TULIP ROOT BEHAVIOUR AND AERATION REQUIREMENTS

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Abstract

Experiments to investigate the minimum aeration requirement of tulip roots were performed in cylindrical vessels. Aeration was regulated by altering the composition of the gasmixture above the soil. Oxygen supply at different depths in the soil column was checked by oxygen diffusion rate (O. D. R.) measurements. Tulip roots were found neither to require an extra high aeration level nor to be especially sensitive to a short period of anaerobiosis. Depth of root penetration downwards was affected both by O. D. R. -level and soil density.

Introduction

In recent years tulip cultivation has been moving into new areas. Special difficulties may be encountered on sandy clay soils, the most serious being incomplete emergence in spring and also retarded growth later in the season. Taking into account that many of these soils are subject to structural deterioration and slaking during the wet winter months, lack of aeration seems to be one of the main detrimental factors. Quite often, temporary pools of water can be observed on fields which later show poor emergence. Our purpose was to investigate the aeration requirements of tulip roots in detail. Certain observations were made in the field, but more attention was directed to experiments with controlled aeration in the glasshouse. An attempt was made to define the minimum aeration requirements of tulip roots on the basis of O. D. R. measurements.

Experimental method

To characterize the aeration, measurement of the oxygen diffusion rate (Lemon and Erickson, 1955) was chosen, since this parameter simulates the conditions under which the root functions. In view of the field work, a very rugged probe was required. The platinum-wire electrode was therefore replaced by a conical tip of dentist's gold, 6 mm long, and 4 mm in diameter at the base. This method provides useful comparative values. Values obtained in different fields and especially in different soils cannot, however, be compared, because a number of soil factors may affect the general level of the currents measured.

For the glasshouse a set-up was designed to permit the study of the influence of different levels of oxygen on tulip root development with as little interference from other soil properties as possible. The basic idea is that aeration is varied by changes in the oxygen content of the atmosphere and that a natural gradient occurs in the soil (Stolzy and Letey, 1964).

For the experiments a number of plastic cylinders were placed in trays filled with water (figure 1). The cylinders were carefully filled with the soil under study, which was tamped down to predetermined densities. The lids of the plastic vessels were provided with a small tube extending down to the soil surface to accommodate the emerging stem. This arrangement left a closed space under the lid that could be flushed with the required gas-mixture. A number of stoppered holes in the side of the cylinder made it possible to insert the O2-probe at different depths. Three oxygen levels were routinely applied: 20% (air), 5% or $2\frac{1}{2}$% O2. The flow rate of the mixtures was 1 to 2 litres per hour through the gas chamber of each vessel.

Results

The experiments were performed during the winter season, starting in 1966. The main experimental particulars are shown in table 1. The tulips were always planted at 5 cm depth, either late in November or in December. The basic treatment was devised to obtain information on the root depths attained under constant levels of aeration. The O. D. R. values, possibly limiting further root growth, could also be established in these trials. Auxilliary experiments ware performed to test the sensitivity of an established root system at different ages to a sudden lowering of the oxygen supply or to a rise in the carbon dioxide concentration. The O. D. R. results clearly show that the imposed treatments indeed resulted in real differences in oxygen supply at different levels (table 2).

Constant-level treatments

Root growth was influenced by differences in aeration. Application of the air-nitrogen mixtures containing less oxygen generally resulted in a certain restriction of root length (figures 2 and 3). However, the expectation that downward penetration of the roots would persist until a more or less fixed low O. D. R. value was reached, was not fulfilled. The lowest O. D. R. values recorded at the level of the root tips showed rather large fluctuations: 6 μAmp in experiment B, 14 μAmp in experiment A, and 23 μAmp in experiment C, and considerably higher values were often found. This variability in level between the experiments can be related to differences in soil type, soil density, and soil temperatures during the experiments.

In experiment B (table 1) the soil medium had a very low impedance as compared to that in the other trials. Also, soil temperatures were appreciably higher, often about 10 $^{\circ}$C in January. Under these conditions the very long roots penetrated so far downward that their tip usually just reached into the reduced - blueish - capillary fringe above the ground water table. The sandy soil used in experiments C and D had the highest soil impedance value, as measured with a penetrometer. In these trials rooting was rather shallow.

