

INFLUENCE OF POTASSIUM DEFICIENCY IN A MEDIUM ON THE PHYSIOLOGICAL REACTION OF SEEDLINGS OF NEW RYE LINES

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Abstract

A hydroponic experiment has been conducted to determine the physiological and biochemical response of four new rye lines – S120, S76, OT1-3 and 541 – bred at the Department of Plant Genetics and Breeding, Agricultural University in Szczecin. Seeds were sown into soil and placed into a phytotron chamber with controlled atmosphere and photoperiod. The relative humidity was 80%, the temperature maintained at 20°C and the intensity of photosynthetically active radiation (Phar) was 700 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. Seed germination occurred after about 5 days. The seeds were characterised by different germination ability: 80% for S120, 100% for S76, 82% in OT1, and just 50% for 541 line. Rye seedlings, at the 2-3 leaf stage, were placed in hydroponic units and a two-factor experiment was set up, with potassium deficiency being the first factor and rye lines the second one. The control variant consisted of seedlings placed on complete Hoagland's medium, while potassium starvation was performed on a medium with 50% deficiency of this element. After seven days, fresh matter was weighed, proline content was measured according to the BATES method (1973) and amounts assimilation pigments were measured according to the method of ARNON et al. (1956). The results were processed statistically, performing a two-factor analysis of variance, while the significance of factors was tested using Tukey's test at $\alpha = 0.05$.

The study aimed at examining selected physiological and biochemical indicators of the resistance response of four rye lines to stress induced by potassium deficiency.

Application of 50% potassium deficiency in a medium induced an increase in the content of assimilation pigments in leaf fresh matter of S120 rye line. A correlation was found between proline content and that of assimilation pigments. The largest proline quantity, 27.2 $\mu\text{g}\cdot\text{g}^{-1}$ f.m., was found in 541 rye line seedlings, but its content decreased together with fresh matter yield. It was also found that the total chlorophyll content was directly

proportional to the content of proline in S120, S76 and OT1-3 rye lines, whereas in the case of other pigments such a relationship existed only for S 120 and S76 rye lines.

Key words: rye lines, assimilation pigments, proline, fresh matter

WPLYW NIEDOBORU POTASU NA REAKCJĘ FIZJOLOGICZNĄ SIEWEK NOWYCH LINII ŻYTA

Abstrakt

Celem doświadczenia było zbadanie reakcji fizjologicznej i biochemicznej 4 nowych linii żyta: S120, S76, OT1-3, 541, wyhodowanych w Katedrze Genetyki i Hodowli Roślin Akademii Rolniczej w Szczecinie. Nasiona wysiano do gleby i umieszczono w fitotronie z kontrolowaną atmosferą i fotoperiodem. Wilgotność względna wynosiła 80%, temperatura 20°C, a natężenie promieniowania fotosyntetycznie czynnego $\text{Phar} = 700 \mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$. Kiełkowanie nasion nastąpiło po ok. 5 dniach. Nasiona charakteryzowały się różną zdolnością kiełkowania: S120 – 80%, S76 – 100% OT1 – 82%, 541 – 50%. W hydroponikach umieszczono siewki żyta w fazie 2-3 liści i założono doświadczenie dwuczynnikowe. Pierwszym czynnikiem był niedobór potasu, drugim – linie żyta. Obiektami kontrolnymi były siewki umieszczone w pożywce pełnej Hoaglanda oraz głodzone potasem (pożywka z 50% niedoborem tego pierwiastka). Po 7 dniach oznaczono świeżą masę (wagowo), zawartość proliny metodą BATESA (1973), zawartość barwników asymilacyjnych metodą ARNONA i in. (1956). Wyniki opracowano statystycznie wykonując dwuczynnikową analizę wariancji, a istotność czynników testowano testem Tukeya na poziomie $\alpha = 0,05$.

