Seminar on Intense Zoysiagrass Management

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Introduction

Zoysiagrass is an ancient grass with documentation of use as turf dating into the 1000 – 1200 AD throughout the Pacific Rim countries. One of the best photos's demonstrating the use of Zoysiagrasses is on the Kings Tombs in Gyeongju, South Korea. According to records the tombs were built between 57BC to 935AD as the final resting place for Kings of the Silla Kingdom. There are a number of mound tombs in the park as today – truly a living outdoor museum (Tumuli Park) [Fig 1]. Zoysiagrass was sprigged to the sites at the time of construction for a couple of practical reasons; the first being erosion control, the second has to do with its winter (dormant) color which is a golden color. In the religious culture of Korea, Zoysia is known as the "Golden Grass". The elevation of the tomb and the grass's winter color are the marks of political importance of the deceased in the Korean Culture [Fig. 2]. It is one of the lasting images that I have in my mind of the resilience of Zoysiagrass. The tomb itself measures some 30 m in elevation, with a circumference of nearly 300 m. It is the sustainability of the grass over eons of time, with minimal cultural inputs and environmental extremes of temperature and drought that convinced me several decades ago that Zoysiagrass is an important grass our global economy and needs to be understood and more effectively utilized in our present society for domestic, sports and amenity turf.

Figure 1. Tumuli Park, South Korea - Kings tombs in background

Figure 2. Kings Tomb dating to 1200 AD

The origin of the Species, in this case the Genus Zoysia, centers in the Asia-Pacific Rim ranging from as far north as Sapporo, Hokkaido, Japan (approx. ~43^{o} N latitude) through the equator to Tasmania, Australia. (-44^{o} S Latitude). Generally the colder the climate, the coarser textured the evolving grasses. Most the finer textured species evolved and survive in the more moderate climates typical of the Sub-temperate and tropical environments around the world.

This broad geographic range of adaptation results in considerable differences in the grasses and gives us the opportunity to exploit this ancient grass for modern conveniences. Which leads us to one of my favorite clique's delivered by the late Stephen Covey, YOU MUST SEEK FIRST TO UNDERSTAND, BEFORE YOU CAN BE UNDERSTOOD. Hopefully, after this seminar you will be able to understand my passion for the grass and why I believe it can be truly a GAME CHANGER when it comes to SUSTAINABILITY of our landscapes.

Biologically there are eleven (11) documented species of grass within the Zoysia genus. Of these only three have had much significance in direct use for turf; namely Z. japonica – most cold hardy; Z. matrella – noted for its fine texture, most desired quality and resilience under traffic, and Z. pacifica – for its finer texture, and excellent shade tolerance. The old timers often referred to Z. pacifica as Zoysia tenuifolia. In reality there is a difference in the species but a mix up in the 1700's taxonomy studies lead to the misnaming of the species.

Figure 1. Mountain climate, high elevation, heavy snow cover

Figure 2. Zoysiagrass on edge of Salt Beds in S. Korea

The genetic diversity of the Zoysia species has brought us tremendous traits which we have incorporated into many of the newer varieties of grass to address these issues. Cold hardiness [Fig. 3], salinity tolerance [Fig. 4], shade tolerance are some of these traits. Meyer Zoysiagrass was the United States industry standard since the early 1950s. It is well known for its cold hardiness, ability to survive with minimal maintenance and excellent performance as a grass for golf course fairways in the upper Midwest. Its performance in the Southern States has been less stellar however and zoysiagrass was slow to "catch-on" as a southern turf. Much of this is also attributed to the availability of numerous turf type bermudagrasses and more recently the Seashore Paspalum,

Even with Meyer and its excellent track record for use on golf course fairways in the upper Midwest there has been a general lack of understanding how to culturally manage it to overcome some of its short comings. Meyer for example is noted for its excellent early spring green-up compared to most other warm-season grasses, but for going off color early in the fall of the year. It is also noted for heavy thatch accumulation and puffy under-footing also occurring in the fall of the year. Meyer doesn't perform well in compacted soils demonstrating heavy thatch and shallow rooting and is prone to suffering from several Patch diseases. Over the past several decades we have concentrated on the biological characteristics which provides for better rooting, shade tolerance and disease resistance. Coupled with the genetic improvements however it had also been necessary to develop appropriate management programs if we wanted to gain any acceptance in the industry.

Since Zoysiagrass is adapted to a broad range of environments, and since the environment heavily influences the grasses performance, I will be addressing several major points of management in a Chapter and Verse format to provide for future reference material. Turf managers in the temperature and sub-temperature regions will face different issues than when managing grasses in the more tropical climes.

CHAPTER 1: CONTROLING THATCH AND SCALPING TENDENCY OF THE TURF

Zoysiagrass, across all of the species, is noted for its extensive rhizome and stolon growth [Fig. 5]. Consequently the plant has the tendency to demonstrate thatching and scalping due to an accumulation of excessive organic material below the turf canopy. The most frequent question asked concerns reducing and or controlling scalping. It's matter of understanding proactive approaches to managing the thatch and organic accumulation. Why does excessive thatching occur and what are the best practices to manage it?

Figure 3. Heavy Rhizomes and Stolon growth

Tendency to thatch is partially under genetic control. Some varieties will naturally create more stolon and rhizome growth especially when "over managed" with excessive fertilizer and irrigation. There are three basic management techniques that are used in managing Organic Material in the root zone: <u>Extraction</u>, <u>Dilution</u> and <u>Decomposition</u>. Each will be discussed in some detail. There is importance in understanding the differences; the implications of each method; and the general outcome of the final product. All grasses will have issues with organic material accumulation; your cultural program and the grasses used will determine the severity of the issues.

- THATCH BUILD-UP IN THE CANOPY:

The zoysiagrass plant has high lignin content; a substance which improves wear tolerance, and makes for a tough and resilient turf. It also a major factor in quickly dulling the mower blades, and cause leaf tips to shred when mowed. As a zoysiagrass plant ages; the lignin content increases; the stolons become coarser and thicker; and the roots tend to get shallower. As the season progresses the turf canopy becomes soft and spongy due to the increase in the thatch layer. Left unchecked the turf will become more difficult to mow as even heavy mowers will ride upon the canopy, increasing the tendency for scalping and consequently having a negative impact of surface playability. An extensive thatch layer will result in

Figure 4. Scalped Zoysiagrass

notable scalping, poor water infiltration, poor nutrient penetration from fertility applications, and potential loss of pesticide efficacy.