In experiment C it was also evident that a difference in soil density effects root growth (figure 3). Here the root depths attained in the soil at a density of 1. 30 g/ml were less at all aeration levels. The number of roots developed does not seem to be influenced by the aeration levels applied. Experiment C provided an indication that root dry weight decreases under decreased aeration, while denser soil seemed to lead to a slightly higher dry weight.

Analysis of the mineral constituents of three plants of each treatment in experiment B showed no differences in N, P, K, or Ca content. In experiment C the N and P levels were again insensitive to a lower oxygen-supply but the K content decreased with lower oxygen-supply and Ca tended to do the same.

Close inspection of the roots showed that restricted aeration impaired root condition to some extent: the high aeration treatments led to whitish coloured roots, the intermediate treatment to yellowish roots, and under low aeration root tips were brown.

Resistance to temporary oxygen deficiency

To investigate the tolerance of tulip roots for flooding, the ground water table was raised to 20 cm above the bottom of some of the cylinders in the first days of March. This treatment lasted 11 days, and resulted in an upward extension of the reduced zone of soil leading to severely damaged roots. The damage consisted of dead root tips in the material treated with 20 and 10% oxygen and half-dead or dead roots in the 5 and 2.5% treatments, respectively. A flooding treatment lasting 7 days hardly affected the roots. Apparently, roots are killed only if anaerobic conditions in their medium persist for more than a week at temperatures between 10 and 15 °C.

In experiment C a 7-day period of extremely poor aeration applied at different ages had no effect on the existing root systems. Real root damage was only observed after a very low oxygen treatment lasting 17 days and applied on the 70th day after planting. These results do not indicate any sensitive period of the root system proper. In experiment D the roots did exhibit some response to the anaerobic or CO2 treatments lasting two weeks. 'Rose Copland' seemed to be slightly more sensitive than cv. 'Apeldoorn'. Treatment in the third and fourth week of growth had a slightly more effect as compared with other periods. In no instance the root system was killed. The damage consisted of a brownish discoloration of the root tips or of a less healthy appearance of the roots. When the lifted plants were placed on water, the roots of the treated plants showed signs of leaching losses, possibly indicating increased permeability. The bulbs themselves showed no evidence of direct damage.

Field observations

A number of aeration measurements were carried out to facilitate the interpretation of some field experiments. In all these experiments readings lower than 15 μAmp were hardly ever recorded at less than 40 cm depth. Since in our two experiments with sandy clay soils live tulip roots were observed at soil levels with O. D. R. values of 15 to 20 μAmp or even less, the above-mentioned value would suggest sufficient aeration. The low temperatures in winter must also be taken into account. This is corroborated by the fact that later in the spring these plots never showed abnormal losses in emergence.

Low percentages of emergence obtained by other authors in numerous field trials were always correlated with soil water levels rising to bulb height for some time. Severe soil slaking and very low percentages of air-filled pore space also contributed to winter damage (personal communications).

Discussion

The results indicate that tulip roots will grow under conditions yielding O. D. R. values of about 15 to 20 μAmp on sandy clay or silt loam soils. In sandy soils, where mechanical resistance is higher, a somewhat higher value might be required.

When compared with data obtained for other crops in the same type of experiment (potatoes about 15, tomatoes about 20, onions about 30, and peas about 15 μAmp), this is not exceptional. In view of the results obtained under short periods of anaerobic conditions, too, tulip roots cannot be considered especially sensitive to lack of aeration. The bulb itself seems more easily affected.

It is clear, however, that a low aeration level influences root growth and possibly performance. The rate of root growth and penetration of denser soils will be impeded. Restricted root growth will impair the uptake of nutrients and lower the supply of available soil moisture, thus restricting crop yield. Periods of anaerobic conditions lasting about a week are not lethal, but root condition is impaired to some degree. In general, our observations supplement those on the requirements for air-filled pore space given by Boekel (1965; 1971).

