A new perspective to grazing management and livestock nutrition - THE RHIZOSPHERE

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Albert Einstein never used any exam questions more than once, except one year. His assistant at Princeton University, who always checked the professor's exam papers before sent to the printers, one year noticed that Einstein used an old exam paper. He thought that the professor might have made a mistake and asked him about it. "No," was Einstein's answer, "that is correct, the questions are the same; it is just that the answers have since changed".

The questions surrounding how to manage veld optimally and still make maximum profit from it have always been constant. It is just the answers that have changed since so much new knowledge has emerged in the last 10 to 15 years, especially regarding the importance of what is happening in the soil.

Previously the focus of veld and herd management was mainly directed at the plants, the rainfall, the grazing animal, as well as supplementary and complementary nutrition. Regarding the plants, the focus was mostly on the quantity and quality of feed it can produce, the carrying capacity, and the influence that rainfall has on it. With the livestock the focus was on breeding and selection. In the case of nutrition, the focus fell on what

Figure 1. The elements of the grazing ecosystem

can/must be fed out of the co-op to provide what the veld cannot provide. These focus areas were also mostly seen in isolation from each other and not as part of a larger whole. In addition, the soil was considered as almost inert (lifeless, inactive, passive) growth medium, in which the plants anchor themselves, and from which they extract their water and minerals.

Returning to the story of Albert Einstein, what has changed in the grazing management area? We know today that the soil is much more than just an inert growth medium where plants anchor themselves and extract their water and nutrition from. On the contrary, the plants and the organisms that live in and between the plants' roots (known as the soil's microbiome) are interdependent on each other. In fact, the one cannot exist and/or function maximally without the other. There is, therefore, a new approach that must be noted. What happens above ground affects what happens underground and vice versa. The components of this new ecosystem approach are illustrated/depicted as simply as possible in Figure 1.

Water is life and all living organisms need water. One of the most important above-ground focus areas for the livestock farmer is to get as much of the annual rainfall into the soil and allow as little of it to run away as possible. The second focus area is to ensure that the soil water that returns to the atmosphere is used productively. Water that evaporates from a bare soil surface is a big loss for the livestock farmer. The goal is that the soil water must go back into the atmosphere by the way of transpiration (through a plant) as transpiration contributes to dry matter production. Transpiration via inferior plants is also a big loss for the livestock farmer. Examples of such plants are encroaching and invasive bush species, as well as unpalatable plants with a low grazing value. The successful management of the water cycle is therefore of crucial importance for any livestock farmer. In the past it was said that cattle farmers actually farm with plants and not livestock. Livestock farmers actually farm with the soil water.

Green plants have the ability to **photosynthesize.** Photosynthesis is the plant's food factory, where the plant takes water, combines it with carbon dioxide gas (CO_2), using energy provided by the sun to produce sugars (as a source of energy) and amino acids (as a source of protein). The basic building blocks of sugars and amino acids are carbon (C – from the CO_2 absorbed from the atmosphere), hydrogen (H – derived from the water H2O absorbed from the soil) and oxygen (O_2 – derived from the air, CO_2 and H_2O). The sugar molecules and amino acids contain all the building blocks that living organisms on earth need, which include C, H, O and a whole range of minerals, which include nitrogen (N) and phosphorus (P). A large percentage of the sugars and amino acids are used by the plants themselves to grow and reproduce. However, a part of it goes to the roots, where a percentage serves as an energy source for the microorganisms present in the soil.

In the soil there is a rich variety of life forms, which include **bacteria, archaea** (single-celled organisms without cell nuclei and which in the past were classified as bacteria) and **fungi.** This consortium of living organisms is known as the soil **microbiome.** Like all living organisms, they require energy for their survival, but do not possess the ability to produce it themselves (like green plants). The question now is, where does their energy for survival, growth and reproduction come from?

As already mentioned, plants translocate a portion of the sugars and amino acids they produce to their roots. In the roots, part of it is used for root growth. The rest is excreted as root exudates (see Photo 1). The fungi, bacteria and archaea that live in the plants' root zone (also known as the rhizosphere) use these root secretions as their source of energy.

Root exudates

The bacteria and archaea secrete gums and resins that cause a sheath of soil particles to form around the roots. This is known as a **rhizosheath** (see Photo 2). The environment within the rhizosheath is high in energy and moisture and low in oxygen, and very micro-organism friendly. The bacteria and archaea consequently live between these rhizosheaths and the roots and feed on the sugary exudates. Some of these microorganisms possess the ability to bind air nitrogen (N2), which means that they break the connection between the two N molecules, which then finally makes the N available to the plant in an absorbable organic form. Similarly, the rhizosphere microbiome has the ability to unbundle P that is bound to other minerals (for example calcium - Ca) and that is inaccessible to plants, and make it available to the plant as absorbable organic P. We know that N and P are important building blocks of amino acids and therefore protein. It is therefore obvious that this provision of N and P to the plant fulfils an important role in the plants' protein content, which in turn is positive for animal nutrition.

A third advantage of the rhizosheath microbiome is that it incorporates the C in the exudates into their bodies, which then becomes part of the soil C content when they die. It therefore contributes to the capture (sequestration) of CO_2 from the atmosphere in the soil, where it is very stable. Furthermore, the capture of carbon in the soil contributes to the soil structure and ability to store water, which in turn is beneficial for the water-holding capacity of the soil, as well as the rate at which water can infiltrate the soil. The better the water holding capacity of the soil, and the better its infiltration capacity, the less water runs off and the more effective the water cycle is. Furthermore, the bacteria and archaea secrete growth hormones, growth stimulants and amino acids which in turn benefit the plant. Truly an incredible relationship between the plants and the rhizosheath microbiome.

