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The Role of Mycorrhizae and Soil in Plant Establishment in Natural Ecosystems

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Israel is located in the south-eastern region of the Mediterranean basin. The northern and central parts ofthe country are affected by a Mediterranean climate and the southern region is strongly affected by the climate of the adjacent deserts. The annual precipitation decreases from the north to the south and also from the west to the east, toward the Afro-Syrian Rift-Valley. The isohyet of 400 mm is considered to be a border line between the Mediterranean vegetation and the other more arid lands in Israel.

In the Mediterran region, especially in the highlands where most of the soils are quite shallow, the more developed vegetation is characterized by sclerophyllous and evergreen trees. In fact, in most parts it has been disturbed by human interference for millenia and, therefore, is replaced by a more common type of mative vegetation which is called "Batha" in Hebrew. The Batha is a plant formation which is typical to all the countries around the Mediterranean area and consists of dwarf shrubs, most of them being sclerophyllous and evergreen as well. The dominant plants in this formation belong mainly to the Cistaceae, Labialae and Rosaceae. The Batha formation grows on soils formed from many types of sedimentry rock-like limestone, dolomite, chalk, marl and sandstone. But when one moves from these soils (that are covered with woods and dwarf-shrubs) towards soils that are derived from basaltic rocks, the Batha disappears at once and grassy formation takes its place. The typical feature of such a grassy formation is tht there is a very low presence of woody vegetation and many native trees and shrubs are totally absent, including most of the dwarf shrubs that are common elsewhere.

*Compiled after her tragic death from notes found on her desk, by Prof. J. Katan

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In a previous work, the role of climate and soil were compared along a gradient from arid climate, 220 m below sea level, up to 900 m above sea level and it was shown that grassy formation was dominant on basaltic soils while batha dwarf-shrubs were dominant on sedimentry rocks, independent of the climatic factor.

Soil analyses showed that the only feature that could explain the difference in vegetation between basaltic soils and soils that originated on sedimentry rock is that basaltic soils always had a much higher level of total phosphorus. The question therefore, is why Batha dwarf shrubs are absent from the basaltic soil?

Most of the study was carried out on *Cistus incanus* from the Cistaceae. This species is very common around the Mediterranean basin. It is also very common in the Mediterranean area throughout Israel but is absolutely absent fromt he basaltic soils. When seedlings were grown in pots, filled with either calcareous terra rossa soil or basaltic soil, they all started to develop well. However, eight weeks later, plants in the basaltic soil degenerated slowly while in the terra rossa soil they grew well. As basaltic soil may have serious problems of drainage during the rainy season I tried to improve aeration by adding special material to the soil that is used in nursery beds and is called "bems" but this did not improve plant growth. The same results were obtained when various mixtures of sand and basaltic soil were tried.

The next step was to grow plants in either basaltic or terra rossa soil. After 55 days, in either soil, the seedlings were transplanted to each of the two soils. After an additional 169 days, the roots were examined for the presence of mycorrhizae and the intensity of mycorrhizal infection (IMI), using a scale of three levels of intensity: $-$ = none + = very poor and local, ++ = intensive and well developed. It was clearly seen that all the plants in the basaltic soil were not infected and all of them degenerated as before, while the plants in terra rossa or the plants that were transplanted from basaltic soil to terra rossa were well-infected and were also welll–developed. However, the results of the treatment in which plants were transplanted from terra-rossa to basaltic soil had a high variability and plants were therefore divided into two subgroups: well-developed and undeveloped, according to their dry weight or total leaf area. It was found that this group was indeed composed of two distinct subgroups according to their IMI. It seems that the variability in the data of the last group is a result of transplanting the seedlings in a very early stage, before all of them were well-infected by mycorrhizal fungi.

To confirm these observations that the cause of the degeneration of *Cistus* plants in basaltic soil is the absence of mycorrhizae, I did another experiment with the two types of soils: basaltic and terra rossa. The treatments included sterilization of the soil, and addition of inoculum to the root system, prepared from fresh mycorrhizal roots or autoclaved inoculum. The plants in the basaltic soil were harvested after 78 days and in terra rossa after 92 days, and therefore a separation between the statistical treatment was made for each group. It was shown again that mycorrhizal infection affects the growth of *Cistus* in basaltic soil and also in terra rossa, and that plants without mycorrhizal infection in both soils degenerate after a few weeks. Again, mycorrhizal plants on basaltic soil were much larger despite the fact that they were harvested earlier. It should be emphasized that in terra rossa soil the infection was spontaneous while in basaltic soil *Cistus* plants did not grow unless artificial inoculation was carried out.

The type of symbiosis was ectomycorrhiza but the fungi were not identified as there are many non-specific candidates from the Ascomycetes and the Basidimycetes. When *Cistus* plants grew in aerated nutrient solution they developed very well, although they were not infected by mycorrhizae and therefore it was suggested that mycorrhizae supply the plants with nutrients that otherwise are not available to nonmycorrhizal plants in the soil.

Irrigating mycorrhizal and nonmycorrhizal plants in basaltic soil and in autoclaved terra rossa with either complete nutrient solution or deionized water showed that it was possible to replace mycorrhizal infection with nutrient solution. Watering plants with minus-phosphorus nutrient solution caused typical symptoms of phosphorus deficiency. This was not the case with minus-nitrogen nutrient solution.

It was concluded therefore, that nonmycorrhizal *Cistus* plants were deficient in phosphorus in basaltic soil despite the fact that this soil has a very high level of total phosphorus and a medium-to-high level of extractable phosphorus. It was found tht phosphorus levels in dry leaves of well-developed mycorrhizal plants was double that of nonmycorrhizal plants, independent of soil type.

These data further confirm the assumption that the principal contribution of mycorrhizae to plants is phosphorus supply, that otherwise is not available to the plant. It was also shown that the availability of phosphorus that was given to the nonmycorrhizal plants as a nutrient solution directly to the root or through the soil declined rapidly since phosphorus is adsorbed to the soil. Mycorrhizal plants were also much more active in reducing the pH of their surroundings as compared with nonmycorrhizal plants. This affects the solubility of phosphorus in the soil and its availability to the plant.

The next question that arose is why ectomycorrhizae do not develop in *Cistus* plants in the basaltic soil. This is puzzling since the basaltic grassland in northern Israel is surrounded by other soils where *Cistus* plants are very common and are sources of seeds and propagules for the establishment of this species. The previous experiments showed that artificially inoculated mycorrhizal plants develop very well in the basaltic soil. Therefore, it is suggested that difficulties in establishing seedlings must occur in an early phase: either during the infection stage of the symbiosis or when the mycorrhizal fungus is still free in the soil.

I looked for the reasons why spontaneous infection does not occur in basaltic soil, but I may only speculate according to my observations. I incorporated fresh inoculum into basaltic soil and stored this soil for different periods of up to 6 months without living plants. *Cistus* plants were then planted in the soil and were later examined for mycorrhizal infection. Mycorrhizal infection declined rapidly in plants grown in basaltic soils after three months of such storage, whereas well-developed infection was recorded in plants growing in terra rossa soil, even after two years of storage. This and other observations suggest that the absence of ectomycorrhizal inoculum in the basaltic soil is positively due to a strong lytic activity of microflora that takes place in basaltic soil and results in rapid decrease of the potential of infection of these fungi. Apparently, the microflora in the basaltic soil suppresses the build-up of ectomycorrhizal fungi as it was shown for certain soils which are suppressive to pathogenic fungi (suppressive soils).

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