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Spectral characteristics of leaves diffuse reflection in conditions of soil drought: a study of soft spring wheat cultivars of different drought resistance

Dmitriy V. Rusakov, Elena V. Kanash*

Department of Plant Lighphysiology and Agroecosystem Bioproductivity, Agrophysical Research Institute, St. Petersburg, Russia

**Corresponding author: rdv_vgsha@mail.ru*

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Abstract: Quick and accurate nondestructive methods of water deficiency detection prior to the appearance of visible symptoms of plant deterioration as well as estimation of photosynthesis parameters are needed to effectively control conditions of plant growth, to manage crop productivity and to implement programs of "smart farming". The aim of our investigation was to analyse spectral characteristics of leaves diffuse reflection as evident in soft spring wheat cultivars (*Triticum aestivum* L.) of different drought resistance in optimal conditions and under the impact of soil drought; another objective was to determine the reflection indices that could serve as criteria in the phenotyping of genotypes according to their photosynthetic apparatus capacity and the efficiency of light use as well as in the forecasting of genotypes potential productivity and their drought resistance. Wheat plants of 4 drought-resistant and 4 non-resistant cultivars were grown under controlled conditions in the protected ground. In the vessels with simulated soil drought, the moisture content was 30% of total field capacity, while in the control sample it was 80%. Spectral characteristics of radiation reflected from the leaf surface were recorded with the spectrometer HR2000, and then reflection indices were calculated whose value is closely related to the activeness of the photosynthetic apparatus. The experiments conducted showed that in the system of interaction between the soil, the plant and the effective layer of the atmosphere all analysed diffuse reflection indices changed with the emergence of water deficit. The index of photosynthetic apparatus capacity (ChlRI) is less susceptible to short-term soil drought than the indices of the efficiency of light use in the process of photosynthesis (R_{800}, photochemical reflection index (PRI_{mod}) and flavonoid index (FRI_{mod})) which change significantly, so that the degree of their change may be a reliable enough indicator of plant stress caused by water deficiency. It is advisable, however, when estimating and comparing the reaction of various plant cultivars, lines and new forms to the developed water deficiency, to include in the array of plants examined those cultivars whose optical properties and the range of their variation resulting from water deficit are known. This will ensure a more reliable ranking of analysed genotypes according to their drought resistance and will enhance the accuracy of the diagnosis.

Keywords: optical criteria; spectral indices; various genotypes; photosynthesis efficiency; water stress

Soil drought is one of the most powerful abiotic stressors that inhibit plant growth and reduce the yields of crops. The plant stress produced by the drought due to the lack of water supply is one of the greatest problems encountered in crop production all over the world. According to estimates, the drought combined with other abiotic stressors may lead to a 70% reduction of the yield (Tuberosa and Salvi 2006, Pennisi 2008). Under the impact of drought plant metabolism is changed and secondary metabolism is activated that provides protection of plant cells from degradation with the help of antioxidants, phenolic and some other compounds. As the first reaction to water deficit, most plant species close

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their stomata, thus reducing the loss of water during transpiration. As a result of stomatal closure, the rate of photosynthesis and the quantum yield of photosystem II (PSII) decrease (Chaves et al. 2002). As a result of a decreased rate of CO_2 assimilation, light energy absorbed by the leaf cannot be used to drive photosynthetic electron transport, and a part of this energy is dissipated as heat, increasing the non-photochemical quenching (NPQ) (Baker and Rosenqvist 2004). If water deficit persists for a long time, plants respond with changes in their growth and in the distribution of metabolites among their organs, which results in the changed anatomical structure of leaves and partial loss of photosynthetic pigments (Schmitter et al. 2017).

A stable advancement of agriculture in the coming decades would be impossible without understanding the process of plant adaptation to drought, which is very important for the enhancement of management methods, the formulation of plant breeding strategies and the development of viable crops. The cumulative effect of global climatic changes and population growth demands further research into the nature of plant adaptation to drought. In this connection, of particular interest is the early identification of plant water stress, which plays a great role in the selection of farm crops as well as in their growing by and large (Mer et al. 2012).

