Effects of waterlogging on soil aeration and on root and shoot growth and yield of winter oats (Avena sativa L.)

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Summary Winter oats were grown outdoors in lysimeters containing monoliths of a sandy loam soil. The soil was either freely-drained throughout the experiment or waterlogged to the soil surface from mid-January until mid-April. After the start of waterlogging the oxygen flux density decreased most rapidly nearer the soil surface and in the upper 50 cm declined to zero. At 80 cm depth the oxygen flux density at the end of the waterlogging still had not diminished to zero. While the soil was waterlogged root growth was negligible in the 20–50 cm zone of the soil profile, whereas below that depth root growth continued, reaching 95 cm by the end of the treatment. During the latter part of the waterlogging period root growth resumed in the upper 10 cm, and in the upper 2.5 cm was greater than in the freely-drained treatment.

At the end of the waterlogging period, the total root length and shoot dry weights were 77 and 60% of those in the freely-drained treatment, tillering was restricted and leaf area index diminished. However, by anthesis, root length and shoot weights of the plants that had been waterlogged were only 10 and 12% less respectively than for the freely-drained plants. At harvest, total dry matter and grain yields were only 9% less, the latter largely through fewer grains per panicle.

Introduction

The heavier crop yields that can result from drainage must be caused in part by improved root growth or function. Widely quoted publications on drainage and soil management, suggest that deeper rooting, facilitating access to water during dry weather, is one of the main advantages of draining the soil. In experiments in lysimeters, pea
roots extracted less total water from the soil after waterlogging, especially from the deeper parts of the profile, suggesting that the capacity of the roots to absorb water had been impaired; but winter wheat that had been waterlogged extracted more water from the upper 20–40 cm and less from below those depths than wheat that had grown in freely-drained soil. Root growth of peas is greatly restricted by waterlogging, and in controlled environments anaerobiosis inhibited root growth of winter oats and winter wheat. However little information exists on effects of anaerobic soil conditions on the root growth of cereals in the field. Recent field studies with winter wheat showed that after the water-table in an undrained clay soil had been about 20 cm below the surface for three months in the winter compared with 45 cm in a drained treatment, root density in April when the water-tables had fallen was greater in the deeper parts of the drained profile; subsequently more water was extracted, and grain yield was about 10% heavier. In this paper we report the results of an experiment on winter oats, grown outdoors in lysimeters where effects of prolonged winter waterlogging on soil aeration, and on root and shoot growth and yield were examined.

Methods

A description of the experimental system of lysimeters, the moveable shelter to exclude unwanted rainfall, the irrigation facilities, the means of controlling the depth of the water-table and of the sandy loam soil, a gley podzol (or aquentic haplorthod), used in this experiment has already been published. Winter oats, cv. Pennal, were grown in 1980–81 in 32 lysimeters, each 80 cm diameter and 135 cm deep, containing soil monoliths.

There were two treatments: (i) freely-drained, with the water-table at 50 cm until mid-January, at 90 cm thereafter in winter, and draining below that depth when water was extracted by roots in the spring and summer, and (ii) waterlogged to the soil surface for 90 days from mid-January, also with the water-table at 50 cm before waterlogging and afterwards at 90 cm as in (i). In earlier work on this soil the oxygen flux density at 50 cm depth had remained relatively large during waterlogging when oxygen concentrations were small. This large flux may have been caused by occluded gas and larger porosity in the subsoil, and may in part explain why wheat crops on this soil have been less affected by waterlogging than those on an adjacent clay soil. To lessen the possibility of oxygen trapped in the deeper parts of the profile offsetting the otherwise damaging effects of waterlogging, the water-table was maintained at 50 cm depth in all lysimeters until the differential treatments started in mid-January. Sixteen replicates of the two treatments were allocated to the thirty-two lysimeters.

The soil and plants were destructively sampled on 5 occasions during the growth of the crop (the number of replications on each occasion is given in parenthesis): at the start of waterlogging, 15 January (1); at the end of the phase of rapid decline in oxygen partial pressure and flux density, 2 February (2); when the oxygen concentration had reached a minimum in the upper part of the soil profile, 12 March (2); at the end of the waterlogging, 14 April (2); and at anthesis, 26 June (2). The remaining 7 replicates were used for yield estimation at maturity. At each sampling measurements of the shoots and roots were made. Shoot measurements were number of tillers, area of leaves and dry weight. At maturity the grain and straw