ИЗМЕНЕНИЯ В ХЛОРОФИЛНАТА ФЛУОРЕСЦЕНЦИЯ НА ЗИМНА ОБИКНОВЕНА ПШЕНИЦА В ЗАВИСИМОСТ ОТ ЗАПЛЕВЕЛЯВАНЕТО И СРОКА НА ВНАСЯНЕТО НА НАБОР ОТ ХЕРБИЦИДИ
CHANGES IN THE CHLOROPHYLL FLUORESCENCE OF COMMON WINTER WHEAT DEPENDING ON THE WEED INFESTATION AND THE DATE OF APPLICATION OF A SET OF HERBICIDES

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Abstract

The aim of the investigation was to determine the effect of weed infestation and the date of application of a set of herbicides on the functional activity of the photosynthetic apparatus according to the parameters of the chlorophyll fluorescence of common winter wheat. The investigations were carried out during 2013–2014 at the Dobrudzha Agricultural Institute. The following herbicides were used: *Derby super VG* (33 g/ha), *Granstar 75DF* (15 g/ha), *Lintur 70VG* (150 g/ha), *Secator OD* (100 ml/ha), *Mustang 306,25 CK* (800 ml/ha), *Palace 75WG* + oil (250 + 1000 g/ml/ha), *Husar Max OD* (1000 ml/ha) from the group of sulfonylureas with various mechanism of action. The preparations were applied in two stages of the common winter wheat cultivars *Aglika* and *Enola* (stages 29 and 32 according to *Zadoks*). The indices of chlorophyll fluorescence were as follows: zero (minimum) chlorophyll fluorescence in dark-adapted leaves (F_0), maximum fluorescence in dark-adapted leaves (F_m), maximum photochemical efficiency of PS_2in dark-adapted leaves (Y_0), moment chlorophyll fluorescence in light-adapted leaves (F`), maximum fluorescence in light-adapted leaves ($F`_m$), actual photochemical efficiency of PS_2 in light-adapted leaves (Y) and electron transportation rate in light-adapted leaves (ETR). The results from the analysis showed that the treatment with the herbicides did not have negative effect on the potential photosynthetic activity of PS_2 in all variants of the two cultivars on both dates of application. The data from the light-adapted leaves in *stage 32* revealed a decrease in the values of the actual photochemical efficiency (Y) and lower rate of electron transportation (ETR) after the use of *Derby super VG*, *Lintur 70VG*, *Husar Max OD*, *Secator OD* and *Mustang 306,25 CK* in the *Aglika* cultivar. In the *Enola* cultivar, the factor “stage” was of a better statistical significance compared with the ETR factor, which was characterized by a lower effect according to the Yindex (0,096*).

Key words: common winter wheat, herbicides, weeds, dates of application, chlorophyll fluorescence.

INTRODUCTION

The problem with the weeds arises from their great specific diversity and their high ecological plasticity. They have variable morphology, biology and ecology. Agriculture suffers enormous damages due to weed competition. They have been classified as the green enemy of humankind (Tonev, 2000). Fetvedgieva et al. (1991) determined that the productivity of the winter cereals decreased under high weed density: wildmustard – over 3 plants/m^2, chamomile species - 3 plants/m^2. The biological threshold of harmfulness of cleavers in the wheat crop is 15 plants/m^2. Under such weed density, plant growth, yield and the economical properties of grain deteriorate (Nakova, 2007; Nakova, 2011). Nakova (2008) pointed out that density of weed infestation with 2 to 8 plants/m^2 of creeping thistle had negative effect on the grain weight per spike of wheat. The choice of products applied to each crop is of primary importance in the chemical control of weeds. Apart from high biological efficiency, the herbicide is required to possess high selectivity as well. This leading property is achieved at the expense of many different factors that can be divided into three groups related to the plants, the herbicides and the environment.

A number of authors (Tonev and Tityanov, 2001; Tonev and Vassilev, 2011) have pointed out that the role of plants in the herbicide selectivity can be related to several main factors: age of the weeds, growth rate of the weeds, morphological peculiarities of the crop and its physiological and biochemical characteristics. The role of the herbicide for the selectivity is primarily related to its mechanism of action. When the herbicides selectivity to the cultural plants is insufficient, they can cause structural and functional damages known as phytotoxicity. According to Tonev and Tityanov (2001), besides being species-specific, the reaction to a given herbicide or a group of herbicides is very often cultivar-specific. The limited selectivity of some herbicides to the cultural plant does not always have visual expression. According to data by Tonev and Vassilev (2011); Mitkov (2012), a significant requirement to the new chemical products used is to determine their efficiency with regard to the weeds and their selectivity with regard to the crop. The stage of wheat development and the date of herbicide treatment affect the crop's susceptibility.

