BRIEF COMMUNICATION

Effect of drought stress on leaf optical properties in drought-resistant and drought-sensitive maize and triticale genotypes

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Abstract

The effect of a short (7 d), prolonged (14 d) soil drought (D) and (7 d) recovery (DR) on the leaf optical properties - reflectance (R), transmittance (T) and absorptance (A) in photosynthetically active radiation (PAR) and near infrared radiation (NIR) range of irradiation (750–1100 nm) was studied for maize and triticale genotypes differing in drought tolerance. The drought stress caused the changes in leaf optical properties parameters in comparison with non-drought plants. The observed harmful influence of drought was more visible for maize than triticale.

Additional key words: drought, leaf optical properties, maize, triticale.

The source of energy for photosynthesis is solar irradiation in the range from 400 to 700 nm (PAR). NIR in the range from 750 to 1100 nm is responsible for signaling processes (phytochrome) and tissues temperature. Irradiation in the range from 280 to 2300 nm, reaching plants, is subjected to physical processes of R, T, and A. Leaf spectral optical properties depend on plant species, stage of plant growth and development, leaf thickness, their position on stem, content of photosynthetic pigments and water content (Carter 1993, Czarnowski and Cebula 1996, Baldini *et al*. 1997, Šesták and Šiffel 1997).

The aim of this work was the estimation of changes in parameters of leaf optical properties in maize and triticale genotypes differing in drought tolerance after the direct influence of soil drought and after the rehydration.

The experiment was carried out on 2 spring triticale (× *Triticosecale* Wittmack) breeding strains and 2 maize (*Zea mays* L.) single cross hybrids. Chosen genotypes differed in the drought susceptibility index (DSI) values, which were calculated using formulas published by Fischer and Maurer (1978). Triticale strain CHD-247 and maize hybrid Tina were included into the group of D-resistant genotypes and triticale strain CHD-12 and maize hybrid Ankora to the group of D-sensitive ones (Grzesiak 2004). Experimental plants were grown in air-conditioned growth cabinets: day/night temperature 23/18 ^{o}C (± 2.5 ^{o}C), relative humidity (RH) 70/60% (± 5 %) and 16-h photoperiod (PAR 350 µmol m^{-2} s^{-1}). Plants were grown in the plastic pots filled with mixture of soil, peat and sand (1:1:3, v/v/v) and till 28th day after sowing plants maintained well-watered (65% of soil field water capacity, FWC). Subsequently, drought treatment (30% FWC) was started and applied for 7 or 14 d. After this period, for the next 7 days well watering conditions were reestablished. The leaf spectral properties: R and T of 5th leaf were taken using *Beckman DK-2A* spectrophotometer (*Beckman Coulter, Inc.*, Fullerton, USA) and the Ulbricht sphere, in the range from 400 to 1100 nm (Knapp and Carter 1998, Pilarski 2004). A was calculated from the formula A = 1- (R+T). Measurements of R and T were taken on 35th, 42nd and 49th d after plants sowing on an adaxial leaf surface. 9 replications (3 plants × 3 measurements) were taken for each of days of plant growth and treatment measurements. Data were submitted to statistical analysis using a *Duncan*'s multiple range tests and standard error of mean was calculated.

In non-drought plants (C) significant differences between D-resistant and D-sensitive genotypes were observed only in T in the PAR range and in A in NIR range. Ratios of D-sensitive to D-resistant genotypes of maize and triticale in PAR-range T were 1.9 and 1.6,

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Abbreviations: A – absorptance of irradiation; C plants – control plants; D – drought; DR – recovery after drought; NIR – near infrared; PAR – photosynthetically active radiation; R – reflectance of irradiation; T – transmittance of irradiation.

