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EMERGENCE AS RELATED TO OXYGEN CONDITIONS OF SOILS

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Introduction

Soil air influences plants directly - through its presence and availability of oxygen and carbon dioxide for plant's roots - and indirectly - through the influence these components upon chemical processes int the soil. The complexity of these influences is the reason why up till now there has not been worked out index measuring the influence of the state of soil aeration on plants.

In most cases the function of the soil air is the same as the function of oxygen indespensible in all the processes of both respiration of the roots of highly organized plants and respiration of microorganisms in the soil.

The availability of soil oxygen for the plant's roots conditions correctness of their metabolic ways which in turn influences the uptake of water and nutritional components. Indirect effects of insufficient oxygenation of the soil are connected with the process of reduction and their products.

The intensity of oxygen diffusion /ODR/ is proposed as an index of oxygen availability for plants' roots better suited for this purpose than the previously used index of the oxygen concentration

in the air.

The redox potential in the soil is the measurement of the state of reduction of the soil, that is of the indirect effects. In the so far conducted studies the development of plants in relation to the direct availability of oxygen expressed as oxygen concentration in the soil air or the intensity of oxygen diffusion used to be in the focus of interest.

Though some species, such as cucumber /19/, can sprout or develop quite well /like for example rice/ without oxygen, most of the plants show a decrease of sprouting abilities at low oxygen concentrations. After ODR as an index of oxygen availability for plants roots has been introduced, there were experiments to use it in studying plants' emergences. Most of plants have a well developed root system already before emergence, and its oxygenation may condition further development of a plant.

Hanks and Thorp /11/ were the first to study winter wheat emergences in soils of differentiated granulometric composition, moisture and compaction. In their studies maximum emergences occured at ODR values above 135 $\mu gm^{-2}s^{-1}$. In the range from 135 to 80 $\mu gm^{-2}s^{-1}$ the number of emergences decreased by about 15 % in relation to the maximum emergence number.

Baver observed that the lack of the sufficient oxygen amount in the soil is probably the greatest limiting factor in the correct development of the plant's root system.

Studies by Erickson and Van Dorem dealt with patatoes, peas and sugar beets.

It was stated that the critical value of ODR for patatoes, i.e. the value at which emergences decline completely, is 42 $\mu gm^{-2}s^{-1}$,

and at the ODR above 100 $\mu gm^{-2}s^{-1}$ emergences were greatest.

Peas do not emerge at all at the ODR equaling 27 $\mu gm^{-2}s^{-1}$, and with increase of ODR up to 115 $\mu gm^{-2}s^{-1}$ the increase in the number of emergences was observed. The same authors wrote about two different reactions on the oxygen conditions in the soil in two different varieties of sugar beets. One of these varieties showed maximum emergences at the ODR of 57 $\mu gm^{-2}s^{-1}$, whereas the other showed a constant increase of the number of emergences with the increase of ODR values up till 70 $\mu gm^{-2}s^{-1}$ which was the highest value attained in that study.

Wengel /22/ stated that corn emergences decreased clearly with the ODR below 32 $\mu gm^{-2}s^{-1}$, reaching 50 % of the maximum number of emergences at the ODR of 17 $\mu gm^{-2}s^{-1}$ and full decline at the ODR of 8 $\mu gm^{-2}s^{-1}$.

All of the reviewed above succesful attemps to use ODR in studying oxygenation of plant's roots at the time of plant's emergence were not confirmed by Kaack and Kristensen's studies /13/. These authors stated that emergence of winter wheat and charlock /Sinapsis alba/ are far better correlated with oxygen concentration in the soil air than with the values of ODR.

Charlock does not emerge when oxygen content was below 2 % and showed consistent increase of emergence with the increase of oxygen concentration up till the maximum concentration of 21 %. Winter wheat emerged even when the oxygen concentration was as low as 0,5 % and showed maximum values already at the concentration of about 10 % of oxygen.

Also Hughes at all /12/ did not find any realtion between the emergences of the two varieties of grass: Cyndon dactylon and Eragrostis

curvula, and ODR in the attained by them range of values from 15 to 150 $\mu gm^{-2}s^{-1}$. They noted, however, that possible critical values of ODR for these plants may be below 15 $\mu gm^{-2}s^{-1}$.

The reviewed studies confirmed in most cases the usefulness of ODR as an index of oxygenation at the time of emergences. Some divergances may be expected when some indirect effects of insufficient oxygenation such as toxicity of the products of anaerobic reduction processes of the soil appear simultaneously or earlier than the effects of the direct anoxia of the roots. Hance, the redox potential of the soil should be also taken into consideration as it shows the state of soil reduction.

Method

The soil material was constituted by samples from the anable layer. The studies were carried out on three soils: 1/ brown soil formed from light loam with 4 % clay, 2/ brown loessial soil with 9 % clay, 3/ grey brown podzalic of sandy texture with 13 % clay.

