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Effect of Simulated Drought on Stomatal Conductance, Transpiration and Growth of Polish Soybean Cultivars

Wpływ symulowanej suszy na przewodność szparkową, transpirację i wzrost soi odmian polskich

Abstract: The objective of the experiment was to determine response to simulated drought of 7 Polish soybean cultivars ('Aldana', 'Jutro', 'Polan', 'Progres', 'Mazowia', 'Gaj', 'Nawiko'). The plants were placed in 15% solution of polyethylene glycol (PEG 20000) in Hoagland nutrient medium. Under the influence of induced drought, stomatal conductance of soybean plants was significantly reduced, also cultivar differences were noticed as the drop concerned 'Aldana', 'Jutro', 'Progres' and 'Polan' cvs (on average by 23.0%) to a lesser degree than the remaining ones (av. by 36.2%). Transpiration rate decreased most clearly for 'Nawiko', 'Mazowia' and 'Gaj', on the average by 46.0%. Under drought conditions, a larger leaf area was characteristic of 'Nawiko', 'Gaj' and 'Mazowia' cvs, but in the control, higher value of this characteristic was shown in 'Polan' and 'Gaj' cvs. In reaction to drought stress the highest drop of produced dry weight of shoots and roots was found for 'Jutro', 'Aldana' and 'Progres'. The highest shoot and root weight under drought was produced by 'Nawiko', 'Mazowia', 'Gaj', and 'Polan' cvs. Simultaneously, these cultivars under the conditions of different water uptake indicated a high decrease of stomatal conductance and transpiration and also they were able to produce a larger area of leaves. On this ground it may be stated that from among 7 Polish soybean cultivars, 'Nawiko', 'Mazowia', 'Gaj', and 'Polan' show increased tolerance to drought.

Key words: cultivars, drought, dry matter, leaf area, soybean, stomatal conductance, transpiration

INTRODUCTION

Soybean (*Glycine max* (L.) Merril) occupies a premier position among crops, being the most important source of both protein concentrates and vegetable oil. As a legume it is capable of utilizing atmospheric nitrogen through biological fixation and is therefore much less dependent on synthetic nitrogenous

fertilizer than most crops. In addition, the introduction of soybean into crop rotation often breaks the buildup of pests and diseases in cereals.

Soybeans have a relatively higher water requirement, for instance, they need 646 kilos of water to produce one kilo of dry matter, whereas corn only 349, sugar beet 377 kilos (Samuel, 1983). Soybean, like other leguminous, belongs to drought sensitive species. As drought causes water deficit in plant tissues which by inhibiting various physiological processes effects negatively growth, development and yielding (Hida *et al.*, 1995a). On the one hand, plant resistance to drought is connected with the size and functioning of the root system capable of efficient water uptake; on the other hand, with anatomic and morphological structure of leaves adapted to reduce stomatal conductance and transpiration (Tanguiling *et al.*, 1987; Buttery *et al.*, 1993; Sameshima *et al.*, 1995; Grzesiak *et al.*, 1996; Serraj *et al.*, 1999). Water supply to the leaf for maintaining turgor pressure in developing cells is an important factor in determining the rate of leaf enlargement (Giovanardi and Ceccon, 1987; Randal and Sinclair, 1989; Hudak and Patterson, 1995) and growth of shoots (Hoogenboom *et al.*, 1987). Soybean genotypes differ in the size of root system; then, they are different in response to low soil moisture (Garay and Wilhelm, 1983; Hida *et al.*, 1995b; Bunce, 1999), although all cultivars performed best when grown under high moisture conditions.

The aim of this study was to estimate the sensitivity of Polish cultivars of soybean to simulated drought conditions and on this ground to show possibly more tolerant cultivars.

MATERIAL AND METHODS

The experiments on nutrient media under controlled conditions were carried out in 1999, 2000 in climatized room. The objective was to determine the reaction response to drought of 7 Polish soybean cultivars ('Aldana', 'Jutro', 'Polan', 'Progres', 'Mazowia', 'Gaj', 'Nawiko') registered in The Research Centre for Cultivar Testing (COBORU). Before the experiment itself, soybean seeds were germinated in Petri dishes, next 4 days' germs of plants were placed into nutrient medium. The plants of each cultivar were grown in 12 flasks at light irradiation of 200 $\mu mol \cdot m^{-2} \cdot s^{-1}$ to for 16 hours and temperature at 25/20°C (day/night). After 2, 3 days nutrient medium was filled up, after each 7 days it was replaced by fresh medium. For the first 3 weeks the plants grew in Hoagland nutrient solution, after this period half of the plants were placed in 15% solution of polyethylene glycol (PEG 20000) in Hoagland nutrient medium. Water potential in this solution amounted to –0.55 MPa (Michel, 1983). Stomatal conductance and transpiration was measured with portable leaf gas analyser LCA-4 (ACD England) after 2 days, when plants began to suffer from water stress. After 3 weeks, when plants were placed at simulated drought conditions (PEG addition) the leaves' area, dry matter production of shoots and roots were measured. The leaves' area was measured using the planimeter. The results were elaborated by statistic methods and differences were verified by the Tukey test with 0.05 level of significance.

