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A ROOT OBSERVATION CHAMBER FOR REPLICATED USE IN A NATURAL PLANT COMMUNITY

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KEY WORDS

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SUMMARY

A relatively small, low cost root observation chamber of steel construction has been designed for replicated use in a natural plant community. An undisturbed soil profile, suitable for detailed study can be obtained by avoiding conventional backfilling methods and despite such factors as the recognized need for the chamber roof to be below ground level. Installation procedure emphasizes preparation of the observation face in established woody plant communities. The technique incorporates microscopic study of roots and simultaneous recording of major soil climatic factors.

INTRODUCTION

Recording of roots behind transparent walls has recently accelerated progress in root ecology and has been regarded as one of the most suitable methods to study root phenology[1]. Since most root observation installations have been designed for use in tilled soil, it is questionable whether all features of these designs can be applied to natural vegetation with altogether undisturbed soil profiles.

A requirement of the South African Savanna Ecosystem Project[5] is for data on seasonal root activity of a mixed herbaceous/woody plant community on sandy soil. Using a wooden root observation chamber (2 m deep and almost 4 m long) from 1977, data on timing of root tip extension were successfully obtained. This chamber, however, had certain limitations, such as difficulty of replication and limited lifespan of materials. Having noted the limitations in this and some other previous designs, a new chamber was designed for the natural vegetation site and installed in the spring of 1979.

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THE DESIGN OF THE OBSERVATION CHAMBER

General considerations

Inherent limitations of glass wall methods include restriction of root growth to two dimensions, possible altered gas exchange conditions behind the windows and severing of existing roots during installation resulting in stimulation of new roots or killing of roots. Effects that can be only minimised by the design include disturbance of normal lateral soil water flow, the effect of some uneven glass/soil contact and the consequences of occasional development of fungal hyphae behind the window.

Basic chamber

The chamber was constructed of material selected to last for several years, reduce possible contamination of the soil and not act as a possible substrate for fungal growth. The basic box (Fig. 1a) was constructed of angle-iron (30 × 30 × 3 mm) and 1 mm galvanised sheet, sealed to exclude water and light. The structure was painted with an epoxy-resin based paint reported to reduce possible contamination effects[10]. The chamber is large enough to take one observer comfortably and to span a full soil profile, but small enough to minimise disturbance of the study vegetation, to reduce costs of replicating chambers and to facilitate transport and installation.

The chamber's outside dimensions are 1.6 × 1.2 × 1.2 m deep, with a rear hatchway raised to project 200 mm above ground. The chamber was designed to be set into soil of an average 1 m depth and 200 mm of bedrock. The hatch's pneumatic shock-absorbers were to prevent slamming and consequent loosening of dry sand grains at the window face. The roof was designed to be 20 mm below ground level at the front edge and to slope down ten degrees to drain roof water away from the front face. The relatively low hatchway positioned well away from the observation face avoided the possible effects of abnormal raindrop splash and rain-shadow above the face.

Observation face

The observation face contains two window types, namely main study windows and smaller, removable windows for direct access to roots. The window spaces are formed horizontally by steel flat bar (10 × 30 mm) and vertically by steel channel (38 × 38 × 3 mm). The two main study windows (500 × 500 mm) are positioned one above the other centre-left of the observation face. A series of small windows (150 × 200 mm) are positioned similarly on the right, with handles to facilitate removal and replacement. Although larger study windows should give better uninterrupted views, they would militate against close soil-/window contact and be structurally weaker. Relatively small windows are needed to permit successful intermittent direct access to roots.

Plate glass windows (6 mm thick) are used with embedded wire grid for reference purposes. Although plastic has been used[2,10] evidence suggests that with plastic the soil/window adhesion is less[11], greater concentration of roots may occur[4], electrical charges may accumulate and wetting ability may be decreased[13]. For these reasons too, a plastic retaining sheet between the soil and the removable windows[3] was avoided.

An essential feature for final positioning of the windows against undisturbed soil is provision for them to be independently set beyond the chamber front. Each aluminium-angle-edged window is fitted into its frame leaving a 5 mm clearance that is packed with foam rubber. The windows are spring loaded on to the soil face, the springs bearing on the aluminium edging and backing on to adjusting bolts set into cover plates which in turn are bolted to the vertical channels of the frame. These adjusting bolts allow the windows to be set up to 20 mm deeper into the soil than the frames, overlap still being maintained between frame and window edging to allow for effective sealing. Spring loaded windows are important to reduce possible soil movement effects[7,8].

