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INFLUENCE OF SOIL OXYGEN AVAILABILITY ON DRY MATTER AND MINERAL COMPOSITION OF SOYBEAN AND WINTER RYE ROOTS

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S y n o p s i s. The changes of the N, P, K, Ca, Mg and Na content in the roots of winter rye and soybean subjected to oxygen stresses for the period of 2 weeks during 3 stages of their development have been examined.

I. INTRODUCTION

The root system is that part of the plant which directly suffers from the shortage of oxygen in soil and the changes of its functioning effect the whole plant. This is expressed by the change of the uptake of mineral elements, transpiration and dry matter production [3].

The changes of mineral content of roots under the conditions of oxygen shortage have been presented in the reviews of Gliński and Stępniewski [3, 4]. What follows from those reviews is that an increase of nitrogen content was observed in the roots of jojoba and a decrease in the roots of oranges, apple trees, barley and ban. In some experiments with the roots of lemon and avocado an increase of nitrogen content was noticed, and a decrease in the others. As phosphorus is concerned the decrease of its content was observed in the case of jojoba, lemon, orange and peas but in some experiments no significant changes were observed (lemon, avocado). The content of potassium decreased in all experiments and these concerned lemon, orange, avocado, apple trees, barley and bean. In the case of calcium an increase of content was noticed in the roots of avocado and a decrease of it in the apple trees, lemon and orange. The content of magnesium decreased in jojoba, avocado and in some experiments in lemon roots. Sodium decreased in the roots of jojoba which were subjected to the oxygen stress and increased in lemon. In the roots of avocado an increase was noticed in one experiment and a decrease in another. As far as other elements are concerned an increase manganese content was noticed (lemon, orange, jojoba) and the decrease of chlorine (lemon, orange, avocado and barley). On the other hand the content of iron decreased in jojoba increased in lemon and orange, while the content of copper increased in the roots of orange, and for lemon it increase in some experiments and decreased in others.

The diversification of the changes in the content of mineral elements in different species and even within the same species, suggest that those changes are conditioned not only in the soil but also in the plants. There is also a posibility of the influence of plant development stage. The aim of this paper was to investigate the changes of the N, P, K, Ca, Mg, Na content in the roots of winter rye (Secale cereale c.v. Dańkowskie Nowe) and soybean (Glycine hispida Max c,v, Progres) subjected to oxygen stresses for the period of 2 weeks during three stages of their development.

2. MATERIALS AND METHOD

The whole experiments comprised 6 cycles carried out in the foil tunnel in 1982-1985. The brown soil formed from loess taken from the plough layer of the cultivated field in Elizówka n. Lublin was used in the experiment.

The oxygen conditions in the soil were differentiated by means of two basic physical parameters, varying in the field conditions, i.e. moisture and soil density. The following bulk density were used: 1.20; 1.35; 1.50 $Mg \cdot m^{-3}$. The range of control moisture (suction 15-80 kPa) and the compaction was chosen in such a way that to avoid the problem of the influence of soil strength on the root penetration in the range of the water optimum and to differentiate oxygen availability without going out beyond the expected optimum range. In this way, after introducing for the period of oxygen stress two levels of increased moisture, six additional levels of oxygenation were obtained in the range of expected oxygen deficiency for the plants.

Each experimental cycle comprised 84 pots of the capacity 6 dm^3 in which 6.5 kg of soil (calculated on absolutely dry basis) was placed.