Close mowing can result in scalping of the turf especially later in the season [Fig. 6]. Scalped turf results from the wholesale loss of multiple growth points in a confined area. Recovery from scalping can be very slow as it demands considerable energy from the plant to develop new growth. Zoysiagrass is particularly slow at initiating new growing points following scalping and may require several weeks for full recovery. Utilizing practices (such as grooming) which continually stimulate new growth throughout the season will greatly reduce the recovery time. If all the leaves are missing, then the plant must use its stored energy supply to support new plant growth. This is detrimental to plant health and if scalping occurs in the fall of the year, the use of stored energy may well reduce the plants ability to survive winter temperatures. New growth in the spring of the years relies totally on stored energy and if any of this energy has been consumed in the fall due to untimely scalping, winter recovery may be compromised.

Mowing is an effective tool in maintaining a quality turf surface. The frequency of mowing is determined by the rate of growth and development of the turf, both being dependent on the season, and the availability of nutrients and water inputs. However, mowing alone doesn't contribute significantly to the management of thatch or organic matter build-up in the turf canopy. Excessive and untimely fertilizer applications will contribute to luxury growth contributing to canopy build-up. If the thatch layer is significant enough some remedial activity must be undertaken to either remove it, or to at least reduce it. Traditionally a seasonal heavy verticut is applied to aid in extraction as much of the thatch as possible, and often this may be accompanied with a core aerification. In either case, the process results in considerable disruption of the playing surface and must be timed during the active growing season to maximize the opportunity for the plant to recover from the resulting physical damage. This extraction process is remedial in nature as we are trying to correct an issue which we have grown into and as with scalped turf can take several days and weeks to fully recover..

Core Extraction is an accepted practice for relieving compaction and believed to aid organic and thatch removal. It is also highly disruptive to the playing surface – sports fields, fairways, tee boxes or greens. The process requires dedicated equipment and usually consumes several man-hours annually to complete. The players don't like it, the management doesn't like it and certainly it is demanding on the amount of time and equipment required to execute the process. The growth and recovery are seasonally dependent as well.

Verticutting, also an extraction process is essential if the thatch layering is being negatively impacting growth and development of the turf. The process is highly disruptive, requires dedicated equipment and the clean-up as with core cultivation becomes a major event annually, semi-annually. When it comes to zoysiagrass management, there is a more proactive approach and that enhances the health of the turf throughout the growing season and reduces the need for remedial management practices such as coring and verticutting.

<u>Grooming -</u> Utilizing turf groomers on a routine schedule (nearly every mowing during growing season) can greatly reduce thatch; reduce or eliminate the need for verticutting and under circumstance core extraction; reduce the plants susceptibility to diseases, improve turf quality, reduce organic accumulation, improve root growth, persistence and more efficient use of water, fertilizers and pesticides; and give the turf manager considerable control over the occurrence of scalping. Groomers will technically scalp a small fraction of the turf canopy with each use. The nature of the cut is to reach deep (10 – 30%) into the turf canopy and remove the stem and growing point of the turf. This technically is scalping but is unnoticeable as it impact only a few plants. These few plants however immediately begin the regrowth process by developing new growing points at the crown area. Turf groomers although similar in appearance differ from verticutters as they are an integral component of the reel and work together by providing a vertical slicing component to complement the horizontal clipping action of the conventional reel. The kerf, or thickness of the groomer blade is finer (~1/8", 3 mm) verse a verticut blade (~3/8" 8-9 mm), the blades are generally spaced between 1/4" (6 mm) to ½" (12mm) and are rotating nearly twice the speed of a verticut blade. Most grooming units available of the market are available with either ¼ or ½" spacing [Fig. 7], the ½" spacing is generally adequate and utilizes less engine power. Ideally, grooming will be initiated early in the spring with new growth and continued through the season. A properly adjusted turf groomer blade should be set to a Height of Cut (HOC) between 10 – 30% below the bed knife of the reel mower. Groomer settings could be deeper, but the power requirement is considerably higher especially when the process is initiated later in the season. When a plant is scalped, the crown area will initiate new growth points provided the crown is not severely damaged. With most zoysiagrasses this new growth initiation may require 2 – several days whereas other grasses such as bermduagrass is much quicker. Consequently the time to recover from scalping will range for a few to several weeks. The impact of grooming will not be immediately noticeable, however after 6 – 8 weeks of judicious grooming, (every time the grass is mowed during growing season), the leaves will mower easier (younger leaf tissue), with little or no noticeable scalping, the growth will be vertical and the canopy and turf will be firm and dry. At this time the depth of the groomer blades can be lowered not to exceed 50% of the HOC. As the groomer blade reaches below the canopy, it continually clips a few more stems and stolons and removes a few more growing points of the plant (controlled scalp), and stimulates new bud formation [Fig. 8]. This is proactive with continuous use, and it is the stimulation of new buds that maximizes the benefit of use of groomers.

Figure 6 1/4" and 1/2 spacing on groomer reels

a. Old tissue is being removed without severe scalping.
b. New buds are being stimulated and younger plant tissue is present in the turf canopy which in the case of Zoysiagrass has less lignin, less silica and is easier to mow.

Figure 5. New bud formation, various stages of growth

c. The new plants are growing vertical, not horizontal and therefore less likely to cause a thatch layer build up.
d. The resulting canopy does not retain as much moisture and therefore is less prone to disease incidence. The more open canopy allows for greater gas exchange within the soil profile encouraging better root growth and development.
e. Groomed turf is less prone to early fall frost since a significant portion of the new leaves are below the turf canopy.
f. The prolonged growing season experienced by groomed turf aids in build-up of carbohydrates for winter survival.
g. The open canopy and vertical growth of the groomed turf is more easily overseeded as the seed will reach the soil interface reducing or eliminating the need for fall verticutting. The seed more easily germinates in this protected environment and overseeding is far more efficient. [Personally I don't recommend overseeding Zoysiagrass].
h. Spring transition is quicker as the soils without excessive thatch are more easily warmed stimulating rapid green-up and growth.

