SOIL PROFILE CHALLENGES TO GROWING HIGH QUALITY TURFGRASS WITH SALINE IRRIGATION WATER

R. R. Duncan, PhD
Platinum TE™ Paspalum

As irrigation water quality (increasing salinity) continues to deteriorate, the issue of site infrastructure and the capability to manage soil salt accumulation on a long term basis has emerged as a primary limitation to growing tournament quality turfgrass, even with the most salt tolerant warm season grass---seashore paspalum.

Paspalum TOLERATES salinity and therefore, due to a genetically programmed regulation of sodium absorption, will leave those excess salts incoming from irrigation water to accumulate in the soil. Paspalum has an extremely high tolerance to ocean-level concentrations of chlorides, sulfates, and magnesium. Paspalum is not a phyto-accumulator of salts.

The following infrastructure components are inter-related and synergistically reactive in sustaining the ecosystem and its subsequent maintenance in order to grow turfgrass with or without increasing secondary soil salinization from irrigation with saline water or exposure to salt spray or tidal influences. The strategy for turfgrass management must be totally oriented to environmental sustainability of the entire ecosystem long term.

Infrastructure components include:

(1) **A high distribution uniformity and efficient (DUE) irrigation system (effectiveness in properly managing and minimizing salt accumulation in the soil is directly correlated to the DUE of the irrigation system and irrigation scheduling). Short duration, frequent applications of saline irrigation water can result in 2-16x higher salts above the incoming salinity of the original irrigation water that can potentially accumulate in the soil profile. You must keep the salts moving downward in the soil to the drainage lines at all times, if possible. Sufficient volume of water needs to be available for not only normal irrigation schedules, but for flushing/ leaching of excess salts periodically and during severe drought stress environmental conditions.**

(2) **Drainage, drainage and more drainage (the premise is to continuously move salts down through the soil profile to the drainage lines and away from the turfgrass root system) and to minimize soil profile salt ion/compound accumulation. Frequent, timely aeration is an essential component for maintaining adequate infiltration/percolation to promote consistent downward migration of salts.**

(3) **Irrigation water treatment equipment (chemigation, acidification, gypsum or hydrated lime injection, fertigation) provides some flexibility in managing turfgrass when there is the constant threat of secondary salinization of the ecosystem. Additionally, any salts that are soluble in the irrigation water (sodium, chlorides, sulfates, magnesium) can potentially be foliarly-fed directly in the turfgrass shoots and stolons and eventually in the roots. In-line water 'conditioners' have very little scientific data supporting agronomics and the question**

is: if these products do not add something permanent to the water or remove something from the water, are they really altering the chemistry and physics of that water molecule even short term? Ask questions beyond 'observations' or 'testimonials' and determine if third party control areas with replicated scientific data and repeated data collection in time and at different locations have been verified.

(4) **<u>Cultivation equipment use and frequency</u>: re-oxygenation and re-hydration (keep oxygen and water moving) through aeration (hydroject, dryject, PlanetAire, solid tines, needle tines, spiking, slicing, vertidrain, soil reliever, Blec, etc.). Keep the salts moving and schedule accordingly!**

(5) **<u>Soil profile adjustments</u>, including sand quality and sizes, minimal fines (silt + clay + sand sizes <0.25 mm in size), common sense application of organic amendments (which generally are biodegradable) and inorganic amendments (that do not break down with microbial activity and are permanent components of the physical structure of the soil profile). Remember that fines physically migrate down in any soil profile and the larger particles tend to localize in the upper zone of the soil profile. With smaller particles and more potential surface area exposure, salts tend to accumulate and form a layer in those zones.**

Most of the time, you do not have much choice on type of native soils on a specific turfgrass site—you have what you have. The question then becomes one of: can you do anything to improve the texture of that native soil profile? The other obvious question concerns: what amendments, if any, should I include in the greens sand profile? Whatever amendments are added or not added, base those decisions on good scientific information and not because some salesman gave you a 'good deal.'