Rhizosheaths around the plant roots
https://soils.vidacycle.com/soil-tests/1-4-rhizosheaths/

Like the bacteria and archaea, there are **fungi** in the soil living in symbiosis with the plant roots, also depending on the root exudates as their source of energy. Fungi are also single-celled organisms linked together using a network of filaments or **hyphae** (see Photo 3). This network of fungi connected via its hyphae is known as the **mycorrhiza.** Some of the fungi physically implant into the roots, while others anchor within the rhizosphere. One of the functions of the mycorrhiza is to bring water to the plant, as well as to bring minerals to the rhizosphere microbiome. Because the fungi consist of such an extensive system of fungal filaments and anchored within the roots or rhizosphere, this effectively increases the surface area to which the plant has access. The fungi can therefore find, fetch, and transport nutrients and water to the plant which is out of reach of the bacteria, archaea, and plant roots. Some of the fungi secrete antibiotics that eliminate plant pathogenic microorganisms in the soil and thus lead to better plant health.

Finally, these fungi play a very important role in the messaging system that takes place in the soil. One could almost say that the fungi are the microbiome's internet. It is not yet known exactly how this works, but what we currently know is that the microbiome communicates with each other, probably via biochemical pathways. This communication determines whether the various components within the microbiome are willing to exchange resources such as water, nutrients, hormones, etc. with each other. The greater the variety of plant roots present in the soil, the greater the variety of microorganisms in the soil, and the better the cooperation between the microorganisms. The opposite is true of a monotonous plant composition, where the plants' microbes associated with them see each other as competition and do not readily exchange resources with each other. Truly just an incredible relationship between fungi and the plants with which they live in symbiosis.

The take home message is this:

- The greater the variety of plants and the denser their cover, and the more effectively they photosynthesize, the more energy is available as a source of nutrition for the soil microbiome and the more and a greater variety of microorganisms the plants can support. The deeper and larger the root systems of the plants, the greater the concentration of the microbiome.

- The more energy available to the soil microbiome and the greater the concentration of microorganisms, the more and better services they offer to the plants, such as better water supply, more nutrients that contribute to better feed quality, protection against pathogenic microorganisms, as well as making growth hormones and growth regulators available. The result of this is plants that are healthier and produce more forage of a higher quality. Furthermore, this healthy soil microbiome also improves the soil structure and quality.

- The better the interaction between the plants and the soil microbiome, the more feed of higher quality is produced for the livestock and the more stable the feed supply. These bring savings in feed costs, even during droughts, while the animals' production and the veld carrying capacity are enhanced. This ultimately leads to higher and more stable profit for the livestock farmer.

- Healthy plants lead to healthy soil. Healthy soil leads to healthy plants. Healthy soil and plants lead to healthy animals (and people who eat their products). Healthy animals lead to healthy profits.

- Truly a win-win situation. This is the new mindset that livestock farmers will have to get used to if they want to remain sustainable. We will have to learn how to activate the microbiome and stop doing things that inactivate it. Water, photosynthesis, and aboveground biodiversity are the primary activators of the microbiome.

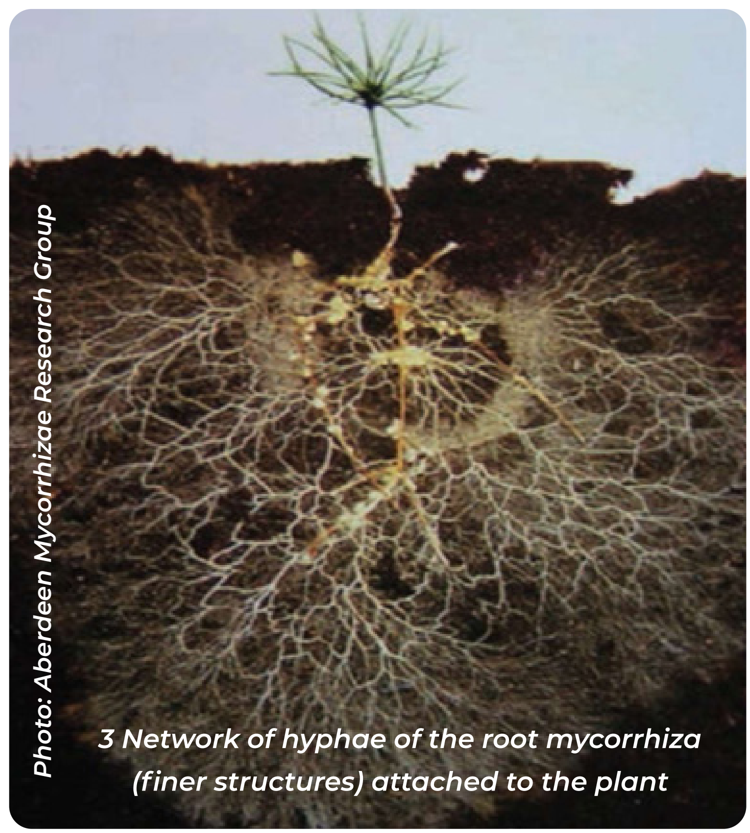

Photo: Aberdeen Mycorrhizae Research Group

3 Network of hyphae of the root mycorrhiza (finer structures) attached to the plant

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