Waterlogging, soil aeration and field crop response

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Transient waterlogging, associated with surface irrigation on slowly permeable clay soils may impose a limitation to the productivity of crops not adapted to low oxygen within the root zone. Field experimentation in 1980/81 (1) indicated that large depressions in soil oxygen occurred in clay soils following surface irrigation. The nature and extent of plant response to the depressions is the subject of this paper. Data is drawn from three seasons of experimentation carried out in specially adapted facilities.

Methods

Periods of transient waterlogging have been imposed on large, undisturbed cores of a transitional red brown earth housed in a drainage lysimeter facility (2). Three crops have been grown in the facility namely wheat, cotton and maize and responses both within the root zone and the plant have been monitored. In addition a crop of cotton was grown in a facility which allowed the rapid introduction of a water table gradient (3). The crop root zone was thus subjected to a continuum of conditions from complete inundation to an absence of a watertable. Plant response was monitored during two periods of flooding.

Results and Discussion

Flood irrigation on clay soils typically results in a rapid initial intake of water which essentially saturates the upper soil layers. Air within these upper layers is displaced and diffusion of O_2 to underlying layers practically ceases. Consumption of O_2 by plant roots and soil microbes causes soil O_2 levels (mg 0 1 soil) to decrease rapidly. A 48 h flooding caused the total profile $16'_2$ (1.5 m deep) to be at 3% of the theoretical maximum (64 g O_2 per cylinder) within 3 days.

One effect of these low O_2 levels is that loss of NO through denitrification is potentially large. Recent work (4) on these soils suggests that actual losses are relatively small (<6%) perhaps due to a carbon substrate limitation. Indications are that root growth (observed non destructively, in-situ) begins to slow down when soil O_2 Levels approach 15% and will stop at around 10%. Other plant responses seem to be associated with reduced root function, in particular reduced uptake of $NO,^-$. Decreased amounts of NO_3 in the xylem sap of the plant tops are detected about 3 days after the start of a flooding event. These decreases coincide with decreased rates of leaf and stem growth which are not accompanied by decreased leaf water potential. Measurements of apparent photosynthesis (APS) and transpiration (E_f) from plant canopies show that APS is depressed independently of E_f at least on some days after flooding. On cotton plants subjected to 8 days of inundation, increased canopy temperatures (indicating decreased E_r) were measured on the last 3 days of flooding. It is suggested that root functions other than the passive uptake of water, are initially affected by low soil O_2. Loss of these functions likely affects APS before E_f while decreased E_r occurs when the hydraulic conductance of the root system decreases. Both wheat and maize show about 40% yield decreases with treatments designed to simulate flood irrigation of unimproved clay soil. Cotton yields are far less responsive (15% decrease). In all cases there are modifying effects from nitrogen supply and internal drainage properties of the soil.

1. Mason, W.K., Meyer, W.S., Barrs, H.D. and Smith, R.C.G. 1984. Reviews in Rural Science 5.

2. Meyer, W.S., Barrs, H.D., Smith, R.C.G., White, N.S., Heritage, A.D. and Short, D. 1984. Aust. J. Agric. Sci.

3. Reicosky, D.C., Meyer, W.S., Schaefer, N.L. and Sides, R.D. 1984.

4. Mosier, A.R., Melhuish„ P.M. and Meyer, W.S. 1984.