2.59 | 2.61 |
| Particle size analysis | mm | % (w/w) | |
| Gravel | >2 | 0 | 0 |
| Total sand: | 2 ~ 0.05 | 97.3 | 98.0 |
| Very coarse | 2 - 1 | 2.9 | 0 |
| Coarse | 1 ~ 0.5 | 5.6 | 2.9 |
| Medium | 0.5 ~ 0.25 | 65.7 | 70.6 |
| Fine | 0.25 ~ 0.1 | 21.0 | 22.5 |
| Very Fine | 0.1 ~ 0.05 | 2.0 | 2.0 |
| Silt | 0.05 ~ 0.002 | 0.2 | 0 |
| Clay | co.002 | 2.5 | 2 |

*Sand amended with 10% CZ (w/w)

*Miniature putting green profiles were used in the greenhouse to investigate using zeolite as a soil amendment and its effect on water use and nitrate leaching.*

to 37% by volume to the unamended sand. For both peat and clinoptilolite, the establishment rate was greater as the amount of amendment increased. In this study, clinoptilolite was as effective as peat in improving the establishment of creeping bentgrass on sand-based putting greens. They also observed that clinoptilolite increased the moisture-holding capacity of the sand mixtures and had high CEC levels with particles less than 0.64 mm in diameter.

A similar establishment and growth study with creeping bentgrass was conducted at the University of Arizona (Ferguson et al., 1986). In this case, a sodium-enriched finer textured (< 1 mm) clinoptilolite was used. Establishment was slowed when a 10% clinoptilolite by volume mix was compared to the 5% mix. At about six months the sodium was leached out of the root zone and there was improved shoot and root growth and fertilizer nitrogen and phosphorus accumulation in the bentgrass clippings observed in both the 5% and 10% volumes of clinoptilolite-amended sand.

## Current Research

The results reported here are from the Ph.D. dissertation of Dr. Arthur Huang, who recently completed his Ph.D. degree at Cornell University. The hypotheses tested in his research were: 1) zeolite would increase the fertilizer nitrogen retained on sand/zeolite putting greens, more of the fertilizer nitrogen would be available to the bentgrass plant and, therefore, there would be less nitrate leaching from the greens; 2) zeolite-amended sand putting greens would retain a greater amount of plant-available water than straight sand greens, A series of highly controlled laboratory and greenhouse studies were conducted to test these hypotheses. The physical and chemical properties of the clinoptilolite and sand used in these studies are shown in Table 1.

## Nitrogen Studies

In laboratory studies it was found that the addition of clinoptilolite (5% or 10%, by weight) in a sand with a particle size range characterized by 97% of the particles between 1 mm and 0.05 mm in diameter, significantly increased the plant-available water (doubled) and increased the cation exchange capacity (from 0.08 cmol/kg of sand to 13 cmol/kg of the sand/clinoptilolite mixture), while still maintaining a high saturated water flow value comparable to the unamended sarrd.

Miniature putting green profiles were constructed, with the root zone media having 10% by weight of clinoptilolite, and sodded with Pencross creeping bentgrass for the greenhouse studies. The green profiles were fertilized with ammonium sulfate as the nitrogen source at yearly rates of 2, 4, and 6 lbs. N/1,000 sq. ft. Unfertilized profiles were used as check treatments. Ammonium was selected as the nitrogen source because it is easily retained on the zeolite. The profiles were 1) properly watered and 2) watered to excess (to produce leachate) on a weekly basis. To track the applied fertilizer nitrogen in the putting green system, the profiles were mowed weeky at %-inch and the amount of fertilizer nitrogen retained in the clippings was determined. The weekly leachate samples were analyzed for concentrations of nitrate and ammonium.

As seen in Figure 3, the amount of fertilizer N that accumulated in the clippings varied with the N application rate and zeolite amendment. As the amount of N applied increased, the percentage of applied N that accumulated in the clippings decreased. For the sand profiles, the percentage of applied fertilizer N that was recovered in the clippings ranged from 62% to 70%. The addition of zeolite to the sand resulted in a greater amount of the fertilizer N ending up in the bentgrass clippings (75% to 93% of the applied N). This difference was most noticeable at the lower N application rate.

As seen in Figures 4 and 5, adding zeolite to sand also resulted in substantially less nitrate leaching. The concentration of nitrate in the leachate from the putting green profiles, as shown in Figure 5, reveals that in no case was the nitrate level in excess of the drinking water standard (10 mg/l) when the sand was amended with zeolite. However, water with much higher nitrate levels was noted leaching from the sand-only putting green profiles at all N application rates, especially at the highest N rate (6 lbs. N/1,000 sq. ft.). In this case, the leachate had nitrate concentrations in excess of drinking water standards at least one third of the time.

## Water Use Studies

In the same greenhouse experiment described above, the amount of water used by the creeping bentgrass plants was determined three times per week by measuring the change in weight of the lysimeters. As seen in Figure 5, applying N to creeping bentgrass increased the shoot growth rate nearly ten times with little or no effect on the water use rate. Shoot growth was also increased by the addition of clinoptilolite to sand, without a substantial increase in the amount of water used by the plant. Thus, better shoot growth can be achieved in pure sand putting greens with the addition of clinoptilolite, and this can be accomplished with less water and less total N.

