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Title	Towards the development of a novel zero-discharge willow wastewater treatment system
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Abstract

Onsite wastewater treatment systems play a vital role in the protection of surface waters, groundwater and drinking water supplies. In areas of low subsoil permeability, where traditional onsite systems are not appropriate, attention has turned to the use of zero-discharge willow wastewater treatment systems (ZDWS). In this thesis, field-scale, meso-scale and lab-scale experimental trials, in combination with field observational studies were carried out, towards the development of a novel ZDWS. Field studies on the use of a polytunnel-covered wetland system found that while evapotranspiration from covered willow systems decreased, the overall efficiency of wastewater removal increased, due to the prevention of incident rainfall from entering the wetland. The development of a novel, polytunnel-covered willow-free wetland system also showed promise, with evaporation rates approaching the evapotranspiration rates achieved by the wetlands containing willows. The use of a winter-active species, *P. fragrans*, to increase winter evapotranspiration was proposed and investigated. Trials found that, due to the inability of the species to tolerate short-duration waterlogging, the distribution of the species in free-draining soils and the low winter evapotranspiration, the use of *P. fragrans* in a zero-discharge system is not effective. In lysimeter trials, willows undergoing an annual coppicing system, necessary for a covered ZDWS, were found to have lower evapotranspiration rates than willows that were not coppiced. Soil clay percentage did not generally affect growth or evapotranspiration for trees undergoing the annual coppicing cycle. Willow crop factors, for use in the sizing of ZDWS in the south of Ireland, were established as part of this trial. Inoculation of the willow trees with a commercial

mixed-species mycorrhizal fungal inoculum increased willow biomass growth. Furthermore, the development of a willow-selected mycorrhizal fungal inoculum led to increased willow shoot biomass and total leaf area compared to treatment with the commercial inoculum. Molecular analysis revealed a change in the relative proportions of the mycorrhizal species, with increased abundances of the disturbance-tolerant species *Glomus mosseae* and *G. intraradices* in the willow-selected inoculum relative to the original commercial inoculum. Overall, despite some modifications and improvements to system efficiency, the achievement of true zero-discharge operation, combined with practical operation, remains difficult in the Irish setting.