Conclusions

Tulip root growth reacts to both the level of aeration and soil resistance. The longest roots are obtained in loose, well-aerated, moist soil. The oxygen requirements of tulip roots are about the same as for many other crops. The tolerance of the roots to a short period of oxygen deficiency is reasonably good.

A low percentage of emergence in spring seems to be mainly due to direct suffocation of the bulb itself, particularly when immersed by high levels of ground-water.

References

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Table 1 - Particulars concerning the series of aeration experiments.

Experiment	No. of cylinders and type of soil	Depth and volume weight of soil (g/ml)	Amount of oxygen in gas mixture (%)	Additional details
A	16 sandy clay	0-70 1. 37	20, 5	Rose Copland unheated glasshouse
B	32 sandy clay	0-40 40-55 55-70 1. 22 1. 30 1. 37	20, 10, 5, 2. 5	Rose Copland glasshouse slightly heated
C	36 humus-rich sand	0-35 35-70 1. 20 1. 35 1. 30 1. 35	20, 5, 2. 5	Apeldoorn glasshouse above freezing
D	48 humus-rich sand	0-35 35-70 1. 20 1. 35 1. 30 1. 35	20, 5, 2. 5	Apeldoorn Rose Copland glasshouse above freezing

Table 2 - Average O. D. R. recordings (in μApm), air-filled pore space, and soil density of some constant-level treatments.

Treatment	Depth below soil level in cm											
	5	10	15	20	25	30	35	40	45	50	55	65
A 20% O_2	48		32		24		19		15		10	10
5% O_2	36		24		19		16		13		10	10
B 20% O_2		39		21		16		14		6. 4		
10% O_2		32		19		13		11		6. 3		
5% O_2		28		18		12		10		6. 5		
2. 5% O_2		30		16		11		9		6. 3		
	% air in soil											
B			23		19		14		8		7	
	Soil density in g/ml											
B			1. 22		1. 22		1. 22		1. 30		1. 30	

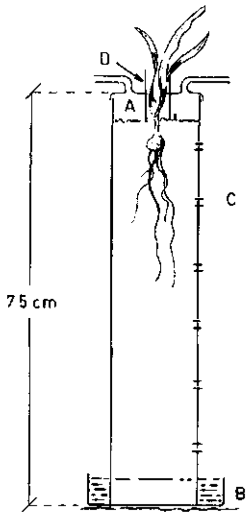

Figure 1 - Schematic representation of the experimental set-up used to investigate the oxygen requirements of roots.

A = gas chamber (regulated atmosphere)
B = dish containing water
C = port holes for insertion of electrode
D = tube

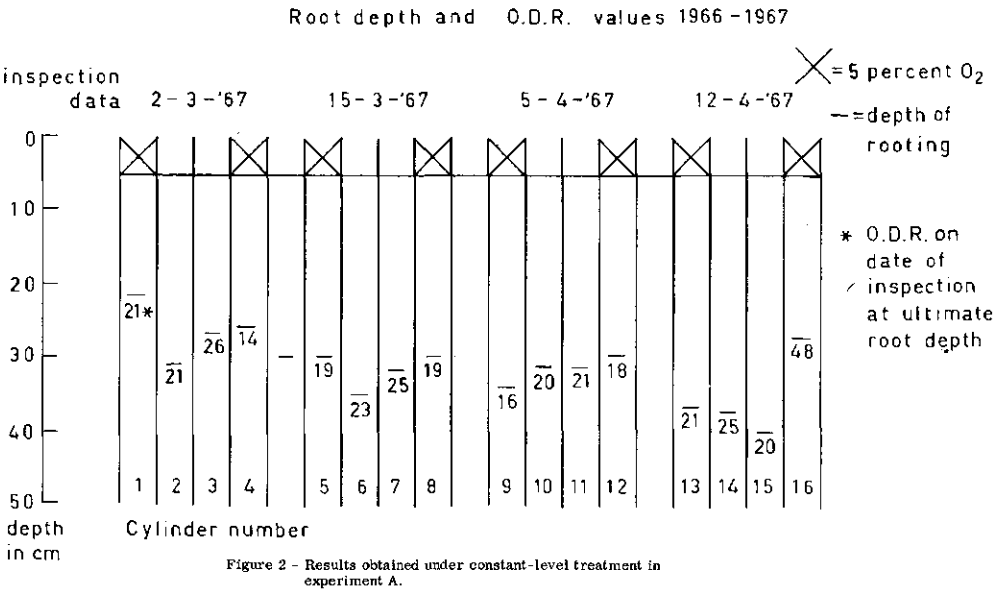

Figure 2 - Results obtained under constant-level treatment in experiment A.