## Summary and Concerns

Amending sand putting greens with a zeolite like clinoptilolite was shown, from these studies, to result in several important advantages. First, nitrate leaching from sand-based putting greens can be reduced. Second, the shoot growth rate and the amount of fertilizer N that ended up in the clippings was enhanced by the addition of clinoptilolite to sand. Third, the improved growth of

FIGURE 3

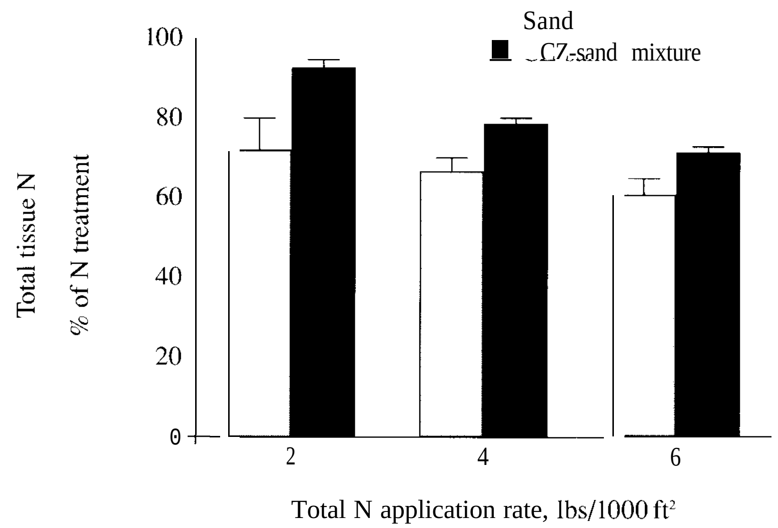



*Figure 3. The influence of clinoptilolite amendment of sand and nitrogen application rate on the amount of nitrogen accumulate in the clippings of creeping bentgrass.*

FIGURE 4

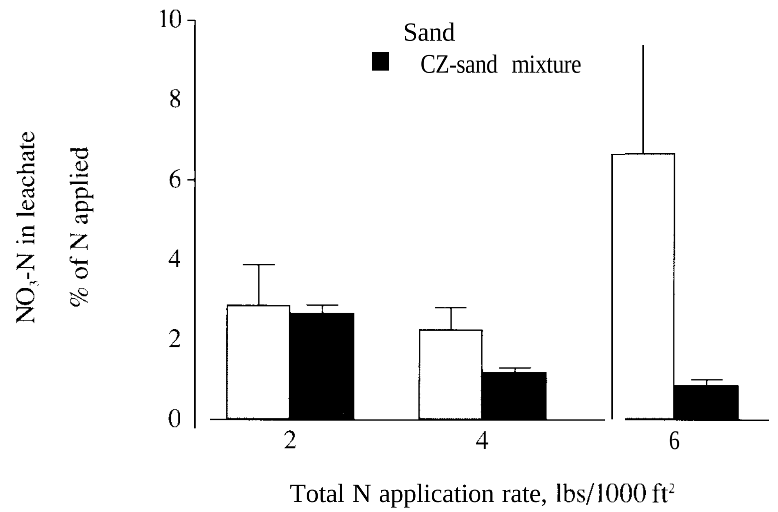



*Figure 4. The influence of clinoptilolite amendment of sand and nitrogen application on the percentage of fertilizer nitrogen leached from putting greens.*