Although windows with the top angled inwards have been used[2] usually to ensure a better soil contact and view of vertical roots (although most roots are plagiotropic), these windows also result in overhang difficulties during installation against undisturbed soil profiles, abnormal rooting density and water concentration at the window, and the need for stronger glass. Although near-surface viewing is important, this is limited by the need for the roof to be below ground. Consequently the upper window frame is made of thinner (10 mm) material, the topmost aluminium window edging is cut away, and the optical viewing system and part of the insulation are appropriately adjustable.

Optical viewing system

A 10/20 × dissecting microscope can be positioned at any point in front of both sets of windows. A microscope with carriage system is essential to discern fine roots, to avoid parallax error by standardising viewing position, to facilitate sequential root recordings, and to aid in matching roots behind fixed and removable windows. The microscope is mounted on a system of horizontally and vertically movable aluminium slides mounted on stainless steel guide piping (Fig. 1b). These slides are driven by rotating brass threaded rods, the horizontal rod being driven by a 12 V D.C. motor (mounted on the one vertical slide), with switching for reversing direction and varying speed. The two manually driven vertical slides, synchronised by means of a chain and sprockets, are motor driven in a replicate chamber currently under construction. Power is supplied to the motor and 12 V microscope light by means of springcoiled cables which allow for the full range of microscope movement. The microscope is rotatable through 360° to enable roots in the upper part of the observation face to be viewed.

Other features

Temperature measurements in the earlier wooden chamber on the same site indicated a need for interior insulation. In addition to the roof soil insulation, the roof, hatch area and side walls are insulated with 50 mm thick sheets of expanded polyurethane. This chamber insulation contributes to the effectiveness of removable sections of similar insulation that fit against individual windows. There is a small removable section of roof insulation to enable viewing near the top of the observation face. Three earth angle-thermometers are mounted through the viewing face at 100, 300 and 600 mm depths to check soil temperatures against nearby standards. Ventilating air during observation is supplied from an external portable battery/fan pack that also supplies power for the microscope carriage motor and light.

INSTALLATION AND RECORDING

An almost flat area with species composition and plant density representative of the natural plant community was tested for soil depth to select sites at which the bottom observation window-edge would be just above bedrock. Knowledge gained from previous study of the rooting habits of plants in the community was used in positioning the chamber relative to the surrounding stems (Fig. 1c), to ensure inclusion of typical roots and exclusion of roots more than 20 mm thick as far as possible.

A hole slightly larger in lateral dimensions than necessary was dug rapidly to avoid excessive desiccation of the soil. To minimise local disturbance, excavated soil was dumped well away from the site. A major difficulty of a chamber study in a multi-species natural community is the species identification of specific observed root-tips. An initial indication of species composition in the vicinity of the observation face was obtained where possible by identifying the excavated

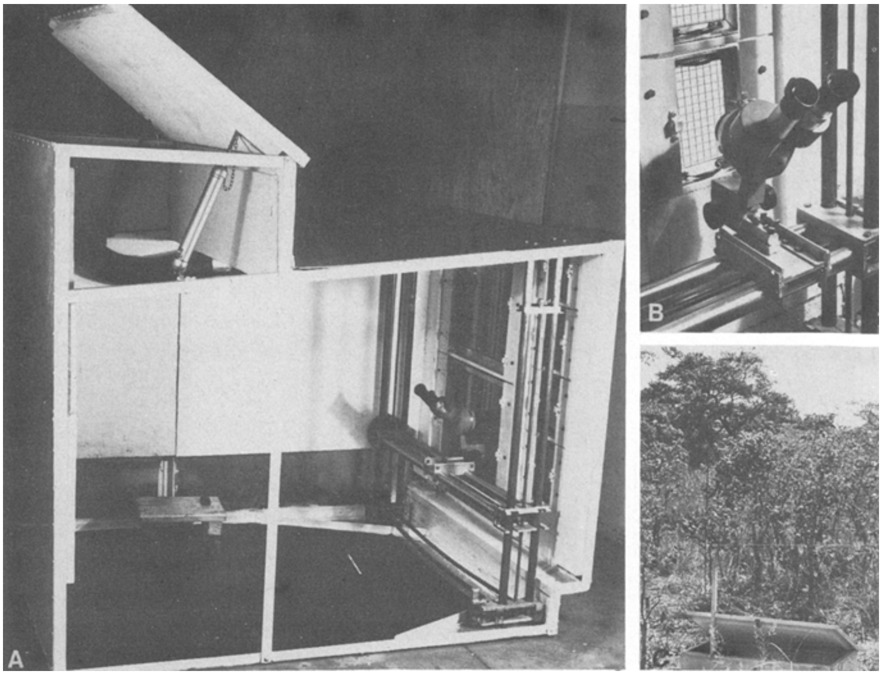

Fig. 1. (a) Side view of chamber during construction; (b) microscope, carriage and removable windows; (c) the installation site.

roots[9]. Identification of selected root tips may be carried out at the end of a study by tracing roots back from the observation face.