In a nut shell: Grooming ultimately redesigns the turfgrass canopy, opening the canopy to allow for improved water penetration, soil gas exchange and a drier turf canopy. The dry canopy alone reduces the incidence of leaf diseases. The newer plant growth is healthier, more resilient to both biotic and abiotic stresses. The proactive mechanical removal of horizontal plant growth reduces the need for frequent verticutting, and allows for better gas exchange within the canopy and into the soil profile. This further supports root growth and development and reduces disease incidences as a drier canopy is less prone to support disease development. Also as the new growth points are tucked neatly into the turf canopy, they are not subject to being removed through the conventional mowing process for a period of 4 to 6 weeks which provides the turf manager with the opportunity to adjust mowing heights at will without concern for scalping or otherwise damaging the turf. Imagine the ability to raise or lower the height of cut in response to providing a faster or slower playing surface depending on the challenges required by the "competition". Want to slow down the playing surface of the outfield during a competitive ball game, simply raise the height of cut for one to several mowing; speed it up then lower the height of cut with little or no noticeable loss of turfgrass quality, why – new growing points are being initiated constantly, and new growth is below the height of cut and not removed.

Why do golfers like it? A groomed turf provides a firmer and faster playing surface resulting in fewer divots and noticeable faster recovery from divoting. Further there is fewer tendencies for disease development and therefore – an overall reduction in the exposure to pesticides and more friendly to the environment. Many of the warm season grasses such as the zoysiagrasses bermudagrass and paspalums are less prone to thatching, and to scalping when regularly groomed. Further the firm vertical growth of the new plant allows for a superior ball lie and playability. Seeing light under the ball on a well grassed fairway is knowing you have a good lie and a naturally "teed" ball.

Chapter 2: Maintaining an active Viable Root System.

The root zone profile: Out of sight – Out of mind. Soil tilth is something we often avoid talking about or doing anything for, yet many of our cultural practices and utilities tend to minimize good soil tilth. If you have access to the internet, I encourage you to refer to: http://attra.ncat.org/attra-pub/soilmgmt.html for an easy read. This is really about the balance in soil porosity, soil fertility, microbial activity and general soil health. A native prairie and out of play site, such as golf course rough areas, generally has some of the best soil structure on the course. The area is vegetated, not excessively trafficked, receives little or no fertility or pesticides and may be or may not be irrigated. Refer back to Fig 2, a turf site over 800 years old with little or no care. Close examination of the soil profile in these out of the way sites will help describe a good soil. Such soils allow for increased water entry, air flow and increased water holding capacity, and they are more erosion resistant as the grass root system reaches deep into the soil profile to anchor the soil particles in place. Contrast the rough with the "in play" areas and the differences are notable. Turfs that are heavily trafficked such as golf course fairways, tee boxes, and greens are subject to physical impacts that can alter the bulk density of the soils and are more prone to weed invasion and pest infestations. Our cultural practices of irrigation, fertilization and pest control coupled with high use levels create most of our environmental stresses.

Aging root zone profile – Loss of macropore space.

In studying a number of publications on aging soils (especially greens) as published in the journals or Golf Course Management Magazine (Iowa State University and University of Nebraska)) compaction or appropriately identified as the compression of the soil profile. It is understood that compressing the soil will result in an alteration of the physical nature of the soil profile in terms of porosity. Habeck and Christens (ISU - GCM 2000) studied three separate sand based greens of varying in age from 1 year, 6 year and 19 year post construction. The greens were planted to all cool season grasses and established on USGA recommend soil profiles of the time. They contrasted at a number of soil physical properties with a major notable difference in type of porosity present in the greens.. Figures 9.1 (total porosity), 9.2 (macro porosity) and 9.3 (micro porosity) exhibit the basic findings of most importance. The slope of the lines are indicative of what is going on. . Fig 9.1 suggest that subtle difference may have been attributed to the method of greens construction. For the most part, however there was only a slight increase (left – right) {young to older} in total porosity, as may be attributed to the gradual degradation of the mineral component of the soil.

Figure 9.1 Changes in Total root zone porosity over 20 years

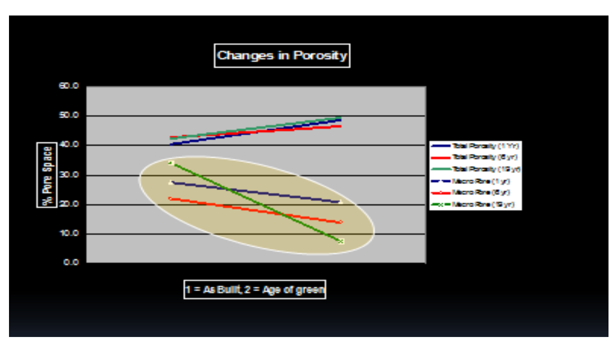

Figure 9.2 - Changes in Macropore space over time

Fig 9.2 and 9.3 suggest a significant change occurred in the types of pore space however. Beginning in the first year there was a significant loss of macropores (Fig 9.2 slope down with age) and this only magnified in older greens. Keep in mind that soil oxygen generally occupies macropores and as the root zone ages a loss of soil air space occurs. In contrast the micropore space increases (Fig 9.3 slope up with age) which technically holds plant available waters. The increase in micropores would be noticeable in the increase in moisture retention, at the expense of oxygen availability. This change based on age of soil profile may be a major contributor to the failure of root growth, persistence and existence of our greens, tees, fairways and sports field. The true failure of these facilities must be attributed to the lack of understanding of the root zone, and the general misconception that occasional aerification linked with top dressing with sands or soils might correct this problem.