Until the initiation of oxygen stresses the same moisture range 0.14-0.18 kg x x kg^{-1} corresponding to soil moisture tension 80-15 kPa was maintained. In order to differentiate oxygenation conditions in the period of 15 days oxygen stress and what follows to differentiate oxygen availability apart from control moisture two different soil moisture treatments were applied i.e.; intermediate moisture corresponding to soil suction 2-5 kPa and surface flooding (suction 0 kPa) where 2-3 mm water layer was maintained on the soil surface. Thus 9 levels of soil oxygenation were obtained which have been characterized by the measurement of oxygen diffusion rate (ODR) according the modified method of Gawlik et al. [2] using the device with automatic control of the effective voltage [6]. The polarization voltage was -0.65 V versus saturated calomel electrode, and the time of polarization was 4 minutes. The measurements were performed twice during each stress using 8 electrodes in each pot (each ODR value is a mean of 32 single measurements. Rye was subjected to oxygen stress in the following development stages: I - the stage of 1-2 leaves (12 day old plants, stage 1-2 acc. to Feekes [5], II - stem elongation (6-7 acc. to Feekes), III - ear emergence (stage 10-10.54 acc. to Feekes). In the case of soybean the oxygen stresses were applied in the floowing development stages: I - flowering stage, II - pod formation, III - pod filling and ripening. This corresponds to the developing stages R_1, R_4, R_5, R_6 according to Fehr et al. [1] for the first, second and third stress, respectively. The plants of soybean and rye were collected reaching full ripeness. The roots were washed out of the soil with a light stream of water on the sieve (1 mm). The mass of the roots was measured and the mineral content and the uptake of N, P, K, Ca, and Na per pot was calculated. The mineral content of plants was determined after mineralization in H_2SO_4 with H_2O_2 added. Nitrogen was determined by potentiometric titration with the use NaOBr, P - by vanado-molybdenate method, K, Ca, Na - by flame photometry and Mg - by ASA in 0.3% solution of $LaCl_3$.

3. RESULTS

The dependence of the dry mass of roots of both plants studied on ODR is shown in Figure 1. As can be seen, in all three years of the studies a significant decrease of root mass of winter rye at ODR below 25 $\mu g \cdot m^{-2} \cdot s^{-1}$ occurred. The decrease was not clearly connected with the plant development stage at which the stress was applied. The lowest values were within 30% of the control values. As the root mass of soybean is concerned the oxygen stresses applied at the stage of flowering and later did not cause significant changes. In the case of significant curvlinear correlation between root mass and ODR a respective equation of regression was added to the figure together with the coefficient of the correlation. Where the differentiation, studied by means of variance analysis, was significant the value of least significant difference (LSD) was put on the diagram at P = = 0.05 (according to Tukey).

The results corresponding to mineral content and the uptake of mineral elements have been presented in the form of diagram (as a function of ODR) only in those cases where a significant dependence on this index was found. The differentiation exceeding the value of LSD was accepted as a criterion of significance.

