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Total Soluble Salts and Soil Amendments in Golf Greens

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Dr. R.N. Carrow, rncarrow@msn.com
Dr. R.R. Duncan, rduncan4612@gmail.com

Issue: Several golf courses have observed difficulty in leaching total soluble salts and specific excess salt ions (such as sodium) when the greens mixes have been constructed with high rates (> 10% by volume and especially in the 15 to 20% by volume range) of calcined clay or porous ceramic products.

The problem seems to occur: a) as irrigation water salinity increases, b) in arid regions or during prolonged drydown periods when greens are receiving the saline irrigation water, but without adequate rainfall leaching, c) as the percent of calcined clay increases in the initial greens mixes – i.e., at > 10% by volume and especially at 15 to 20% by volume, and d) as the normal organic dynamics in those greens profiles stabilize between year 2 to 3 after grassing or when excess thatch/mat accumulation occurs in those soil profiles.

The organic and inorganic amendments or sand substitutes are designed for specific functions, and these amendments are excellent in performing their functions. The residual problems occur when excess volumes are added to the soil profiles.

Comments: Since this issue has become a reoccurring one that must be dealt with in the field on site-specific courses exhibiting this problem, we have proposed the following hypotheses based on the current scientific knowledge concerning saline soils in combination with our field observations and experience. For ease of understanding, we present the comments in a series of individual statements.

1. We do not believe that this is solely an issue with calcined clays, other inorganic amendments (i.e., sand substitutes), or peat/organic amendments. **Rather, it is an issue of the magnitude or quantity of micropores or capillary pores (< 0.10 mm) present in the rootzone media**, especially those that retain plant unavailable water. The source of the micropores is really not that relevant – any material that increases the quantity of micropores to an excessive level in the rootzone is a problem, whether added by clay, silt, inorganic amendments, or organic amendments.

2. **The quantity of micropores is important, especially the quantity of very small micropores that do not release water for plants, but retain the water and any soluble salts that accumulate within these micropores, because it is well documented that as the quantity of micropores increase, so does: a) the potential for greater salt retention, and b) leaching requirements for more leaching water volume and more time to remove these retained salts (Carrow et al. 2004).** For example, the research of Bigelow et al. (2004) illustrated that water release from the 4 inorganic amendments leveled off (i.e., water did not release further from the amendments) at a soil water potential of -0.006 MPa down to the permanent wilt point of -1.5 MPa and this retained water represented about 20 to 40% microporosity when using the straight sand substitute materials (Figures1 and 5 of their paper). This water retention issue was apparent in both the lab moisture retention study and the plant bioassay (perennial ryegrass ability to extract soil moisture). Plant available water on golf greens is primarily within the -0.004 to -0.05 MPa range (Bigelow et al., 2004).

3. **Why is salt retention in the micropores a problem?** During consistent irrigation with saline irrigation water, the internal micropores of inorganic amendment particles will equilibrate to at least the salinity level of the irrigation water. Also, micropores from any other sources (organic such as from peat moss, higher clay or silt contents) would exhibit the same response. In an arid region or during a drier period with high ET, soil salinity normally is 1.5 to 2.0+ greater than the original

irrigation salinity due to the constant dynamics of solution drying and concentrating salts in the soil profile, which then diffuse into the micropores. Specific salt cations such as sodium (a primary water film retention salt ion) can accumulate in those greens soil profiles at 3-4 times greater concentrations than the incoming water due to the CEC sites that retain cations. These internally retained salts are a problem because:

- Leaching events may not be of sufficient time to allow these salts to move out of the micropores and into the soil solution to be leached. Thus, only the macropores and plant available fraction of the micropores may leach, thereby leaving the salts in the 20 to 40% microporosity range at high salinity accumulation levels. The more the quantity of plant unavailable microporosity, the greater the salt retention.
- After leaching, these salts start to diffuse out and re-salinize the soil solution. Additionally, in routine lab tests for soil salinity (by saturated paste extract or dilute extracts, where the latter procedure generally has relatively short equilibration times), the normal time period for analysis is insufficient to extract these salts; so this "hidden salt" only becomes apparent and measurable after a longer period of extraction time, such as 24+ hours. You have to request these longer extraction times when analyzing greens mixes containing inorganic amendments.
- Micropores are best leached by water applied to create unsaturated flow (pulse irrigation or a long, slow rain) that moves water uniformly through the macro- and micro-pores. This pulse irrigation strategy is a time and manpower allocation issue, primarily on greens and tees and rarely can be implemented on other larger areas of the golf course because of sheer grass and soil volume. In the article by Carrow et al. (2004), the results illustrated that as the percent of clay and silt increase (i.e., as quantity of <u>micropores</u> increase), so does the volume of water needed to achieve the same degree of effective leaching and, thereby, the time required for leaching is also increased.
- Improper irrigation strategies (short duration, frequent cycles) with saline irrigation water can result in 2-6x higher soil salt concentrations above the initial salt concentration in the water in soil profiles within as short a time frame as 17-21 days, especially in arid, semi-arid, and prolonged high ET areas.

