

Soil Anxiety Effects Influencing Symbiotic Microbial Activity in the Soil

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Abstract

The soil environment is under a constant state of change and can be relatively stressful for both macro- and microorganisms. Soils represent one of Earth's most productive ecospheres, accounting for a majority of primary and successional productivity. Consequently, microbes, plants, and other soil inhabitants have evolved to adapt to the ever changing and often inhospitable soil environment. Based on the above facts, in this paper we can speak of stress factors originating in the soil. In many cases these factors are resulted from biotic factor which includes the living components such as plants, animals, and microbes which has its own energy and material fluxes. The second major soil stress factors that include potentially adverse effects of acidity, salinity, drought, flooding, waterlogging, nutrient deficiency, high temperature and are abiotic or an environmental factor in the soil. These factors interrupts, restricts, or harmfully accelerates the normal metabolic processes of a plant and symbiotic microorganism.

Keywords: Stress; Soil; Rhizobia; Plant

DOI: 10.7176/JEES/9-12-02

Publication date: December 31st 2019

1. Introduction

The soil environment is under a constant state of change and can be relatively stressful for both macro and microorganisms. The fluctuations have been recorded in soil pH, nutrient availability, temperature, and water status. Therefore, the variation which occurs in different soil characteristics prominently influence the growth, survival and metabolic activity of soil microorganisms and plants, and their ability to enter into symbiotic interactions. In the plant- microbe, symbiotic association the *nodD* gene can be viewed as a global regulatory gene which, together with plant flavonoid-signal molecules, activates transcription of other inducible nodulation genes (Long, 2001). The flavonoid *nod*-gene inducers are specific for a particular legume-*Rhizobium* interaction and their production is influenced by environmental variables, like plant fertility, pH, and nod factors (Schmidt et al., 1994). Repressor proteins also play a role in *nod*-gene regulation (Stacey et al., 2002).

The two common consequences of inadequate soil management due to fragile soil structure, erosion, low soil organic matter and inappropriate farming technologies are nutrient depletion and soil acidification (Giller and Wilson, 1993). Plant development and successful crop production require proper soil conditions, including adequate water and nutrient supply. Unfavorable soil conditions (environmental stress (Takeoka Y et al., 1992; Bohnert et al., 1995) salinity and/or sodicity (Bauder J.W. and Brock T.A. 1992; Qadir et al., 1996), inadequate nutrient supply have an adverse effect on the life of the plants, sometimes seriously hindering their effective production. Despite this situation, soils represent one of Earth's most productive ecospheres, accounting for a majority of primary and successional productivity. Consequently, microbes, plants, and other soil inhabitants have evolved to adapt to the ever changing and often inhospitable soil environment.

Based on the above facts, we can speak of stress factors originating in the soil; that is, such unfavorable soil conditions which cause, or contribute to, the stress factors that plants and crops are exposed to. Stress is here considered to be any external factor that results in a less than optimal growth rate (i.e., any factor that interrupts, restricts, or harmfully accelerates the normal metabolic processes of a plant). It is impossible to list all or most of such factors in a short introductory review. Therefore, I limit the range of this manuscript objective to a highlight of soil stress factors behavior and its function in nature and production as well as to an outline of some of the most serious factors originating in stress affected soils in relation to soil microbial activity. For more in-depth information regarding stress affected soils, the readers are referred to the more comprehensive available sources.

2. Biotic factors

Agricultural expansion impacts and fragments natural ecosystems; human activities have already transformed 33-50% of the earth's surface. Consequences include extinction of some plant species and reduction in the population size, diversity, and function of others (Young and Clarke, 2000). Differing in colony morphology, DNA finger prints, rates of N₂ fixation, and strain competitiveness (Ferreira *et al.*, 2000; Galli-Terasawa *et al.*, 2003; Santos *et al.*, 1999). Hungria and Vargas (2000) suggest that genetic instability is increased by the high temperature/acid soil conditions, and note that superior genetic stability is essential for any strain recommended for use in commercial inoculants in Brazil.

Legumes and cereals are often intercropped, a traditionally to enhance land-use efficiency and reduces farmer dependence on a single plant species (Woolley *et al.*, 1991). Given the proximity over time of cereal and *Rhizobium*, it is not surprising that a number of these organisms have acquired the ability to act as endophytic organisms.

However, the soil includes different phases (solid, liquid, gaseous), living and nonliving substances, plants, animals, and microbes and has its own energy and material fluxes. Therefore, it can be considered an ecosystem in itself. In this respect, when speaking of soils versus their plant cover, we can consider the soils of a given location as the basis, ladder, and foothold, a well-defined plant cover develops and very often the soil properties promote or limit the living conditions of certain plant species or associations.

Different researches reported that soils are affected due to the direct biological interference where high electrolyte contents, extreme pH conditions, over flooding and nutrient depletions limit the development of the majority of plants and it retards biological nitrogen (N₂) fixation is a critical and key unenthusiastic impact in sustainable land management, where N is the nutrient that most frequently limits crop production.