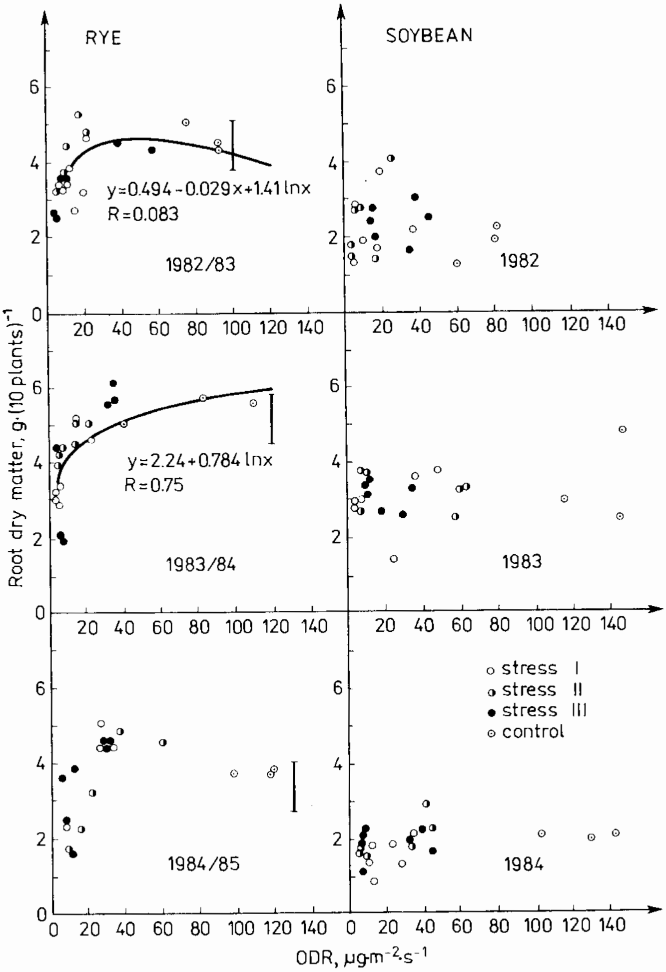

Fig. 1. Dependence of dry matter of the roots of winter rye and soybean on ODR in consecutive years of the experiment. The vertical bars on the diagrams denote LSD acc. to Tukey at p - 0.05 calculated jointly for 3 years of studies

Fig. 1. Relation entre la matière sèche de racines du seigle d'hiver et du soya et ODR au cours des années d'etudes particulières. Les segments verticaux aux diagremmes designet PDS d'après Tukey p - 0.05 calculé pour 3 ans d'essais, pris ensemble

When no significant influence of ODR on the content or uptake of an element was noticed we did not present the detailed data. In these cases only general values of the content of each elements are provided. They were: 1.06% N; 0.221% P; 0.872% K; 1.36% Ca; 0.133% Mg and 0.130% Na for the roots of winter rye and 1.40% N; 0.175%P; 0.497% K; 1.95% Ca; 0.178% Mg and 0.155% Na for the roots of soybean.

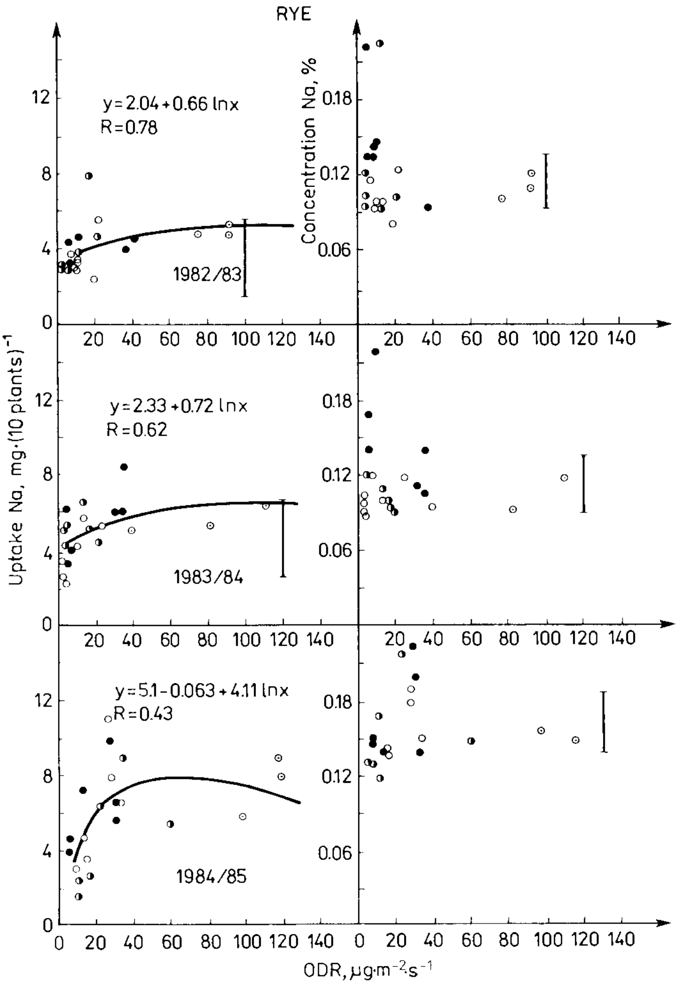

Fig. 2. Dependence of the content and uptake of sodium by the roots of winter rye on ODR (descriptions as in Fig. 1)

