XYLEM AND PHLOEM TRANSPORT, ASSIMILATION AND PARTITIONING OF NITROGEN IN *RICINUS COMMUNIS* UNDER SEVERAL NUTRITIONAL CONDITIONS

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INTRODUCTION

On land, higher plants face the problem of having the site of photosynthesis, which is responsible for capturing light energy to fix CO_2, displaced from the site where water and mineral nutrients are taken up. The problem is solved by the existence of the two long distance transport systems: xylem and phloem. The xylem transports water, mineral nutrients, products and signals from the root to the shoot. In contrast, the phloem transports assimilation products from shoot to root, and, from photosynthetically active – 'source' tissues, to growing areas within the shoot – the so called 'sinks'.

Of the mineral nutrients taken up by the plants, nitrogen is not only taken up at greatest rates, but, is also metabolised and transported to a large extent between organs in higher plants. Since most N is taken up by roots, the shoots must be supplied with N via the xylem. Furthermore, a considerable amount of N is recycled via the phloem. Nitrogen must be assimilated before it can be used in plant metabolism (disregarding some other functions of inorganic N, such as osmotic, charge effects, or signals) and this requires energy and C-skeletons for the synthesis of amino acids.

According to the main site of N-assimilation, plants can be classified in two groups: (1) N-assimilation takes place in the root, and (2) it takes place in the shoot. If inorganic N is assimilated in the root, the necessary energy and C-skeletons must be transported to the root. After assimilation, amino acids are transported in the xylem to the shoot. If inorganic N is mostly assimilated in the shoot, inorganic N must be loaded into the xylem and transported to the shoot after the uptake into the root cortex. In this case, counterions are necessary for N-transport in the xylem. Amino acids are then synthesised in the shoot, and consequently the root must be supplied with organic N by basipetal transport in the phloem. Naturally, the reduction of nitrate and assimilation of resulting ammonium takes place in both root and shoot. The partitioning of nitrate reduction depends on a number of factors.

C is needed to provide energy for reduction of nitrate, assimilation of ammonium and also to provide C-skeletons. Therefore, C is transported within the plant between different organs to varying degrees. Primarily, C and N must be transported from sites of acquisition to sites which are likely to be growing i.e. N moves from the root to leaves or C from the leaves to the roots.

The long distance transport, assimilation and incorporation of N (and other elements or ions) in a whole plant can be investigated by modelling of ion and element flows (Pate *et al.*, 1979a; Jeschke *et al.*, 1985; and Jeschke and Pate, 1991a). For this method the proportion of ions or elements in the transport fluids and their incremental increases in those ions or elements within different organs are necessary. These models allow us to make positive statements about uptake, flow in xylem and phloem, and incorporation of elements and ions in the whole plant. For compounds which can be metabolised it is also possible to make statements about the site and extent of net-metabolism (synthesis or degradation). The models reported

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SUMMARY *Ricinus communis* plants were grown with nitrate or ammonium as N-source, salt stress, high or low nitrate supply, deficiency of nitrogen, phosphorus or potassium, and with foliar application of nitrogen. During the experimental period (41 to 51 days after sowing) the flows of elements and ions were modelled according to the method of Pate et al. (1979). These models permit quantification of uptake, transport in xylem and phloem, and incorporation in organs. For ions, which can be metabolised like inorganic nitrogen, the sites of assimilation, synthesis or degradation can be also shown. Most of newly taken up nitrogen was transported in the xylem to the shoot (100% of uptake including recycled N), where only a part of it was used for growth. The rest was recycled back to the root, about 23% of the xylem born N. In well-fed plants, 70-80% of N was incorporated in the shoot. Nutrient deficiency shifted this portion in favour of the root, whereas under mild salt stress more N was used in the shoot. Inorganic N was not mobile in the phloem, and ammonium was not transported in the xylem, but was always assimilated at the site of uptake. When supplied to the leaves, ammonium was assimilated in the shoot. Nitrate can be reduced in roots as well as in shoots. The contribution of the shoot in reduction increased with increasing supply. Deficiency of N and K as well as mild salt stress shifted the reduction more to the root, P deficiency enhanced the reduction in the shoot. Foliar supplied nitrate was almost exclusively reduced in the leaves. For the distribution of nitrate reduction between root and shoot effects of xylem transport might be responsible. In well-fed plants about 50% of photosynthetically gained C was used for shoot growth and 25% for respiration. In the case of nutritional limitation the cost for root growth and respiration (50%) increased relatively. Additionally, the loss of C by phloem export was increased, if the root was the major site of N assimilation, as was the case under conditions of NO_3^- and K-deficiency, salt stress and ammonium nutrition. This demonstrated the role of N assimilation as a major sink for C, since carbohydrates were needed as energy sources and C-skeletons for amino acid synthesis. Beneath the interactions of N and C, other ions affected or were affected by nutritional conditions of N. For example the uptake and flows of chloride were increased, if nitrate was limiting. The xylem transport of nitrate was influenced by salinity or potassium. In ammonium- vs. nitrate-fed plants and when ammonium was applied to the shoots only, cation flows were decreased.