4. **Peat moss additions versus inorganic amendments.** The question often arises about whether inorganic amendments are more of a problem than peat moss. The answer is yes and no!! We believe that the reason that peat amended greens do not seem to exhibit as much of a problem compared to inorganic amended greens with >15% volume inorganic amendment is that if organic matter content becomes too high (i.e., thereby adding excessive micropores) that the green profile oxygenation and water infiltration decline, causing many secondary problems (algae colonization at the surface; soil borne pathogen attack, such as take-all). Thus, during initial construction, care should be taken to avoid excessive organic matter additions and during routine maintenance, operations are regularly scheduled to control organic matter content in concert with adequate microbial activity in those soil profiles.

   When excessive peat is added to any sand, it results in the sand particles becoming surrounded by organic matter and often results in the plugging of pore spaces between the sand particles. Thus, a rapid "negative feedback" is produced when too much organic matter is added initially into the soil profile. In contrast, addition of too many micropores by inorganic amendments may not be evident until much later as the organic dynamics in those specific soil profiles naturally stabilize and salt accumulation increases from regular irrigation cycles.

5. **Excessive organic matter does contribute to excessive salt retention.** In instances where an excessive organic matter zone is present at the surface and saline irrigation water is applied, salts can accumulate more readily. In these cases, leaching appears to be much easier than if the micropores are from inorganic amendments, possibly because the micropores inside the inorganic amendment may be more difficult to move the water through the soil profile compared to peat moss with micropores that are generally more dispersed throughout the surface zone. As previously noted, cations may be preferentially retained on the CEC sites under these conditions.

6. **Sometimes Ksat or Saturated Hydraulic Conductivity values of inorganic amended greens versus organic amended greens are used to "prove" one better than the other; but this comparison must be used with caution.** First, when SHC is at or above 6 inches/hour, this rate is very good for leaching and higher values often do not offer any benefit. Remember that the most effective leaching, especially for micropores, is at low water application rates (pulse irrigation or slow rainfall rates). Second, in the field, the soil surface conditions control SHC in most instances and one of the most important factors is the surface zone where organic matter may accumulate ---

and this occurs whether the initial construction was with inorganic, organic, or no amendment to the sand.

Sand dilution by topdressing and producing temporary macropores via hollow tine core aeration or venting operations will maintain surface SHC. In fact, if a salt laden surface is cultivated to create macropores prior to leaching, care must be taken to apply the leaching water as unsaturated flow or all the water moves into the cultivation "macropores" and not into the micropores between the cultivation holes --- illustrating that when it comes to effective leaching especially with saline irrigation water, rapid application of water due to high Ksat is really not beneficial.

7. **On greens or other sites with excessive micropores, what can be done?**
   - If the source of micropores is surface organic matter due to peat moss additions or is created by aggressive turfgrass growth and subsequent thatch/mat accumulation, any management practices to encourage organic matter decomposition, dilution, and creating temporary macropores by scheduled cultivation events are beneficial.
   - On sites with too many micropores due to excessive clay, silt, or inorganic amendment additions, one fact is evident – it is difficult to remove those micropore sources once they are present in the soil profile. Those amendments do not biodegrade over time. Thus, the best management practice is initial prevention by not infusing too much in the initial greens mixes if conditions as noted in the beginning are present.
   - Maintaining a higher soil moisture content between irrigation events and including a leaching fraction with every irrigation event will help to prevent salts from concentrating in the internal pores—something that can and frequently happens with persistently high ET and subsequent surface drydown.
   - Using a good penetrant wetting agent that reduces soil surface moisture retention may help to allow better water penetration into the inorganic amendment micropore spaces for better leaching progress and particularly between aeration holes (macropores).
   - Similarly, a wetting agent or agents that maintain surface wetting during leaching for a more uniform wetting front movement will enhance leaching efficiency.

8. **Preventative measures**

   The appropriate time is during greens construction to ensure recommended sand size composition and to select rootzone amendments that do not contain too many fines or do not contain too many micropores. Various organic and inorganic amendments can be used to enhance soil moisture retention or CEC, but the quantities selected when saline irrigation water is to be used must not result in excessive micropores. For inorganic amendments, it appears based on actual field situations that including over 10% by volume of the product has the potential to become a problem, especially if saline water is used for irrigation. Following the USGA specification for greens mixes and avoiding >10% by volume for sand substitutes that contain primarily small micropores are key factors to consider. If a sand substitute contains a higher percentage of plant available water and, thereby, does not have as many micropores, then it may be possible to use more volume of the product without hindering leaching effectiveness. We would encourage complete physical analyses and testing of any greens mixes under the conditions noted at the beginning of this document to refine these recommendations.

REFERENCES

Carrow, R.N., M. Huck, and R.R. Duncan. 2000. Leaching for salinity management on turfgrass sites. USGA Green Section Record (November/December):15-24.

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