Fig. 2. Relation entre la teneur des racines en sodium et son absorption par les racines du seigle d'hiver et ODR (description cf. Fig. 1)

The change of the content and uptake of sodium is shown in Figure 2. As follows from the data presented the content of this element increased, especially under the influence of the third stress in the first and the second year of the research at ODR below 20 $\mu g \cdot m^{-2} \cdot s^{-1}$ and in the third year the maximum content was observed at ODR between 20-40 $\mu g\ m^{-2} \cdot s^{-1}$. However, the uptake of sodium decreased considerably at ODR below 25 $\mu g\ m^{-2} \cdot s^{-1}$.

As far as the uptake of nitrogen and phosphorus is concerned for winter rye (Fig. 3) it decreased in all three experiments at ODR below 30 $\mu g \cdot m^{-2} \cdot s^{-1}$. The minimum values of the uptake vary within the limit of 30% of control values. It should be stressed that no visible influence of the time of the stress was

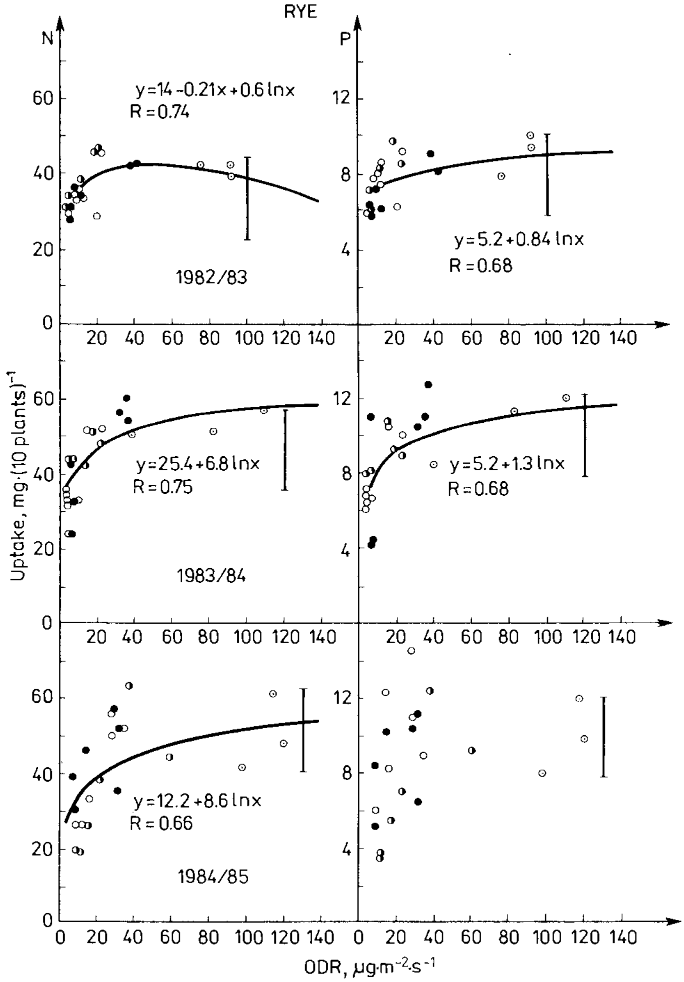

Fig. 3. Dependence of the uptake of nitrogen and phosphorus by the roots of winter rye on ODR (descriptions as in Fig. 1)

Fig. 3. Relation entre le prélèvement de l'azote et du phosphore par les racines du seigle d'hiver et ODR (description cf. fig. 1)

noticed because the points refering to all the three stresses decreased. Also the minimum values reffer to different stresses in each year. On Figure 4, the uptake of K and Ca by the roots of winter rye is shown. What follows from the data is that the uptake of K and Ca decreased in all years of the experiment at ODR below μg·m^{-2}·s^{-1}. The content of K and Na in the roots of soybean (Fig. 5) incerased at ODR below 20 μg·m^{-2}·s^{-1}.

