Creating an excellent playing surface 1:
Managing the Rootzone

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1. Summary

The R&A define sustainability as *optimising the playing quality of the golf course in harmony with the conservation of its natural environment under economically sound and socially responsible management*. When we apply that broad definition to managing the golf course rootzone in Asia, we can identify some concrete ways to *optimise the playing quality* and *conserve the natural environment* in an *economically sound* way.

- Manage the soil pore space
- Manage soil organic matter
- Manage soil water content
- Manage soil air content
- Create conditions to optimize root growth
- Adjust soil chemical properties

By properly adjusting these rootzone properties to fit the needs of a specific site, the playing quality of the course will be optimized. The natural environment will be conserved and money will be spent in an economically sound way by only performing the essential maintenance activities that produce the desired rootzone conditions.

2. Soil Pore Space

We can consider the rootzone to consist of solid matter and pore space. The pore space is further divided into aeration porosity and capillary porosity. The aeration porosity consists of those larger pores from which water drains freely under the force of gravity. Capillary porosity consists of the smaller pores in the soil, in which adhesive forces (between water and soil) and cohesive forces (between water molecules) hold the soil water against the force of gravity.

The total porosity will typically be from 35 to 55% of the soil volume. Capillary porosity in a sand meeting USGA specifications would be from 15 to 25%, and aeration porosity would be in the range from 15% to 30%. As turfgrass grows, it produces organic matter than causes an increase in capillary porosity and a decrease in aeration porosity. If the soil pore space is not managed, turfgrass surfaces become soft, prone to scalping, have poor root growth, and more disease problems occur, among other potential problems.

For a new project, ensure that the rootzone has the desired pore space. For success with an existing turfgrass stand, manage the pore space to stay within the recommended ranges.

3. Managing soil organic matter

Soil organic matter can be managed by removal (verticutting, coring) or by dilution (sand topdressing). In practice, both removal and dilution are necessary for the management of organic matter. On sand-based rootzones, I would not want to have more than 2% organic matter (by weight). Here are some general guidelines for managing soil organic matter. Remove 20% of the green surface area by coring each year, filling the coring holes with a suitable rootzone material free of organic matter. By using an optimum tine spacing and tine size combination, the number of coring events in a given year can be minimized. Table 1 shows how different tine sizes and tine spacings impact the surface area of the turfgrass.

Tine Diameter (mm)	Tine Spacing (cm)	Holes per m^2	Surface Area Affected (%) by 1x Coring	How Many Coring Events to Reach 10%?	How Many Coring Events to Reach 20%?
6	5 x 5	400	1.1	9	18
8	5 x 5	400	2.0	5	10
10	5 x 5	400	3.1	3	6
12	5 x 5	400	4.5	2	4
14	5 x 5	400	6.2	2	3
16	5 x 5	400	8.0	1	2
18	5 x 5	400	10.2	1	2
6	2.5 x 5	800	2.3	4	9
8	2.5 x 5	800	4.0	2	5
10	2.5 x 5	800	6.3	2	3
12	2.5 x 5	800	9.0	1	2
14	2.5 x 5	800	12.3	1	2
16	2.5 x 5	800	16.1	1	1
18	2.5 x 5	800	20.4	1	1
6	2.5 x 2.5	1,600	4.5	2	4
8	2.5 x 2.5	1,600	8.0	1	2
10	2.5 x 2.5	1,600	12.6	1	2
12	2.5 x 2.5	1,600	18.1	1	1
14	2.5 x 2.5	1,600	24.6	1	1
16	2.5 x 2.5	1,600	32.2	1	1
18	2.5 x 2.5	1,600	40.7	1	1

Table 1. Calculated surface area affected from different combinations of tine size and spacing.

In combination with coring, sand topdressing is also used as a means of maintaining the desired aeration porosity in the soil and managing the accumulation of organic matter. I suggest an annual total topdressing amount of 0.015 m^3/m^2, equivalent to 15 mm of sand, or 15 L spread over 1 m^2. Application of this quantity of sand will generally be adequate to dilute the organic matter that accumulates and to maintain a balance of aeration and capillary porosity in upper reaches of the rootzone. Light and frequent applications of sand topdressing (sand applied every seven to fourteen days) will be most effective in creating a good playing surface while at the same time managing the organic matter content in the rootzone.

4. Manage soil water content

Managing the soil water content is a matter of controlling the water held in the capillary pore space. Once a rain stops, or irrigation stops, then water rapidly drains from the large pores (aeration porosity) in the soil. The water left in the soil will be held in the capillary pores. By taking steps to manage the pore space and the organic matter in the soil, it is possible to create the desired condition of having a soil with capillary porosity somewhere in the range of 15 to 25%. Let us consider a rootzone which has 50% total pore space and 50% solid matter, and of the pore space, there is 30% aeration porosity and 20% capillary porosity, that is, 20% of the soil volume consists of small capillary pores that are capable of holding water against the force of gravity.

During a rainfall event, even the aeration porosity would be filled with water, but after the rain stops, water drains from that 30% aeration porosity, under the force of gravity, and there remains 20% water in the soil. In a rootzone 10 cm in depth, that is equivalent to 20 L of water in 1 m^2. To have the best playing surfaces and the healthiest turfgrass, one would try to maintain the soil moisture content at somewhere around 10 to 15%, allowing the roots to take up water from some of the capillary pores, and increasing the air content of the soil as the capillary pores lose their water. One would generally try to keep the soil moisture at just above the wilting point of the turfgrass. The wilting point depends on turfgrass species, soil type, soil nutrient status, and cultural practices employed on the turf, but we can estimate that the wilting point may be about 5% soil moisture.

