Plant and Soil **44**, 267–271 (1976) Ms. 2754

SHORT COMMUNICATION

Uptake of Zn^{65} from dry soil by plants

Summary

Absorption of Zn^{65} by plant roots from a layer of dry top soil (suction > 15 bar) was measured using a technique that obviated water stress in the plant.

Roots growing through the dry layer absorbed significant amounts of Zn^{65} provided they absorbed water from lower depths. Mucilage accumulated around the roots in the dry soil and may have facilitated ion transfer in the immediate vicinity of the root. The ability of roots to grow in dry soil and to absorb Zn^{65} varied between plant species.

Introduction

In many soils most of the plant nutrients occur within the upper most horizon. Commonly, this horizon dries out for extended periods. Plants then derive their water supply from the subsoil, where the supply of nutrients is generally scant. Deficiencies of major nutrients have been found in plants under such conditions[3 5]. However, recent studies on the effect of drying of the topsoil on micronutrient uptake have shown that roots can absorb Mn, Zn and Cu from the dry topsoil in amounts that are significant in their nutrition and growth (Nambiar, unpublished).

Evidence is presented to show that plant roots growing through a layer of soil drier than wilting point can absorb significant amounts of Zn^{65} provided they have access to water elsewhere.

Methods

The soil used was a light sandy loam with a pH (1 : 5 H_2O) of 6.5 and exchangeable Zn (1*M* NH_4OAc, pH 7.0) content of 0.1 ppm. It retained 3.8 per cent (w/w) water at 15 bar suction. Air dry soil had 1.5 per cent water content. The soil was equilibrated with carrier free Zn^{65} ($ZnCl_2$) at a dose rate of 1.0 μCi g^{-1}.

Plants were grown in perspex containers having internal measurements of 17.8 × 12.7 × 0.6 cm and a wall thickness of 1.3 cm. All sides of the containers except the top were covered with aluminium foil. Within each container a 1.5 cm deep layer of radioactive soil (Uptake-layer), bounded by 2 mm thick wax membranes, was sandwiched between an overlying 1 cm deep layer of initially wet non-radioactive soil (Seed-bed) and an underlying

13 cm deep layer of wet sand. The uptake-layer was initially adjusted to 3.5 percent water content (Suction > 15 bar) and a bulk density of 1.3 g cm^{-3}. Plant nutrients other than Zn were mixed with the underlying sand. Uptake of Zn^{65} was measured for four species. There were three replicate containers for each species; each replicate containing 6 plants.

Germinated seeds were planted in the seed-bed 1 cm above the uptake-layer. Roots grew through the uptake-layer into the wet sand. The sand was kept wet by injecting water frequently through a side inlet. Plants were grown in a growth cabinet maintained at 20 ± 0.5°C and 50% R.H. Light intensity was 2×10^4 lux with a 16/8 h light/dark period. Plants were harvested after 12 days. No condensation appeared on the inner walls of the container.

Results and discussion

All species absorbed Zn^{65} from the dry uptake-layer (suction > 15 bar) with negligible concomitant uptake of water from this layer (Table 1). Although most of the root length was in the wet sand, there was no evidence of rewetting of the bulk soil in the uptake-layer by outflow of water from the root. This agreed with an earlier observation[2]. Although the roots produced in the dry uptake-layer accounted for only 10 to 16 per cent of the total length of root (Table 2), the amount of Zn absorbed from this layer was appreciable – 1.0 to 3.0 ppm of dry matter depending on the species. Short term uptake measurements showed that the rate of Zn^{65} absorption by unbranched seminal roots of oats from layers initially wetted at 0.3 and > 15 bar suction were 3.1 and 1.4 nCi cm^{-1}, day^{-1}, that is, Zn^{65} absorption per unit length of root from the dry soil was 40 percent of that from the wet soil.

In the dry uptake-layer all species accumulated a band of mucilage around the root (Fig. 1). In a separate experiment, where the seed-bed was kept wet continuously, there was a sharp demarcation between the root zone

TABLE 1

Shoot and root growth and Zn^{65} uptake

Species	Water content of uptake layer		Dry weight (mg/plant)		^{65}Zn in plant (nC/mg	
	Initial	Final	Shoot	Root*	Shoot	Root*
Lucerne (*Medicago sativa* L) var. Hunter River	3.50	3.28	5.1	1.5	0.46	1.00
Clover (*Trifolium subterraneum* L) var. Geraldton	3.50	3.50	6.3	1.7	0.67	1.56
Oats (*Avena sativa* L) var. Avon	3.50	3.09	27.9	14.4	1.10	0.86
Wheat (*Triticum aestivum* L) var. Gabo	3.50	3.09	31.8	17.5	1.42	1.99

* Root in the sand layer only.

TABLE 2

Root length (cm/plant) in different layers

	Lucerne	Clover	Oats	Wheat
Seed bed	4.0	3.7	4.4	13.8–
Uptake layer	1.7	3.0	12.2	16.9
Sand layer	11.2	11.2	81.5	111.0

within the seed-bed, which retained little soil after washing, and the subjacent zone in the uptake-layer on which an annulus of soil remained (Fig. 2). Sand adhering to the underlying roots was readily washed away. Plants are known to exude more material from roots when subjected to water stress[4]. In the present experiment however, the plants were well supplied with water, and copious exudation of mucilage occurred only within the dry layer (Fig. 2). The epidermis and cortex in the dry layer may have experienced water stress leading to the local exudation of mucilage, while tissues lying within the stele remained well supplied with water.