FIGURE 5

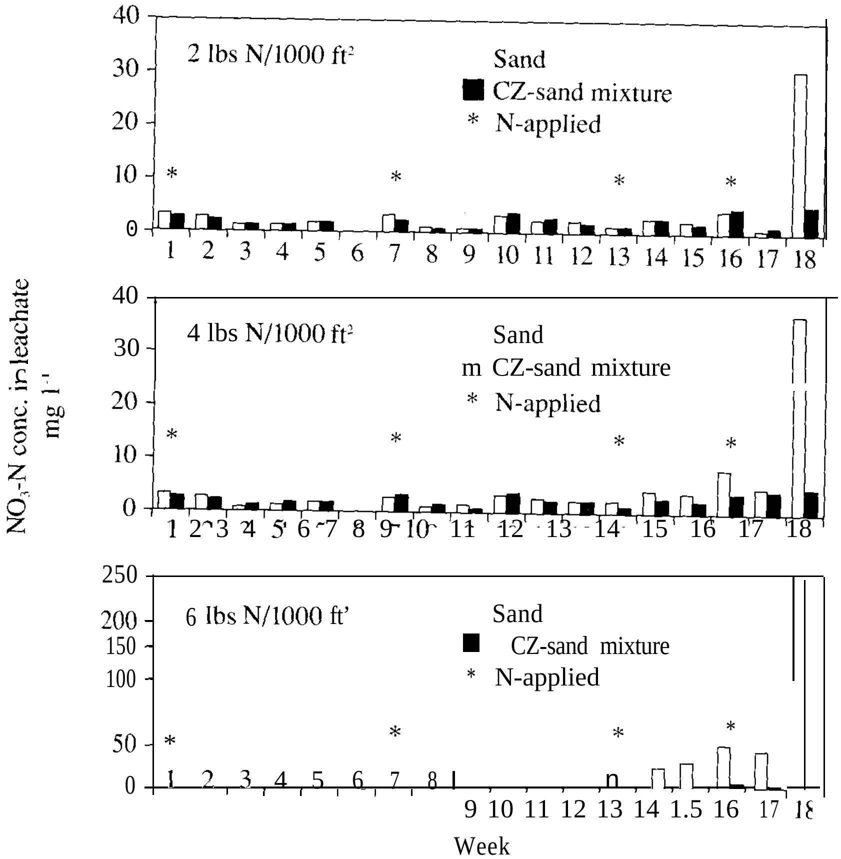
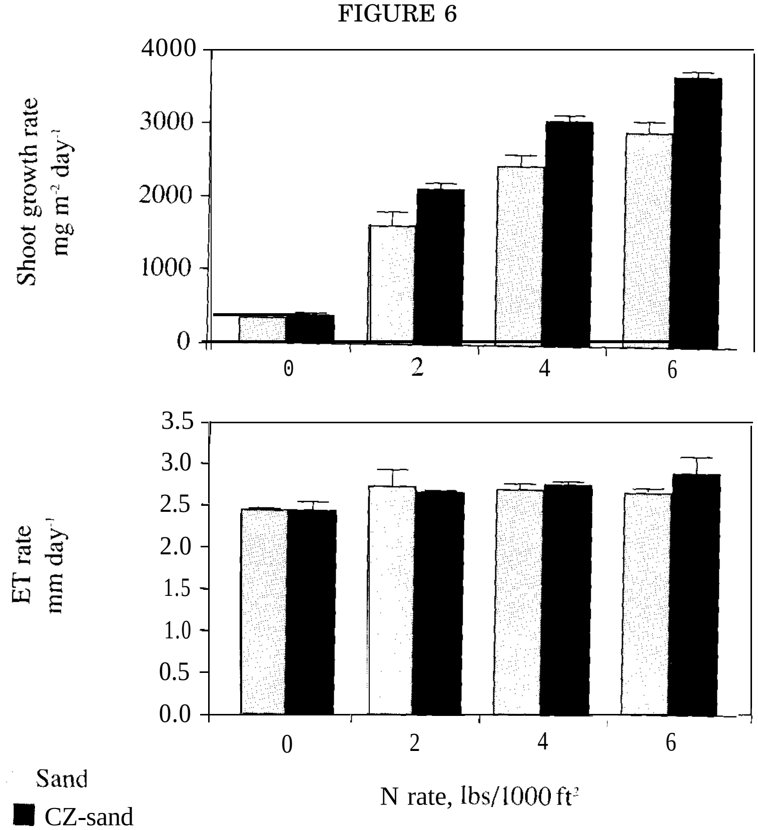



FIGURE 6




expense of using more water. The creeping bentgrass plants were more efficient in using water and N to produce growth.

With such strong findings, coupled with the results from previously published research, it appears that clinoptilolite could make an excellent amendment of sand for putting greens. Some words of caution should be noted, however. To my knowledge, only a handful of golf courses have used clinoptilolite to either amend new greens or to use as a topdressing on existing greens. To date the results have been encouraging. The long-term stability of the crystalline structure is one major question that still needs to be addressed. If the zeolite weathers or is crushed by traffic, will it remain a sand-size particle or become silt/clay size, clogging the highly pervious sand? We are initiating several short- and long-term studies to answer these questions. Long-term evaluation on actual golf courses with clinoptilolite-amended sand greens is necessary.

Another point to consider is that the properties of clinoptilolite can vary between, and possibly within, deposits. There are some deposits that are naturally high in sodium, potassium, or ammonium, and some can contain some clay. High-sodium-content clinoptilolite should be leached to remove the sodium before using it with low-salt-tolerating grasses. The hardness of the clinoptilolite also varies with each deposit. Some are very hard and would be less likely to be damaged by traffic, whereas others are soft and are more easily crushed. The results of the next series of studies will help establish guidelines in selecting a source of clinoptilolite based upon measurable properties.

LITERATURE CITED


Ferguson, G. A., I. A. Pepper, and W. R. Kneebone. 1986. Growth of creeping bentgrass on a new medium for turfgrass growth: clinoptilolite zeolite-amended sand. Agron. J. 78: 1095-1098.

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*(Above left) Figure 5. The influence of clinoptilolite amendment of sand and nitrogen application rate on the concentration of nitrate in the water draining from putting greens.*

*(Left) Figure 6. The influence of clinoptilolite amendment of sand and nitrogen application rate on the shoot growth rate and evapotranspiration (ET) rate of creeping bentgrass.*