Publication

Common mycorrhizal network as facilitator of bioirrigation for rainfed agriculture tested in legume – millet intercropping system

Thesis (Dissertationen, Habilitationen)

ID 4527510
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Year 2019
Title Common mycorrhizal network as facilitator of bioirrigation for rainfed agriculture tested in legume – millet intercropping system
Type of Thesis Dissertation;
Start of thesis 01.06.2014
End of thesis 04.10.2018
Name of University University of Basel
Name of Faculty Philosophisch-Naturwissenschaftliche Fakultät;
Supervisor(s) / **Fachvertreter/in** Kahmen, Ansgar ;

Food security for growing population and achieving the zero hunger target by 2050 is a major challenge for mankind. Sustainable intensification of agriculture, i.e. increased food production without causing environmental damage has been foreseen as the way forward to address this challenge. In this study we tested a sustainable legume – millet intercropping model based on “bioirrigation” and biofertilization to mitigate drought induced yield loss in rainfed areas of arid and semiarid tropics. “Bioirrigation” is based on the principle of hydraulic lift (HL) where transfer of water occurs through roots from wet deep soil layers to dry top soil layers as a consequence of a soil water potential gradient. Specifically, the process of bioirrigation describes the transfer of hydraulically lifted water from a deeprooted plant to a neighbouring shallow-rooted plant. The main challenge for bioirrigation derives from distance between rhizospheres of the two plants, water released into the rhizosphere of bioirrigator is not available to neighbouring plant since it is tightly held up
in to the rhizosphere. In this study, we tested a potential solution to facilitate bioirrigation between rhizosphere of deep-rooted pigeon pea and shallow-rooted finger millet by connecting the rhizosphere through a common mycorrhizal network (CMN) using arbuscular mycorrhizal fungi (AMF).
In this study, we conducted several pot experiments under controlled conditions inside the greenhouse at University of Basel to test the hypothesis of CMN mediated bioirrigation between pigeon pea and finger millet. The results of pot experiments clearly showed that pigeon pea does perform HL, and when roots of pigeon pea and finger millet are connected through AMF network water relations of finger millet are supported by pigeon pea through bioirrigation. In our experimental set up, after testing the role of CMN in pot experiments, we scaled up (approx. 3 times) the pot size to mimic the field like conditions and test if bioirrigation facilitated through CMN can help shallow-rooted to survive a long drought period of 10 to 11 weeks. The results from scaled up pot experiment did not show significant effect of CMN on water-relations (stomatal conductance) of finger millet in intercropping treatments, but finger millet in treatments with CMN had significantly lower foliar damage percentage and mortality than treatments without CMN. The results from pot experiments show the importance of bioirrigation for rainfed agriculture i.e. if bioirrigation based intercropping is practiced, shallow-rooted plants would be able to tolerate the drought period.
To test the efficacy of bioirrigation driven intercropping system, we conducted field trials at two experimental sites (GKVK, Bengaluru and Kolli Hills, Tamil Nadu) in southern India to optimize the spatial

arrangement of pigeon pea and finger millet and test its effect on yield and water-relations of finger millet. The field trial results demonstrated that, planting two rows of pigeon pea and flanking eight rows of finger millet showed improved yield of finger millet compared to pigeon pea plants planted in between eight rows of finger millet plants in a mosaic fashion. However, the effect of spatial arrangement varied with change in experimental site. At Kolli Hills site, within row plantation of pigeon pea and finger millet performed similarly to row wise (2 pigeon pea : 8 finger millet). However, the intercropping effect was not driven by the CMN facilitated bioirrigation because finger millet in intercropping treatments had lower leaf water potential than monoculture treatments due to interspecific competition between pigeon pea and finger millet. We envision that sustainable intercropping on the basis of our bioirrigation and biofertilization model will help to design appropriate intercropping system especially in rain-fed areas that could provide sustainable food security, particularly for the marginal farmers in arid and semi-arid tropics.