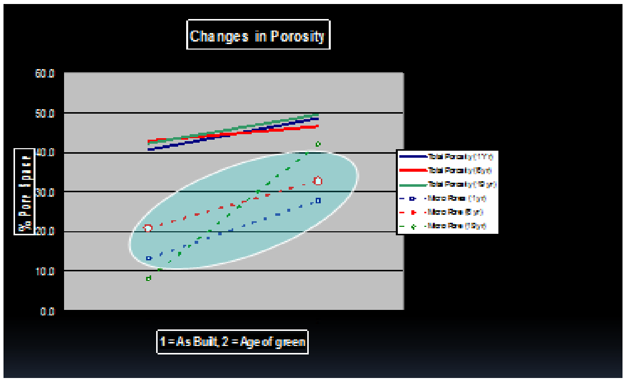

Figure 9.3 Changes in Micropore space over time

Target Root Zone Aerification Programs – Manufacture pore space

Good agronomic practices incorporate aerification of the soil profile to maintain a high level of macropores in the root zone. A well-aerated soil is cooler in the summer and warmer in the winter. In contrast, a saturated soil will freeze easier in the winter, and will experience higher respiration in the heat of the summer. Roots respiration rate is elevated as is the respiration rate of soil microbes. This results in consumption of higher levels of soil oxygen. The combined increased respiration and depletion of soil oxygen will result in root tissue suffocation, and loss of microbial activity. This is a primary reason that roots are generally lost during the heat of the summer (Carrow, 1996). A “good” soil will have 45% minerals, 2 – 5% organic matter and the balance in air and water. Air occupies the large pore spaces and ideally will be 25% with water residing in the smaller or micropore space. Soil moisture levels should be maintained at or below field capacity. Heavily trafficked soils will be characterized by having much less air space and a tendency to be saturated; be more prone to storm water runoff; a much shallower root system; a higher thatching tendency; and less efficiency on the use of fertilizers and pesticides.

One of the major keys to excellent soil management is recognizing the impact of use (geens, tees, fairways, sports fields) and taking necessary measures to compensate for heavier use. If age of the root zone is as simple as the loss of macro pore space, then the remedial approach would be to create more pore space. A good cultural program will allow for creating macropores frequently enough to compensate for their loss. Several years ago the term VENTING was proposed to describe frequent deep penetration into the soil profile with minimal surface disturbance.

Figure 10. Comparative size of venting tines

VENTING is just another name for aerification, however in most sports communities; aerification has such a negative perception that VENTING is an easier sell. This slicing or penetration of the root zone results in a downward and/or sideward movement (compression) of the soil and leaves a puncture hole, slit or Vent ie., macropores. The star-tine (90 mm length) and the bayonet venting tine (150 mm) [Fig 10] are good examples of solid tines which have proven to be effective in promoting good root zone health. Creating pore space does not require core (extraction) cultivation. These types of solid tine are particularly effective in sandy and sandy silt loam soils. In clay soils the potential for some horizontal compaction may be noted, however the drying advantage of these vertical shafts will provide considerable benefit even to clay soils. VENTING has a positive impact on greens, and all surfaces that are intensely managed. A major GAME CHANGER for improving cultural programs is to introduce and judiciously use solid tines (VENT), and VENT frequently. In unpublished trials at Texas A&M, the longevity of macropores generated by various types of aerification tines varied from as little as 1-2 days with the pencil tines and water injection equipment (Hydrojet), to as much as 8 -10 days with these bayonet type tines. The air columns provide much needed avenue for water infiltration, and evaporation, and soil gas exchange to support both plant root and microbial population development. VENTING is a minimally disruptive practice of generating the much needed macropores. Venting should be done primarily during the hot seasons of the year to permit maximum infiltration of water during rain, irrigation or FLUSHING events and provide maximum evaporation of excessive water following irrigation or a rain event. If a major rain event is forecasted such as a hurricane or typhoon, it would be reasonable to exercise a complete venting on all sensitive surfaces such as greens, tees and low lying fairways to promote better infiltration and drying.

DECOMPOSITION: As stated, venting also opens the soil structure to enhance rooting, improved gas exchange, and improves microbial activity. The organic layering typical of many putting greens was eliminated through a judicious venting program (Fig. 11) resulting in a clean, deep (17" soil) root system which was maintained at or below field capacity without the use of any pesticides. Not to be overlooked is the importance of this living- breathing microbial population which is essential to **decomposition** of organic material and the **recycle** and **release** of nutrients back into the soil profile. This effectively reduces the amount of fertilizer required to promote healthy turf, and further reduces the incidence of diseases which also feed on high nutrients. Microbes contribute to degradation of organic matter via decomposition with a substantial decrease in organic layering. Excessive organic layering further contributes to restrictions in water and air movement in the soil. Reducing the thatch, managing the organic matter and maintaining appropriate air/water exchange in the soil profile will improve turf health and further reduce the natural incidence of diseases. As a side note, Pathogenic organisms are also microbes and if given a favorable environment to proliferate, they will do so at the expense of a healthy balanced microbial population (low oxygen saturated soils). Put the native microbes under-stress and the opportunistic virulent (pathogenic) organisms will increase the incidence of disease. A vigorous venting program during the summer months will help maintain high levels of air in the profile and therefore a

Figure 11. 42 cm soil profile on a 23 year old USGA type green. June 2005, Texas

cooler and drier root zone and healthier roots and beneficial microbes. A deep, functioning root system allows the plant to transport water through its tissue in the transpiration process which enhances self-cooling. .

The simplest approach to turfgrass management: – Don't do any more than you have to do, but DO EVERYTHING THAT YOU NEED TO DO!

DILUTION: Periodic top dressing is also essential with the new generation of putting and sports field grasses. All prone to produce higher levels of organic material in the upper root zone must be met with a vigorous sand top dressing or **dilution** program to intermix sand or soil with the organic material.

The combination of a timely **extraction** (core cultivation, verticutting), **dilution** following extraction processes (top dressing) and periodically through the growing season helps to keep the Organic level in check, coupled with a good venting program to promote **decomposition** will result in a highly sustainable playing surface, regardless of its utility.

Chapter 3: Dealing with environmental extremes

Global warming, extended drought conditions, extended extreme temperatures, poor irrigation waters all add up to an increase in environmental abiotic stresses. For example, it is often cited that bentgrasses go into late summer decline due to a prolonged heat stress, we see a definite reduction in the depth of rooting and often to the point that few if any roots are available to support plant growth.