Changes in optical properties of leaves in response to the impact of various abiotic stressors have been studied extensively enough. The light-harvesting capacity and the photosynthetic performance of a given leaf are both determined by the organisation and the properties of its structural elements, with some of these having evolved as adaptations to stressful environments (Karabourniotis et al. 2021). The investigations carried on with various species and cultivars of plants were concerned with their behaviour under the influence of elevated temperature (Dobrowski et al. 2005), heavy metals (Rosso et al. 2005), ultraviolet radiation (Kanash et al. 2013), water deficiency (Dobrowski et al. 2005, Graeff and Claupein 2007, Kanash and Osipov 2009, Yakushev et al. 2017) and nutrition (Kanash et al. 2013, Yakushev and Kanash 2016). In many of these investigations, spectral characteristics were considered from the point of view of forecasting the deterioration of plants and reduced yield. The interrelation between the physiological state of plants and optical characteristics of their leaves or the crop canopy formed by vegetative plants is defined by unfavourable conditions of growth causing morphological, physiological and biochemical changes that are liable to detection by various optical methods of research. Being to a certain extent multi-purpose, these methods are a valuable tool for phenotyping with high performance, especially in the system of the interaction between the soil, the plant and the effective layer of the atmosphere.

The phenotyping of such major traits of crops as productivity, quality of the harvest and tolerance to the effect of abiotic stressors is a laborious and technically complicated task because it requires research conducted in different environmental conditions for several seasons entailing considerable costs. Modern phenotyping methods, such as non-invasive imaging techniques as well as contact and remote spectroscopy have high throughput and do not destroy plants (Araus et al. 2002, Liu et al. 2015). The relations between reflection indices defining the activity of photosynthetic apparatus and other physiological characteristics have been discussed in many publications (Graeff and Claupein 2003, Kanash et al. 2013, Yakushev et al. 2017), but information about their use in the identification of promising genotypes with desirable economically valuable features is practically absent. The method that may be applied in the screening of physiologically optimal genotype is the analysis of the spectral reflective power of plant leaves or crop canopy in the visible and near-infrared regions. At present, however, we still do not have any exact index that could be recommended for breeding programs as a means of screening highly productive genotypes tolerant to the effect of abiotic stressors.

MATERIAL AND METHODS

Wheat plants (*Triticum aestivium* L.) of drought-resistant cultivars (Albidum 28, Saratovskaya 29, Dobrynya, Neeva 2) and non-resistant ones (Leningradskaya 97, Leningradka, Belorusskaya 80, Trizo) were grown in polypropylene vessels with a capacity of 3 L (5 vessels per cultivar, each containing 10 plants). The seeds were picked from VIR's genetic collection of soft spring wheat (Vavilov All-Russia Institute of Plant Genetic Resources). The vessels were filled with sod podzolic soil (pH 5.9) containing 198 mg/kg of mobile phosphorus, 112 mg/kg of mobile potassium, 18.2 mg/kg of nitrate, and 34.6 mg/kg of ammonia. Plants were grown in lighting installations with HPS-400 (High-Pressure Sodium Lamp, Saransk, Russia) lamps at the irradiation of the upper leaves of 50 ±

