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Dehydration Tolerance in Spring Wheat Seeds

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Abstract. Studies performed on seeds of several cultivars of spring wheat (*Triticum aestivum* L. var. *lutescens*) revealed differences in the studied seed dehydration tolerance affecting seed germination and seedling emergence. Among the cultivars studied, seeds of Kolibri showed capability to maintain both high germination energy and high emergence rate at diminished water potential of the environment. Seed dehydration tolerance was increased when the parent plants were subjected to drought.

Previous experiments (ZAGDAŃSKA and PACANOWSKA 1979) showed that the Kolibri cultivar of spring wheat was able to adapt to soil drought conditions through an increased flag leaf dehydration tolerance as well as through an increased tiller formation. The question remains whether the capability of spring wheat to adapt to drought conditions also applies to the earlier stages of development *i.e.* germination and emergence and whether the drought to which the parent plants were subjected, causes any change in the physiological and chemical properties of the seeds. The literature data concerning these problems are very scarce despite the extensive studies performed on seed resistance to water stress (HEYDECKER 1977). To answer the questions, seeds of Kolibri and other cultivars were studied and compared.

MATERIAL AND METHODS

Seeds collected from several cultivars of spring wheat (*Triticum aestivum* L.) cultivated in the same agricultural area or from some cultivars cultivated in "wet" and "dry" agricultural regions (regional classification according to UTRATA 1976) were used in the experiments. A part of the experiment was carried out on seeds yielded from Kolibri and Kaspar plants, which had been subjected to soil drought conditions in the shooting phase (drought I) or in the heading phase (drought II), or in both stages of development (drought I + II) as described in the previous paper (ZAGDAŃSKA and PACANOWSKA 1979).

In the present paper the following determinations were carried out in order to characterize the physiological state of the seeds studied.

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Germination energy was determined by estimation of germination percentage after four days at 25 °C in the dark under high humidity conditions. The appearance of a 2—3 mm long coleoptile was accepted as the germination criterion in all the experiments. In the experiments concerning seeds obtained

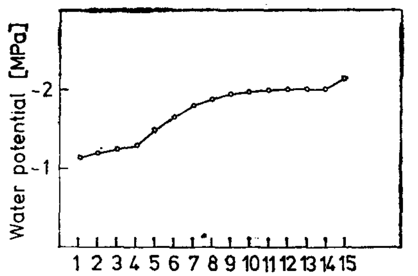

Fig. 1. The values of critical water potential for seed germination of different cultivars harvested in the same agricultural region. — 1. Kaspar, 2. Nadgoplanka, 3. Nagradowicka, 4. Opolska, 5. Carola, 6. Melchior, 7. Drabant, 8. Hebrard, 9. Bastion, 10. Hatri, 11. Urbanka, 12. UH, 13. Kolibri, 14. Sappo, 15. Ostka Chłopicka.

from drought-treated plants (ZAGDAŃSKA and PACANOWSKA 1979) the agricultural criterion for energy of germination (10 mm long coleoptile) was additionally used as the germination criterion (according to the recommendations of the Polish Standards).

Criterial water potential for germination according to STREBEYKO and DOMAŃSKA (1953) was estimated by determination of germination energy of seeds subjected to KNO_3 solutions of various concentrations from 0.1 to 0.9 M. Germination energy was plotted against water potential of KNO_3 solutions and the value of water potential at which 50% of seeds germinated was interpolated.

Soil water absorption capacity of the germinating seeds was evaluated on the basis of the seedling emergence from low moisture soil determined 21 days after sowing (STREBEYKO and DOMAŃSKA 1962). Soil moisture was kept at the level of 25% of soil capillary water capacity.

Coleoptile length and dry matter was measured for seeds collected from plants subjected to critical water saturation deficit at different stages of development.

Protein nitrogen content in seeds of control and drought-treated plants was determined by the micro-method of Kjeldahl. The data obtained from experiments were subjected to analysis of variance.