The experiments were carried out on 9 different plants: winter rye /Secale cereale ssp. Cereale/, winter wheat /Triticum aestivum ssp. vulgare/, spring barley /Hordeum sativum ssp. polistichon/, oat /Avena sativa L./, corn /Zea mays LL. sp. saccharata Korn/, sugar beet /Beta vulgaris sp. esculenta Salish var. saccharifera/, flax /Linum indehiscens Vav. et Ell./, beans /Phaseolus vulgaris L. var. vulgaris/, tomato /Lycopersicon esculentum Mill./.

Ability of germinating of corn was about 75 %, ability of germinating other plants ranges from 94 to 98 %.

The experiments were carried out in the thermostatic room at 22 $\pm$ 2°C in the plexiglass chambers. The oxygen conditions were differentiated by introducing 5 mixtures of air aud nitrogen /21; 15; 5; 3; 0,5 % of oxygen/ and 3 soil suction levels /10, 50, 100 hPa/.

The experiment was conducted for 8 days, making 3 runs with each plant. During experiments the measurements of ODR and E_h were carried out every day as well as the number of emerged plants was recorded. For 8 plants the experiments were performed 8 days, while in case of corn - 11 days.

For interpretation of the results an average value of 32 measurements of ODR and E_h /i.e 8 measurements x 4 pots in each combination/ was taken.

Results

In the present studies the so called final emergence of plants, i.e. the number of plants that emerged on the last day of the experiment, was measured. To compare effectivness of the three studied indices of soil oxygenation /i.e. oxygen cocentration, ODR, E_h/, the plots of relation between final emergence of plants and values of individual studied indices were drawn. Example of these can be seen on fig. 1-3.

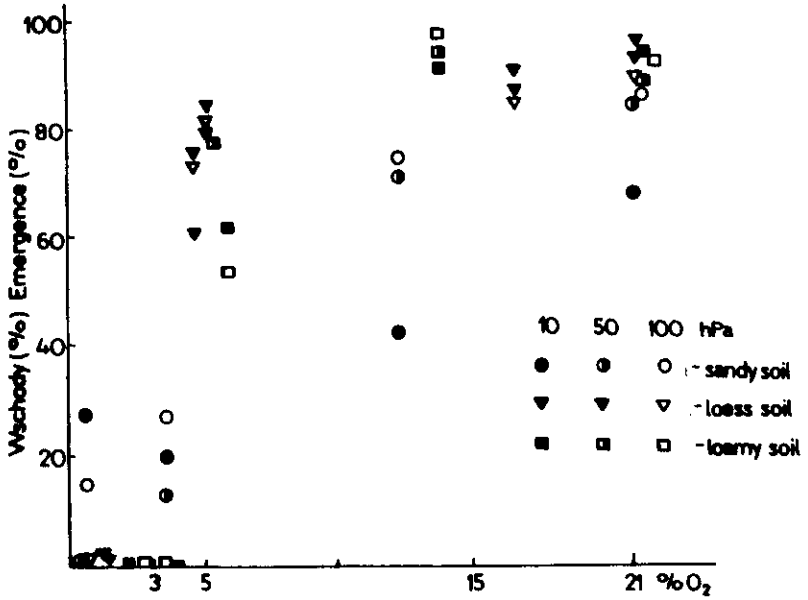

Fig. 1. Dependence of final emergence of oats on oxygen concentration in soil air. $L_{0,05}$ = 16 %

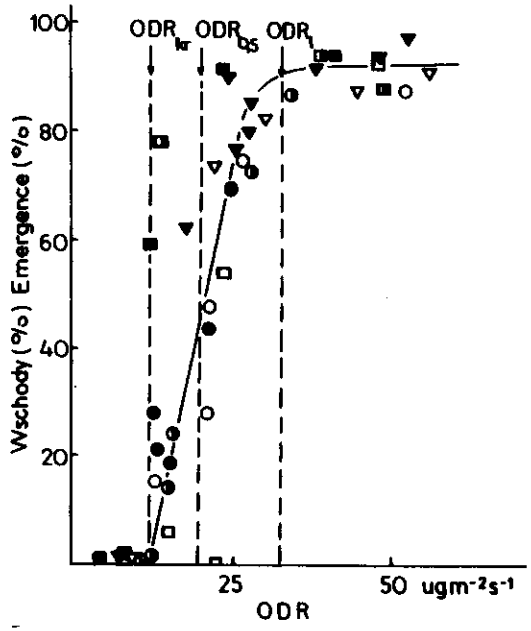

Fig. 2. Final emergence of oats versus ODR explanations as in Fig. 1.

