GOOD SOIL BIOLOGY

The Answer to Practical Sustainability

By Martin Ward

Much of the discussion on how to design and implement sustainable practices, both financial and environmental in course management is about as effective as designing a two legged stool, because it concentrates on soil chemistry and physics and almost completely ignores the vital role played by soil biology in grass management.

In healthy grass systems the indigenous soil and soil biology provides the plant with all the chemistry it needs. True sustainability will never be achieved if we continue to override hundreds of millions of years of evolution.

The idea of applying minimal amounts of ammonium and ferrous sulphate for nutrition and hollow coring to remove thatch sounds reasonable at first hearing but, is in fact seriously flawed. It may work on those special few fescue dominant links courses which need very little nutrition but practical experience shows that when applied to heavily trafficked parkland courses is almost certainly destined to fail.

Ammonium sulphate and ferrous sulphate are mostly made by combining ammonia (a toxic gas) or scrap iron with concentrated sulphuric acid in temperatures over 800^{0}C . These products have salt indices of 69 and 85 respectively. Repeated additions of mineral salts kills the soil biology and creates many of the problems that take up the greenkeepers working day and much of their budget.

To apply 100Kg N per hectare as ammonium sulphate means you apply a salt equivalent of about 350Kg. Iron accumulation is partly responsible for the black compacted soil, iron bands, aggregated fines forming root breaks and concentrations of iron oxides familiar to all green keepers. In excess it has fungicidal properties and as we shall see beneficial fungi are essential for fine grasses, root growth, nutrient retention, low disease and friable free draining soil.

Dead soil of with excess thatch iron bands, black layer, compacted soil, no life and no roots.

Until recently, overlooking soil biology was due to lack of knowledge. But commercial laboratories now analyse soils for all the groups of microbes that make up healthy soil and compare the types of bacteria, fungi nematodes and protozoa that live under the different grasses found on golf courses.

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Electron microscopy unveils the soil food web *(Photo courtesy Laverstoke Park Lab)*

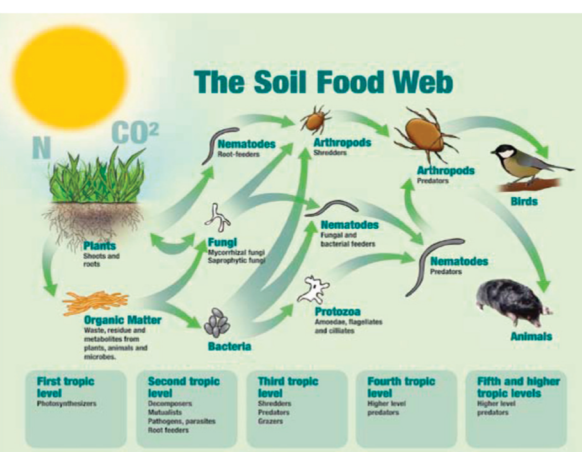
We often hear comments like, "there are lots of bugs in turf rootzones" and in many cases there are, but not necessarily the correct microbes to grow fescue or bent in low input, disease - free conditions. When sports turf rootzones are analysed, you often find the biology to grow Poa annua and plant pathogens which is very different to that needed for healthy perennial grasses to thrive.

So how do we develop the correct soil biology for sustainable fine grass management and how does it work?

Growth without fertiliser

First we have to understand how nutrients get into the soil without added fertiliser.

Grass produces a huge amount of energy via photosynthesis. In fact, grass feeds the planet providing the world with most of its proteins and carbohydrates through flour, meat and milk. Grass however leaks about 50% of its proteins and carbohydrates underground. In chemically managed systems most of this energy is wasted but it is this energy that must be used to grow healthy perennial grasses.



The biological make up of healthy rootzones. Moles and birds excluded. *(Picture courtesy SoilFodWeb Inc)*

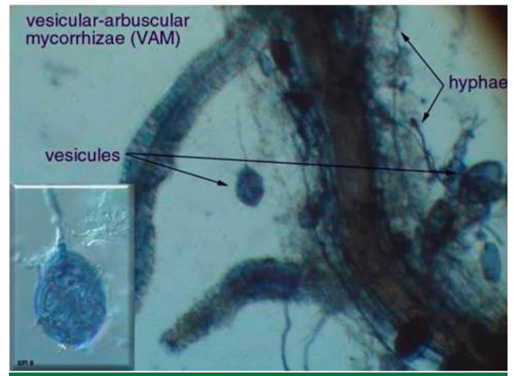
As grass grows as a natural part of its metabolism it leaks proteins and carbohydrates through its roots, bacteria live around the root system feeding on this nutrient and fix nitrogen from the air. Protein also contains a lot of nitrogen. When the bacteria in turn get eaten by protozoa or nematodes higher up the soil food web they excrete ammonium which is recycled back to the plant providing the grass with the nitrogen it needs.

