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A method for determining the K-uptake from subsoil by plants

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Summary Rb was applied to the topsoil in order to trace the potassium which was taken up from the topsoil by plants. The resulting K/Rb ratio in plants increased when plants came into contact with the Rb free subsoil. This change in the K/Rb ratio enables the calculation of the K uptake from the subsoil. The average of the K uptake from the subsoil by spring wheat was 35% of the total uptake.

Introduction

Little attention has been paid to K uptake from subsoil by crops. In this paper a method is proposed to measure the K uptake from subsoil by tracing K in the topsoil with Rb. Work by Baligar and Barber[1] and Baligar *et al.*[3] showed that plants take up K and Rb in the same ratio as present in the nutrient solution. This indicates that plant roots do not distinguish between K and Rb. In the soil Rb is held more tightly than K[2,6,8]. Therefore, the K/Rb ratio in the soil solution is higher than on the exchange sites. The K/Rb ratio in plants growing in soil is between those two values, *i.e.* it cannot be characterized by either one of them, as found by Baligar and Barber[2]. Therefore, in order to characterize the uptake ratio of K/Rb, plants have to be grown in the soil used for investigation. The proposed method is based on two sets of plants. One is grown in topsoil enriched with Rb without contact to the subsoil. The K/Rb ratio of these plants shows the ratio by which K and Rb is taken up from top soil. The other set is grown in the same top soil also enriched with Rb, but the roots are allowed to penetrate the subsoil. Any increase of the K/Rb ratio in this set compared to the former is due to the K taken up from the Rb free subsoil. With this arrangement the different adsorption power of K compared to Rb in soil does not have to be considered since the pots with contact to subsoil and without contact contain the same topsoil and the K uptake from subsoil can be calculated from the K/Rb ratio in plants.

Materials and methods

Experimental procedure

After thorough mixing, 25 kg of topsoil enriched with 5 g RbCl and fertilized with 1.5 g NH_4NO_3 were filled into 20 l pots and sown with 30 grains of spring wheat (Triticum aestivum) cv. Horizont. After germination the number of plants was reduced to 25. The pots remained in the greenhouse until 2 weeks after germination.

Thereafter, for each experiment, the bottoms of 4 pots were removed and then the pots were inserted in the topsoil of a wheat field, allowing the roots to grow into the subsoil. The other 4 pots, with the bottoms not removed, were left in the greenhouse, 25 km from the field so that watering could be done properly.

Two harvests were performed, one at 1st node stage and one at ear emergence (end of K uptake). Each time 2 pots with and 2 pots without subsoil contact were harvested. After dry ashing shoots were analysed for K and Rb by flame emission with a Perkin Elmer 4000.

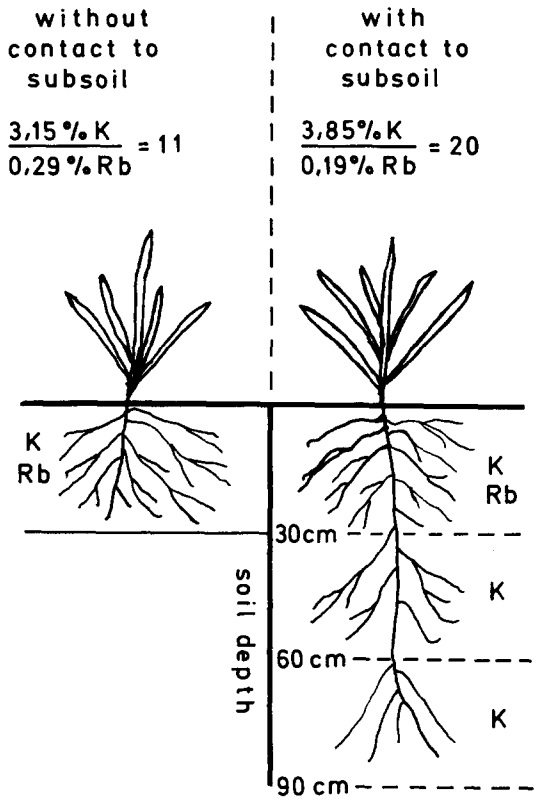

Fig. 1. Determination of K uptake from subsoil by K/Rb ratio in plant shoot (soil: loess – parabrown soil; plant analysis: the whole shoot at ear emergence; spring wheat).