0.5 W/m^2 photosynthetically active radiation (PAR), photoperiod 16 h and soil moisture 80% of total field capacity (TFC). Elvidge et al. (2010) detail the spectral characteristics of high-pressure sodium lamps. During the interfacial period of tubing and earing, some of the plants were exposed to short-term soil drought. The drought lasted 3 days with soil moisture equal to 30% of TFC (test sample). The loss of water in leaves and plant biomass were determined by weighing the test and the control samples at the temperature of 85 °C after drying them to constant weight. The spectra of radiation reflected from the leaves of both drought-resistant cultivars (Albidum 28, Saratovskaya 29, Dobrynya, Neeva 2) and non-resistant ones (Leningradskaya 97, Leningradka, Belorusskaya 80, Trizo) were recorded *in situ* 3 days after reaching the soil moisture level of 30% of TFC and maintaining it (the end of the drought period). Diffuse reflection of leaves was recorded with a miniature fibre optic spectroradiometer system of the USA company Ocean Insight that provides an optical resolution of 0.065 nm in the range from 300 to 1 000 nm in increments of 0.3 nm; the software used was Spectra Suite (Orlando, USA). The optical system for diffuse reflection measurement included reference tungsten-halogen light (LS-1) and reference sample (WS-1). Prior to measurements, the reflection spectrum of a reference sample manufactured from spectralon (material reflecting > 99% of incident radiation within the measured wavelength range) was recorded. The diffuse reflection spectrum of a leaf (percentage of the reference reflection) was displayed on the screen and was available for saving in digital form. After recording reflection spectra, spectral reflection indices were calculated for the evaluation of the photosynthetic apparatus capacity and its work efficiency. The formulas of the indices calculation are shown in Table 1. Since sometimes photochemical reflection index (PRI) and the flavonoid index (FRI) under stress can have negative values, the introduction of the constant carbon (C) into their calculated formulas provides a more convenient comparison of the studied indicators and their presentation on Kanash and Osipov (2009) and Kanash et al. (2013). The C values were selected empirically and for this experiment was equal to 0.7. Statistical processing of the results was performed using programs MS Excel 16 (Armonk, New York, USA) and Statistica 12 (Palo Alto, USA). The average values of the indicators studied were determined. The validity of differences between the variants was estimated by parametric statistics methods (student's *t*-test). The differences between the variants were considered significant at $P \leq 0.05$. The correlation between the two parameters was considered significant if the correlation coefficient significance was $P \leq 0.05$. The effect size η^2 of a factor (short-term soil drought) is determined on a percentage basis as a relation between the respective sum of squared deviations of examined optical and biometric parameters from their average values and the total sum of squares. It measures the proportion of variance explained by a given variable of the total variance remaining after accounting for variance explained by other variables in the model.

RESULTS AND DISCUSSION

Photosynthesis is a complex hierarchical process governing plant productivity. The indicators characterising it may be divided for convenience into "capacity" indices and "intensity (efficiency)" indices. Quantitatively, the relation between productivity and photosynthesis is usually described by the following equation (Hall and Long 1993):

$$P_n = Q\beta\varepsilon - R$$

where: P_n – net productivity of photosynthesis; Q – amount of incident light; β – share of incident light absorbed by

Table 1. Spectral indices used in the evaluation of the capacity and the efficiency of photosynthetic apparatus of drought-resistant and non-resistant wheat cultivars

Index of:	Calculation formula	Index authors
Chlorophyll (ChlRI)	$(R_{750} - R_{705})/(R_{750} + R_{705} - 2R_{445})$	Sims and Gamon (2002)
Light diffusion by the leaf (R_{800})	R_{800}	Sims and Gamon (2002)
Photochemical reflection (PRI_{mod})	$C - [(R_{570} - R_{531})/(R_{570} + R_{531})]$	Peñuelas et al. (2013)
Flavonoids (FRI_{mod})	$C - [((1/R_{410}) - (1/R_{460})) \times R_{800}]$	Merzlyak et al. (2005)

Indices photochemical reflection index (PRI_{mod}) and flavonoid index (FRI_{mod}) were calculated with a C constant of 0.7

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green plant organs; ε – efficiency of photosynthetic conversion of absorbed energy to biomass; R – biomass spent on respiration.

The amount of incident light depends on the climatic conditions in the region and can be measured with great precision during the vegetation of individual or all sown plants, taking into account in the latter case non-uniform lighting over the field. Two other components of the equation designating the capacity of the photosynthetic system and its efficiency may be determined with the help of sensors that do not destroy plant tissues, though the methodology of their evaluation is not sufficiently developed as yet. When diagnosing the condition of crops, attention is usually paid only to the plant ability to absorb light energy, while the efficiency of its transformations in photochemical processes of photosynthesis is taken into consideration much less often.

