Mathematical models on diffusion of oxygen to and within plant roots, with special emphasis on effects of soil-root contact

Derivation of the models

P. DE WILLIGEN and M. VAN NOORDWIJK
Institute for Soil Fertility, Haren (Gr.), The Netherlands

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Summary A mathematical model is presented for diffusive transport of oxygen inside the root, for the case that oxygen can enter only through part of the root's perimeter because the remainder is blocked by soil-root contact. Without soil-root contact, concentration profiles inside the root can be shown to converge rapidly to a steady-state solution. For the case of soil-root contact a steady-state solution is presented. Steady-state solutions have also been obtained for the presence of a water film, with and without rhizosphere respiration inside the water film. Results are presented in the form of isoconcentration lines.

Introduction

Recent reviews of the literature[1,2,3,6,10] emphasize the complex nature of anaerobiosis in soils. Poor aeration may cause the accumulation of various gasses and toxic waste products, but depletion of oxygen below critical levels can, however, be considered as a major effect on plant roots[6], except for plants with special structural adaptions to overcome problems of poor oxygen supply. For practical, agricultural purpose the question then is what level of oxygen is critical. The concentration of oxygen in soil is determined by the supply of oxygen to the soil and the consumption by the soil biomass and roots plus rhizosphere. Both supply and consumption vary with soil type, water status, crop, temperature, soil tillage and organic matter inputs. The balance between supply and consumption has a high spatial heterogeneity and large temporal variation. Anaerobic spots may occur locally inside large aggregates in an otherwise well aerated soil. During periods of (partial) waterlogging after heavy rainfall, the anaerobic zones spread out and for a brief period a large part of the soil profile may become anaerobic before the larger pores have drained[7]. These highly dynamic aspects of anaerobiosis are hardly open to realistic quantification as so many parameters are involved. Somehow the problem has to be split up. A convenient way of doing this, is to distinguish 'macro-' and 'micro' models. Macromodels generally use average values of or relations between trans-