3. Abiotic factors

The abiotic factor is one of the most important challenges facing on soil fertility. Abiotic stress can persistently limit the nutrient availability, microbial diversity and agricultural productivity over large areas and extreme events can lead to total crop production failures. Abiotic stresses adversely affect the livelihoods of individual farmers and their families as well as national economies and food security. The major soil stress factors include potentially adverse effects of acidity, Salinity, Drought, Flooding, waterlogging, Nutrient deficiency, High temperature and Low temperature.

3.1. Soil acidity

In the worldwide, more than 1.5 Gha of acid soils limit agriculture production (Von Uexkull H and Mutert E. 1995). Here there is a range of effects of soil pH on rhizobia, but relatively few grow and survive well below pH values of 4.5-5.0. Competitive interactions have been shown to be influenced by soil pH. The bradyrhizobia are more acid tolerant than the rhizobia. The influence of soil pH on the behavior of rhizobia in soils can be dramatic.

Generally, *S. fredii* is more competitive than *B. japonicum* in soybean nodulation in neutral soils in Spain, but *B. japonicum* USDA 110 out-competed *S. fredii* in soil at pH 4.9. The fact that *R. etli* is more competitive than *R. tropici* in nodule formation with beans. Many rhizobia from acid soils are sensitive to acidity. They suggested that soil microniches protect these rhizobia from extremes of soil pH. So, merely isolating a rhizobial strain from root nodules of plants grown in acid conditions does not guarantee that the isolated strain will be acidresistant (Graham, 1992). But the recent studies showed this acid and alkaline resistant could be related to local adaptation since small farming is being done at the salinity soils of Ethiopia where chickpea is commonly grown along with intercropping of wheat which is highly beneficial for the farmers (Wubayehu G *et al.*, 2018) as well as the rhizobial strains could grow well in wide range of pH from acid to alkaline i.e. 5-9.5 and this was consistent with chickpea production on calcareous soils in India (Rhitu *et al.*, 2012).

Furthermore, metals, such as Al, Cu, and Mn that become more soluble at lower pH, may also secondarily contribute to the inhibition of the growth and persistence of rhizobia in acid soils nutrients. Tolerance to acid conditions in rhizobia is often correlated to the strains ability to maintain an internal pH approaching neutrality (pH 7.2-7.5). This ability has been suggested to be due to proton exclusion enhanced cytoplasmic-buffering capacity. the presence of acid-shock responses, the presence of glutathione. Although the microsymbiont appears more pH sensitive than the host partner acidity also influences both the growth of the legume plant and the infection process interestingly, nodulated legumes appear more sensitive to metal toxicity by Mn and Al than to their N-fed control counterparts.

Soil acidity affects early steps in the infection process, including the exchange of molecular signals between symbiotic partners and attachment to the roots. Release of nod-gene inducers by soybean and common bean roots was less at pH 4.5 than at pH 5.8 (Hungria and Stacey, 1997), with some nodulation genes, including *nodA*, switched off as the pH falls (Richardson *et al.*, 1988a,b). In addition, McKay and Djordjevic (1993) have reported that low pH can affect the production and excretion of nodulation factors in strains of *R. leguminosarum* bv. *trifolii*. Other stages of nodule establishment and function are also impacted by acidity, as is the growth of the host plant (Graham, 1981; Munns, 1986).

Recently, using molecular techniques and proteomics, Glenn and colleagues have shown that rhizobial genes, such as *actA*, *actP*, *exoR*, *lpiA*, *actR*, *actS*, and *phrR*, are essential for growth at low pH.

3.2. Soil Salinity

Salinity and sodicity problems are common in arid and semiarid regions, where rainfall is insufficient to leach salts and excess sodium ions out of the rhizosphere (Miller and Donahue, 1990). These problems are present in

nearly every irrigated area of the world and also occur on non irrigated croplands and rangelands. Thus, virtually no land is immune from salinization. Therefore, for sustaining life on earth, control of these problems and finding new ways to utilize these extensive saline and sodic soils and water resources, at least for agricultural purposes, are vital and urgent.

In nature, usually particular plant species grow on specific soils. Thus, specific relationships exist between a particular soil and the vegetation cover of that specific soil. According to an early Food and Agriculture Organization (FAO) study (Massoud, 1974), salt-affected soils occupy 7 percent of the world land area, and salinity is also a problem that is increasing rapidly (Pessarakli, 1999), having more than doubled in the past two decades. It is estimated that the world is losing at least 10 ha of arable land every minute and 3 ha of this is lost by salinization. In this way, 1.6 mha of arable land is lost every year.

Since beneficiary microorganisms are available in all arable lands in the globe edaphic factors have long been known to influence soil microbes and a number of reviews have already documented the importance of different edaphic stresses to rhizobial persistence, subsequent nodulation, and nitrogen fixation by (El Sheikh, 1998; Miller and Wood, 1996; Zahran, 1999) indicates giving an emphasis will decide the productivity fate of these huge area in the world.

