Mechanics of root elongation and the effects of 3,5-diiodo-4-hydroxybenzoic acid (DIHB)

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Summary This paper reports the results of two series of experiments. In the first the effects of DIHB on the rate of root elongation were compared on unstressed roots and on roots stressed by mechanical impedance and by inadequate levels of aeration. Barley plants were grown in beds of small glass spheres through which nutrient solution was circulated. Mechanical impedance of 25 kPa was applied by subjecting the beds to a confining pressure. Inadequate aeration was obtained by reducing the oxygen concentration in the nutrient solution to 5%.

The second series examined possible effects of DIHB on the elastic modulus of root tips of wheat and pea. Elastic modulus gives an indication of the behaviour of roots in structured soil where penetration of peds can be limited by the buckling of root tips. The elastic modulus was measured in experiments of the static cantilever type on roots previously immersed in solutions of polyethylene glycol of different osmotic potential. Elastic modulus measurements can also detect any changes in turgor pressure and wilting characteristics of roots and can therefore help to identify the mechanisms of action of DIHB.

DIHB caused increases in root elongation relative to controls in all cases: 26 ± 5.7% in unstressed roots, 14 ± 6.4% in mechanically impeded roots and 54 ± 9.8% in roots growing in 5% oxygen. DIHB had no effect on the elastic modulus, osmotic or turgor pressure of the roots. It is concluded that DIHB acts by modifying the cell wall extensibility factor.

Introduction

There have been a number of reports that small amounts of 3,5-diiodo-4-hydroxybenzoic acid (DIHB) can increase the rate of root elongation. Wilkins et al. tested the effects of DIHB on root growth of pea (Pisum sativum L. cv. Meteor). At concentrations of $10^{-6}$ and $10^{-4}M$ in the soil solution, root length was increased by around 30% and 20% respectively in compacted soil. However, there was no significant effect in loose soil.

Saini used 200 ml of $10^{-2}M$ DIHB to each 1.7 kg of top-soil (equivalent to 0.46 g per kg) and this increased root length of lucerne (Medi-
cago sativa L. cv. Saranac) in the underlying compact sub-soil by 54% compared with the untreated controls. Jackson et al.\(^7\) tested the effects of DIHB on the roots of barley (Hordeum vulgare L. cv. Midas), oilseed rape (Brassica napus L. cv. Primor) and rice (Oryza sativa L. cv. RB3) in well-aerated nutrient solution. Root elongation was increased by 10% in oilseed rape with \(5 \times 10^{-6} M\) DIHB and by 30% in barley with \(10^{-6} M\) DIHB. When barley roots were subjected to an oxygen concentration of only 5% in the solution, addition of DIHB increased the rate of elongation but only to that of well-aerated controls without DIHB.

There are several possible modes of action of DIHB. A plant root may be considered as an assemblage of cells acting together such that the internal and external mechanical pressures balance and

\[
\Pi_i = -\psi_o + W + \sigma \quad (1)
\]

Here, \(\Pi_i\) is the (positive) internal osmotic pressure of the cells which is given by \(\Pi = -\pi\) where \(\pi\) is the (negative) osmotic potential of the solution within the cells. \(W\) is the (positive) pressure induced in the cells by tension in the cell walls, and \(\sigma\) is any external (positive) pressure arising, for example, from soil resistance to root extension. \(\psi_o\) is the total potential of the water external to the root and may have a matric suction (negative) component and an osmotic (negative) component.

Empirically it has been shown that the rate of elongation, \(R\), can be related to the tension in the cell walls and hence to \(W\) by

\[
R = m(W - W_c) \text{ for } W > W_c \quad (2)
\]

where \(W_c\) is a critical wall pressure component which has to be exceeded for elongation to occur, and \(m\) is the constant of proportionality and called the extensibility factor\(^4\),\(^5\),\(^6\).

Combining equations (1) and (2) gives the elongation rate as

\[
R = m[\Pi_i + \psi_o - W_c - \sigma] \quad (3)
\]

The addition of very small quantities of DIHB to the growth medium will not affect its water potential, \(\psi_o\), or the resistance to root elongation, \(\sigma\). Therefore, any effects of DIHB must be through one or more of \(m\), \(\Pi_i\), or \(W_c\). Changes in \(W_c\) cannot account for much of the observed changes in \(R\), and therefore DIHB must act directly or indirectly mainly through \(m\) or \(\Pi_i\).

Changes in \(\Pi_i\) are related to changes in the elastic (Young's) modulus, \(E\), of the plant material by

\[
E = a\Pi_i + b \quad (4)
\]

where \(a\) is a constant and \(b\) is the contribution from the elastic stiffness of the cell wall material\(^12\). The \(b\) term is negligible for fresh, young plant