Using wetting agents can be especially helpful in allowing water to be distributed more evenly through the soil. When water is distributed more evenly, less water must be applied to maintain the soil water in the optimum range. Also, wetting agents can help prevent the development of hydrophobicity in soils. When soils are allowed to dry to the wilting point, they may (and sands almost always do) become hydrophobic. So not only do wetting agents allow less water to be used because they can help water be distributed more evenly in the soil, wetting agents also allow less water to be used because they reduce the risk of developing hydrophobic spots in the soil.

Keeping the soil moisture content at less than the full capillary porosity but above the wilting point will increase rooting, create a firmer playing surface, and produce healthier turfgrass.

5. Manage soil air content

Keeping soil air content at 25% or above will tend to produce good turfgrass and good playing conditions. If your rootzone does not have enough aeration porosity, steps should be taken to modify the porosity of the soil (through reconstruction, or through coring or other aerification procedures that involve introduction of an improved growing medium). Cultural practices such as solid-tine aerification, slicing, or spiking can all help to introduce air into the soil, and these can be very useful techniques in situations when the rootzone's aeration porosity is too low. The aforementioned management of soil organic matter and management of soil water, if practiced as noted above, will result in an optimum soil air content.

The importance of soil air cannot be overstated when it comes to managing a turfgrass sward to create a playing surface for golf. However, the air comes, in my mind, as an aftereffect of proper management of the soil organic matter and the soil water.

6. Create conditions to optimize root growth

We don't play golf (or other sports) on roots, and as long as the playing surface provides the desired condition, then I really don't care about roots. However, it is a lot easier to produce a good playing surface if there are roots. Here is my short summary of everything I know of how to increase root growth or root system health.

- Maximize the amount of air in the soil. Keep the soil moisture as low as possible, but still above the wilting point.
- Optimize nutrient availability in the soil. Keep soil pH above 5.5 to minimize soluble aluminum that can be toxic to roots. Make sure soil phosphorus is at 35 ppm or above (on a Mehlich 3 soil test). Apply the right amount of nitrogen (3 g N m^{-2} $month^{-1}$ is a good first guess, adjust for your site). Make sure soil potassium is at least 50 ppm (on a Mehlich 3 soil test).
- Maximize the mowing height of the turfgrass. If there is more leaf area, there can be more photosynthesis, and if there is more photosythesis, there can be more root development.
- Application of kelp-based products may help with the maintenance of a root system during periods of stress, particularly through the action of the cytokinin plant hormones that are usually contained in kelp products.
- Use of Primo Maxx (trinexapac-ethyl) may increase turf quality and stress tolerance, and there can be an increase in the proportion of photosynthates directed to underground plant parts, because the leaf expansion is slowed, although photosynthetic rate of the turfgrass can be the same as turfgrass untreated with trinexapac-ethyl.

Of these, the most important are to maximize the air space in the soil and to eliminate any nutrient deficiencies. If we have waterlogged soils or a phosphorus deficiency, for example, raising the mowing height and spraying cytokinin will have no effect on rooting at all.

7. Adjust soil chemical properties

The playing surface is dependent to some extent upon having a turfgrass that has a controlled growth rate. If the soil chemical properties veer too far from the desired levels, then turfgrass growth could be too rapid or too slow, or diseases and other maladies could affect the turf. Here is a quick summary of the most important things to be concerned about for soil chemical properties.

pH - The soil pH is the controlling factor in a number of reactions in the soil, including many that relate to the solubility of different elements. Soil pH should be kept above 5.5. When the pH is less than 5.5, soluble aluminum increases and may be toxic to turfgrass roots. The optimum level of nutrient availability is in the range from 6 to 7, but turfgrasses can grow well and produce a good playing surfaces across a range of soil pH, from less than 5 to more than 8. Ideally, though, keep the soil pH in a range from 5.5 to 7.

Phosphorus - If there is already enough phosphorus in the soil, adding more has no effect on the grass. A Mehlich 3 soil test result of 35 ppm phosphorus or more indicates that there is enough phosphorus in the soil and none needs to be added as fertilizer. Phosphorus is relatively immobile in soils, and is used by the grass in much lower levels than are either nitrogen or potassium, so once you have established that there is enough phosphorus in the soil, you can generally avoid applying it as a fertilizer until another soil test is performed. I recommend soil testing at least once a year.

Potassium - If there is already enough potassium in the soil, adding more as fertilizer will have no effect on the grass. A Mehlich 3 soil test result of 50 ppm or more indicates that there is enough potassium in the soil to meet the immediate needs of the grass. However, potassium, unlike phosphorus, is quite mobile in the soil, and is also used by the grass in large amounts, second only to nitrogen. The ratio of nitrogen to potassium in turfgrass leaves is usually about 2:1. In most situations, applying nitrogen and potassium as fertilizer in an approximately 2:1 ratio will provide adequate potassium to the turfgrass.

Nitrogen - Nitrogen is the most important element applied as fertilizer and applying the proper amount of nitrogen is critical to the success of any turfgrass management program. For hybrid bermudagrass, 5 g N m^{-2} per active growing month would be a good estimate of nitrogen requirement; for other warm season turfgrass species 3 g N m^{-2} per active growing month would be more suitable. This is dependent on a number of factors and should be modified to suit the desired playing conditions at a particular site.

Soluble salts - Soluble salts (soil salinity) above a critical level act as a growth regulator on turfgrass by restricting plant water uptake. This is rarely a problem in humid climates (areas where precipitation exceeds evapotranspiration) but is often a problem in arid ones (evapotranspiration exceeds precipitation). You should be aware of the salt content of irrigation water and of the soil to ensure there is not a potential problem at your location.