Observations over the past three (3) decades on the decline of turf in late season suggests it is almost always associated with high temperatures, prolonged dry period, excessive irrigation, thatch accumulation in the upper root zone, and/or generally poor water management techniques. Close examination of the root zone often reveals an increase in the level of organic matter in the upper profile top 4" (0-10 cm). The advent of recent prolonged dry periods has been revealing to the crux of the problem. Yes, the situation is almost always associated with prolonged dry periods, and high ambient temperatures. The turf surface often seals up and even with excessive irrigation there is poor soil infiltration.

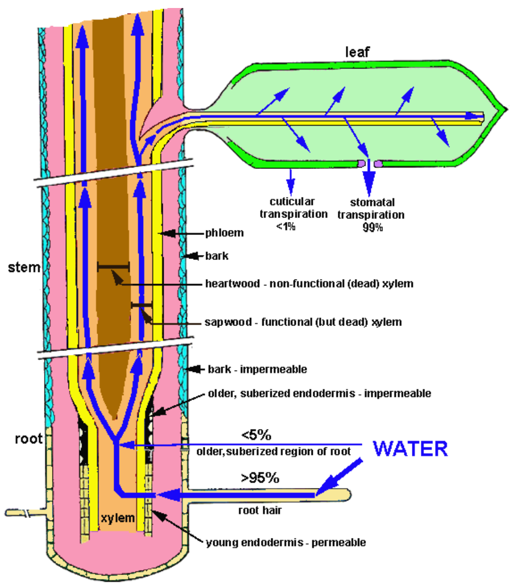

Figure 12. Plant Water Cycle adopted from Turgeon

The Plant Water Cycle: From an environmental stand point it is important to understand the water cycle. The key point is how water moves through the soil profile into the plant (Fig. 12), and that water is the carrier for all nutrients and other soluble chemical compounds (salts).

For a closer look at the water cycle let's start with either a natural rainfall event or possibly even an irrigation event. Water in its liquid phase (droplets) is applied to the ground surface. Generally through gravitational force the water enters the soil through channels or vent holes created by insect bores (earth worms), macropores associated with soil particle composition and arrangement or vacated root channels. In essence these channels provide the entrance and exits points for water infiltration, water evaporation and gas exchange. By shear nature of the composition and arrangement of soil particles the root zone profile is also noted for having considerable pore space, space between soil particles (Figure 13) . The total pore space is relatively constant among most soils and ranges between 35 – 55% by volume. The type of pores (either macropores or micropores) created in the soil root zone is dependent on the soil particles in the root zone. Clay particles which are magnitudes smaller than sand grains when stacked together create small pore spaces, whereas sand particles aligned together have much larger pores (macropores). The micropores which retain water through adhesive forces also provide water to the plants (roots) and microbes in the soil. The macropores will contain primarily soil gases (Nitrogen, Oxygen and Carbon dioxide) as the heavy water molecule is moved by gravity and exits the macro pore space and is replaced by soil gases (air).

The water molecule (rain drop) enters into the soil through surface pores and by gravity moves downward past all the soil particles This moving water molecule will also dissolve any soluble chemical compounds. Depending on the rate of infiltration and the volume of water applied these soluble compounds (fertilizer, salts, etc.) will be moved deeper into the soil root zone. Normally the recently released (decomposed) nutrients and those from fertilizers are distributed through the root zone and become available for uptake by plant root hairs. High infiltration rates and large volumes of water (Flushing) can move these compounds deep into and possibly through the root zone

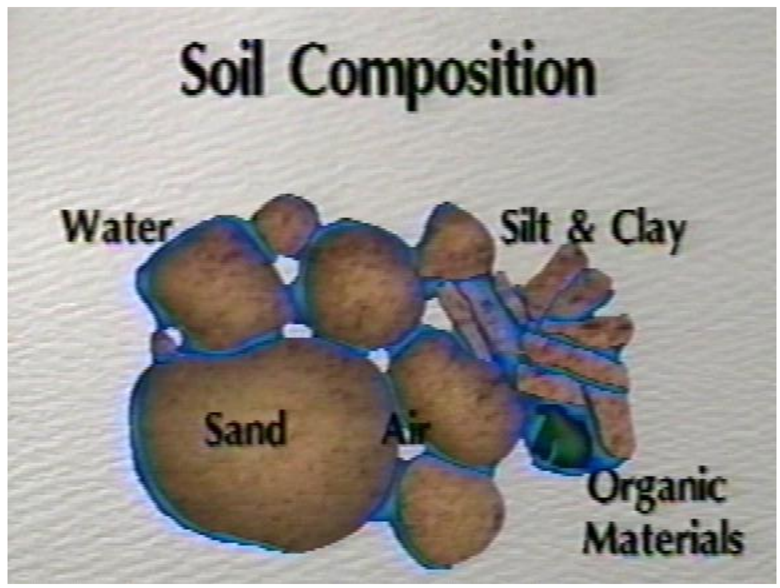

Figure 13. Soil composition and structure

Soil moisture containing dissolved nutrients are absorbed and redistributed to the plant to support growth and development. The movement of the water molecule through the plant also aids the plant in being able to cool itself (Fig. 12). The water molecule releases the nutrients to the plant biological functions and then leaves the plant through the process known as transpiration. Essentially transpiration is the movement of water through the plant exiting the stomata or pores in the leaf surface as water droplets (liquid phase). The water droplet sitting on the leaf tissue is exposed to an environment which has lower water content and therefore will evaporate (gas phase). The change from liquid phase (water droplet) to gas phase (humidity) results in major heat exchange which allows the plant surface to be cooler. Air flow across the leaf surface is important to allow the water droplet to evaporate to a drier micro climate enabling the cooling process as well.