Calculations

Calculations will be demonstrated for the data of Fig. 1. The K/Rb ratio in the plants without subsoil contact is 11. This means for each part of Rb 11 parts of K are taken up from the topsoil. The increase of K/Rb ratio to 20 in the plants with subsoil contact indicates that 9 parts of K out of 20 came from the subsoil. Expressed as percentage we can write:

Percentage of K uptake from subsoil

$$= \frac{[\text{K/Rb (with contact)} - \text{K/Rb (without contact)}] \times 100}{\text{K/Rb (with contact)}}$$

$$= \frac{(20 - 11) \times 100}{20} = 45$$

Results and discussion

By the above described method K uptake from subsoil by spring wheat was investigated on predominantly 'loess-parabrown' soils. Table 1 shows the results of experiments carried out on 6 different sites in 1982. The K uptake from subsoil until ear emergence varied on the different fields from 22% to 49% and was on the average of 35%. The percentage of K uptake from subsoil was not related to K content of the subsoil nor to K uptake of topsoil. The K

Table 1. Percentage of K uptake from subsoil (below 30 cm of soil depth) during different growth periods (spring wheat; 6 different sites; 1982)

Sites	Soil layer	K content of soil (mg K/100 g soil, $CaCl_2$-extraction)*	Percentage of K uptake from subsoil: Beginning of vegetation until 1st node stage	Between 1st node stage and ear emergence	Beginning of vegetation until ear emergence
	Top soil	10			
1	30–60 cm	2	5	53	39
	60–90 cm	1			
	Top soil	12			
2	30–60 cm	2	10	43	25
	60–90 cm	1			
	Top soil	5			
3	30–60 cm	2	1	37	22
	60–90 cm	2			
	Top soil	19			
4	30–60 cm	10	16	58	45
	60–90 cm	4			
	Top soil	14			
5	30–60 cm	3	13	68	49
	60–90 cm	2			
	Top soil	10			
6	30–60 cm	2	3	54	32
	60–90 cm	1			
	Average		8	52	35

* $CaCl_2$-method: extraction with 0,025 n $CaCl_2$, soil: solution = 1: 10, for 1 h.

uptake from the subsoil was on the average only 8% in the early growth stage, increasing to 52% between 1st node stage and ear emergence. This finding is in accordance with the root distribution pattern found by Böhm[4] on similar soils, *i.e.*, the percentage of roots in the subsoil amounts to 20% at 1st node stage and 35% at ear emergence. In addition to the higher percentage of roots in the subsoil at later growth stages, drying of the topsoil and therefore lower availability of K would explain the relatively high uptake from subsoil between 1st node stage and ear emergence. Results from 1981 (3 experiments) and 1983 (1 experiment) were similar to those in Table 1.

It is difficult by the described method, to determine accurately small amounts of K taken up from the subsoil (at 1st node stage), because of the variability in the K/Rb ratio between the 2 replicates. This variability was relatively small compared to the absolute differences at ear emergence and the results obtained at this stage are more reliable.

This method is based on two main assumptions, *i.e.*, the added Rb does not move into the subsoil and the uptake ratio of K/Rb from topsoil is the same in the pots with and without contact to the subsoil.

Rb movement into the subsoil is probably negligible since Rb concentration in soil solution remains low and a large part is even nonexchangeable[1]. In addition in the pots which were placed in the field in spring the amount of water moving through the topsoil into the

subsoil during the growing season was relatively small. The second assumption requires that the K/Rb uptake ratio from topsoil is the same in pots with contact to subsoil (field) and in pots without contact to subsoil (greenhouse). The ratio of K/Rb uptake is mainly determined by soil factors as discussed in the introduction. Since plants in the greenhouse and in the field are grown on the same topsoil, they will have the same K/Rb uptake ratio from topsoil, even though the total K and Rb uptake could be different.

One might expect the root density to be somewhat higher in pots without subsoil contact than with subsoil contact. Therefore, K uptake from nonexchangeable fraction would be higher too[5]. However, added Rb goes to a large extent into the nonexchangeable fraction[1]. In addition, the same authors have shown that an increase of root density from 2 to about 10 cm per ccm of soil did not significantly affect the K/Rb ratio in the plant. Different rooting pattern in the pots with and without contact to the subsoil is not expected to vary as much as in the cited paper and therefore the second assumption seems reasonable.

Even though the proposed method has not been compared with other methods in the same experiment, data from Grimme *et al.*[7] on similar soils based on mass flow and diffusion calculations show similar results.

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