3.3. Soil Water Stress

Soil water influences the growth of soil microorganisms through processes of diffusion, mass flow, and nutrient concentration is related to soil pore space. Internal pore spaces are more favorable environments for the growth of rhizobia and most soil microbes. Soil-water content also directly influences the growth of rhizosphere microorganisms, like rhizobia, by decreasing water activity below critical tolerance limits and indirectly by altering plant growth, root architecture, and exudations. Usually, at matrix water potentials of -0.5 to -1.5 MPa, growth and nitrogen fixation are affected in tropical areas. The low availability of soil water would be aggravated by the removal of deep-rooted vegetation and the conversion of natural forests or savannas to crop production or pasture, with increased runoff and evaporation. Poor nodulation of legumes in arid soils is likely due to decreases during the dry season.

Water activity (A_w) and water potential (z) values are parameters often used for describing water relations with respect to microorganisms. Rhizobia vary widely in their tolerance to water stress, and there is correlation to taxonomic criteria and phylogenetic relationships. However *bradyrhizobia* suggested being more resistant to water stress mostly by the intracellular accumulation of inorganic and/or organic solutes. Water stress affects rhizobial survival, growth and population structure in soil, the formation and longevity of nodules, synthesis of leghaemoglobin and nodule function. Furthermore, severe stress may lead to irreversible cessation of N_2 fixation (Sprent, 1971; Vincent, 1980; Walker and Miller, 1986; Venkateswarlu et al., 1989; Guerin et al., 1991). In rhizobia (and all bacteria), both cell membranes and walls play a pivotal role in tolerance to water-potential stress.

Many microbes, including rhizobia, accumulate compatible solutes, such as amino acids and salts as a means to equilibrate internal and external osmotic concentrations. Osmoregulation is a complex problem for rhizobia because they must be able to adapt to unfavorable and changing environmental conditions, as well as to osmotic- stress conditions associated with the infection process itself and life in the nodule.

3.4. Soil temperature stress

Temperature has a marked influence on survival and persistence of rhizobial strains in soils. rhizobia from the hot dry Sahel-savannah of West Africa grow at 37°C, and more than 90% of the strains isolated from this region grew well to 40°C. The influence of temperature on rhizobia appears to be both strain and soil dependent. *Bradyrhizobium* sp. (lupins) was less susceptible than *R. leguminosarum* bv. *trifolii* to high soil temperatures, but addition of montmorillonite and illite remediated this problem in sandy soils (Marshall, 1964). Soil temperature also greatly influences competition for nodulation. This effect due to a temperature-induced delay in nodulation or the restriction of nodules to the sub-surface region (Munns et al., 1977).

The highest and lowest temperature extremes influence the soil temperature on the growth and survival of rhizobia, however rhizobia isolated from temperate regions often survive at 4°C, little growth occurs at this temperature (Trinick, 1982). The symbiosis itself is sensitive to low temperatures; cooler root-zone temperatures limit nodulation and nitrogen fixation in the soybean-*B. japonicum* symbiosis (Zhang et al., 1995). However, excessive temperature shock has been shown to cure plasmids in fast-growing strains and some strains, which were isolated from high-temperature environments, have a Fix⁻ phenotype.

Effective high- temperature (40°C) tolerant rhizobia that are capable of nodulating and fixing nitrogen with *Phaseolus vulgaris* (Hungaria et al., 1993) acacia (Zerhari et al., 2000) and prosopis (Kulkarni and Nautiyal, 1999) has been reported. The high-root temperature has also been shown to influence infection, N_2 - fixation ability, and legume growth. It appears that every legume/Rhizobium combination has an optimum temperature relationship, which is around 30°C for clover and pea, between 35-40°C for soybean, peanut and cowpea, and

between 25-30°C for common bean (Michiels et al., 1994).

Exposure of both symbiotic partners to the extreme temperature above or below these critical temperatures impairs infection, nodulation, nodule development, and general nodule functioning as well as both plant growth and productivity. High soil temperatures also restrict nodulation to sub-surface regions where cooler temperatures prevail. Nevertheless, elevated temperature directly influences the production or release of nod-gene inducers from soybean and bean it alters nodule functioning due to leghemoglobin synthesis, nitrogenase activity, and hydrogen evolution, and, besides, hastens nodule senescence although, heat-shock proteins have been found in rhizobia.

4. Conclusion

It is impossible to list all stress factors that influence the microbial activity, according to its behavior, it can be summarized in to biotic and abiotic factors. Biotic factors mainly, related to the crop management system, biodiversity and direct biological interferences. Beyond biotic factors the major stress factors which have a potentially adverse effect are the abiotic factors. These include soil acidity, salinity, waters stress and temperature are the major influences.

5. Acknowledgement

All authors cited in this review are highly acknowledged.

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