RESULTS

The values of critical water potential for germination of seeds of different cultivars harvested in the same agricultural region are presented in Fig. 1. Ostka Chłopicka was found to be the most tolerant cultivar and Sappo, Kolibri, Urbanka and Hatri cultivars exhibited somewhat less tolerance to osmotic drought. Cultivars: Kaspar, Nadgoplanka, Nagradowicka and Opolska appeared to be the most sensitive to osmotic drought. If soil water conditions under which the seeds are formed can influence seed drought tolerance, two effects may be expected: germination energy and/or the seedling emergence rate should be changed by plant drought treatment. The influence of environmental conditions ("dry" or "wet") during plant maturation on seed resistance to osmotic drought is shown in Fig. 2. Of the three cultivars tested, seeds of Kolibri and Urbanka cultivars collected from "dry" conditions showed higher germination energy at decreasing water potentials of the bed. However, the opposite is true of Kaspar plants — higher germination energy was observed if seeds were obtained from "wet" conditions.

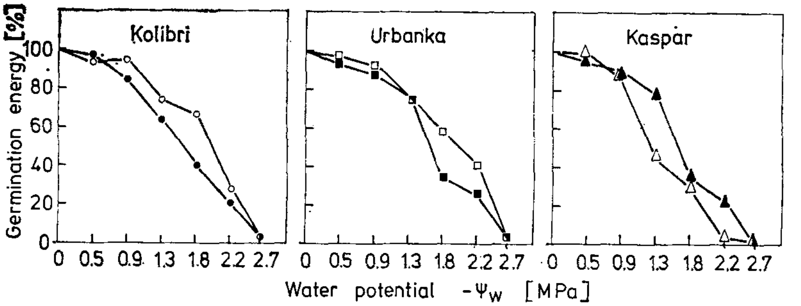

Fig. 2. The influence of plant growth conditions on the resistance of seeds to osmotic drought. Open and closed marks mean "dry" and "wet" conditions, respectively. For further explanation see Methods.

Since water conditions of the environment in which seeds were produced were not well defined, in further experiments we used seeds obtained from plants subjected to soil drought, resulting in the critical water saturation deficit in the leaves (ZAGDAŃSKA and PACANOWSKA 1979). We found (Fig. 3 top) that seeds produced by drought-affected plants did not differ in their germination energy when formation of a 2—3 mm long coleoptile was taken as a germination criterion. However, pronounced differences in germination energy were observed (Fig. 3 bottom), when the agricultural criterion for germination was used (10 mm long coleoptile). Seeds obtained from plants subjected to single soil droughts (I or II) causing critical water deficit in leaves had higher germination energy (in terms of the agricultural criterion) than the control seeds. Twice-applied drought (drought I + II) decreased germination energy of Kolibri and Ostka Popularna seeds to the level of the control. This effect was not observed for Kaspar seeds.

TABLE 1

Spring wheat emergence from low moisture soil (21 days since sowing)

Cultivar	Emergence [%] — Seed origin: "dry" area	Emergence [%] — Seed origin: "wet" area
Kaspar	31.0	43.0
Opolska	39.2	—
Kolibri	48.0	36.8
Ostka Pop.	48.0	—

LSD (0.05) 2.0%.

Comparison of data presented in Fig. 3 indicates that drought has affected rather the growth capabilities of coleoptile than the germination ability. Data shown in Table 2 indicate that seeds originating from plants treated with drought during shooting or heading phase form longer and/or higher dry matter coleoptiles during four days of growth. Twice-applied drought diminished or even did away with the effect of a single drought

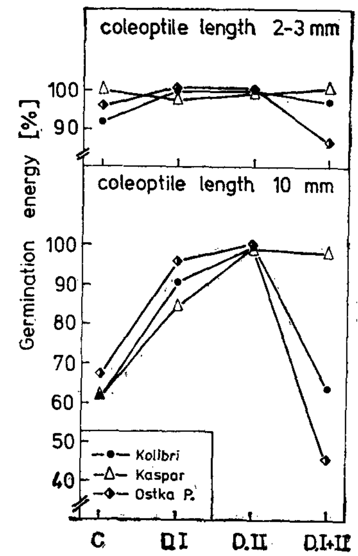

Fig. 3. Germination energy of seeds produced by drought-affected plants. C — mean control plants; D. I. — drought applied in the shooting phase; D. II. — drought applied in the heading phase; D. I. + II. — twice applied drought (both in the shooting and heading phase).

treatment in Kolibri and Ostka Popularna cultivars. Only Kaspar seeds showed increased coleoptile growth after two consecutive drought treatments. However the dry matter of these coleoptiles was also decreased after drought I + II.