In the uptake-layer, cereals exuded more mucilage around the root than did legumes (Fig. 1) and also produced more roots (Table 2). Cereals also absorbed more Zn^{65} per unit weight of shoot (Table 1). Zn^{65} absorption values per unit length of root were 2.5, 2.7, 2.7 and 3.9 nCi cm^{-1} for clover, lucerne, wheat and oats respectively, oats roots being more efficient in absorbing

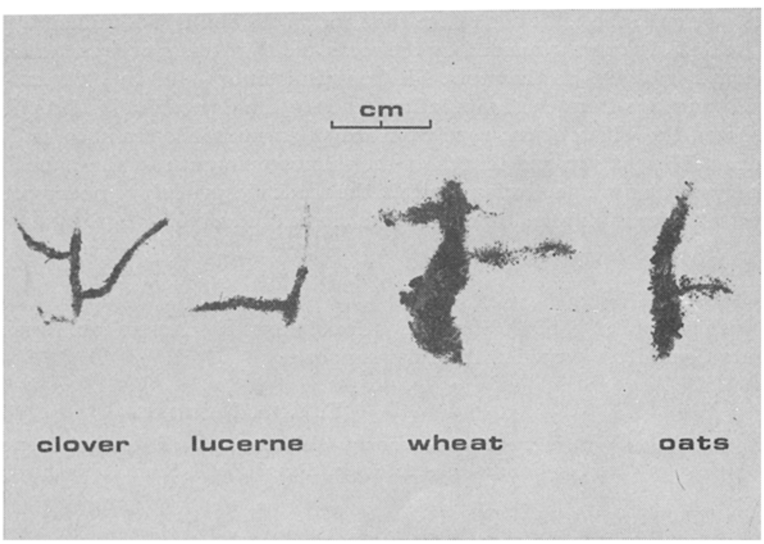

Fig. 1. Annulus of soil adhering to roots in the dry uptake layer after washing the roots gently in water.

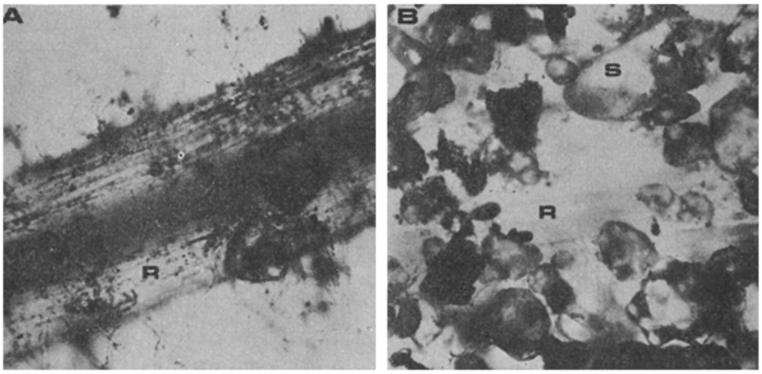

Fig. 2. Soil grains (S) adhering to root epiderm (R) of seminal root of oats after washing (× 33). Roots grown for 4 days through a continuously wet seed bed (**A**) into a dry layer (**B**). The apical part of the root (not photographed) grew in wet sand.

Zn^{65} than others. This ranking in absorption differs from that observed for the same set of species grown in solution culture[1].

When the soil water suction exceeds 15 bar, water minisci retreat to pores of diameter $\leqslant 0.2\ \mu m$. These pores are inaccessible even to root hairs. The water films in the soil become discontinuous, and bulk diffusion of Zn is extremely slow[6]. It is suggested that, when the soil is dry, continuity between liquid water in the cell walls of the root and in the soil is maintained by the infiltration of mucilage exuded by the roots and that this mucilage facilitates the transfer of ions to the roots. The radial distance – 100 to 1000 μm – to which mucilage from the roots infiltrates into the dry soil (Fig. 1) is likely to exceed the width of the zone from which an immobile ion such as Zn is depleted. The nature and length of the microscopic path in the immediate vicinity of the root, particularly within the mucilage, is likely to be important in ion transfer in dry soil, and warrants closer study.

Acknowledgements

I wish to thank Dr. K. P. Barley for discussions. The Australian Research Grants Committee provided financial support.

E. K. S. NAMBIAR

Department of Agronomy, Waite Agricultural Research Institute, The University of Adelaide, Glen Osmond, South Australia, 5064.

Received 10 February 1975

References

1 Carroll, M. D. and Loneragan, J. F., Australian J. Agr. Research **19**, 859–868 (1968).
2 Clarke, A. L. and Barley, K. P., Australian J. Soil Research **6**, 75–92 (1968).
3 Garwood, E. A. and Williams, T. E., J. Agr. Sci. **69** 125–130 (1967).
4 Hale, M. G., Foy, C. L. and Shay, F. G., Advances Agron. **23**, 89–109 (1971).
5 Simpson, J. R. and Lipsett, J., Austrialian J. Agr. Research **24**, 199–209 (1973).
6 Warncke, D. D. and Barber, S. A., Soil Sci. Soc. Am. Proc. **36**, 39–42 (1972).