Turk et al. (2003) found out that the selective action of 2,4D decreased with the later stages of the crop development. According to data by Tityanov (2006), selectivity of wheat at stage full tillerging was found out after application of the preparations Derby 175CK (5 ml/da), Secator VG (30 g/da), Lintur 70VG (15 g/da), Granstar 75DF (1,5 g/da), Puma super 7.5EV (100 ml/da), Topik 080EK (30 ml/da), Grasp 25CK (120 ml/da), Izor 500CK (300-500 ml/da). Tityanov et al. (2010) determined that the herbicides Aksial 050EK (90 ml/da), Topik 080 EK (50 ml/da), Puma super 7,5EV (100 ml/da), Palace 75WG (25 g/da), Husar Max OD (100 ml/da) demonstrated high selectivity to wheat when applied at two stages of the crop – full tillering and 1st – 2nd node, and occurrence of phytotoxicity was not detected. Paciorek et al. (2005) pointed out that the auxins (2,4 Dand 2M-4X) suppressed the respiratory metabolism in the plant cell. The end result was destruction of the membranes and disintegration of the mitochondria. The herbicides caused chromosome anomalies and inhibited cell division (Topaktas and Rencuğullari, 1991). Decrease of mitotic activity was observed, which is related to inhibition of the DNA synthesis and formation of irregular and disorganized phragmoplasts (Lehnen et al., 1990). According to Tonev et al. (2007), the visible symptoms of damage cased by this type of herbicides are wilting of leaves, epinasty on the petioles along the stem and leaves, tumor knots on the stem, formation of long adventitious roots. The stems of plants remain green longest. Tomlin (2003) found out that 2,4D is a phenoxy acid of auxin type. It affects the gene action causing chlorosis at growth points and stunted plant growth resulting in membrane destruction. The products based on 2,4 Dand 2M-4X are phenoxy herbicides – growth regulators which affect respiration, translocation and cell division. Rao (2000) pointed out that the herbicides based on dicamba modified the nucleic acid metabolism which destroys the development of the susceptible weeds. According to data by Amann et al. (2000), the mechanism of action of the herbicides inhibitors of acetolactate synthase (ALS) is in the process of clarifying. It is considered that these inhibitors are linked irreversibly to products of the reactions, which ceases the biosynthesis of the amino acids (valine, leucine, isoleucine). Rao (2000) and Vencill (2002) pointed out that the herbicides from the group of the sulfonylureas suppress plant metabolism by inhibiting the ALS enzyme, which is crucial for the bio synthesis of the amino acids isoleucine, leucine and valine. They inhibit the activity of ALS and damage the meristem tissues. Zhou et al. (2007) found that the products from this group had weaker effect on the perennial broad-leaved weeds due to the reduced transportation in the plant's phloem. The results are occurrence of chlorosis and necrosis on the plants (Tomlin, 2003).

According to Baker et al. (2001), the chlorophyll fluorescence is an indicator of the photochemical processes and the functional activity of PS_2, and is particularly suitable for analysis of genotypes susceptible to stress influences. It provides information on the plants' photosynthesis and allows evaluation on the relation between wheat fluorescence and productivity of wheat. A correlation was found between chlorophyll fluorescence and the efficiency of the photosynthetic apparatus.

The aim of this investigation was to find out what was the effect of the weed infestation and the date of application of a set of herbicides on the functional activity of the photosynthetic apparatus determined according to the parameters of the chlorophyll fluorescence of common winter wheat.

MATERIALS AND METHODS

The investigations were carried out in 2013 and 2014 at DAI – General Toshevo. The field experiment was designed according to the block method in four replications, the size of the trial area being 15 m^2. Two checks were involved: K_1 – a weed-free variant manually weeded till stage heading of wheat, and K_2 – a variant infested till the end of the crop's vegetation.