RESULTS AND DISCUSSION

The data presented in table 1 prove that under the influence of induced drought, stomatal conductance of soybean plants was significantly reduced. The negative effect of water stress on this characteristic was also observed for soybean by Hoogenboom *et al.* (1987), Hida *et al.* (1995a), Bunce (1999), Buttery *et al.* (1993), Sameshima *et al.* (1995), Grzesiak *et al.* (1996), Serraj *et al.* (1999). Cultivar differences were noticed as the drop concerned 'Aldana', 'Jutro', 'Progres' and 'Polan' cvs to a lesser degree (on average, by 23.0%) than the remaining ones (av. by 36.2%). Transpiration rate decreased most clearly for 'Nawiko', 'Mazowia', and 'Gaj', on the average by 46.0%. A clear decrease of transpiration was observed for soybean under drought stress Tanguiling *et al.* (1987), Sameshima *et al*. (1995), Serraj *et al.* (1999). It has been reported that these cultivars are less economical with water and therefore they are drought sensitive. It is possible that they have more stomatal aparatures (Buttery *et al.*, 1993). Under drought conditions, a larger leaf area, on the average by 0.28 dm^2, was characteristic of 'Nawiko', 'Gaj' and 'Mazowia' cvs, but in the control, a higher value of this characteristic was shown in 'Polan' and 'Gaj' cvs, (Tab. 2).

Table 1. Effect of 48 hours' induced drought on stomatal conductance and transpiration of soybean leaves (means for 1999, 2000)

Experimental condition (A)	Cultivars (B)							Mean for A	$LSD_{0.05}$ for A
	Aldana	Jutro	Polan	Progres	Mazowia	Gaj	Nawiko		
Stomatal conductance (mol · m^{-2} ·s^{-1})									
Control	0.26	0.30	0.42	0.39	0.52	0.46	0.52	0.41	
Drought	0.21	0.24	0.31	0.29	0.33	0.29	0.32	0.28	0.03
% Decrease	19.0	21.0	27.0	25.0	37.0	36.0	38.0	34.0	
Mean for B	0.23	0.27	0.36	0.35	0.42	0.37	0.42	0.34	
$LSD_{0.05}$ for B	0.04								
Transpiration (mmol · m^{-2} ·s^{-1})									
Control	2.87	2.73	2.68	2.67	2.59	2.64	2.42	2.65	
Drought	1.97	2.04	1.65	1.76	1.43	1.47	1.18	1.65	0.04
% Decrease	31.0	30.0	37.0	34.0	47.0	42.0	49.0	38.0	
Mean for B	2.42	2.38	2.16	2.21	2.01	2.05	1.80	2.15	
$LSD_{0.05}$ for B	0.08								

It is also underlined by Giovanardi and Ceccon (1987), Randal and Sinclair (1989), Hudak and Patterson (1995) that drought had a negative effect on the leaf area. In the reaction to drought stress the highest drop of produced dry weight of shoots and roots was found out for 'Jutro', 'Aldana', and 'Progres', at shoots 41.7% on the average, and roots by 36.0%. The data for the remaining ones were 26.7% and 25.7%, respectively (Tab. 2). The research results showed that the decrease of roots dry matter production was lower than for shoots, under drought conditions, it confirms the mechanism of defence to water stress in plants, because roots are less exposed to drought. Similar opinion was presented by Garay and Wilhelm (1983) and Hida *et al.* (1995b) for soybean.