With a healthy soilfoodweb you only need to stimulate photosynthesis by aeration or applying very low amounts of potassium, nitrogen or even iron to get lots of nutrient leaking from the roots. Sustainability is converting this nutrient to ammonia to ensure a constant supply of nitrogen is available for grass growth. It is quite possible to grow agrostis on a USGA specification rootzone using less than 40Kg N per hectare per year

Protozoa eat bacteria and excrete ammonium

Reducing fertiliser use

Research has shown (publications in STRI Journal July 1997) that grass inoculated with mycorrhizal fungi grows better in low nutrient conditions. All new constructions should be inoculated with mycorrhizae to ensure low fertiliser inputs. Mycorrhizal grass absorbs water and nutrient much more effectively reducing fertiliser and irrigation costs.



Mycorrhizal fungi massively extend the root system and form a protective barrier against disease and salt.

Get the chemistry right

Biology and chemistry must be managed together. Golf greens and tees are designed to maximise drainage at the expense of high fertiliser input and leached nutrient. Best practice chemistry and biology are overlooked in the design and build. To reduce fertiliser inputs there are several simple steps the course manager can take to improve soil chemistry by increasing cation exchange capacity (CEC) and base saturation.

Essentially, CEC measures the potential of soil to hold on to positively charged nutrient ions and base saturation measures the proportions of these alkaline (base) nutrients that are actually in the soil. The main alkaline positive ions in the soil are calcium, potassium, magnesium and sodium. Another essential positive ion is ammonium.

Opposites attract so the higher the CEC i.e. the more negative ions in the soil, the greater the amount of the essential plant nutrients that will be held in the soil.

In most soils the majority of negative ions are on clay and humus, both in very short supply in a new USGA or 80/20 rootzone. All good agronomists and fertiliser suppliers will analyse soil for CEC and base saturation and it is very easy and inexpensive to add calcium, magnesium and potassium in the correct ratios to ensure that the soil contains adequate base cations instead of other common cations such as hydrogen, aluminium and iron. CEC can be increased by adding zeolites or naturally by degrading thatch and converting it to humus and at this point we need to discover just how important thatch is to sustainable management.

Thatch is a friend

Thatch is part of the foundation for healthy grassland soil, everybody knows dead grass degrades and releases nutrient but it does so for four very important reasons involved with:-

1. *The promotion of fine grasses over Poa annua.*
2. *Providing resistance against plant diseases.*
3. *Ensuring soil friability and therefore good drainage and oxygen transfer.*
4. *Increasing the CEC and nutrient holding capacity of the soil.*

i.e. the key elements for sustainable grass management with minimum surface disruption.

Soil fungi degrade thatch and can easily be introduced; there is no need for aggressive hollow coring and top dressing with sterile rootzone, unless the rootzone does not drain. Apart from the physical disruption, financial cost, loss of income and the simple fact that most members won't allow it aggressive hollow coring and top dressing is counterproductive to sustainable management.

Growing perennial grasses

Poa annua is genetically programmed to seed and die for a very good reason. Annual seeding plants form the first stages of plant species progression; they colonise bare or compromised soils then in time perennial grasses, shrubs, deciduous trees or coniferous forest will colonise the soil. Perennial grasses predominate when the grass is cut or grazed.

New or bare soils can be quite sterile as there is no thatch to feed fungi and bacterial levels are quite low so Poa annua has growth mechanisms and a shallow root system that rely on the limited bacteria in the soil. Poa annua puts most of its energy into producing seed and relatively little goes underground to associate with mycorrhizae or to feed the supportive food chain (which is why poa annua needs more fertiliser than other grasses).

When poa annua dies, thatch is formed and this is food for fungi and a more complex soil food web can now form that supports perennial grasses.

If you weigh the bacteria and fungi found around the root system of Poa annua there is about 10 x more bacteria than fungi and little or no mycorrhizal fungi in the root systems.

However around the root systems of fescues or agrostis in healthy soil you find approximately equal amounts of bacteria and fungi and mycorrhizal colonisation of the root system.

