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BRIEF COMMUNICATION

The Relationship Between Electric Capacitance and Some Other Parameters of Plant Roots

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Abstract. Using regression analysis a proof of the relation between the electric capacitance and the root surface in maize, sunflower, oats and onion plants was given. This dependence is possible to exploit in the selection of plants (of the same population grown under the same conditions) for a well — developed root system.

The relation between electric capacitance and root surface in maize (*Zea mays* L. cv. Kočovská), sunflower (*Helianthus annuus* L. cv. Maják), oats (*Avena sativum* L. cv. Český), onion (*Allium cepa* L.) and rape (*Brassica napus* L. cv. Třebíčská) plants was investigated in order to find a method for the measurement of the root surface directly in the soil.

Maize, onion and sunflower plants (Experiment No. 2) were grown in quartz sand. Clayish soil was used for cultivation of oats and sunflower plants in another experiment (No. 3). In experiments No. 2 and 3 the electric capacitance was measured at maximum moisture of the substrate. In experiment No. 4 the Mitscherlich vessels were heavily weed-grown. The roots of the weeds were carefully removed during the rinsing of the substrate. All the plants were grown in vessels.

The surface of the onion roots was calculated from the length and from the mean diameter of the individual roots and that of the maize roots was estimated according to the sorption of the methylene blue (KOLOSOV 1962). A highly significant correlation was found between the fresh weight, dry matter, volume and the surface area of the root. With respect to this fact only the fresh weight, dry matter and also the volume of roots were estimated for the other plant species.

The electric capacitance was measured as follows: one terminal of a capacitance or impedance bridge was connected with the root neck and the

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TABLE 1

CORRELATION AND REGRESSION COEFFICIENTS of electric capacitance and of other root parameters (**y** = capacitance)

Experiment No.	Plant	Correlation**	Correlation coeff.	Standard error of r s_r	Significance of r at the significance level [%]	Regression coefficients		Standard deviation of regression		Number of replications n
						b_{yx}	b_{xy}	s_{b_y}	s_{b_x}	
1	Maize	*B*—*A*	0.858	0.110	99.9	46.86	0.016	5.98	0.002	24
		C—*A*	0.853	0.111	99.9	0.59	1.228	0.08	0.160	24
		D—*A*	0.855	0.108	99.9	46.36	0.016	6.00	0.002	24
		E—*A*	0.814	0.123	99.9	93.01	0.007	14.88	0.001	24
2	Sunflower	*B*—*A*	0.957	0.088	99.9	12.37	0.074	1.04	0.006	15
		C—*A*	0.947	0.096	99.9	0.30	3.023	0.03	0.285	15
		D—*A*	0.959	0.088	99.9	12.97	0.071	1.07	0.006	15
3	Sunflower	*B*—*A*	0.832	0.196	99.9	128.53	0.005	30.29	0.001	10
		C—*A*	0.657	0.266	99.0	1.69	0.254	0.69	0.103	10
4	Oats	*B*—*A*	0.752	0.183	99.0	1 193.30	0.001	289.92	0.0001	15
		C—*A*	0.681	0.203	99.0	10.47	0.044	3.12	0.013	15
5	Onion	*B*—*A*	0.752	0.190	99.0	0.10	5.887	0.03	1.490	14
		C—*A*	0.738	0.195	99.0	1.31	0.418	0.34	0.110	14
		F—*A*	0.727	0.198	99.0	1.64	0.322	0.45	0.088	14
6	Rape	*B*—*A*	0.285	0.240						18
		*C**—*A*	0.380	0.231						18

* without radical root

TABLE 2

REGRESSION EQUATIONS OF THE ELECTRIC CAPACITANCE and of other root parameters (y = capacitance)