Simultaneously water is moving through the soil profile by capillary action from micro-pore to micro-pore regardless of the direction (Fig. 13). Capillary water flow moves from wet areas to dry areas and during prolonged dry weather the drier micro-climate is near or at the turfgrass canopy (soil – turf surface). Although these water molecules are not moving through the plant, they still contain a major soluble supply of compounds (salts). Since salts will not volatilize (evaporate), they are deposited on the surface of the soil or thatch of the turf where over a period of time they will accumulate. The rate of accumulation is dependent on 1) relative ambient humidity, 2) surface air flow, and 3) concentration of nutrients and salts in the root zone. Periodic rains will re-dissolve these salts and move them proportionately downward away from the crown area of the plant. A significant rain event following a dry period will often be noted by having a flush of new growth and rejuvenation of the turf. This significant rain event effectively moved the accumulated salts from the crown (growing points of the plant) deeper into the soil profile. The depth of movement of the salts is directly dependent on the permeability of the soil and the quantity or water applied. If the rain (irrigation) events are only modest, the salts will only move out of the crown area, soon to return with evaporation as the dry cycle begins. If a significant rain event occurs, the salts will be moved considerably out of the effective root zone and could be several days or dry weather before the salts return.

Too often misunderstood is the impact of the water source. The use of effluent and brackish waters definitely accelerate the process of salt accumulation since more salts are being applied to the turf. It is important to understand however that turfs being irrigated with potable water will also be vulnerable to salt build up in the soil profile over time. It may take a bit longer however the accumulation of salts will occur just the same. These salts have the same impact on the turf. 1) Sodium (Na) based salts will interact with clay and silt particles and cause a flocculation of the soil particles, destroy soil structure and create a layering effect which can seal the surface preventing water infiltration and imped gas exchange, and 2) create a negative chemical environment with excessive salts (salinity) in which many of our plants will cease to grow. Learning to recognize these conditions can often make the difference between having plants exposed to unnecessary abiotic stresses.

Monitoring changes in soil salinity is often done through extensive, time consuming lab based soil test. All too often, however most of the soil samples tested in the laboratory exclude the upper 5-10mm of organic material and they concentrate on soils fractions below. These upper fractions which were discarded actually contain the compounds that we are looking for since we are trying to examine a dynamic situation. Recall the salts are being deposited by evaporation at the soil surface. Therefore the surface fraction must be assessed to determine the severity of the salinity build-up. A quick Google search will reveal the possibility of numerous inexpensive instruments which have been developed to effectively monitor the relative level of salinity and total dissolved salts in the field. Most of these are electronic in nature, and are designed to measure soil conductivity which can be a measure of moisture, salinity, etc. My personal favorite for field assay are variations of this unit (Fig. 14) which has the ability to log data, simultaneously monitor soil temperatures and most importantly when merely inserted into the soil profile will provide an instant relative reading. Under field assay conditions

Figure 14. Field Scout salinity probe.

the value read on the meter is only relative. The first reading of a site provides a reference base to establish back grounding or a start point. A second reading indicates the relative change in the electro-conductivity of the area and suggest the rate at which salts are being accumulated. It is also possible with this unit to determine with some degree of precision where the salts are accumulating in the profile and where they have been moved to following a rain or irrigation event. The sensors are located on the very tip of the probe and take an immediate measurement. As the probe is pushed through the profile, it meter is providing a real time response to the location of the sensors.

Once a salinity situation is recognized, the process to remediate the saline soils has multiple possibilities. Aeration, **venting**, flushing and **chemical exchange process** aid in salt remediation. Most of the salts will accumulate in the micropore space created by the accumulation of organic material in the upper root zone.

Aeration – or the process of extraction with a core aerifier targets the management of the organic layer in the upper root zone. By itself, core aeration is an ineffective method of removing salts, however it is an important and essential process to keep the accumulation of organic matter (thatch) in check **[Extraction]**.

Venting, or the process of creating vertical air channels and optimizing macropore space is likewise important in organic matter management and providing exchange sites for movement of soil water and soil air. It turns out venting, or manufacturing macro pores" is one of the most important cultural management practices which will enhance root zone performance regardless of the soil profile as it is integral to supporting degradation of Organic material **[Decomposition]**..

Flushing or leaching of soil salts on the other hand will directly impact the movement of salts deeper into the soil profile away from the crown and growing points of the plant, depending on how effectively water can be introduced into the saline soil environment. Low to moderate levels of Organic Material, and the presence of **vent** shafts greatly aids both water flow (entrance) and air exchange. Salts can be re-dissolved and through gravity or siphon will be drawn deeper into the ground. A proper drainage system such as created by the use of the USGA root zone soil profile can be an effective way to completely eliminate excessive salts. An understanding of the perched water table is important in knowing the value of flushing the salts from the soil profile, however as greens age the ability to flush greens changes due to the dynamics of the greens construction itself as previously discussed. Depth of root zone and a major shift in porosity to micropores impedes the movement of salts and oxygen in the soil profile. Although the examples are given relative to a sand based green (USGA types) a similar principle of water movement occurs in all soils, just at difference rates.

With the advent of the improved zoysiagrasses we have however a major alternative to using excessive and precious water supplies to control salts, and for that matter the plants ability to deal with salts basically eliminates the need for expensive sand based root zone construction. This applies to greens, tees, fairways as well as sports fields.

<u>This new generation of </u>grasses have the ability to extract salts from the soil profile by drawing the salt molecules up through the plant to the leaves where they can be mechanically removed. The halophyte plants such as paspalums exclude salt uptake and still require 20 – 30% more available water to manage the salts. The case in point is demonstrated by the photo below (Fig. 15) which is a sand based green built in 1972 and was irrigated with a saline water source through 2005. This photo was

taken in 2006. A major drought in the area resulted in the saline levels of the irrigation source to increase dramatically, and with poor internal drainage in the aged greens, the saline levels through the soil profile increased to near 17000 ppm (half of sea water). The soils failed, the bentgrass failed and the putting surface was mostly salt/sand combination. In the spring of 2006 a portion of the greens were planted to Diamond zoysiagrass, notable the solid turf area in the photo below.

Figure 15. Diamond zoysiagrass putting green, soil profile 17 ppt

Soils on this site were approaching 17,000 ppm where anything in excess of 3500 pm is considered highly toxic to the plant. The example demonstrates Diamond' Zoysiagrass surviving in heavily saline soils. When the leaf tissue was analyzed it demonstrated the salt glands had removed up to 10,000 ppm with every mowing. The grass survives on less water, does not require water to leach the salts and will aid in remediating poor quality soils and water supplies.