The following herbicides were used: Derby super VG (florasulam+aminopyralid- potassium) - 33 g/ha, Granstar 75DF (tribenuron-metil) - 15 g/ha, Lintur 70VG (triasulfuron+dicamba) - 150g/ha, Secator OD (amidosulfuron+iodosulfuron) - 100 ml/ha, Mustang 306.25CK (florasulam+2.4-D ester) - 800 ml/ha, Palace 75WG+oil (pyroxulam) - 250+1000 g/ml/ha and Husar Max OD (mesosulfuron+iodosulfuron+ antidot) - 1000 ml/ha. The preparations were applied at three stages of common winter wheat cultivars Aglika and Enola (end of tillering and first – third node: stages 29 and 32 according to Zadoks et al. (1974)).

Prior to sowing of wheat, artificial infection background was created imitating infestation with the most common weeds in the region of DAI – General Toshevo: annual weeds (ivy-leaved speed weell-*Veronica hederifolia* (L.), wild mustard - *Sinapis arvensis* (L.), cleavers - *Galium tricorne Stok*, the German chamomile – *Matricaria inodora* (L.), field chamomile - *Anthemis arvensis* (L.), Royal knight`s spur - *Consolida regalis Gray*) and perennial broad-leaved weeds (creeping thistle - *Cirsium arvense* (L.) *Scop* and fieldbindweed - *Convolvulus arvensis* (L.)).

The density of weeds per unit area was determined quantitatively after the application of the herbicides on plants collected from a surface of 0.25 m^2. The efficiency of the herbicides was estimated 25-30 days after their application on the plants taken from the above area: quantitatively by species and as dry weight (g) per square meter.

Plant material

Cultivar Aglika is of high quality and belongs to the group of strong wheats with excellent baking and milling properties. It gives very good results after sowing at norm 500–550 germinating seeds/m^2 (Tsenov et al., 1998).

Cultivar Enola is a medium early cultivar, with very good productive tillering and very good cold and winter resistance. It belongs to the group of medium-quality wheats with increased strength. The cultivar gives very good results after sowing with 450-500 germinating seeds/m^2 (Kostov et al., 1998).

Parameters of chlorophyll fluorescence

The parameters of chlorophyll fluorescence were determined in intact leaves by pulse-modulated fluorometer MINI-PAM (H. Walz, Effeltrich, Germany) according to Schreiber et al. (1986). After 60 min dark adaptation of leaves, the following parameters were read: initial (null) fluorescence (F_0) at intensity of the measuring red light 0.15 μmol $m^{-2}s^{-1}$ and frequency 0.6 kHz; maximal fluorescence (F_m) under saturating light pulse of 0.8 s and light intensity (PAR) above 5500 μmol m^{-2} s^{-1}. The variable fluorescence ($F_v = F_m – F_0$) and the potential photochemical activity of PS_2 (potential quantum yield). After 30 min light adaptation the following parameters were determined: F,F_m', Y, ETR. Stationary fluorescence (F), maximal fluorescence (F_m') (under saturating light impulse of 0.8 s and light intensity (PAR) above 5500 μmol m^{-2} s^{-1}). Based on these indices, the actual quantum yield $Y = (F_m' – F)/F_m'$, (Genty et al., 1989) and the electron transport rate (ETR) (Horton et al., 1996; Nogués and Baker, 2000) were automatically calculated. Three measurements per each variant were carried out.

Statistical analyses

Statistical evaluation was made to represent and characterize the significance of the effect of the investigated factors by applying three-factor dispersion analysis with Biostat 7.0. (Chiang, 2003).

RESULTS AND DISCUSSION

In cultivar Aglika, the herbicides Derby super VG, Lintur 70VG, Secator OD and Mustang 306,25CK demonstrated highest efficiency of 100% on the investigated weeds during both cropping seasons (Table 1). The herbicide products Granstar 75DF, Palace 75WG+oil and Husar Max OD had partial herbicidal effect (60-75%). Granstar 75DF had weaker effect on cleavers and creeping thistle. The accumulated dry matter varied from 13.6 до 57.7 g/m^2 in comparison to 150.4 - 237.6 g/m^2 of the weeded check. Palace 75WG+oil and Husar Max OD were characterized with lower herbicide efficiency to cleavers, the German chamomile, field chamomile and Royal knight`s spur. The dry matter accumulated after treatment with Palace 75WG + масло varied from 15.1 to 38.8 g/m^2, and after application of Husar Max OD - from 6.4 to 19.4 g/m^2 as compared to 150.4 - 237.6 g/m^2 of the weeded check.