The capacity of the photosynthetic apparatus may be estimated by the value of the chlorophyll index and serve as an indicator of the plant potency to absorb light. The index value is closely related to the chlorophyll content in plant tissues and may characterise the capacity of the photosynthetic apparatus and the potential ability of the plant to absorb solar radiation. The degree of the change of this index in the conditions of drought depends on the intensity of drought and its duration as well as on the cultivar tolerance to water deficit. As was shown previously with spring wheat cv. Krasnoufimskaya 100 whose resistance to drought is medium, the power of influence of moderate soil drought (50% of TFC) upon ChlRI equals 4% ($P = 0.015$) while in case of more severe drought (30% of TFC) this parameter increases up to 17% ($P < 0.0001$) (Yakushev et al. 2017).

Short-term soil drought created in our experiments did not have a reliable influence upon the ChlRI value of drought-resistant cultivars (Figure 1, Table 2). The response of non-resistant cultivars in the same conditions was more variegated and depended on the decreased water content in leaves due to water deficiency. The most powerful impact of drought was observed in plants of cv. Leningradka ($\eta^2 = 14.25$; $P = 0.047$). Cv. Leningradskaya 97 demonstrated no reliable effect of drought on ChlRI in spite of significant dehydration of leaves ($\eta^2 = 7.62$; $P = 0.154$). Two other non-resistant cultivars, Trizo and Belorusskaya 80, did not reveal a reliable influence of drought on chlorophyll index either.

Other researchers (Drozdova et al. 2004, Nikolaeva et al. 2010) came to similar conclusions about the relative stability of wheat pigment apparatus in conditions of dehydration and stable operation of electron transport chain of photosynthesis under the effect of moderate soil drought.

Short-term soil drought wheat plants were exposed to was accompanied by a water loss that was especially pronounced in cultivars non-resistant to drought (Figure 2). The maximum water loss occurred in cvs. Leningradskaya 97 and Leningradka (48% and 40%, respectively). In the same conditions, plant leaves of the non-resistant cv. Belorusskaya 80 lost only 12% of water as compared with its initial content in the control sample. Plants of drought-resistant cultivars lost from 9% to 13% of water under the

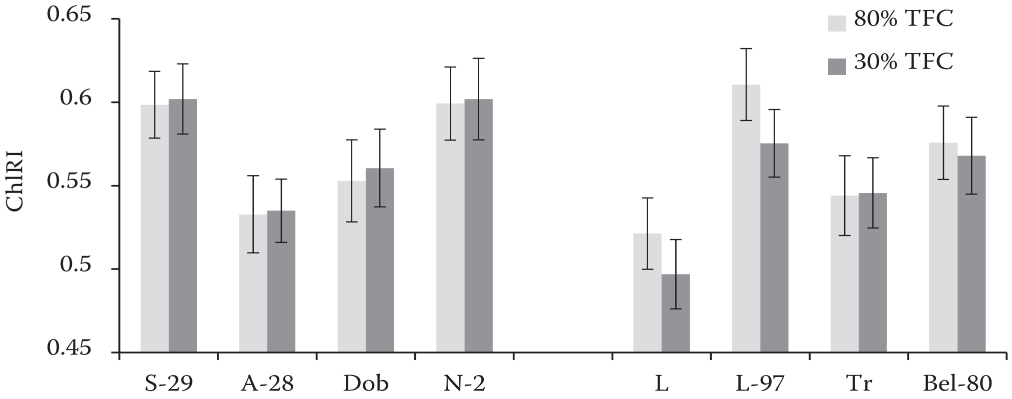

Figure 1. Changes in chlorophyll index (ChlRI) caused by short-term soil drought. The value 80% of total field capacity (TFC) refers to the control sample, 30% of TFC – to the test one. Drought-resistant wheat cultivars are: S-29 – Saratovskaya 29; A-28 – Albidum 28; Dob – Dobrynya; N-2 – Neeva 2; non-resistant cultivars: l – Leningradka; L-97 – Leningradskaya 97; Tr – Trizo; Bel-80 – Belorusskaya 80. Error bars indicate the confidence interval ($P \leq 0.05$) around the ChlRI mean value