The biological explanation is the presence of salt glands on the leaf surface (Fig 16) which extract the salts from the soil profile into the plant where the molecules are excreted to the leaf surface. This is a passive but remedial process and over time actually removes salts from the soil. In 2007 these golf course greens were solid sodded to zoysiagrass with continued use of the same saline water supply. By 2009 a field check of the soil profile failed to identify any appreciable levels of salts (they had been removed through-out the profile). The fact that salt is brought to the surface and excreted from the leaves of the plant also suggest that in order to reduce the level of salts for the area, it will be imperative that the clippings are mechanically removed. While many consultants and others advocate returning the clippings to take recycle the nutrients, such is not the case as the salts must be removed. Considering that zoysiagrasses are used throughout the turf community, clipping removal is often not practical, however during periods of extended drought, when ET rates are excessively high, salt accumulation will ultimately result in failure of the soil structure – then all turf fails. With paspalums, the grass can tolerate high saline levels, but only to a point. That point is just prior to soil failure, and the only way to dissipate soil salinity with Paspalum is to flush the salts back into the soil profile, only to return again. With zoysiagrass, the removal of the clippings is an effective and efficient means of totally eliminating the excess salt from the site, not to be returned through the wet-dry cycle, nor does it require excessive applications of precious waters to flush the salts from the profile.

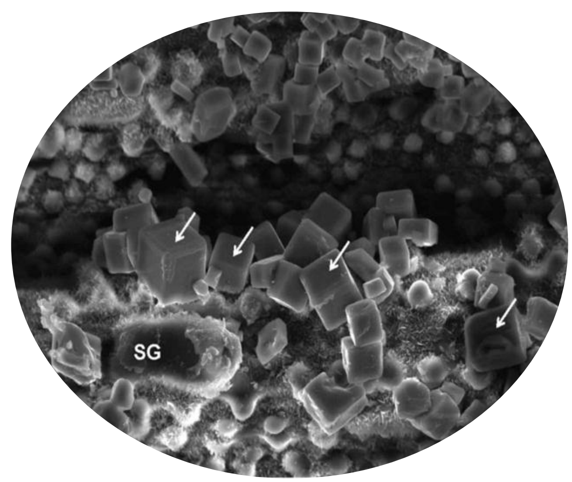

Figure 16. Salt glands at 400x on surface of Diamond Zoysiagrass

Studies are underway now to compare the salinity tolerance mechanism with other grasses such as the paspalums, however keep in mind that Paspalums can survive in the presence of high salt levels, eventually the soils must be flushed to avoid soil failure. As with all species of grasses, it is important to understand the differences between varieties of grasses, as not all zoysiagrasses will have the same level of salt gland activity, but all zoysiagrasses extract salt from the soil water and soil profile the same way.

- Key Learning Points: Salinity is accumulating in the organic layer and upper 13 mm of the profile.
    - Salt accumulation in the upper soil profile is not unusual, and properly managed does not create problems. Occasionally, and especially during the grow-in phase and also during periods of prolonged drought (high ET rates) salinity can increase to the point that it is impacting plant growth and development, then it must be dealt with, and dealt with when it occurs, regardless of the time of year.
    - Sodium is taken up in the plant and displaces potassium, a macro element essential to plant growth and development. In excess then sodium will slow plant growth and generally yield a less than desirable appearance of the turf.
    - An accumulation of sodium will result in a loss of soil structure and can cause the soils to lose macro-pore space and effectively create an impervious layer. This is typical of what is happening when water cannot penetrate the surface and combines with the organic layer to retain more water and to prevent water infiltration, gas exchange or availability of oxygen to the root zone.
    - During cool weather, the excess water will keep the soil profile colder – further slowing plant growth, and in the summer time will keep the soil profile warmer – increasing respiration and accelerate use of limited soil oxygen. Air in the root zone is the best insulator against temperature swings and therefore along with the oxygen is essential to maintaining good plant and microbial development.
    - Removing sodium for the root zone is accelerated by chemical compounds which can displace the sodium ion (Na^+) such as calcium (Ca^{++}). In Dallas area soils, which are primarily alkaline in nature (pH higher than 7.0) we normally will use gypsum ($CaSO_4$), or more recently Calcium nitrate ($CaNO_3$). The calcium ion will loosen the Na ion from the soil particle and allow the Na ion to be washed away (flushed) into the lower soil profile away from the growing plant.
        - The evidence of rapid green up and a spurt of plant growth after a rain is often evidence of excessive salt accumulation in the crown area of the plant.
        - The USGA green is specifically designed with its constructed layering system i.e., sand over gravel which creates a perch layer (or passive valve) to allow for the greens to be flushed for maximum salt management.
        - The frequency of Calcium application and necessity of flushing the greens is highly dependent on the rate at which salts accumulate. Therefore I recommend frequent monitoring of the salinity levels in the upper ½" of the root zone. The

sensors are located in the tip of the probe and are easily inserted to the depth desired.

Miscellaneous Key Points and other tidbits and ramblings:

Traffic Tolerance:

The extensive rhizome and stolon system found in today's modern zoysiagrass varieties result in improved traffic tolerance including tolerance against divoting and soil compaction. The improved rooting structure and depth afford the zoysiagrass the ability to provide high performance at moderate to even minimal cultural inputs, especially in terms of water and nutrition.

Low nutrient demand:

The nutrient and water mining capacity of the modern zoysiagrasses enable the turf to be maintained more economical and environmentally friendly. The deep root nutrient mining is coupled with a reduction in nutrients required for excellent turf production, and this results in lower cultural inputs required for top performance.

Low water demand:

This extensive fibrous root system is also highly effective in water management. With today's emphasis on water conservation and politically imposed water restrictions, most of today's zoysiagrasses are STAGE THREE READY, irrigation one to two times per week is generally adequate in sustaining quality turf, even under heavy play.

