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the effect was also observed after treating the leaves with fungal elicitor. In addition, we could obtain some evidence that altered $Ca^{2+}$-translocation across membranes could be involved in the mediation between the recognition event and host cell response.

## CARBOHYDRATES AND RUST FUNGI

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Sucrose is the main product of photosynthesis in most healthy source leaves. It has three main fates: export in the phloem, temporary storage, or metabolism - notably to fructans or in respiration. The effect of infecting with a rust fungus will be considered for each of these, and for a fourth fate - uptake by the fungus. Particular attention will be paid to integrating work with rusted leaves with recent advances in understanding of the metabolism of healthy source leaves. Work with leaves of barley infected with brown rust will be used to draw up a balance-sheet for carbon to demonstrate the major effects of infection. It will be shown that neither overall carbohydrate status, nor diel changes in carbohydrate content, are greatly affected by rust infection. By contrast, export of sucrose in the phloem is much reduced, but the velocity of phloem transport is unaltered, implying a reduced concentration of sucrose in the phloem. The uptake of carbohydrate by the fungus is considered in relation to the frequency and activity of haustoria. The greatly increased respiration characteristic of diseased leaves will be interpreted in terms of the demand for ATP and the activity of the alternative oxidase. Mechanisms responsible for achieving these changes in carbohydrate metabolism will be considered briefly.

## COLONIZATION OF ROOTS BY VESICULAR-ARBUSCULAR MYCORRHIZAL FUNGI IN RELATION TO THE PHOSPHORUS AND CARBON NUTRITION OF THE HOST

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The development of vesicular-arbuscular (VA) mycorrhizal root systems is a highly dynamic process, with the fungus colonizing a host which is also growing. The effects of VA mycorrhizas on the host cannot be fully understood unless processes that control colonization of root systems by the fungal partner are studied and clarified. Many factors of the physical and chemical environment of the plant influence the formation of VA mycorrhizas but in particular high concentrations of phosphorus (P) in soil markedly inhibit colonization: current evidence shows that it is the concentration of P within the plant and not in the surrounding soil that is responsible. We present results of studies into the mechanism of the inhibitory effect of high P supply, in which we extensively used leek plants (Allium porrum L.) colonized by the fungus Glomus mosseae as a model system.





It is axiomatic that the fungal partner gains its carbon from the photosynthate of the host. This has led to suggestions that colonization by VA mycorrhizal fungi is controlled by availability of carbon substrates in the cortex of the roots of the host.

A.D. Robson and his colleagues have presented evidence that the concentration of soluble carbohydrates in roots changes inversely with increased P supply and they suggest that lack of soluble carbohydrate at high P supply inhibits mycorrhizal colonization. Our experiments did not support this idea. On the contrary we found that over a wide range of P supply mycorrhizal plants contained a higher concentration of soluble carbohydrates (sucrose, fructose and glucose) than did non-mycorrhizal plants of similar shoot percentage P, implying a unique effect of mycorrhizal infection in diverting host assimilates to the infection court. Other experiments with $^{14}C$ showed that there was increased downward translocation from the shoot of mycorrhizal plants to the root system and associated with this increased sink strength was doubling of the activity of soluble acid invertases that were probably principally of host origin. An hypothesis to explain this sink effect of VA mycorrhizas will be suggested.

We propose that the carbon demand of the fungus is small and can probably be easily met by the gross efflux of carbon into the apoplastic pool of the root cortex. The theory of J.A. Menge and associates that exudation of soluble carbon compounds by roots controls colonization by VA mycorrhizal fungi, is discussed in this context.

We present evidence that roots of leek and clover are most susceptible to invasion by VA mycorrhizal fungi in a narrow zone behind the root tip. A major effect of high P supply is to narrow this 'window of opportunity' which appears to be regulated by the anatomy of the cortical cells, principally the cells of the hypodermis.

## THE ROLE OF PHOSPHATE IN CARBON METABOLISM AND EXCHANGE OF METABOLITES IN BIOTROPHIC SYMBIOSES

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Phosphate is indispensible for photosynthesis and the classical equation, which omits phosphate, should be replaced by the following in which Pi represents orthophosphate:

$$3CO^2 + 6H_2O + Pi \xrightarrow{h\nu} \text{Triose phosphate} + 3H_2O + 3O^2$$

Phosphate is not only involved directly in this synthesis of triose phosphate but also in its export from chloroplast to cytoplasm where it is converted to translocatable carbohydrates, especially sucrose.

Data on the ways in which concentration of phosphate can control both the synthesis and partitioning of carbohydrate in uninfected plants will first be presented. Then, the ways by which both antagonistic leaf-infecting and mutualistic root-infecting biotrophic fungi potentially could perturb the carbon balance of the plant by interfering with concentration of phosphate will be explored. Whether or not phosphate is involved in this manner will then be thrown open to discussion.