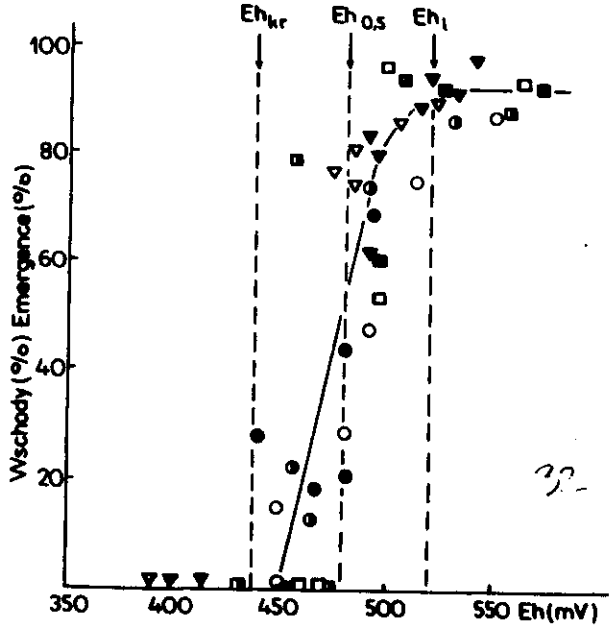

Fig. 3. Relationship between final emergence of oats and E_h eksplanations as in Fig. 1.

The results were elaborated separately for each plant by means of variance analysis for the threefold cross classification. The above mentioned analisys showed that beside oxygen, all of the main factors such as soil moisture and type have influence on studied plants, together with all the threefold interactions and most of the twofold interaction between these factors.

To compare final emergences of plants and to confirm the importance of their differen-tiation in realtion to oxygen concentration, ODR and E_h only Tukey's half-intervals of confidence were used. It is obvious that the very fact of the importance of soil moisture and type eliminates oxygen concentration as an effective index of soil oxygenation. It is clearly shown in Fig. 1. where the values of final emergence of oat though showing a rising tendency with the increase of oxygen concentration are at the same time considerably scattered at a given oxygen concantraction value. The scattering is greater than the values of the half-interval of confidence for oat, i.e. 16 % at P = 0,05 /for the threefold interaction: oxygen concentration x soil x suction pressure/.

These relations in case of other studied plants are of similar character, and the scattering surpasses values of respective half--intervals of confidence in all cases.

The realtions between final emergences of oat and ODR /Fig. 2/ and E_h /Fig. 3/ are typical for all the studied plants.

Starting from the highest values of ODR and E_h a flat segment can be observed at the begining where differentiation of emergences is not significant /does not surpass the half-interval of confidence for the threefold interaction equaling 16 %/. Then after going beyond the so-called threshold value causing a considerable decrease of final emergences in relation to sprouting ability, a rapid decrease

of the number of final emergences with the decrease of the ODR and E_h values is observed, till the complete decline of emergences with the so-called critical value kr which makes any emergences impossible.

Between the critical and threshold values there is the so-called value of half emergences /0,5/, i.e. the values at which emergences reach the value of half of the ability for sprouting. For oat these values are the following:

ODR_1 - 30, $ODR_{0,5}$ - 20, ODR_{kr} - 12 $\mu g m^{-2} s^{-1}$

Eh_1 - 520, $Eh_{0,5}$ - 480, Eh_{kr} - 440 m V

The results for the other studied plants are given in table 1.

Threshold ODR and Eh values for the plants studied

Plant	ODR_1	$ODR_{0,5}$	ODR_{kr}	Eh_1	$Eh_{0,5}$	Eh_{kr}
Barley	25	17	8	400	380	370
Oats	30	20	12	520	480	440
Bean	33	25	12	510	ca 450	360
Wheat	40	-	8	460	ca 390	370
Flax	40	25	13	-	-	430
Maize	40	27	16	400	ca 370	340
Tomato	40	30	25	520	470	450
Sugar beet	50[x]	30[x]	13	-	-	400
Rye	50	33	12	540	480	430

Indices: 1; 0,5; and kr denote limiting, half emergence, and critical values, respectivity

[x] Values sufficient for emergence, but not further survival of the plants

Summary

The so far conducted experiments of the influence of soil oxygenation on plants emergence showed that oxygen concentration is of little value as an index of oxygen availiability for these plants' roots in the period of their emergence. But they confirmed the effectiveness of ODR and Eh and ODR proved to be more precise. In most of the cases the relation between final emergence and ODR showed a smaller scater than the realtion between ODR and these emergence.

The derermined values of ODR and Eh for the plants' appearanoes showed a significant differentiation of plants' demands as for oxygen: critical values of ODR ranged from 8 to 25 $\mu gm^{-2}s^{-1}$, $ODR_{0,5}$ - from 17 to 33 $\mu gm^{-2}s^{-1}$, ODR_1 - from 25 to 50 $\mu gm^{-2}s^{-1}$.

On the basis of the values of ODR_1 and $ODR_{0,5}$ we can rank the studied plants acaording to their sensitivity to the lack of oxygen at the time of emergences in the following way: barley, oats, been, wheat, flax, corn, tomato, sugar beet, rye.

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