Soil Temperature Sensitivity:

The species or variety of grass isn't going to change unless you have a natural disaster such as a deep freeze, disease infestation or insect plaque, but understanding the unique growth patterns of the selected grass is essential. The cool season grasses (bentgrass, bluegrass, perennial ryegrass, fescue family of grasses etc.) will generally have optimum growth when soil temperatures range between 45 – 80 degrees F[7 – 26 C]. Colder and they will tend to stay green, but will be slow in growth. Cool Season grasses in the Temperature climates may enter winter dormancy as well especially if the frost zone extends below the crown of the plant. Many of the northern courses will experience frost layers (frozen ground) as deep as 48"[1.2 m]. The sites will be shut down, the irrigation systems drained and one can hope for a good snow cover to protect the plants. In open winters, it is essential to monitor soil moisture however as too often winter kill may be from desiccation rather than just cold temperatures. Winter desiccation is not limited to temperate climates. Many winters can been particularly concerning throughout the sub-temperate climates especially when drought conditions prevail and ET rates are excessive. Irrigation can be as important during the winter months when drought periods are extended.

The critical soil temperature for many warm season grasses will be in the high 50's F[low teens C] but with Zoysiagrass the critical soil temperature when roots initiate nutrient uptake is 65 F [18 C]. Some species are more prone to winter injury or poor spring transition and too often we fail to prepare the plants for entering in to winter dormancy properly. The key to a strong spring transition is to be certain the plant has the opportunity to store adequate carbohydrates in the fall and to avoid late season cultural practices which put pressure on CHO accumulation and storage.

FERTILITY PRACTICES:

Adjust your fertility level to match the growing season, avoiding applying more than ¼ to ½ # of N per growing month. Never apply N based fertilizers during cool wet weather (early spring, late fall) when the grass is green and not growing. Ideal time to fertilizer is when the plant is dormant in those climates where the plant goes into winter dormancy. Neither the plant nor pathogenic organisms are active. This will greatly reduce the incidence of patch diseases.

WATER – A CRITICAL NATURAL RESOURCE

A: Water Quantity. A major factor of concern in developing sustainability systems is the demand for our natural **water** resources. By developing and utilizing plants that have a strong penetrating prolific root system we can ensure the plants ability to mine available soil moisture and soil nutrition. A deep root system doesn't reduce the demand for water; however it does allow the plant access to a greater stored water supply between rain and or irrigation events. Further this prolific root system has better access to **soil nutrients** which are being released from organic and inorganic degradation from microbial activity.

Each of these factors however is also dependent on the maintenance of soil structure, balance in soil gases and soil chemistry. Loss of structure through constant flooding, poor soil drainage, compaction or poor cultivation practices will reduce the plant ability to develop the necessary supporting roots system. Loss of soil macro-pores through compaction, flooding or chemical imbalance can result in the loss of soil oxygen. Oxygen is essential to support root growth and development, and just as important for healthy microbial activity. Reduce the Oxygen availability in the root zone and the consequences will result in shallow rooted, weak thatchy turf which will fail to stand up to the rigors of a desired sports turf area; golf course, sports turf or playground.

SOIL CHEMISTRY: Chemical Balance and Imbalance

Managing Salinity Issues in the Soil Profile: Whereas with saline water supplies we are learning to management our soils through the use of appropriate grass species, and through judicious and timely water management. If salts accumulate in the root zone it is without doubt that soil structure will be influenced negatively and depending on the severity of saline accumulation, could result in root zone failure. There are few alternatives to dealing with accumulation of salts in the soil profile all require some form of remediation. Even with the use of salt tolerant species such as Paspalum the salts must eventually be flushed through timely rainfall or heavy flushing irrigation to move the excess salts from the crown area of the plant and surface layer of the soil. While most of the Paspalum varieties used for turf, especially on greens and heavy use areas are known to be salt tolerant, they survive in the presence of salt by excluding salt uptake, which results in a rapid accumulation of salts in the root zone and crown

area of the plant. During prolonged dry periods, with the lack of rainfall, the salt levels can reach a point where the soil structure is compromised, ie., the Na ion displaces other ionic elements and cause the soil particles to plate out – flocculate. When this happens, the soil structure will create layering which in turn will seal the soil and basically result in failure to have either air or water movement in the profile. The roots of the plants will suffocate, the microbial organisms in competition for the soil oxygen will likewise suffocate. The result will be black layering, anaerobic soil conditions and total loss of life in the soil profile, including Paspalums or any grass trying to grown under such conditions.
REMEDIATION OF SOIL PROFILE:

FLUSHING: There few ways to remediate the soil which such happens is to open the canopy, apply an active Calcium (Ca) source to displace the Sodium (Na), and apply copious quantities of excess water to flush the salts deeper into the soil profile. This flushing action, done properly will also help to drawn soil air deep into the soil profile, however while it is flushing Na it is also potentially removing other desirable nutrients. It may be necessary to apply modest levels of N-P-K following flushing. FLUSHING OR LEACHING OF THE SOIL PROFILE: Will be discussed in detail during the seminar.

REMOVAL OF LEAF TISSUE: Removal of salt from the soil surface can also be accomplished by using plant species which actively remove the Na from the soil profile, bring the salts into the leaf canopy and eventually expel the crystals on to the leaf surface. Many of the new Zoysiagrass varieties on the market today are noted for having this ability. The process is supported in the plant by the presence of salt glands, which appear to have special ion pumps capable of identifying Na and removing it from the plant sap. Different than Paspalums which exclude Na, and results in accumulation in the soil profile, Zoysiagrass will move the Na from the soil, up through the plant, and deposit in on the leaf surface. This affords the turfgrass management an alternative to using excess water, namely it is a matter of removing the leaf tissue from the site. Failure to remove the salt crystals will result in an accumulation in the soil as well and eventual failure of the system will occur. Doing nothing is not a good alternative. Either plant a grass than can exclude salts such as the Paspalums, followed with periodic application of excess water to flush the root zone, or use a Zoysiagrass with strong salt gland activity and remove the clippings from the site without having to use excess water. In times where water is becoming a limiting factor, gathering and disposing of clippings is become a desirable option. More will be discussed on this issue in detail during the seminar.