Significant differences in the values established for the index Y_0 after treatment with the herbicides during the two cropping seasons of cultivar Aglika (Table 2) were not found. They were within the range 0.75-0.83. The treatment with the herbicides did not have negative effect on the active centers of PS_2.

Таблица 1. Заплевеляване на посев пшеница сорт Аглика преди и след внасяне на хербицидите „фаза 29 и 32“, по години

Table 1. Weed infestation in a crop of wheat cultivar Aglika before and after application of herbicides at stages 29 and 32, over years

Варианти Variants	2013			2014		
	Преди/Before Plants/m^2	След/After Plants/m^2	Тегло/Weight g/m^2	Преди/Before Plants/m^2	След/After Plants/m^2	Тегло/Weight g/m^2
Дерби супер ВГ	*325	0	0	154	0	0
Derby super VG	**296	0	0	113	0	0
Гранстар 75ДФ	380	137	27,5	136	9	13,6
Granstar 75DF	311	76	57,7	120	29	39,2
Линтур 70ВГ	383	0	0	123	0	0
Lintur 70VG	306	0	0	104	0	0
Секатор ОД	354	0	0	107	0	0
Secator OD	35	0	0	118	0	0
Мустанг 306,25СК	340	0	0	216	0	0
Mustang 306,25CK	319	0	0	85	0	0
Палас 75ВГ + масло	438	80	25,6	154	28	15,1
Palace 75WG + oil	245	107	38,8	141	27	29,6
Хусар Макс ОД	286	42	11,0	171	2	6,4
Husar Max OD	245	54	19,4	153	10	12,0
Контрола заплевелена	472	429	182,4	208	198	150,4
Weeded check	314	306	237,6	133	106	161,0

*Легенда/Key: * - фаза/stage 29, ** - фаза/stage 32*

Таблица 2. Влияние на набор от хербициди върху максималната фотохимична ефективност на ФС2 в тъмнинно адаптирани листа при сорт Аглика – „фаза 29 и 32”, по години

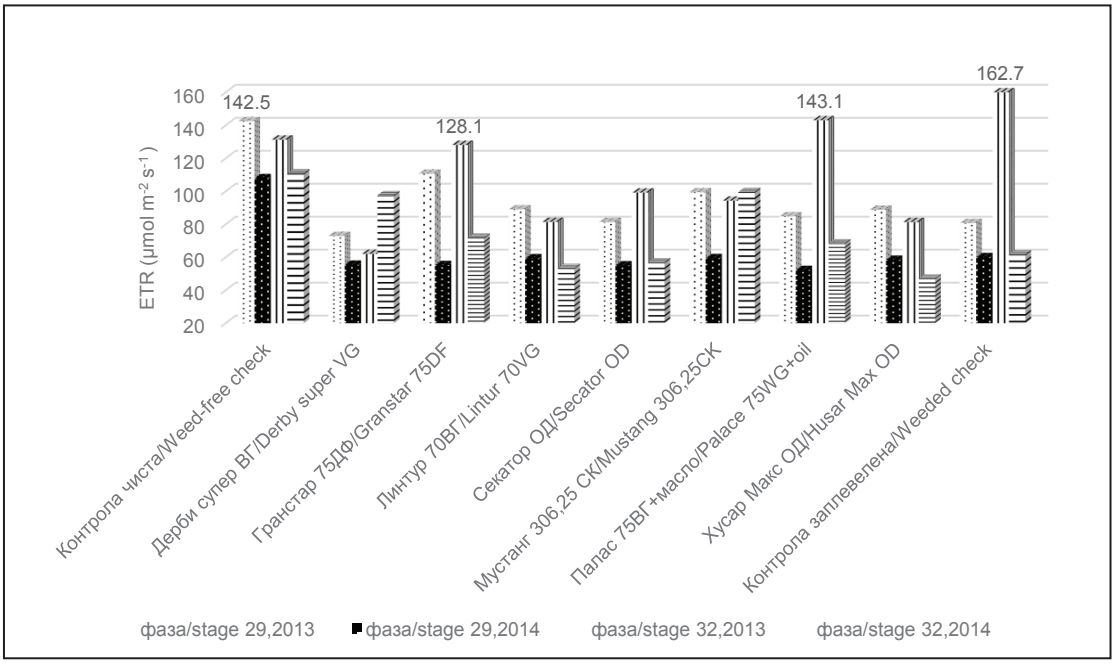
Table 2. Effect of a set of herbicides on the maximum photochemical efficiency of PS_2 in dark-adapted leaves of cultivar Aglika at stages 29 and 32, over years