<u>NATIVE SOILS</u>

Very few golf courses or sports venues are being built on prime loamy soils. The range of native soils can include, but not be limited to variations of: caliche (insoluble calcium carbonate) pulverized and varying in particle sizes from powder to 1-2 mm sizes; decomposed granite (DG), pulverized volcanic pumice; substandard round sands such as directly from beaches, expanding/contracting heavy clays, non-expanding clays, 'marine' clays, and heavier soils capped with sand of varying depths and quality.

Each native soil type brings its own individual management challenges as far as salt accumulation, water retention, nutrient retention and stability, capability for cultivation, and irrigation scheduling. Planting, establishment, and grow-in of any turfgrass is a challenge, especially when saline irrigation water is being applied. Since salt is a growth regulator (essentially acts as a gibberellin inhibitor similar to Primo®), grow-in to full canopy density is often slowed down to an unexpected growth rate. Superimpose topography changes, steep slopes, bunker surrounds, low drainage areas, lack of air movement, and mounds that are exposed to high evapotranspiration rates with changing site-specific environmental conditions and 4-5 week delays to achieve final grow-in (full canopy density) are generally a normal scenario.

Another aspect of dealing with heavy clay soils concerns whether those native soils should be capped with sand to improve water and salt movement. Drainage line installation is usually a key infrastructure addition that should be considered prior to any sand capping.

Solid tining (soil reliever, vertidrain, etc.) into the native soil followed by application of either gypsum or lime and then capping with sand will keep the downward salt accumulation (through the sand) and salt upconing (from previously accumulated salts in the native soil profile) battle zone at the native soil:sand cap interface and minimize the upward movement of initial residual salts through the sand capped zone.

The depth of sand for capping over the native soil should be based on a complete physical analysis of the sand quality that includes water retention and water release curves. Application of too little sand or too much sand can create excessively wet or persistently dry drought-prone areas in which the turfgrass will struggle to establish and persist over time.

MICROBIAL COMMUNITIES

Except for maybe the native clay soils mentioned above, most of the other soil profiles are semi-sterile to sterile and initially devoid of or have quite low microbial populations initially. There is almost always a lag period under which the microbes will establish or re-establish into a specific soil profile. Some of the microbes will be carried with sprigs or sod to the new site and take time for the population to increase to a properly functioning community.

This situation is one of the few times in which I recommend microbial additions to the 'new' soil profile---on a new course or sports field or perhaps a new reconstructed green that has been completely renovated with new 'sterile' sands or sand composite mix in the greens cavities. These microbes need a carbon source and some nitrogen for population redevelopment in those greens, bunker surrounds, slopes, or mounds areas.

ORGANIC AMENDMENTS

Peat moss is the traditional organic source that is added to greens mixes. With saline irrigation water, I generally recommend starting with 5% by volume of peat moss in a greens mix, depending on sand sizes and quality, and send that sample in for a complete physical analysis (sand + silt + clay size fractions, saturated hydraulic conductivity, moisture retention, total + capillary + air porosity) to verify where that sample stands in comparison with USGA specifications.

I generally do not recommend increasing the peat moss concentration above 10% by volume since previous experience has shown those mixes with 15-20% peat moss by volume generally have salt accumulation challenges by year 3 after grassing due to the normal process of organic component stabilization in the soil profile, lack of microbial decomposition below the 6 inch upper profile zone, and subsequent accumulation of excess salts that are not flushed down to the drainage lines.

The peat moss should initially provide some water holding capability and a small amount of temporary cation exchange sites for nutrient retention until microbial populations increase and decompose the organic matter, utilizing carbon and nutrients that are found in the peat moss, to increase the populations in the soil.

Addition of peat moss to slopes or bunker surrounds and mounds (those high evapotranspiration zones) to slow down moisture upward flux is a good strategy, especially if the peat moss (usually combined with sand for easier distribution) is mixed with sand and applied following an aeration event in those areas. The decomposing peat moss should help to escalate the development of a proper-sized microbial population in these zones that traditionally are slow to grow in and achieve full turfgrass canopy density on a timely schedule. Low flow sprinklers may be needed in these areas.