Experiment No.	Plant	Substrate	Current frequency [Hz]	Regression**	Regression equations	
1	Maize	sand	800	B—A	$y = 128.81 + 46.86\,x$	$x = -1.63 + 0.016\,y$
				C—A	$y = 106.49 + 0.59\,x$	$x = -88.93 + 1.228\,y$
				D—A	$y = 135.85 + 46.36\,x$	$x = -1.79 + 0.016\,y$
				E—A	$y = 149.98 + 93.01\,x$	$x = -0.89 + 0.007\,y$
2	Sunflower	sand	5 000	B—A	$y = 84.41 + 12.37\,x$	$x = -5.74 + 0.074\,y$
				C—A	$y = 81.72 + 0.30\,x$	$x = -218.81 + 3.023\,y$
				D—A	$y = 86.96 + 12.97\,x$	$x = -5.69 + 0.071\,y$
3	Sunflower	clayish soil	5 000	B—A	$y = 100.05 + 128.53\,x$	$x = 0.12 + 0.005\,y$
				C—A	$y = 133.42 + 1.69\,x$	$x = 47.51 + 0.254\,y$
4	Oats	clayish soil	5 000	B—A	$y = 244.72 + 1\,193.3\,x$	$x = 0.013 + 0.0005\,y$
				C—A	$y = 247.40 + 10.47\,x$	$x = 9.45 + 0.044\,y$
5	Onion	sand	1 000	B—A	$y = -38.02 + 0.096\,x$	$x = 693.48 + 5.887\,y$
				C—A	$y = -46.56 + 1.31\,x$	$x = 58.48 + 0.418\,y$
				F—A	$y = -44.76 + 1.64\,x$	$x = 46.10 + 0.322\,y$

**A — electric capacitance of roots [pF]
B — fresh weight of roots [g]
C — dry matter of roots [mg]
D — root volume [ml]
E — root surface according to KOLOSOV [m^2]
F — root surface calculated from their length and diameter [cm^2]

second one was grounded. The accurate C bridge, Tesla BM 400 and the small capacitance bridge, Tesla 354, were employed in the measurements. These two instruments were later supplemented with the impedance bridge, Tesla BM 394 E which also makes possible the measurements of higher values of the tangent line of the loss angle. All measurements were taken at a voltage of 12 V and at a current frequency of 0.8 to 5.0 kHz. As the conductive current in soil was much higher than the displacement one the effect of possible polarization was not taken into account and the measured electric capacitance was considered as the capacitance of the root system.

If it is possible to consider the same thickness of the dielectric layer and the same dielectric constant for plants of the same population which are grown and measured under the same conditions then the recorded capacitance is proportional to the surface of the dielectric layer, *i.e.* to the surface of the roots.

Using the regressive analysis of results (Tab. 1 and 2) a significant relationship between the root surface and recorded electric capacitance ($r = 0.727$ to 0.814) was found. This relationship may be, in the case of maize and onion plants, expanded to the relationship between the capacitancy and the mass (or volume) because of the already described significant correlation between the root surface and the mass (or volume). The same is possible to consider for sunflower and oats plants but not for rape plants whose radical root has a big mass and a small surface. This is apparent from the fact that the removal of the radical root resulted in the increase of the correlation coefficient. This indicates that the described method may be successfully used for these plants.

The significant effect of the substrate in which the plants were grown (99.9%) on the regression coefficients was found for sunflower plants for the relations between fresh weight and capacitance. A smaller effect (90%) on the regression coefficients was found for the relation of dry matter and capacitance. The effect of plant species was tested in the case of sunflower and oat plants grown in clayish soil. The measurements were carried out at the same current frequency 5 kHz. For the relationship between the fresh weight and the capacitance as well as that of dry matter and capacitance, the regression coefficients were significantly dependent on plant species (99 and 98 %, respectively).

The values of the regression coefficients differ significantly in the described experiments. In addition to the shape of the root surface the size of the dielectric constant is most probably responsible for these differences.

The described method may be useful *e.g.* in the selection of plants from the same population grown under the same conditions when the size of the root system is a selection criterion.

Reference

KOLOSOV, I. I.: Poglotitel'naya Deyatel'nost Kornevykh Sistem Rastenii. [Sorption Activity of Plant Root Systems.] — Izdat. Akad. Nauk SSSR, Moskva 1962.