So why does nature start with poa annua and develop fescues and bents while many golf courses do the opposite? Thatch is the preferred food for fungi so biological thatch degradation will provide the fungal dominant conditions needed for perennial grass growth.

The mineral salts in inorganic fertilisers and anaerobic conditions caused by water logging or compaction and excessive use of fungicides kill fungi and create the bacterial dominant conditions for Poa annua.

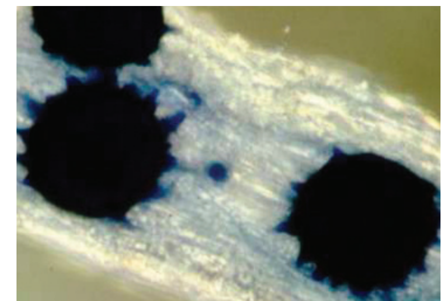
Fescue and Agrostis without stress

You do not have to stress poa annua to convert a green from poa annua to fine grass. Create a fungal dominant soil by degrading thatch to feed fungi, colonise the roots with mycorrhizae, use the root exudates as a source of nitrogen so reducing the use of inorganic salts, do not overwater and perennial grasses will grow.

Disease management

Fungal diseases attack weak plants and in the majority of cases it is unrealistic to provide blemish free surfaces without occasional use of fungicides. However, beneficial fungi and bacteria in the thatch layer and rootzone play a major role in limiting disease. There are four natural mechanisms that turf managers can use to reduce the incidence of disease.

1. *Mycorrhizal fungi, soil fungi and bacteria recycling root exudates provide a protective barrier around the root physically preventing pathogens from attacking the root.*
2. *Some soil fungi and bacteria will eat pathogens to prevent them from killing the host plant.*
3. *A high population of beneficial fungi in the thatch and soil will competitively exclude many pathogens,*
4. *Some soil microbes produce toxins that kill pathogens, this is the basis for many of the new strobilirium fungicides.*



With no protective barrier the root is open to attack by fungal disease (stained blue)

Nematodes

Many courses report damage by root feeding nematodes. This is a symptom of poor soil. In a healthy soil food web predatory nematodes will eat root feeders. There are many more beneficial nematodes than root feeders. They play an essential role in creating healthy soil. Image of predatory nematode eating a root feeding nematode is shown on the cover, and on pages 24-25.

Healthy Soil

Healthy sandy soil is a rich brown friable mix with lots of air and no compaction.

This contrasts starkly with older golf greens which often have a number of root breaks caused by top dressing on old turf, a build up of fines and iron to form a pan, chemical build up and black layer, general compaction or just poor construction.

Good soil biology creates friable soil that requires less physical disruption and top dressing. Again, it is fungi and beneficial nematodes that do the job. Bacteria and fungi produce polysaccharides, which help soil to aggregate, while fungal hyphae move through the soil followed by fungal feeding nematodes which break up the soil forcing the particles apart creating air space. The nematodes create small channels coated in excreted ammonium creating ideal conditions for root hairs and roots to penetrate. This in turn breaks down soil pans and root breaks releasing locked - up nutrient for plant growth.

The great advantage of using microbes to create friable soil is that you do not have to hollow core to replace your biologically active root zone, with its high CEC and correct base saturation ratios - with sterile topdressing.

Root zone profile of 108 yr old green with a complete soil food web.
(Picture courtesy Strawberry Hill Golf Club)

Turn thatch into plant food

Remove thatch physically, compost it and you get humus rich compost full of trace elements and macro nutrients. Degrade it in situ and you get the same results without the physical disruption and the costs of top dressing, labour, machine use and course closures; giving financial sustainability. Thatch will degrade with thatch reducing microbes, moisture and oxygen.

Some swards have a biomass of thatch degrading fungi and bacteria to do the job, but you may need to use a commercial inoculant or compost teas. Reputable suppliers will guarantee their thatch eating microbes. Sorrel rolling, scarification or new liquid aeration technologies will provide the oxygen required in all but the most horrendous thatch without major disruption.

Sustainability

When thatch degrades, nutrients are released and humus is created which increases CEC and reduces the need for inorganic fertilisers allowing the soil biology to thrive. Soil biology converts the proteins and carbohydrates released by the plant through its roots into ammonia and plant food. Thatch provides food for fungi creating the fungal dominant food web needed for perennial grasses. Fungi and nematodes create a friable open root zone. Plants are healthy and disease is excluded except under very high stress.

This is the path to sustainability.

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