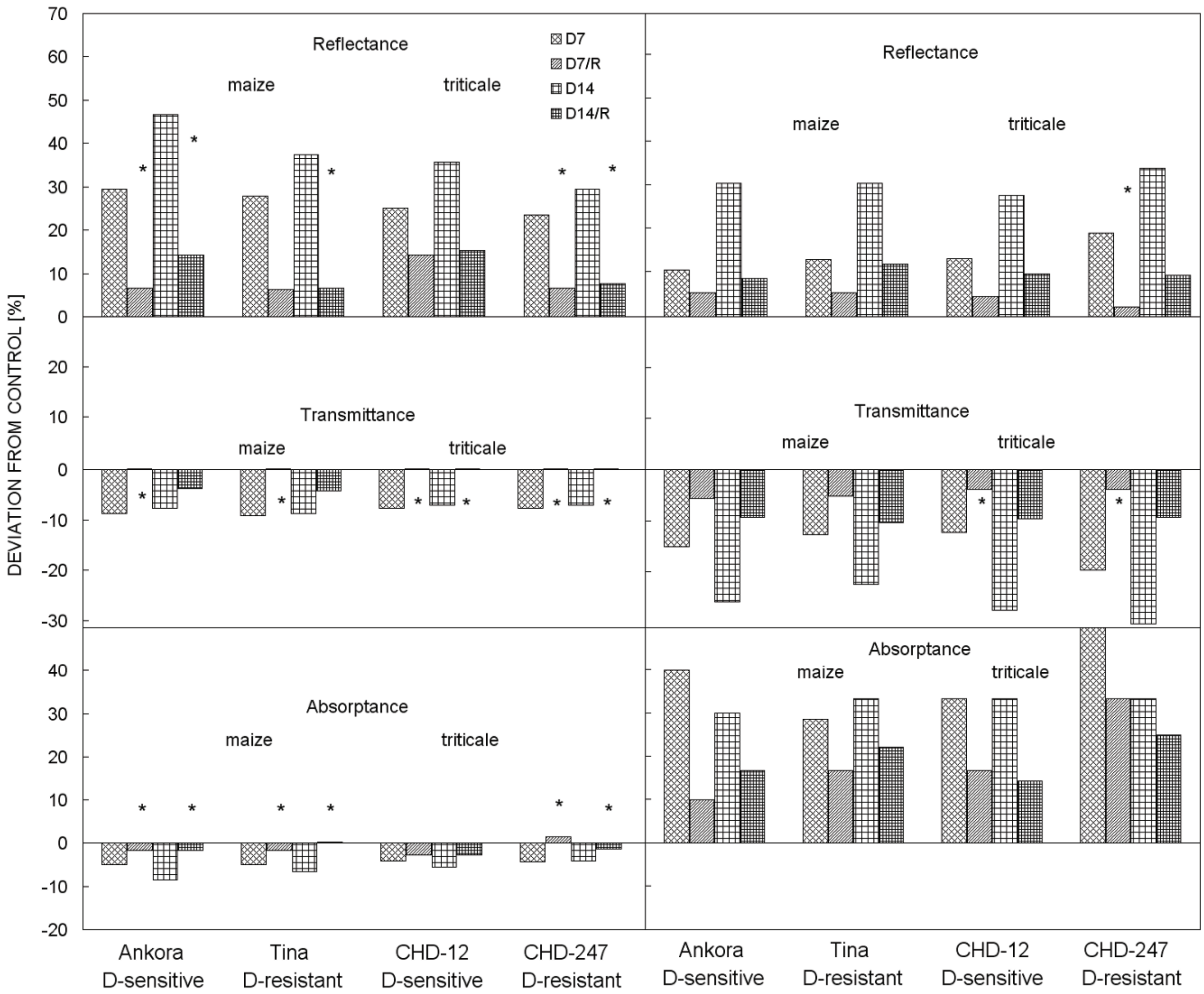

Fig. 1. Direct- (D7, D14) and after effect (D7R7, D14R7) of drought on leaf spectral properties in PAR (500–600 nm) and NIR (700–1,100 nm) ranges of D-sensitive and D-resistant maize and triticale genotypes. Results are shown as a deviation from control plants in percent. The symbol * shows lack of significant difference with control treatments according to *Duncan*`s multiple range test p=0.05, n = 9.

respectively, and in NIR-range A were 1.7 and 2.1, respectively (Table 1).

The drought stress caused the changes in leaf optical properties parameters. In the PAR range the largest changes of optical properties parameters were observed in R, on the contrary, changes in T and A were not considerable. Increase of R both in maize and triticale was larger in plants of treatment D14 than in plants of treatment D7, in comparison with C plants. In PAR and NIR range the increase of R was larger in D-sensitive genotypes Ankora and CHD-12 than in D-resistant genotypes Tina and CHD-12. In comparison to control plants, decrease of T and A in the PAR range and increase of A and decrease in T in NIR range were observed. After 7-d recovery (D7/R, D14/R), in comparison to C plants, the significant differences remained in majority of cases, which shows that period of 7-d rehydration is too short to remove the harmful effect of the soil drought (Fig. 1).

Leaf optical properties are strongly affected by abiotic and biotic stresses. Studies on changes caused by environmental stresses including water stress were carried out (Vogelmann 1993, Carter 1993, Carter *et al*. 1995, Vogelmann and Han 2000). According to Carter *et al.* 1995 and Carter and Knapp (2001) in response to water stress, increase of R is the result of a decrease of photosynthetic pigments content since in the PAR range R is effectively determined by a chlorophyll content. In NIR range changes in R are attributed to changes in leaf water content because water is a major light absorber. The profiles of changes in R depend on a kind of stress. In the visible range (400–760 nm), the increase of R in plants stressed by herbicide, pathogen, ozone, and insufficient mycorrhizas was higher than in case of the dehydration.