Table 2. The efficiency of short-term soil drought influence on reflection indices of wheat leaves

Cultivar	Reflection indices							
	ChlRI		R_{800}		PRI_{mod}		FRI_{mod}	
	η^2	*P*	η^2	*P*	η^2	*P*	η^2	*P*
Drought-resistant cultivars								
Neeva	1.28	0.551	5.20	0.704	2.78	0.379	18.72	0.021
Albidum 28	0.07	0.905	31.49	0.004	21.53	0.052	10.72	0.004
Saratovskaya 29	1.45	0.575	0.014	0.965	13.15	0.116	26.52	0.010
Dobrynya	1.90	0.520	6.55	0.227	0.09	0.904	4.90	1.7×10^{-7}
η^2_{mean}	1.18		10.55		9.39		15.21	
Non-resistant cultivars								
Belorusskaya 80	0.53	1.521	76.39	9.6×10^{-6}	48.98	0.002	34.43	0.010
Trizo	0.02	0.939	13.32	0.039	20.86	0.014	26.22	0.005
Leningradskaya 97	7.62	0.154	26.70	0.028	28.05	0.011	61.46	1.2×10^{-3}
Leningradka	14.25	0.047	35.44	0.014	29.01	0.014	43.41	0.003
η^2_{mean}	5.60		37.96		31.72		41.37	

η^2 – effect size of a factor (3 days, 30% of total field capacity (TFC)); ChlRI – reflection index of chlorophyll; R_{800} – that of light diffusion inside the leaf; PRI_{mod} – that of photochemical processes activity; FRI_{mod} – that of flavonoids; η^2_{mean} – average value of the factorial influence for 4 cultivars; *P* – significance of factorial influence (the differences between the variants were considered significant at $P \leq 0.05$)

impact of drought. Biomass of all cultivars studied diminished due to the drought, the most significant in cvs. Leningradskaya 97 and Leningradka.

The deficiency of water caused changes in spectral characteristics of radiation reflected from the leaves, which was more pronounced in cultivars non-resistant to drought than in resistant ones. After a short-term soil drought, the total amount of radiation reflected from leaves of non-resistant cultivars increased on average by 23% in the green region of the spectrum, by 22% in the yellow one, by 24% in the orange region and by 15% in the near-infrared one. In drought-resistant cultivars, the amount of reflected radiation did not change in the visible region of the spectrum except for a small increase in the near-infrared region, where the difference between control and test samples was 7%.

Water deficiency intensified also the diffusion of radiation by leaf tissues, as evidenced by the increase

