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EFFECT OF INTERRUPTION OF AERATION OF THE ROOT MEDIUM ON DISTRUBUTION OF DRY MATTER, SUGAR AND STARCH IN YOUNG PLANTS OF PHASEOLUS VULGARIS

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SUMMARY

The effect of an interruption of the aeration in the root medium on distribution of dry matter, sugar content and starch content in the roots and the hypocotyl of seedlings of *Phaseolus vulgaris* was investigated. The interruption resulted in a shift in the distribution of dry matter from roots to hypocotyl, a higher sugar content in roots and hypocotyl and a lower starch content in the distal part of the root. Restoration of aeration after one day resulted in renewed root growth and decreased sugar contents of the hypocotyl and the roots. Accumulation of starch within the hypocotyl continued. Inhibition of root growth was not caused by a deficiency of assimilates in the roots.

1. INTRODUCTION

Several authors (e.g. BROUWER 1977, PAPENHUIJZEN 1979) have reported on the effect of aeration on the growth and morphology of the roots of *Phaseolus vulgaris*. In subsequent experiments we found that elongation of roots of aerated plants ceased as soon as the aeration was turned off, but was resumed if aeration was restored within a day.

It has been suggested (NURITDINOV & VARTAPETIAN 1980) that under anaerobic circumstances not only a deficiency of oxygen, but also a shortage of assimilates is a cause of inhibition of root metabolism and growth processes. Data on the effect of an anaerobic root medium on sugar supply to the roots are contradictory. According to several authors (VAN DER HEIDE et al. 1963, LIMPINUNTANA & GREENWAY 1979, DE WIT 1974) oxygen deficiency in the root medium leads to an increase of sugar content in the roots. PAPENHUIJZEN & ROOS (1979) observed, that on cessation of aeration starch grains disappeared from the amyloplasts in root tip cells. The starch was presumably converted into sugar. On the other hand there are reports from VARTAPETIAN (1978) that the destruction of cells of intact plants and of detached organs under anaerobic conditions could be prevented by supplying them with glucose in the nutrient medium. This suggests a deficient sugar supply within these tissues. NURITDINOV & VARTAPETIAN (1980) observed inhibition of sucrose translocation from the shoot to the root under anaerobic conditions.

In the present experiments we looked for a possible relation between the carbohydrate content of the roots and root growth under conditions of oxygen deficiency. This was investigated by determining the contents of soluble sugars

and starch in roots of *Phaseolus* plants when the aeration of the root medium was suddenly ended, and in roots recovering from the effects of a short interruption of the aeration.

As a possible inhibition of translocation of assimilates to the roots could be accompanied by an increase of carbohydrates in the hypocotyl, sugar and starch determinations were also made in this part of the plants.

2. MATERIALS AND METHODS

Seeds of *P. vulgaris*, cv. Berna, were germinated in humid sand. One week old seedlings were placed on containers with a half strength Hoagland solution (STEINER 1968, STEINER & VAN WINDEN 1970) and micro-elements according to CHALLA (1976). A 16 h light period was used. TLF 65/33 lamps provided about 45 Watt.m^{-2} at the level of the primary leaves. Temperature was c. 23 °C. Air was bubbled through the nutrient solution. After three days in some of the containers the aeration was turned off for 24 h, in another part permanently, whereas the others remained aerated. The oxygen content of the nutrient solution was measured with a platinum membrane electrode and expressed as the percentage saturation. In the aerated control solutions oxygen saturation was 96–98%. Where the aeration had been turned off, oxygen saturation was 45–55% after one day and 15–35% after three days. If, after 24 h, aeration was restored, saturation was again 94–98%.

Elongation of the axes of the primary root system was studied in experiments with roots, coloured with Fe-tannin (ERICKSON 1946).

On the first and the third day after the aeration had been turned off, plants were harvested and divided in shoot, hypocotyl, proximal part of the root (up to 5 cm from root basis) and distal part of the root (more than 5 cm from root basis). The material was dried at 75 °C. Dry weights of the plant parts were determined apart for each plant. Then, of the four plants of each container, the hypocotyl and the root parts were sampled and ground for the sugar and starch content determinations. Soluble sugars were extracted from the dried material with 80% ethanol, starch was extracted with 35% perchloric acid, both for 16 h. In the sugar extract the main components were identified by paperchromatography (MUKERHERJEE & SRIVASTAVA 1952).

Sugar and starch determinations were made by way of the anthron reaction, with 1.5 g anthron per liter 75% H_2SO_4 using calibration curves of glucose. Absorption was measured spectrophotometrically at 625 nm.