Wykazano, że niedobór potasu w pożywce spowodował wzrost zawartości barwników asymilacyjnych w świeżej masie liści żyta linii S120. Stwierdzono zależność między zawartością proliny a zawartością barwników asymilacyjnych. Największą ilość proliny (27,2 $\mu\text{g} \cdot \text{g}^{-1}$ ś.m.) stwierdzono w siewkach linii 541, jednak jej zawartość malała wraz z plonem świeżej masy. Zawartość chlorofilu całkowitego była wprost proporcjonalna do zawartości proliny (S120, S76, OT1-3), natomiast pozostałych barwników tylko w przypadku linii S 120 i S76.

Słowa kluczowe: linie żyta, barwniki asymilacyjne, prolina, świeża masa, sucha masa.

INTRODUCTION

Soils contain large resources of potassium, up to 50 t·ha⁻¹ in a horizon to 20 cm depth, but potassium available to plants makes up only 1% of its total content. Particular cereal species show different ability to take up this chemical element from soil, with the highest activity observed in oats (100%); this activity in rye is 85% (CZUBA 1998). JAROCIŃSKI (2005) claims that cereals are vulnerable to potassium deficiency; even a moderate deficit of potassium in plant, visually hidden, manifests itself in increased transpiration, loss of turgor, accelerated wilting, decreased assimilation of CO₂ and retarded growth rate and in susceptibility to bacterial and fungal diseases. Deficit of chemical elements, including potassium, in a plant is a stress factor, which, according to some authors (BANDURSKA 1991, CLAUSSEN 2002), initiates the synthesis of proline, an amino acid which is increasingly more often used for

determining the stress level. BANDURSKA (1991) and HAWRYLAK (2007) suggest that this amino acid can fulfil a function of an adaptive metabolite, although there is no simple answer to clarify the relationships between proline accumulation and plant resistance to stress. However, it should be emphasised that proline accumulation under conditions of prolonged stress is a result of irreversible and unfavourable changes such as protein or chlorophyll decomposition and can be a symptom of injuries (BANDURSKA 2005, 2008).

This study aimed at examining selected physiological and biochemical indicators of the immune response of four rye lines to stress induced by potassium deficit.

MATERIAL AND METHODS

In order to determine the physiological and biochemical response of four new rye lines, S120, S76, OT1-3 and 541, grown at the Department of Plant Genetics and Breeding of the Agricultural University in Szczecin, a hydroponic experiment was set up. Seeds were sowed into soil and placed in a phytotrone with controlled atmosphere and photoperiod. The relative humidity and temperature were, respectively, 80% and 20°C, while the intensity of photosynthetically active radiation Phar was $700 \mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$. Seed germination took place after about 5 days. Seeds were characterised by different germination ability, i.e. 80% for line S120, 100% for line S76, 82% for line OT1, and only 50% for line 541.

Rye seedlings were placed in hydroponic units in the 2-3 leaf stage according to a two-factor experimental design. Seedlings in Hoagland's complete medium were a control variant, while the second factor consisted of potassium-starved seedlings placed in a medium where potassium was in deficit amounts (50% of the recommended dose).

After seven days the following were determined: fresh matter yield (by weighing), proline content by the method of BATES et al. (1973) and assimilation pigment content by the method of ARNON et al. (1956). The experiment was carried out in four series and six replications.

The results were processed statistically performing a two-factor analysis of variance, while significance of factors was tested with Tukey's test at $\alpha = 0.05$ and correlations were examined between the proline content and the other analysed parameters.

RESULTS AND DISCUSSION

Potassium plays an important role in water economy of plants and activation of enzymes. It also contributes to increasing the resistance of plants to frost. Under conditions of the growing deficiency of this component, chloroses of older leaves can occur (GRZEBISZ a,b 2004). The effect of potassium deficiency on the amount of assimilation pigments, proline and fresh matter yield in four rye lines is presented in Table 1 as major effects. As far as the significance of interactions is concerned, the results are presented in Figure 1. In Table 2 are the relationships between the proline content and the content of respective pigments in the four rye lines.