The repacking of a thin layer of soil behind the windows is reported to now be the most common procedure for installing root observation windows[1]. However, a key aim of this project was to avoid repacking, since this may lead to root growth unrepresentative of that in natural communities. A spirit level and straight edges were used for preparing the soil face, uncovered roots being pruned as they appeared. Effective removal of roots was limited to those under 20 mm diameter using nip shears. Interior chamber working space below window level was required. To obviate the additional necessity for including bedrock in the smooth front face, the lower front edge of the chamber was recessed (Fig. 1a). Once the chamber front was placed flush with the pre-smoothed soil face, further precise smoothing was done from inside with variously-sized glass sections. Finally a few small pockets unavoidably formed around some thicker roots while pruning were refilled with the same soil moistened for adhesion. The installation experience suggested that as area of window increases, the time needed for preparing the corresponding smooth flat soil face increases exponentially. The small gaps at sides and back of the chamber were refilled and A horizon soil was spread over the roof at original soil surface level. A fence excludes large animals from the immediate vicinity.

Root intercepts along grid-lines are counted[6] at monthly intervals and periodically related to root length per unit viewing area[12]. Root intercept angles and root thickness and other characteristics are individually mapped on fewer lines to aid interpretation of root turnover rates. Regular readings of soil temperature (see above) and soil moisture are made, the latter by means of a neutron probe in access tubes positioned so that the observation face is not irradiated.

REPLICATION COSTS

Material costs per chamber were equivalent to US $500 (1979). An initial additional outlay of US $350 was required for the microscope, power source and fan for use in all chambers. Transport and maintenance costs for this size and type of chamber are relatively low.

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REFERENCES

1 Böhm, W. 1979 Methods of studying root systems. Ecological Studies **33**, Springer-Verlag, Berlin, 188 p.

2 Fernandez, O. A. and Caldwell, M. M. 1975 Phenology and dynamics of root growth of three cool semi-desert shrubs under field conditions. J. Ecol. **63**, 703–714.

3 Glover, J. 1967 The simultaneous growth of sugarcane roots and tops in relation to soil and climate. Proc. Ann. Congr. S. Afr. Sugar Technol. Assoc. **41**, 143–159.

4 Huck, M. G. 1977 Root distribution and water uptake patterns. Range Science Department Science Series No. **26**, Colorado State University, Fort Collins. pp 215–226.

5 Huntley, B. J. and Morris, J. W. 1978 Savanna ecosystem project: Phase I Summary and Phase II progress. South African National Scientific Programmes Report No. **29.**

6 Huxley, P. A. and Turk, A. 1975 Preliminary investigations with Arabic Coffee in a root observation laboratory in Kenya. E. A. Agric. For. J. **40**, 300–312.

7 Ovington, J. D. and Murray, G. 1968 Seasonal perodicity of root growth in birch trees. *In* Methods of productivity studies in root systems and rhizosphere organisms. International Symposium, U.S.S.R. Aug. 28 – Sept. 12 1968, Nauka, Leningrad. pp 146–154.

8 Rogers, W. S. 1969 The East Malling root-observation laboratories. *In* Root Growth. Ed. W. J. Whittington Butterworths, London. pp 361–376.

9 Rutherford, M. C. 1980 Field identification of roots of woody plants of the savanna ecosystem study area, Nylsvley. Bothalia **13**, 171–184.

10 Soileau, J. M., Mays, D. A., Khasawneh, F. E. and Kilmer, V. J. 1974 The rhizotron – lysimeter research facility at TVA, Muscle Shoals, Alabama. Agron. J. **66**, 828–832.

11 Taylor, H. M. and Böhm, W. 1976 Use of acrylic plastic as rhizotron windows. Agron. J. **68,** 693–694.

12 Taylor, H. M., Huck, M. G., Klepper, B. and Lund, Z. F. 1970 Measurement of soil-grown roots in a rhizotron. Agron. J. **62,** 807–809.

13 Voorhees, W. B. 1976 Root elongation along a soil – plastic container interface. Agron. J. **68,** 143.