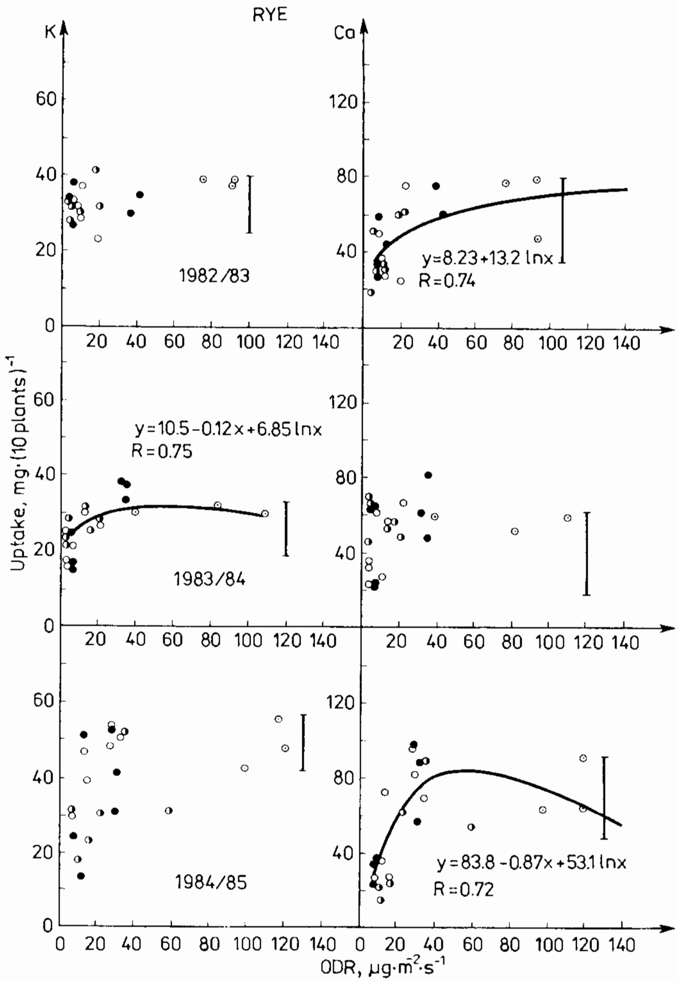

Fig. 4. Dependence of the uptake of potassium and calcium by the roots of winter rye on ODR (descriptions as in Fig. 1)

Fug. 4. Relation entre le prélèvement du potassium et du calcium par les racines du seigle d'hiver et ODR (description cf. fig. 1)

CONCLUSIONS

1. The hypoxia of the winter rye roots for a period of two weeks (2-3 leaves stem elongation and ear emergence stages) casued a decrease of the dry mass in the stage of full maturity (up to 30%) additionally it caused an increase of the content of Na and the decrease of the uptake of N, P, Na, K and Ca. Those changes were usually observed at ODR below 20-30 $\mu g \cdot m^{-2} \cdot s^{-1}$.