Table 1

Mean content of fresh matter, assimilation pigments and proline in four rye lines

Rye lines	Fresh matter (g)	Dry matter (g)	Proline ($\mu\text{g}\cdot\text{g}^{-1}$ f.m.)	Assimilation pigments ($\mu\text{g}\cdot\text{g}^{-1}$ f.m.)			
				chlorophyll a+b	chlorophyll a	chlorophyll b	carotenoids
S120	0.242	0.036	5.0	1950	1372	577	542
S76	0.288	0.039	9.3	1305	908	396	383
OT1-3	0.184	0.021	11.6	1017	824	358	342
541	0.135	0.016	27.2	1219	882	336	392
LSD _{0.05} (I)	0.094	0.015	7.00	500	253	123	98
Control deficiency of K	0.221	0.034	13.4	1149	863	369	365
	0.203	0.032	11.3	1595	1131	465	464
LSD _{0.05} (II)	n.s.d	n.s.d	n.s.d	263	132	64	51
LSD _{0.05} (IxII)	n.s.d	n.s.d	n.s.d	860.1	431.0	209.8	167.6

n.s.d. – non-significant differences

Many authors (HERNANDEZ et al. 2000, CHEN LI 2002, SONG et al. 2005) suggest that accumulation of free proline is an indicator of stress intensity as well as a factor that decides about an organism's repair abilities. In general, it is larger in plants that are characterised by larger resistance to stress.

Based on the results of analysis of variance, significant differences were found between the fresh matter content in the rye lines examined. Its largest yield was found in lines S76 and S120, whereas the smallest one in line 541 (Table 1). However, no significant differences were observed between the mean fresh matter content in the control variant and after application of the stress factor. Significant differences were also found between the mean

Table 1

Correlations between proline content and fresh matter yield and assimilation pigments content

Character	Character	Line S120	Line S76	Line OT1-3	Line 541
Proline	fresh matter	-0.28	-0.72*	-0.12	-0.81*
	dry matter	0.32	0.45	0.36	0.53
	chlorophyll a +b	0.84*	0.96*	0.89*	0.32
	chlorophyll a	0.84*	0.95*	0.52	0.24
	chlorophyll b	0.85*	0.90*	-0.10	0.49
	carotenoids	0.87*	0.91*	0.30	0.06

* significant

proline content in the rye lines. Line 541 was characterised by the largest content of this osmoregulator, i.e. $27.16 \mu\text{g} \cdot \text{g}^{-1}$ f.m. (Table 1). In the other three rye cultivars [lines], the content of proline in leaves was considerably smaller: $11.58 \mu\text{g} \cdot \text{g}^{-1}$ f.m. in line OT1-3, $9.289 \mu\text{g} \cdot \text{g}^{-1}$ f.m. in line S76 and $5.055 \mu\text{g} \cdot \text{g}^{-1}$ f.m. in line S120 (Table 1). Also BANDURSKA (2001) found significant differences in the content of proline in leaves in four barley cultivars. These results are the evidence that the proline level in these lines is an individual trait. Similar results in cereal plants were found by BANDURSKA (2008) and NAYYAR, WALIA (2003). On the other hand, no differences were found in the mean proline content between the control and potassium-starved seedlings, which is verified by the results of other studies (BRAY et al. 1991, LEI et al. 2006), although BANDURSKA (2001) found that more proline was accumulated in leaves of plants which grew under a high potassium level. It is assumed that the role of potassium consists here in stimulating the activity of arginase, which catalyses conversion of arginine to proline (HERNANDEZ et al. 2000).

Potassium deficiency contributed only slightly to degradation of assimilation pigments (Table 1, Figure 1) in line S76, which points to a small resistance of this line to deficit of this chemical element in soil. On the other hand, S120 was characterised by the significantly largest content of assimilation pigments, with their concentration increasing after application of potassium in a dose smaller by 50% than the recommended one.