INORGANIC AMENDMENTS

Inorganic sand substitutes in root zone mixes should be applied based on their specific purpose for improving the soil profile. The amendment volume should be based on irrigation water quality (salinity) in combination with a comprehensive science-based physical analysis of the composite sample.

The purpose of these inorganic amendment substitutes in greens mixes include:
➔to improve moisture retention (calcined clays or porous ceramics, diatomaceous earth products) via internal micro-porosity (<0.10 mm) of the substitute product
➔to prevent or alleviate localized dry spots due to improved moisture stabilization (porous ceramics, diatomaceous earth products)
➔to increase cation exchange capacity (CEC) and stabilize nutrient holding capabilities (zeolites)

The purpose of these inorganic amendment substitutes in native heavy soils include:
➔improve aeration (oxygen flux or re-oxygenation of the soil profile)
➔increase macropore (>0.12 mm) space and pore continuity with sand additions and large aeration holes
➔alter soil texture, such as during grow-in
➔enhance infiltration/percolation (moisture flux)

Processed Soil Inorganic Physical Amendments

Calcined clays (CC) are hard porous minerals derived by calcining (heating to just below the melting point: 1500-1800 °F or 815-982 °C) a clay material to remove water and stabilize it both physically and chemically. These products are also called porous ceramics, as long as they contain some calcined or heated clay. Their primary purpose is water retention involving micropore spaces. The CEC range is generally up to 33 cmol/kg.

Diatomaceous earth (DE) products: inorganic material that is derived from diatoms (deposits of fossil diatoms that are primarily SiO_2). Their primary purpose is water retention involving micropores. The CEC of DE and non-calcined DE products range from 1.2-27 cmol/kg.

Examples of Products:
➔Profile: porous ceramic—heat-treated illite calcined clay; 74% SiO_2, 74% micropore space, CEC range of 16.9-35 cmol/kg
➔Greens choice: porous ceramic—heat-treated shale based clay; 64% SiO_2 + 16% Al_20_2
➔Zoneite Green: porous ceramic—heat-treated illite calcined clay
➔Axis (calcined): diatomaceous earth product; poorly crystalline SiO_2 ; 81% micropore space.
➔Lassenite: kiln fired or calcined diatomaceous earth product that is amorphous silica from volcanic ash being deposited into fresh water lakes containing protozoa that eventually formed diatoms composed mainly of $Si0_2$; saturated hydraulic conductivity at 10.9 in/hr; 68% microporosity
➔PSA: natural diatomite or diatomaceous earth; 82-83% micropore space; 90.4% silica; kiln fired but not at a temperature high enough for calcining; CEC range 27.1-34.1 cmol/kg
➔Isolite: extruded diatomaceous earth with 5% non-calcined clay binder; 74% micropore space
➔Additional products: Turface—porous ceramic native soil conditioner; montmorillonite clay plus silica crystalline quartz
➔Terragreen: calcined attapulgite clay
➔ Perm0_2pore: calcined clay

++
……

Product	CEC (cmol/kg) or (meq/100 g)	Saturated Hydraulic Conductivity (in/hr)
Ecolite	35.1	17.36
Profile	21.5	22.24
Soil Master	21.7	20.96
Axis	7.8	10.20
PSA	34.1	17.80
Sand	0.7	24.40
EcoSand (Zeolite)	97.8	25.24

……
From: Travis Shaddox Doctoral Dissertation, 2004. University of Florida.
++
Non-Processed (Non-Heat Treatment) Natural, Mined Inorganic Amendments

Zeolites: natural mined alumino-silicate amendment designed primarily for increasing CEC (avoid the synthetic products since they are not as stable physically and can contain high levels of sodium). These natural zeolites are tectosilicate volcanic clay ($Si0_2$ + $Al0_4$) with a ratio of 1 to 20 (Si + Al); contain a negative charge; and the better quality products have a CEC of 100-230 cmol/kg (or meq/100 g). High quality zeolites have a preference for potassium and a non-preference for sodium. The selectivity preference order for cations on these CEC sites is: (highest) K^+, NH_4^+ > H^+ > Na^+ > Ca^+ > Mg^+ (least). Recent research has revealed that zeolites have some water retention capability, but not on the same scale as the porous ceramics.