Table 1. Leaf optical properties - reflectance (R), transmittance (T), absorptance (A) and ratio of D-sensitive to D-resistant genotypes of non-drought stressed plants of maize and triticale genotype in the PAR and NIR range. Mean values with measurements on 35th, 42nd and 49th day after sowing ± SE. (n = 9).

Genotype	R	T	A
PAR (500–600 nm)			
Maize			
Ankora (D-sensitive)	0.151 ± 0.012	0.254 ± 0.017	0.595 ± 0.005
Tina (D-resistant)	0.140 ± 0.012	0.132 ± 0.008	0.728 ± 0.005
Ratio	1.08	1.92	0.82
Triticale			
CHD12 (D-sensitive)	0.162 ± 0.012	0.229 ± 0.008	0.609 ± 0.005
CHD247 (D-resistant)	0.153 ± 0.016	0.139 ± 0.008	0.708 ± 0.008
Ratio	1.06	1.65	0.86
NIR (700–1100 nm)			
Maize			
Ankora (D-sensitive)	0.359 ± 0.012	0.541 ± 0.005	0.100 ± 0.009
Tina (D-resistant)	0.432 ± 0.016	0.509 ± 0.012	0.059 ± 0.005
Ratio	0.83	1.06	1.70
Triticale			
CHD12 (D-sensitive)	0.357 ± 0.021	0.572 ± 0.014	0.071 ± 0.012
CHD247 (D-resistant)	0.434 ±0.021	0.532 ± 0.012	0.034 ± 0.008
Ratio	0.82	1.08	2.09

Opposite, in NIR range and particularly in FIR range changes in R were very large in the case of dehydration, however in the case of other studied stresses the changes were small (Carter 1993). Similarly to results presented by other authors, in our research, in the range of 500–600 nm (PAR) and 700–1,100 nm (NIR) drought caused the large change of R, however, the influence on T and A was considerably weaker. In conclusion, our results confirm studies of other authors (Vogelmann 1993, Carter 1993, Carter *et al*. 1995, Pilarski 2004), who show meaning of changes in the parameters of leaf optical properties among plant species or cultivars under stressed environments.

References

Baldini, E., Facini, O., Nerozzi, F., Rossi, F., Rotondi, A.: Leaf characteristic and optical properties of different woody species. – Trees **12**: 73-81, 1997.

Carter, G.A.: Response of leaf spectral reflectance to plant stress. – Am. J. Bot. 80:239-243, 1993.

Carter, G.A., Knapp, A.K.: Leaf optical properties in higher plants: lining spectral characteristics to stress and chlorophyll concentration. – Am. J. Bot. **88**: 677-684, 2001.

Carter, G.A., Rebbeck, J., Percy, K.E,: Leaf optical properties in *Liriodendron tulipifera* and *Pinus strobus* as influenced by increased atmospheric ozone and carbon dioxide. – Can. J. Forest Res. **25**: 407-412, 1995.

Czarnowski, M., Cebula, S.: Effect of leaf area index on the spectral transmittance of solar radiation in greenhouse cultivation of sweet pepper plants. – Folia Horticult. **8**: 53-72,1996.

Fischer, R.A., Maurer, R.: Drought resistance in spring wheat cultivars. 1. Grain yield responses. – Aust. J. Agri. Res. **29**: 897-912, 1978.

Grzesiak, M.T.: [Effect of drought stress on photosynthetic apparatus and productivity of triticale and maize genotypes differing in drought tolerance]. – Doc. thesis, Cracow Agricultural University, Cracow 2004. [In Polish]

Knapp, A.K., Carter, G.A.: Variability in leaf optical properties among 26 species from a broad range of habitants. – Am. J. Bot. **85**: 940-946, 1998.

Pilarski, J.: Optical properties of plants. – In: Filek, M., Biesaga-Kościelniak, J., Marcińska, I. (ed.): Analytical methods in plant stress biology. The Franciszek Górski Institute of Plant Physiology, Polish Academy of Sciences, Krakow 2004.

Šesták, Z., Šiffel, P.: Leaf-age related differences in chlorophyll fluorescence. – Photosynthetica **33**: 347-369, 1997.

Vogelmann, T.C .: Plant tissues optics. – Ann. Rev. Plant Physiol. **44**: 231-251, 1993.

Vogelmann, T.C., Han, T.: Measurement of gradients of absorbed light in spinach leaves from chlorophyll fluorescence profiles. – Plant Cell Environ. **23**: 1303-1311, 2000.