The relationships between the proline concentration and the yield of fresh matter and the content of assimilation pigments were also analysed in the study (Table 1). In the case of lines S 76 and 541, the proline concentration was positively correlated with the fresh matter yield. In lines S120 and S76, the content of assimilation pigments was directly proportional to the proline concentration. Similar results were obtained by GADALLAH (1999), who examined the influence of water stress on *Vicia faba*. He found that the contents of chlorophyll a and b enlarged with an increase in the proline content.

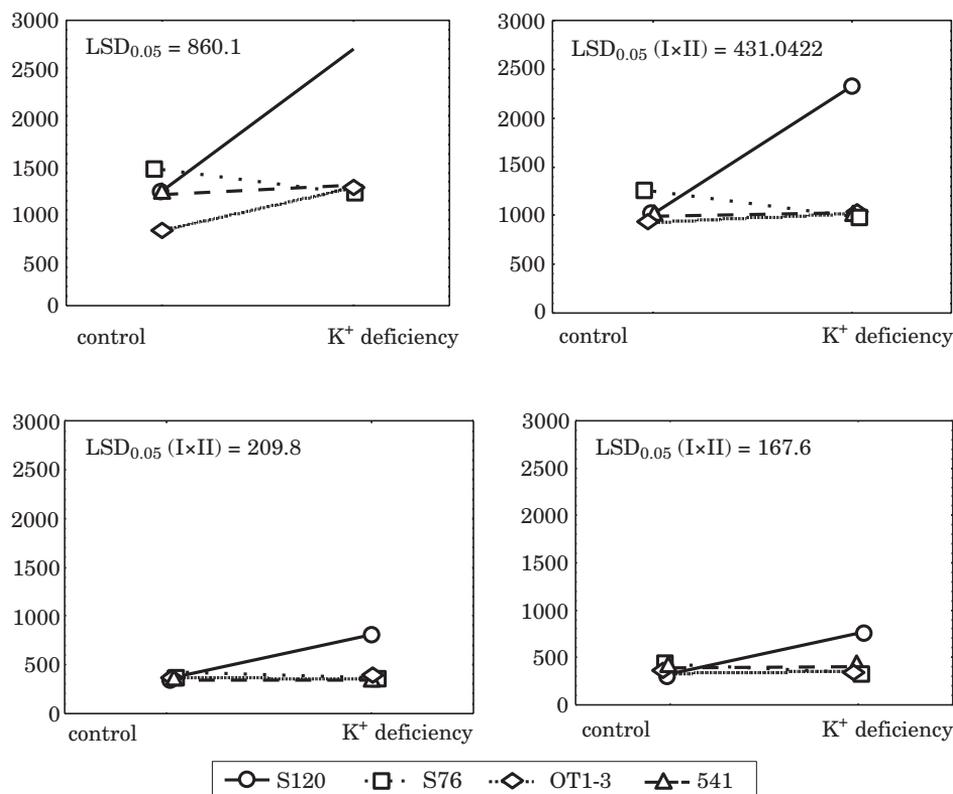


Fig. 1. Effect of potassium deficiency on assimilation pigments content

CONCLUSIONS

1. Potassium deficiency in a medium induced an increase in the content of assimilation pigments in fresh matter in rye line S120. It was also found that increase in the content of assimilation pigments occurred with a simultaneous increase of the proline content in leaf fresh matter.

2. The largest amount of proline was found in line 541 seedlings, i.e. $27.2 \mu\text{g}\cdot\text{g}^{-1}$ f.m.; moreover, the content of proline in this line and in line S-76 increased with a simultaneous decrease in the yield of fresh matter in seedlings.

3. Line S76 proved to be most vulnerable to potassium deficiency in medium; the effect of the stress factor induced a clear decrease in the contents of assimilation pigments and of fresh matter.

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