Clinoptilolite= (Na_3K_3) $(Al_6Si_{40})0_{96} \cdot 24H_20$ where the red zone is the primary exchange site with other cations. This high structural strength inorganic amendment is applied to sites with low CEC (generally <2.5 cmol/kg) due to low clay or organic matter content. Zeolite with a CEC of 150 cmol/kg can be applied at a rate of 225 lbs/1000 sq.ft. and mixed into the surface 4 inches of the soil to raise the CEC by 1 cmol/kg. The target CEC should be 2.5-3.0 cmol/kg in the top 4 inches of a soil profile for seashore paspalum and 4.5-4.5 cmol/kg for bermudagrass, zoysiagrass, and bentgrass.

Product list

➔**Ecosand/Zeosand/Z-Ultra/Zar-min: natural clinoptilolite (5 silica:1 alumina ratio)**
➔**Z-Plus: clinoptilolite**
➔**Ecolite: clinoptilolite natural K-alumino-silicate; CEC 35.1 cmol/kg**
➔**ZeoPro™: 90% clinoptilolite impregnated with 10% apatite {(calcium hydroxyl phosphorus or $Ca_{10}(PO_4)_6(OH)_2$)}; CEC 100 cmol/kg (Also called 'Z-mendit Pro')**
➔**Clinolite: clinoptilolite**
➔**Z-Mendit™: clinoptilolite, light green color; CEC 165 cmol/kg**
➔**Escott: hydrated alumino silicate from Australia; CEC 120 cmol/kg; 26.6% microporosity and 15.8% macroporosity**
➔**Umdemin®: clinoptilolite from Turkey (Rota mines) (Ca,K_2,Na_2,Mg) $4Al_8Si_40{\cdot}O_{96}{\cdot}24H_2O$**
➔**Chinese source: clinoptilolite with opaline silica (66.40% SiO_2 + 00.75% MgO + 4.89% K_2O + 10.4% Al_2O_3 + 2.43% CaO + 1.60% Fe_2O_3 + 0.49% Na_2O + 0.20% P_2O_5)**
➔**JZT: brown phillipsite type zeolite from Jordan; CEC 73.9 cmol/kg**
➔**BGZ: clinoptilolite from Bulgaria; CEC 116.1 cmol/kg**

SUMMARY COMMENTS ON ORGANIC AND INORGANIC AMENDMENTS

The organic amendments such as peat moss will decompose over time, but infusing >10% peat moss by volume in an initial 12-inch depth greens mix when saline irrigation water will be applied to the golf course can lead to salt accumulation and differential soil profile zone microbial decomposition problems between year 2-3 after grassing if not properly managed.

Inorganic amendments will not decompose over time and inclusion of high volumes >10% has caused persistent problems with surface algae scum when excess porous ceramics and diatomaceous earth products were added to soil profiles. These products are designed for water retention and they do an excellent job in that role. These products retain water and any salt ions (in micropores) that are solubilized in that water. Leaching of micropores laden with excess salts can only be accomplished by pulse irrigation cycles.

The primary purpose of adding zeolites into any soil profile is to enhance nutrient holding (CEC) capability of the soil profile. The rule is to start with 5% by volume in any greens mix and submit that mix for a complete physical analysis to ensure that USGA specifications have been attained and not exceeded. Topdressing of zeolite into the top 2-4 inches aeration holes in the soil profile with established grass canopy is the ultimate goal of reaching a CEC of 3-4 cmol/kg for nutrient stabilization. High quality zeolites have a preference for potassium and a non-preference for sodium. With new soil profiles, application of zeolites into soil profile zones below 4 inches is not advantageous since most turf roots will not be extending down below 4 inches. The increase in CEC for any turf ecosystem needs to be localized in the 3-4 inch upper zone for efficient fertilizer amendment programs and for optimum turf plant uptake/utilization.