

Physiological role of the cyclic hydroxamic acids

M. Pethő

University of Debrecen, Centre of Agricultural Sciences, Debrecen, Hungary

ABSTRACT Roots of young seedlings of barnyard grass, maize, rye and wheat secrete hydroxamic acids. Their complexes with Fe(III)-ions are available sources of iron. It is possible that the cyclic hydroxamic acids play a role in the alternative mechanism of iron uptake. The hydroxamic acids secreted by barnyard grass roots have an allelopathic role by inhibiting the roots growth of rice.

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KEY WORDS

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The cyclic hydroxamic acid, 2,4-dihydroxy-1,4-benzoxazin-3-one (DIBOA) and its methoxy analogue, 2-4-dihydroxy-7-methoxy-1,4-benzoxazin-one (DIMBOA), occur as glycosides in the Poaceae, including maize, wheat and rye, and are implicated in the resistance of plants to pathogens and insects (Niemeyer 1988). In addition to their toxic properties, the cyclic hydroxamic acids have also been associated with detoxification of triazine herbicides (Hamilton 1964), inhibition of plant growth regulators (Hasegawa et al. 1992), and may even have allelopathic properties (Pérez and Ormeno-Nunez 1991).

The grasses possess a special iron uptake mechanism. They exude mugineic type compounds (phytosiderophores) through their roots into the rhizosphere, where they form complexes with the iron. The grasses take up these mobilized chelates (Römheld and Marschner 1986). There are great differences in phytosiderophore activity between the plants. So maize and sorghum exude very little amount of phytosiderophore (Kawai et al. 1988). The cyclic hydroxamic acids also form complexes with the Fe(III)-ions, and already Tipton and Buell (1970) supposed them to play a role in the iron uptake.

We have studied primarily their role in the iron acquisition by plant roots.

Materials and Methods

The plants were grown on a culture fluid described by Römheld and Marschner (1986) under constant aeration and 14 hours illumination. The hydroxamate-glycosides were extracted from the heated plant materials with 50% ethanol. The root exudates were collected two hours after the beginning of the light period, the nutrient solution was replaced with distilled water. After four hours the root washing was extracted by n-butanol. The organic phase was evaporated. Both the tissue extracts and the root washing were preliminary purified with paper chromatography and the UV-detected strips were extracted with 70% methanol. The HPLC analyses of the samples were basically done according to method by Lyons et al. (1988).

Results and Discussion

In the roots of two-week-old maize plants grown in culture fluid containing FeCl₃, the quantity of DIMBOA-glycoside rises, and the extent of rise is a correlation with the FeCl₃ concentration. Iron given in complex form (Fe-EDTA) has no influence on the DIMBOA-glycoside content of roots. Roots of plants grown at different rates of iron supply excrete DIMBOA in a quantity growing parallel with the concentration of iron. On the basis of the data it is probable that this cyclic hydroxamic acid - similarly to the hydroxamate type siderophores of microorganisms possesses a phytosiderophore-like function. (Pethő 1992a).

Roots of young seedlings of wheat and rye also secrete cyclic hydroxamic acids. Hydroxamic acid secretion by rye roots is increased by Fe(III)-ions added to the nutrient solution and Fe-chlorotic symptoms are moderated. Cyclic hydroxamic acids probably play a role in the Fe-uptake (metabolism) of cereals (Pethő 1992b).

The iron complex of the cyclic hydroxamic acids is a source of iron available for plants. The complex taken up through the root is translocated to the shoot, where the iron increases the chlorophyll content and moderates the chlorosis. The roots of maize take up the iron complex of the DIBOA-glycoside and even transform it enzymatically. The intensity of uptake and the rate of transformation are determined by the iron status: iron deficient crops take up more complex, their metabolism is increased compared to those grown in culture solution containing iron. Uptake of the iron complex of hydroxamic acids can also be noted in rice and oat, which do not contain these compounds. The mechanism of uptake is not thus restricted to plants containing hydroxamic acid. The results render it probable that the cyclic hydroxamic acids represent a new form of the phytosiderophores (Pethő 1993b).

It is possible that side by side with a moderate secretion of phytosiderophore by maize, cyclic hydroxamic acids may also play a role in the Fe-uptake of the plant. The dynamics of the release of phytosiderophores of the mugineic acid type and that of cyclic hydroxamic acids are different: the secretion of the latter is enhanced not by a deficiency but by the presence of iron. Its daily pattern is also different, and its

maximum is rather more characteristic of the dark period (Pethő et al. 1997).

Wheat and rye plants release relatively large amounts of phytosiderophores but they secrete only moderate amounts of cyclic hydroxamic acids. The secretion of phytosiderophores is enhanced by iron deficiency. On the other hand, the moderate phytosiderophore secretion of maize is accompanied by a relatively large release of cyclic hydroxamic acids, which is enhanced by the presence of iron. It is possible that the cyclic hydroxamic acids play a role in the alternative mechanism of iron uptake (Pethő 2000).

The tissues of barnyard grass (*Echinochloa crus-galli* (L.) P.B.) synthesize cyclic hydroxamic acids, which are secreted by its roots in free or glycosidic forms. Hydroxamic acids inhibit rice root growth. The concentration of hydroxamic acids accumulating in the rhizosphere exceeds the level that is necessary for a 50% root growth retardation of rice. Based on this, we assume that in the interrelationship between rice and barnyard grass, the cyclic hydroxamic acids secreted by barnyard grass roots have an allelopathic role by inhibiting the root growth of rice (Pethő 1993a).

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