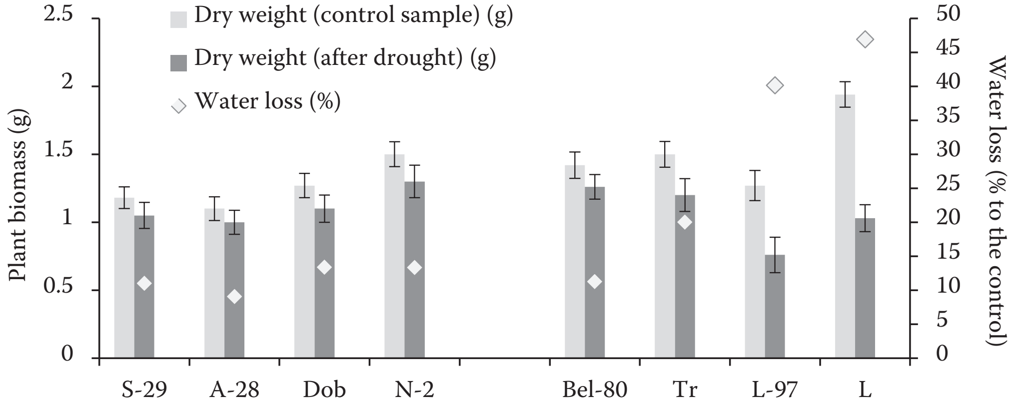

Figure 2. Biomass of spring wheat plants at optimal watering (80% of total field capacity (TFC)) and after the loss of water by leaves due to short-term soil drought (30% of TFC). Drought-resistant wheat cultivars are: S-29 – Saratovskaya 29; A-28 – Albidum 28; Dob – Dobrynya; N-2 – Neeva 2; non-resistant cultivars: l – Leningradka; L-97 – Leningradskaya 97; Tr – Trizo; Bel-80 – Belorusskaya 80. Error bars indicate the confidence interval ($P \leq 0.05$) around the plant weight mean value

of index R_{800} value, more pronounced in non-resistant cultivars. Reliable changes of R_{800} after short-term drought were observed in all non-resistant cultivars and one resistant cultivar, Albidum 28 (Table 2).

The relationship between leaf reflectivity in the near-infrared region at R_{800} of 800 nm and its structural features was previously studied with 48 cultivars of Angiosperms (Slaton et al. 2001). The 800 nm wavelength was chosen by the authors with the purpose to distinguish the influence of the structure from that of the leaf chemical composition or the amount of water in it. Multiple regression analysis showed that R_{800} correlated both with the fraction of mesophyll occupied with intercellular air spaces and with the ratio of the surface area of the cells of mesophyll having intercellular air spaces to the unit of the leaf surface area. It was also reliably established that R_{800} is related to the cuticle thickness ($r = 0.93$), however, the researchers did not observe any statistically significant linear relationship between light diffusion and such variables as leaf thickness, the content of water in the leaf, its specific weight and the percentage of dry weight in it (Slaton et al. 2001, Sims and Gamon 2002).

The difference in the value of R_{800} between drought-resistant and non-resistant cultivars of soft spring wheat shown in Table 2 may be presumably explained partly by their different tolerance to water deficit, namely, by their ability to reduce the intensity of transpiration when the loss of turgor takes place (Quartacci et al. 1995, Lizana et al. 2006). With a small water deficit, the loss of turgor and the reduction of transpiration are reversible, especially in drought-resistant plants.

Thus, R_{800} can serve as a criterion in the diagnosis of water stress and the evaluation of cultivar reaction to the effect of drought. However, different wheat cultivars, lines and forms have different leaf structures, so their comparative assessment based on only one criterion, the diffusion of light (R_{800}), may give erroneous results. This can be seen in Table 2, which demonstrates the power of the factorial influence of short-term drought on wheat species varying in drought resistance.

Whereas the photosynthetic capacity of leaf tissues can be easily evaluated by chlorophyll content in them, actual photosynthesis is determined by the efficiency of using absorbed radiation, especially in unfavourable conditions. The PRI was developed to estimate the level of xanthophyll cycle activity and the efficiency of using PAR. It has been demonstrated that PRI allows tracking the reduction of PAR usage efficiency caused by the effect of various unfavourable factors, such as lack of nutrition (Filella et al. 1996) or water deficiency (Tambussi et al. 2000, 2002). As shown in later works, changes of PRI are related not only to the transformation of pigments of the xanthophyll cycle but also to varying contents of chlorophyll and carotenoids, as well as to the relationship between these pigments (Gitelson et al. 2017). Sang et al. (2019) concluded that PRI was significantly correlated with canopy radiation use efficiency both under climate change and drought stress conditions, indicating the applicability of PRI for tracking the drought, however, it is necessary to develop an integrated model for stress diagnosis using PRI by minimising the influence of physical and physiological factors on PRI and incorporating the effects of other vegetation indices.