3. RESULTS

One day after cessation of the aeration the total dry weight of aerated and non-aerated plants did not differ, but there was a difference in the distribution of dry matter within the plants. In comparison with the aerated control a larger share of the total dry weight was found in the hypocotyl and a smaller one in the distal part of the roots of non-aerated plants *(table 1)*. Whereas root axes

Table 1. Dry weights of plant parts in mg (with standard deviations), one and three days after cessation of aeration. Data are based each on 36–40 plants from 5 experiments. The significance of differences was tested at a 5% level with the sign test or by pairing of observation (Dixon & Massey, 1957).

Treatment	Shoot		Hypocotyl		Root				Total plant	
					proximal		distal			
	1st day	3rd day	1st day	3rd day	1st day	3rd day	1st day	3rd day	1st day	3rd day
non aerated	225.2	376.3	68.6	90.1	45.1	41.0	28.8	22.9	367.1	530.0
for 3 days	± 42.7	± 52.0	± 12.9	± 11.2	± 9.0	± 10.0	± 11.2	± 8.4	± 60.9	± 68.7
aeration interrupted		424.1		80.6		54.2		46.9		605.5
for 1 day followed by 2 days aeration		± 65.9		± 14.0		± 10.8		± 16.2		± 90.0
constantly aerated	225.6	400.9	61.0	65.1	45.0	53.1	36.2	67.8	367.6	587.9
(control)	± 42.7	± 56.0	± 13.1	± 12.5	± 11.1	± 10.8	± 12.4	± 12.4	± 64.2	± 79.0

Table 2. Sugar contents (with standard deviation) of plant parts as percentage of dry weight, one and three days after cessation of aeration. Data are based each on 8–10 determinations from 5 experiments.

Treatment	Hypocotyl lower part		Root, proximal part		Root, distal part	
	after 1 day	after 3 days	after 1 day	after 3 days	after 1 day	after 3 days
aeration stopped	7.7 ± 0.8	9.9 ± 1.0	5.0 ± 1.4	5.2 ± 0.8	5.1 ± 0.6	4.5 ± 0.7
aeration stopped for 1 day, followed by 2 days aeration		6.5 ± 1.7		3.0 ± 0.6		2.7 ± 0.7
constantly aerated control	5.3 ± 1.6	2.8 ± 0.7	3.7 ± 0.4	2.5 ± 0.5	3.2 ± 0.5	2.1 ± 0.6

Table 3. Starch content of plant parts as percentage of dry weight, one and three days after cessation of aeration. Data are based each on 8–10 determinations from 5 experiments.

Treatment	Hypocotyl		Root, proximal part		Root, distal part	
	after 1day	after 3 days	after 1 day	after 3 days	after 1 day	after 3 days
aeration stopped	3.9 ±1.1	5.6 ± 1.9	3.4 ± 1.3	3.3 ± 0.6	3.4 ± 0.7	3.8 ± 0.8
aeration stopped for 1 day, followed by 2 days aeration		5.6 ± 1.1		4.2 ± 1.0		3.9 ± 0.8
constantly aerated control	4.1 ± 1.0	4.3 ± 1.0	4.0 ± 0.8	4.3 ± 0.8	4.0 ± 0.6	4.0 ± 0.5

of aerated plants showed an elongation of 3–4 cm, no elongation had taken place after cessation of the aeration. The sugar contents of hypocotyl and roots were higher, the starch content in the distal part of the root was lower than in the controls *(tables 2 and 3)*. Two days later the roots of the non-aerated plants were deteriorating *(table 1)*, while in the hypocotyl both the sugar and the starch content had increased *(tables 2 and 3)*.

If aeration was restored after an interruption of one day, two days later the roots had resumed elongation (3–5 cm, control roots (6–9 cm) and increased in weight *(table 1)*.

Sugar content in both hypocotyl and roots had decreased, whereas starch content in these plant parts had increased *(tables 2* and *3)*.

Paperchromatography of the sugar extracts showed sucrose, glucose and fructose as main components.

4. DISCUSSION

A comparison of the content of soluble sugars in roots kept in aerated, and for one day not aerated solution shows that, contrary to the suggestion of VARTAPETIAN (1978), lack of sugars is not the cause of the inhibition of elongation

in the latter case. It seems rather, that the roots were unable to use the available sugars during the period of non-aeration. This may have been a consequence of compartmentation of sugars in the root cells but also of the low oxygen content of the medium.

The shift in the distribution of dry matter from the roots to the hypocotyl and the accumulation of starch in the hypocotyl are in agreement with reports on an inhibition of the translocation of sucrose from the shoot to the roots, as a result of oxygen deficieney (NURITDINOV & VARTAPETIAN 1981). As under such conditions these authors could stimulate the translocation of sucrose by the addition of glucose to the medium, it could mean that the use of sugar within the roots was inhibited by some other factors rather than by O_2 deficiency.

If, in our experiments, after an interruption of one day, the root medium was aerated again, translocation of assimilates from the shoot to the roots was restored: the roots increased in weight and resumed elongation.

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