Physiological and structural response of soil microbial communities and their metabolites to varying magnitudes of osmotic and matric stress

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Introduction

- Drying and salt accumulation lowers the availability of water and poses greater stress on the soil microbial communities.
- It is known from pure culture and salt induced water stress studies that microbes accumulate some organic osmolytes like proline, sucrose, polyols to maintain cell turgor.
- Yet, the evidence that this process occur in *insitu* soil microbes is predominantly anecdotal.

Objective of the study: To evaluate the physiological and structural response of *insitu* soil microbial communities to low matric and osmotic stress.

Hypothesis

To cope up with low water potentials the *insitu* soil microorganisms accumulate organic osmolytes in the cytoplasm and the amount and nature of osmolytes increases with decrease in water potential.

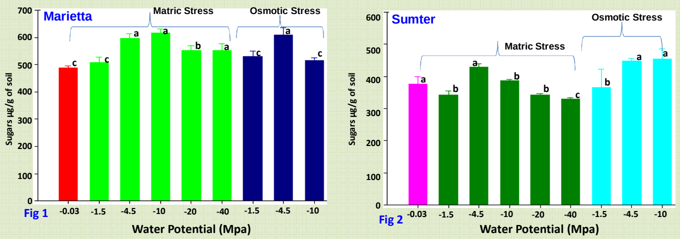
Experimental Procedure

- Types of water deficit(2): 1) Matric 2) Osmotic
- Soil Types (2): 1)Marietta (Silty loam) 2)Sumter series (Silty clay)
- Top 15-cm soil was collected, sieved and stored at 4ºC until used.
- Approximately 10g of soil(dry weight) was weighed into specimen cups and all the samples were brought to water potential of -0.03MPa and preincubated for 5 days.
- Soil maintained at -0.03MPa, with no salt addition is considered as control.
- Matric Stress: Water potential of soils was lowered to -1.5, -4.5, -10, -20 and -40MPa by air drying over a period of 3 days.
- Osmotic Stress: Water potential was lowered to -1.5, -4.5 and -10MPa by gradual addition of NaCl salt to the soils.
- Soils were extracted using chloroform and 0.01*M* K_2SO_4 (1:4ratio).
- Extracts were analyzed for sugars and amino acids by Phenol sulfuric acid assay and Ninhydrin assay respectively.
- Extracts were derivatized using BSTFA solutions and analyzed on Varian 3600 GC-MS.

Results

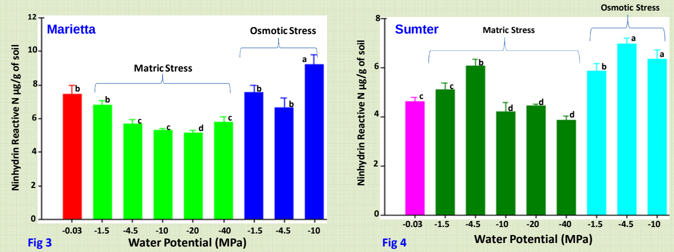
Physiological Response of Soil Microbes to Matric and Osmotic Stress

Fig 1&2 : Phenol sulfuric acid analysis of Marietta and Sumter soil extracts for sugars.



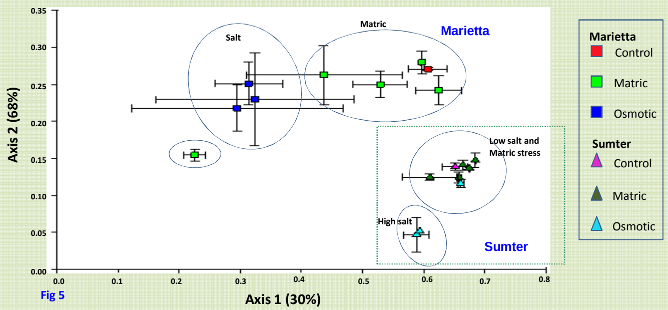
- Marietta: Sugar concentrations increased with decline in matric and osmotic potentials.
- Sumter : Variable response was noticed with matric stress, but sugars increased with decrease in osmotic potentials.

Fig 3&4 : Ninhydrin analysis of Marietta and Sumter soil extracts for amino acids.



- Ninhydrin reactive N significantly decreased at higher levels of matric stress both in Marietta and Sumter soils.
- Osmotic stress resulted in accumulation of more Ninhydrin reactive N than matric stress in both the soils.

Fig 5: Multi-dimensional analysis of mole percentages of metabolites identified at different levels of osmotic and matric stress in Marietta and Sumter soils



- A range of sugars and sugar alcohols including glucose, galactose, fructose, turanose, sorbitol, xylitol, glycerol and myo-inositol were identified in the GC-MS analysis.
- The nature of metabolites and their concentrations varied between the soils.
- The metabolite abundance changed most with osmotic treatment.

Results

Structural Response of Soil Microbial community to Matric and Osmotic Stress

Fig 6&7 : Total PLFA of Marietta and Sumter soils at different matric and osmotic stress treatments

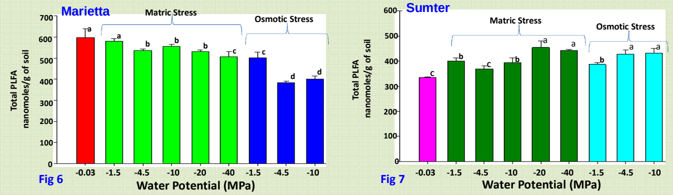
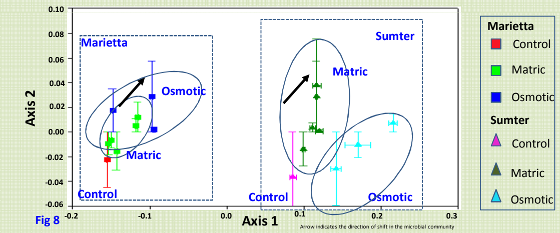


Fig 8 : Non-metric multidimensional analysis of mol% of PLFA of Marietta and Sumter soils at different levels of matric and osmotic stress



- Microbial biomass (PLFA) decreased with increase in water deficit in Marietta soil whereas it increased in Sumter soil.

Conclusions

- Presence of more extractable sugars in soils prone to drying and osmotic stress than continuously moist soils is consistent with the osmolyte accumulation hypothesis.
- Increase in sugar alcohols like glucitol, xylitol and inositol in stressed soils is also consistent with previous studies on osmolyte accumulation and it is highly correlated to the fungal biomass.
- Salt has a detrimental affect on the soil biomass in Marietta soil.
- Soil type has greater effect on microbial community structure than water deficit.
- Microbes utilize osmolytes to cope with low water potentials in soil. However, other mechanisms of coping may exist.

Citations

- Harris, R. F. 1981. Effect of water potential on microbial growth and activity, p. 23–95. *In J. F. Parr, W. R. Gardner, and L. F. Elliott (ed.), Water potential* relations in soil microbiology. Soil Science Society of America special publication no. 9. Soil Science Society of America, Madison, Wis.
- Schimel, J.P., Balser, T.C. & Wallenstein, M. (2007) Microbial stress-response physiology and its implications for ecosystem function. *Ecology, 88, 1386–1394.*