In spite of the fact that the value of PRI_{mod} in drought-resistant cultivars increases after a three-day drought, no reliable changes in the activity of photochemical processes of photosynthesis were evident (Figure 3, Table 2). Non-resistant cultivars responded to the effect of short-term soil drought with increasing PRI_{mod}. Changes observed in the photochemical reflection index are indicative of the high sensitivity of the criterion and of the possibility to use it for early detection of water deficit and in the diagnostics of the tolerance of soft spring wheat cultivars.

Since the chlorophyll content both in drought-resistant and non-resistant wheat cultivars did not change, except in cv. Leningradka (Table 2), it may be suggested that variations in PRI_{mod} are mainly associated with changes in the pool of carotenoids and with the transformation of the xanthophyll cycle pigments, which is accompanied by thermal dissipation and the ensuing reduction of the efficiency of using PAR.

Another indicator of reduced efficiency of photosynthesis processes due to short-term soil drought was, in the cultivars studied, the increase in the flavonoid content (FRI_{mod}), more significant in the non-resistant cultivars (Figure 4, Table 2). The accumulation of flavonoids, estimated by the value of flavonoid reflection index FRI, was observed not only after the drought but also under the action of other unfavourable environmental factors causing oxidative stress, such as UV B radiation, increased soil acidity and nitrogen nutrition deficiency (Kanash et al. 2013, Chesnokov et al. 2019).

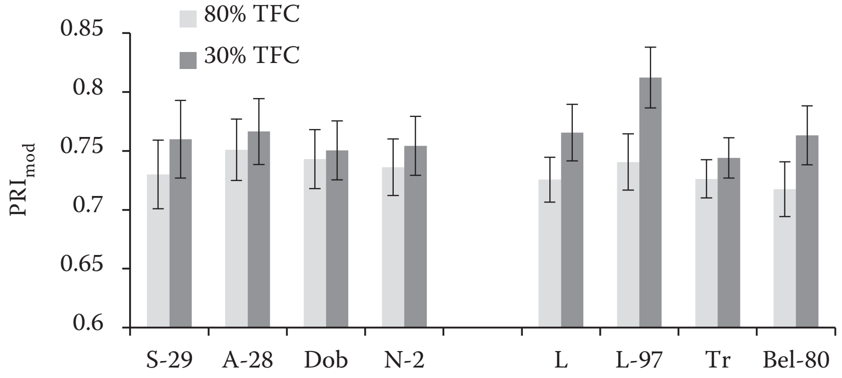

Figure 3. Photochemical reflection index (PRI$_{mod}$) of the leaves of drought-resistant and non-resistant cultivars in conditions of optimal watering (80% of total field capacity (TFC)) and after a short-term drought (30% of TFC). Drought-resistant wheat cultivars are: S-29 – Saratovskaya 29; A-28 – Albidum 28; Dob – Dobrynya; N-2 – Neeva 2; non-resistant cultivars: l – Leningradka; L-97 – Leningradskaya 97; Tr – Trizo; Bel-80 – Belorusskaya 80. Error bars indicate the confidence interval ($P \leq 0.05$) around the PRI$_{mod}$ mean value

Taking into consideration changes in the average values of reflection indices occurring under the impact of short-term soil drought, it may be concluded that non-resistant cultivars were more susceptible to water deficit (Table 2). In the drought-resistant cultivars, the average value of factorial drought influence (η^2_{mean}) on ChlRI was equal to 1.18%, while in the non-resistant cultivars it was 5.60%. Although reliable losses of chlorophyll due to the drought were revealed only in one non-resistant cultivar, namely, Leningradka, the observed tendency of changes in ChlRI and differences between the two groups of cultivars suggest that in conditions of water deficit non-resistant cultivars are more likely to exhibit the reduction in the pool of chlorophylls and the ensuing decrease of photosynthetic apparatus capacity than drought-resistant ones.