Fig.3

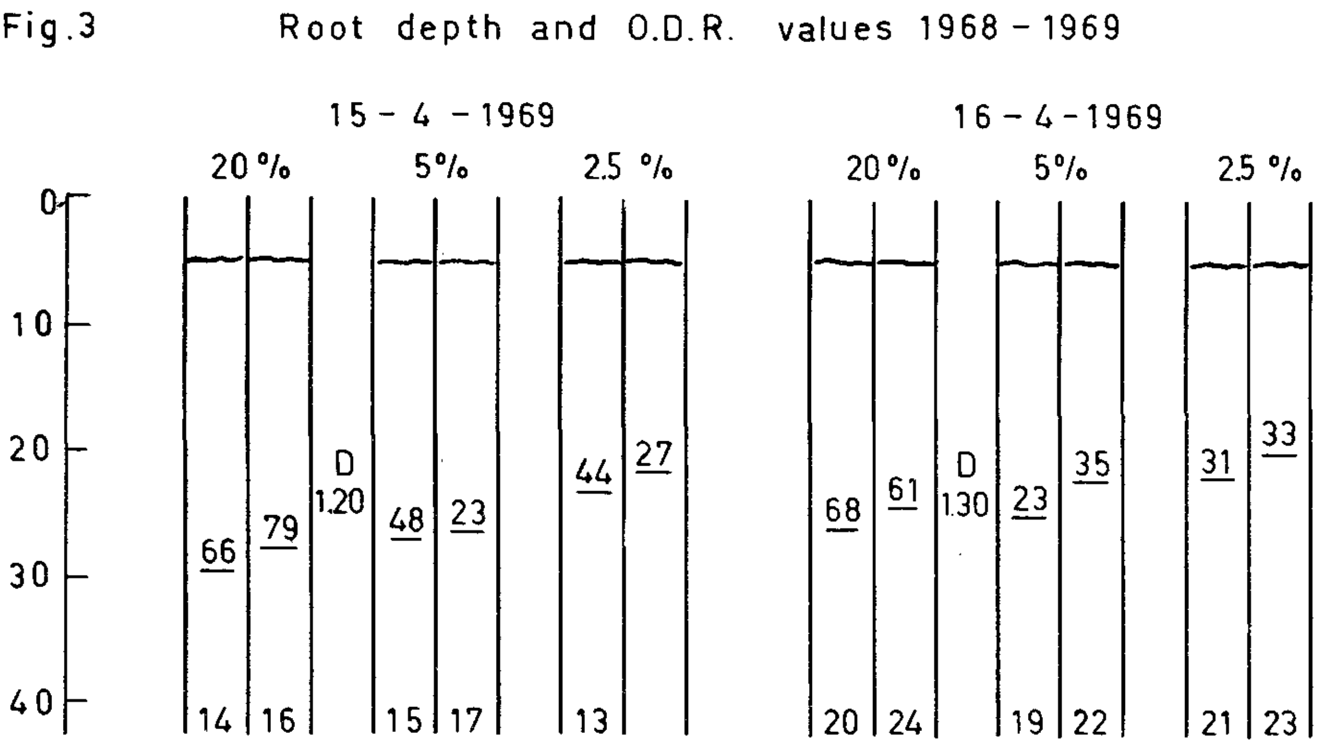

Figure 3 - Results obtained in experiment C under constant aeration levels.

-- depth attained by roots

66 O. D. R. value at the depth attained by the roots

D
1. 20 soil density in g/ml