Table 2. Effect of 3-week induced drought on total leaf area, dry matter of shoots and roots of soybean plants (means for 1999, 2000)

Experimental condition (A)	Cultivars (B)							Mean for A	$LSD_{0,05}$ for A
	Aldana	Jutro	Polan	Progres	Mazowia	Gaj	Nawiko		
	Total leaf area ($dm^2 \cdot plant^{-1}$)								
Control	3.19	3.17	3.67	3.30	3.39	3.56	3.49	3.39	
Drought	1.38	1.36	1.65	1.56	1.74	1.75	1.82	1.61	0.11
% Decrease	56.0	57.0	55.0	52.0	48.0	51.0	48.0	52.0	
Mean for B	2.28	2.26	2.66	2.43	2.56	2.65	2.65	2.50	
$LSD_{0,05}$ for B	0.17								
	Shoots dry matter ($g \cdot plant^{-1}$)								
Control	1.28	1.35	1.71	1.58	1.79	1.70	1.86	1.61	
Drought	0.82	0.75	1.24	0.96	1.33	1.21	1.41	1.10	0.06
% Decrease	42.0	44.0	28.0	39.0	26.0	29.0	24.0	33.0	
Mean for B	1.05	1.05	1.47	1.27	1.56	1.45	1.63	1.35	
$LSD_{0,05}$ for B	0.10								
	Roots dry matter ($g \cdot plant^{-1}$)								
Control	0.30	0.30	0.37	0.32	0.43	0.39	0.48	0.37	
Drought	0.18	0.19	0.26	0.22	0.32	0.28	0.36	0.26	0.02
% Decrease	39.0	37.0	28.0	32.0	25.0	27.0	23.0	30.0	
Mean for B	0.24	0.24	0.31	0.27	0.37	0.33	0.42	0.31	
$LSD_{0,05}$ for B	0.03								

The influence of simulated drought on the yield of seeds was not studied in this research but it is seems that it should be similar to the effect of soil moisture deficit. In these conditions, Heatherly (1993) and Sneller and Dombek (1997) indicated the decrease of the pots number on the plants and seeds in the pots and, therefore, the drop of seeds yield.

The highest shoots and roots weight under drought was produced by 'Nawiko', 'Mazowia', 'Gaj', and 'Polan' cvs. Simultaneously, these cultivars under the conditions of different water uptake indicated a high decrease of stomatal conductance and transpiration and also they were able to produce a larger area of leaves. On this ground it may be stated that from among 7 Polish soybean cultivars, 'Nawiko', 'Mazowia', 'Gaj', and 'Polan' show increased tolerance to drought.

CONCLUSIONS

1. Simulated drought significantly reduced stomatal conductance and transpiration of all studied cultivars of soybean; however, the most of a drop concerned 'Nawiko', 'Mazowia', and 'Gaj' cvs.

2. Under water stress the highest leaves area, shoots and roots dry matter were produced by 'Nawiko', 'Mazowia', 'Gaj', and 'Polan' cvs.

3. Increased tolerance to drought among the Polish soybean cultivars is shown 'Nawiko', 'Mazowia', 'Gaj', and 'Polan' cvs.

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STRESZCZENIE

Celem przeprowadzonych badań było określenie reakcji 7 polskich odmian soi ('Aldana', 'Jutro', 'Polan', 'Progres', 'Mazowia', 'Gaj', 'Nawiko') na symulowaną suszę. Rośliny umieszczono w 15% roztworze glikolu polietylenowego (PEG 20000) w pożywce Hoaglanda. Pod wpływem indukowanej suszy została istotnie zredukowana przewodność szparkowa roślin soi. Stwierdzono przy tym różnice odmianowe, ponieważ stopień redukcji u odmian 'Aldana', 'Jutro', 'Progres'

i 'Polan' (średnio o 23,0%) był mniejszy niż u pozostałych odmian (średnio o 36,2%). Poziom transpiracji najwyraźniej obniżył się u odmian 'Nawiko', 'Mazowia' i 'Gaj', średnio o 46,0%. W warunkach suszy największą powierzchnią liści charakteryzowały się odmiany 'Nawiko', 'Gaj' i 'Mazowia', natomiast w kontroli najwyższą wartość tej cechy wykazywały odmiany 'Polan' i 'Gaj'. W reakcji na stres suszy największy spadek suchej masy pędów i korzeni stwierdzono u odmian 'Jutro', 'Aldana' i 'Progres'. Największą masę pędów i korzeni w warunkach suszy wykształciły odmiany 'Nawiko', 'Mazowia', 'Gaj' i 'Polan'. Jednocześnie odmiany te w warunkach zróżnicowanego zaopatrzenia w wodę przejawiały wysoką redukcję przewodności szparkowej i transpiracji a przy tym były w stanie wytworzyć największą powierzchnię liści. Na tej podstawie można stwierdzić, że spośród 7 polskich odmian soi, zwiększoną tolerancję na suszę przejawiają odmiany 'Nawiko', 'Mazowia', 'Gaj' i 'Polan'.