Although the value of factorial influence on the light scattering indicator R_{800} of leaves of non-resistant cultivars (η^2_{mean} = 37.96) is, on the average, 3.6 times lower than that of the drought-resistant ones (η^2_{mean} = 10.55), the change in R_{800} value due to the drought in the drought-resistant cv. Albidum 28 was close to that in the non-resistant cvs. Leningradka and Leningradskaya 97 (Table 2). The differences observed may be associated with the peculiarities of leaf structure and different cuticle thickness, as well as with the presence and the density of trichomes on the leaf surface. For this reason, the evaluation of drought-resistant wheat cultivars, lines and forms

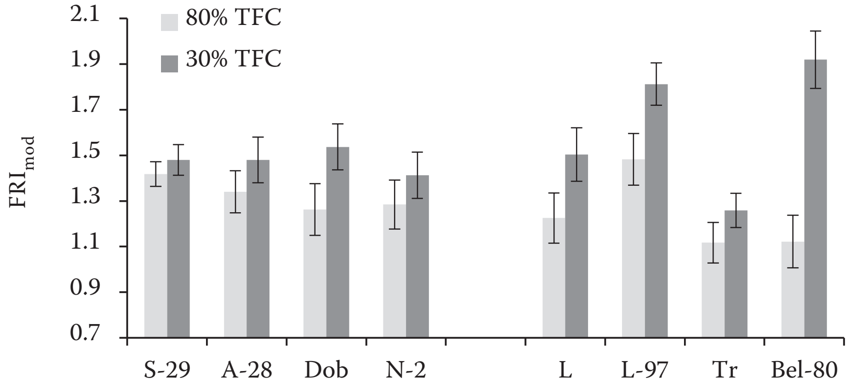

Figure 4. Changes in the flavonoid index (FRI$_{mod}$) caused by short-term soil drought in the drought-resistant cultivars of spring wheat. Drought-resistant wheat cultivars are: S-29 – Saratovskaya 29; A-28 – Albidum 28; Dob – Dobrynya; N-2 – Neeva 2; non-resistant cultivars: l – Leningradka; L-97 – Leningradskaya 97; Tr – Trizo; Bel-80 – Belorusskaya 80. Error bars indicate the confidence interval ($P \leq 0.05$) around the FRI$_{mod}$ mean value

whose anatomical and morphological structure is insufficiently studied may be inaccurate.

Two other reflection indices, PRI_{mod} and FRI_{mod}, characterising the efficiency of light usage in the photochemical processes of photosynthesis are sensitive to water deficiency and change noticeably both in drought-resistant and non-resistant cultivars. On average, the effect size of a factor (η^2) on PRI_{mod} was 9.39% in the drought-resistant cultivars and 31.72% in the non-resistant ones (Table 2). Respective values for FRI_{mod} were 15.2% and 41.4%. Thus, average values of factorial influence (η^2_{mean}) on PRI_{mod} and FRI_{mod} of drought-resistant cultivars exceeded that of non-resistant ones 3.7 and 2.7 times, correspondingly.

The results obtained show that changes in the optical characteristics of wheat leaves allow to evaluate both the capacity of the photosynthetic apparatus and the efficiency of light usage by various genotypes and to select the most valuable of them. In the system of interaction between the soil, the plant and the effective layer of the atmosphere all analysed indices of the leaf diffuse reflection change with the emergence of water deficit.

The indicator of the photosynthetic apparatus capacity is less susceptible to the effect of the short-term soil drought than the indices of light usage efficiency in the process of photosynthesis (R_{800}, PRI_{mod} and FRI_{mod}) which change significantly, the extent of their change being able to serve as a reliable enough criterion in the identification of plant stress caused by water deficit. When evaluating and comparing the reaction of different cultivars, lines and forms of soft spring wheat to water deficit in the system of the interaction between the soil, the plant and the effective layer of the atmosphere, it is advisable to include in the set of cultivars studied those with known optical properties and known range of their changes under the effect of water deficit. That will ensure a reliable ranking of analysed genotypes according to their drought resistance and increase the accuracy of the diagnostics of their resistance to drought.

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