The drought-differentiated growth capabilities of coleoptiles might be related to the drought-modified protein nitrogen content in the seeds (Table 3). Drought was found to stimulate an accumulation of protein nitrogen in the seeds, drought II being more effective than drought I, particularly in the case of the Kaspar cultivar. Twice-applied drought diminished or even did away with the stimulating effect of drought I. When correlation between protein nitrogen content and coleoptile growth was calculated for Kolibri seeds, the correlation coefficient was 0.80.

TABLE 2

Coleoptile length [mm] and dry matter [mg] after 4 days of germination

Cultivar	Control		Drought I		Drought II		Drought I + II	
	[mm]	[mg]	[mm]	[mg]	[mm]	[mg]	[mm]	[mg]
Kolibri	18.1	179.3	30.1	198.3	32.6	322.6	21.0	196.7
Kaspar	14.1	152.6	26.6	195.5	30.8	267.7	33.3	258.4
Ostka Popularna	17.8	225.4	27.8	329.8	35.7	352.8	15.3	162.8

TABLE 3

Protein nitrogen content in seeds of spring wheat cultivars

Cultivar	Protein-N			
		Drought given at		
	Control	Shooting	Heading	Shooting + heading
Kolibri	11.25	16.56	19.59	16.85
Kaspar	10.84	11.08	26.99	15.86
Ostka Popularna	10.38	11.72	23.49	24.02

DISCUSSION

Results shown in this paper revealed that soil drought affecting seed forming plants changed the properties of the produced seeds, the effect being dependent on the cultivar studied.

Seeds of Kolibri cultivar showed relatively high dehydration tolerance during germination, and what's more, their dehydration tolerance was increased when the parent plants were subjected to soil drought. This was manifested by the seed ability to germinate on a bed with relatively low (more negative) water potential and by the seed ability to maintain both high germination energy and high emergence rate at diminished water potential of the environment. It is interesting that seedling emergence rate has been increased even when seed formation was not directly affected by the drought conditions *i.e.* plants were subjected to drought during the shooting phase. A higher emergence rate resulted — as we have indicated — from higher growth capability of seedlings in terms of coleoptile growth. This might result from the altered metabolite content in the drought-affected seeds, *e.g.* from the drought-modified protein nitrogen content in the seeds. For Kolibri seeds we found that correlation between protein nitrogen content and the rate of seedling growth was high (correlation coefficient = 0.80). According to TARCHEVSKIĬ 1957, STUTTE and TODD 1968, enhanced leaf senescence could alter the quality of metabolites reaching the ear. In our experiments with drought-pretreated plants, enhanced leaf senescence was actually observed (ZAGDAŃSKA and PACANOWSKA 1979). That might have changed the metabolite pattern of the seeds. The negative effect of twice-applied drought observed for Kolibri and Ostka Popularna seeds seems to be due to the insufficient photosynthate level for formation of seeds, not only on the main stem but also on the tillers (drought-enhanced tiller formation was previously described for Kolibri plants, ZAGDAŃSKA and PACANOWSKA 1979).

Among the cultivars studied, Kaspar seeds were found to be the least tolerant to low water potential of the environment in terms both of germination energy under osmotic drought conditions and of the emergence rate from low-moisture soil. Drought applied to the parent plants did not alter the germination energy of Kaspar seeds either. However, those seeds did contain more protein nitrogen and showed enhanced coleoptile growth in terms of coleoptile length, even after twice-applied drought to the plants. The enhanced growth was however not accompanied by dry matter increase. This resulted in a lower emergence rate under soil drought conditions.

Thus, the results obtained in the present paper indicate that the cultivars of spring wheat studied differ not only in the dehydration tolerance and adaptation ability of the grown-up plants as was previously stated (ZAGDAŃSKA and PACANOWSKA 1979) but they also show marked differences in the seed response to the drought conditions.

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