Structure, attachment properties, and ecological importance of the attachment system of English ivy (Hedera helix)

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Abstract

Root climbers such as English ivy (Hedera helix) rely on specialized adventitious roots for attachment, enabling the plants to climb on a wide range of natural and artificial substrates. Despite their importance for the climbing habit, the biomechanical properties of these specialized adventitious roots compared with standard roots and their performance in the attachment to different host species or inert substrates have not been studied. Here organs and tissues involved in the attachment are characterized and their significance in regard to a broader functional and ecological aspect is discussed. Depending on the substrate, the root clusters show different types of failure modes at various frequencies, demonstrating the close interaction between the climber and its substrates. With a Young’s Modulus of 109.2 MPa, the attachment roots are relatively stiff for non-woody roots. The central cylinders of the attachment roots show a high tensile strength of 38 MPa and a very high extensibility of 34%. In host trees naturally co-distributed with English ivy, a ‘balanced’ occurrence of failure of the attachment system of the climber and the bark of the host is found, suggesting a co-evolution of climber and host. Maximum loads of root clusters normalized by the number of roots match those of individually tested attachment roots. In comparison with most subterranean roots the properties and structure of the attachment roots of English ivy show distinct differences. There exist similarities to the properties found for roots of Galium aparine, suggesting a trend in not fully self-supporting plants towards a higher extensibility.

Key words: Attachment system, biomechanics, English ivy, Hedera helix, maximum strain, root climber, substrate, tensile strength, Young’s Modulus.

Introduction

English ivy (Hedera helix L., Araliaceae) is an evergreen root-climbing liana which has been used for centuries as greenery. In its Old World natural habitat, H. helix typically grows in gallery forests (Schnitzler, 1995) but behaves as an invasive species in the New World (Larocque, 1999). Recent interest in the protective and insulating properties of house greeneries (Stec et al., 2005; Wong et al., 2010) has brought the permanent attachment systems of climbing vines and lianas also into the focus of applied sciences. English ivy has an adaptable attachment system which allows the plant to climb on various substrates such as tree barks, rocks, and mortar. English ivy develops specialized unbranched adventitious roots at the substrate-facing side of its shoots. If the shoots are in contact with soil, typical nourishing subterranean branched roots are developed. The unbranched attachment roots enable English ivy to attach to the substrate and to climb to heights of up to 30 m, provided that appropriate conditions of light, moisture, and touch stimuli are provided (Bruhn, 1909; Negbi et al., 1982; Metcalfe, 2005). The mechanisms...