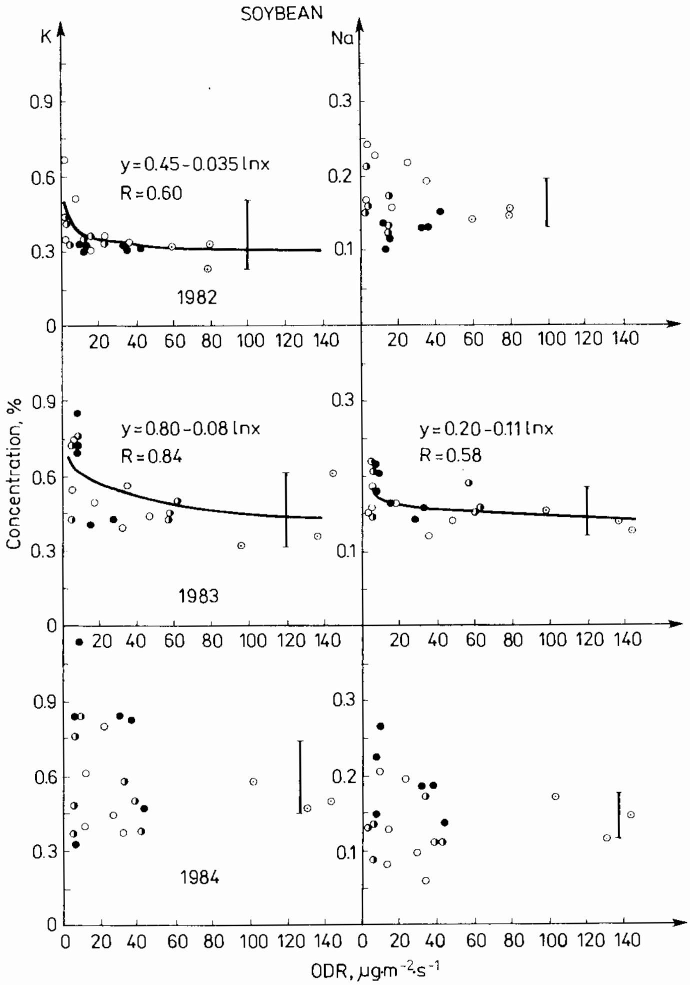

Fig. 5. Dependence of the content of potassium and sodium in the roots of soybean on ODR (descriptions as in Fig. 1)

Fig. 5. Relation entre la teneur des racines de soya en potassium et sodium et ODR (description cf. fig. 1)

2. Similar oxygen stresses in the case of soybean (flowering stage, pod formation and pod filling and ripening stage) caused only an increased of K and Na content at ODR $< 20\ \mu g \cdot m^{-2} \cdot s^{-1}$.

REFERENCES

1. Fehr W. R., Cariness C. E., Burmood D. T., Pennington J. S.: Stages of development descriptions for soybeans (Glycine Max.) Mem. Crop Sci. Agr. J., 11, 926, 1979.

2. Gawlik J., Malicki M., Stępniewski W.: The problem of effective voltage control in measurements of ODR in soil. Polish J. Soil Sci., 1, 7, 1971.
3. Gliński J., Stępniewski W.: Soil Aeration and its Role for Plants. CRC Press. Inc., Boca Raton, Florida, USA, 1985.
4. Gliński J., Stępniewski W.: Influence of oxygen supply on root growth and function. Zesz. Probl. Post. Nauk Rol., 385, 7, 1990.
5. Large E. C.: Growth stages in cereals. Illustrations of the Feekes scale. Plant Pathol., 3, 391, 1954.
6. Malicki M., Walczak R.: A gauge of the redox potential and the oxygen diffusion rate in the soil with an automatic regulation of cathode potential. Zesz. Prob. Post. Nauk Rol., 220, 457, 1983.

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EFFET DES CONDITIONS D'OXYGÈNE DANS LE SOL SUR LA MASSE ET LA COMPOSITION MINÉRALE DES RACINES DU SOYA ET DU SEIGLE D'HIVER

R é s u m é

L'objectif de ce travail a été d'étudièr l'effet des conditions d'oxygène, en trois phases de développement du seigle d'hiver (Secale cereale c.v. Dańkowskie Nowe) et du soya (Glicyne hispida Max. c.v. Progres) sur la masse des racines et la teneur en N, P, K, Ca, Mg et Na.

