Plant and Soil 113, 111–119 (1989)

PLSO 7752

Model calculations on the relative importance of internal longitudinal diffusion for aeration of roots of non-wetland plants

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Received 13 April 1988. Revised September 1988

Key words: aeration, oxygen diffusion, root porosity, root respiration, soil porosity

Abstract

A model is presented with which the contribution of longitudinal oxygen diffusion to total oxygen requirement of a root can be estimated. Oxygen transport in and respiration of the soil are taken into account. Given the air-filled root porosity, root diameter, coefficient of oxygen transfer between root and soil, root and soil respiration rate, and the coefficient for oxygen diffusion in the soil, the maximum length a root can attain with an adequate oxygen supply to the root tip can be calculated. Results show the importance of root porosity for root aeration also in unsaturated soils. For thick roots (radius > 0.03 cm), diffusion along the internal pathway can provide 50–75% of the total oxygen requirement even at modest values of the root porosity.

Introduction

An important condition for proper functioning of root systems is a sufficient supply of oxygen to all root cells. Although roots of some plant species can cope with temporary anaerobic conditions by switching from aerobic to anaerobic forms of metabolism, a sustained supply of molecular oxygen seems to be essential to support active growth and functioning of roots (Armstrong, 1979). The source of oxygen is the atmosphere and for diffusive flow of oxygen from the atmosphere to a certain location in the root two pathways, or combinations thereof, are possible:

a. through the soil to the soil-root interface and then radially through the root tissue (the external pathway);
b. through the aboveground plant parts (leaves, stem), and longitudinally through the root (the internal pathway).

Continuity of gas-filled pores is a prerequisite for longitudinal transport to be of significance. Continuity of air channels exists when aerenchyma (gas spaces) is present. Luxmoore *et al.* (1970) have presented a mathematical treatment of longitudinal transport from shoot to root through such channels. Calculations showed that a considerable part of the oxygen requirement of the root can be provided by the aboveground parts in species adapted to permanently wet soil, *e.g.* rice. For such conditions those properties which limit gaseous exchange between the root and its environment, *i.e.* large root radius and thick water film, improve the supply to the root tip. Aerenchyma is not found in roots of non-wetland species growing under aerated conditions, but usually gas-filled pores form a continuous pathway in longitudinal direction in roots of these species as well (Armstrong, 1979). Even with an effective porosity of no more than 3%, which can be considered a low value for such roots (Armstrong, 1979; see Table 1) there are situations where longitudinal transport of oxygen contributes significantly to the respiratory requirement of the root, as will be shown below. Moreover, when roots of some important non-wetland crops such as maize (Konings, 1983; Yu *et al.*, 1969), wheat, barley (Yu *et al.*, 1969), are growing in a more or less permanently anaerobic environ-