L'expérience a enfermé 6 cycles d'etudes, effectuées dans les essais en vases, au cours des années 1982-1985. Dans chaque cycle d'essais on s'est servi de 84 vases de 6 dm^3 dont chacun contenait 6,5 kg de sol brun formé du loess. Les conditions d'oxygène du sol ont été modifiées à l'aide de deux facteurs physiques fondamentaux, changeants au champ, c'est-à-dire l'humidité et la compacité du sol. On a appliqué le compactage 1,2; 1,35 et 1,50 $Mg \cdot m^{-3}$. Outre l'humidité témoin au niveau de 80-15 kPa, on a appliqué l'humidité du sol qui correspondait à la succion 2-5 et 0 kPa. Le seigle a été soumis au stress d'oxygène dans les phases suivantes du développement: 1) phase de 1-2^e feuille (plantes de 12 jours), 2) phase de montaison, 3) phase d'épiaison. Dans le cas du soya, les stress d'oxygène ont été appliqués dans les phases suivantes: 1) phase de floraison, 2) phase de formation des casses, 3) phase de développement des cosses et de mûrissement des semences. Pour les mesures ODR on s'est servi des électrodes en platine, le temps de polarisation de l'électrode 4 min. et la tension -0,65 V. Le déficit d'oxygène pour les racines du seigle d'hiver, pendant la période de deux semaines, a entraîné la diminution de la masse sèche de racines à maturité pleine (jusqu'à 30 %). l'augmentation de la teneur en Na et la diminution du prélèvement de N, P, K, Na et Ca. Ces changements ont été observés à ODR au-dessous de 20-30 $\mu g \cdot m^{-2} \cdot s^{-1}$. Dans le cas de soya, ces stress hydriques n'entraînaient que l'augmentation de la teneur en K et Na a ODR < 20 $\mu g \cdot m^{-2} \cdot s^{-1}$.

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WPŁYW WARUNKÓW TLENOWYCH W GLEBIE NA MASĘ I SKŁAD MINERALNY KORZENI SOI I ŻYTA OZIMEGO

S t r e s z c z e n i e

Celem pracy było zbadanie wpływu warunków tlenowych w glebie w trzech fazach rozwojowych żyta ozimego (Secale cereale c.v. Dańkowskie Nowe) i soi (Glycine hispida Max.c.v. Progres) na masę korzeni i zawartość N, P, K, Ca, Mg i Na.

Całość eksperymentu obejmowała 6 cykli badawczych przeprowadzonych w doświadczeniu wazonowym w latach 1982-1985. Każdy cykl doświadczalny obejmował 84 wazony o poj. 6 dm^3, w których umieszczono po 6,5 kg gleby brunatnej wytworzonej z lessu. Warunki tlenowe w glebie różnicowano za pomocą dwóch podstawowych czynników fizycznych zmieniających się w warunkach polowych, tj. uwilgotnienia i zagęszczenia gleby. Stosowano zagęszczenia 1,2; 1,35 i 1,50 $Mg \cdot m^{-3}$. Oprócz wilgotności kontrolnej na poziomie 80-15 kPa, stosowano uwilgotnienie gleby odpowiadające ciśnieniu ssącemu 2-5 i 0 kPa. Żyto poddawane było stresom tlenowym w następujących fazach rozwojowych; I - faza 1-2 listka (12-dniowe rośliny), II - faza strzelania w źdźbło, III - faza kłoszenia. W przypadku soi stosowano stresy tlenowe w fazach rozwojowych: I - faza kwitnienia roślin, II - faza tworzenia się strąków, III - faza wypełniania się strąków i dojrzewania nasion. Do pomiarów ODR używano elektrod platynowych, czas polaryzacji elektrody wynosił 4 min., a napięcie -0,65 V.

Niedotlenienie korzeni żyta ozimego przez okres dwu tygodni powodowało zmniejszenie suchej masy korzeni w stanie dojrzałości pełnej (do 30%), wzrost zawartości Na oraz zmniejszenie pobrania N, P, K, Na i Ca. Zmiany te obserwowano zazwyczaj przy ODR poniżej 20-30 $\mu g \cdot m^{-2} \cdot s^{-1}$. Podobne stresy tlenowe u soi powodowały jedynie podwyższenie zawartości K i Na przy ODR < 20 $\mu g \cdot m^{-2} \cdot s^{-1}$.