Варианти/Variants	Фаза 29/Stage29		Фаза 32/Stage 32	
	2013	2014	2013	2014
Контрола чиста/Weed-free check	0,782	0,829	0,761	0,825
Дерби супер ВГ/Derby super VG	0,809	0,835	0,818	0,837
Гранстар 75ДФ/Granstar 75DF	0,767	0,805	0,801	0,836
Линтур 70ВГ/Lintur 70VG	0,826	0,837	0,809	0,831
Секатор ОД/Secator OD	0,803	0,832	0,822	0,828
Мустанг 306, 25СК/Mustang 306,25CK	0,793	0,825	0,803	0,833
Палас 75ВГ + масло/Palace 75WG + oil	0,775	0,806	0,797	0,838
Хусар Макс ОД/Husar Max OD	0,810	0,832	0,828	0,835
Контрола заплевелена/Weeded check	0,834	0,790	0,774	0,834

In cropping season 2013, highest values of the electron transportation rate were found after treatment with Granstar 75DF, Palace 75WG+oil and in the weeded check (Figure 1). These two preparations were characterized with lower effect on the weeds. In the weeded check, the higher values of this index were due to the higher amount of weed mass in comparison to the other tested variants. In cropping season 2014, the investigated index was characterized with lower values of the data at both dates of treatment due to the unfavorable meteorological conditions during the investigation. The lower values of the electron transport in both years after treatment with Lintur 70VG and Mustang 306,25СК

at stage 32 were the result from the expression of phytotoxicity. It was manifested as anthocyanin coloration of spikes and occurrence of partial to full sterility more evident after treatment with Lintur 70VGand less - after Mustang 306,25CK. The low ETR values in some of the variants were the result from the presence of weeds not affected by the herbicides.

The factor year conditions in cultivar Aglika had the highest effect on the index electron transport rate (ETR), followed by the actual photochemical efficiency of FS_2 (Table 3). The factors herbicide and stage of treatment were significant (*P = 0,05) for the index ETR. The statistical analysis was performed for dirk-adapted and light-adapted leaves.



Фиг. 1. *Влияние на набор от хербициди върху скоростта на електронния транспорт при сорт Аглика – „фаза 29 и 32", по години, (µmol $m^{-2}s^{-1}$)*

Fig. 1. *Effect of a set of herbicides on the rate of electron transport of cultivar Aglika at stages 29 and 32, over years (µmol $m^{-2}s^{-1}$)*

Таблица 3. Средно квадратично отклонение на параметрите на хлорофилната флуоресценция при сорт Аглика, за периода 2013/2014 г.

Table 3. Mean square deviation of the parameters of chlorophyll fluorescence in cultivar Aglika during 2013/2014

Параметри Parameters	Фактори/Factors			Грешка Error
	Хербициди Herbicides	Година Year	Фаза Stage	
Тъмнинно адаптирани листа/dark-adapted leaves				
F_0	48435,09	195069,4*	75304,2	23305,97
F_m	1119777	2860045*	83722,5	560239,9
Y_0	0,0007*	0,0062***	0,0068***	0,00028
df	7	1	1	17
Светлинно адаптирани листа/light-adapted leaves				
Y	0,007	0,041**	0,005	0,003
ETR	1643,7*	10140,5***	2084,2*	422,1
df	7	1	1	17

*** P = 0,001; ** P = 0,01; * P = 0,05

In cultivar Enola, the herbicides Derby super VG, Lintur 70VG, Secator OD and Mustang 306,25CK demonstrated the highest efficiency to weeds for the two investigated years (Table 4). Granstar 75DF had lower effect on cleavers and creeping thistle. The accumulated dry matter varied from 17.4 to 56.6 g/m^2 in comparison to 153.5–244.1 g/m^2 of the weeded check. Palace 75WG + oil and Husar Max OD were characterized with lower herbicide efficiency to cleavers, the German chamomile, field chamomile and Royal knight`s spur. The dry matter accumulated after treatment with Palace 75WG + oil varied from 15.6 to 44.6 g/m^2, and after the use of Husar Max OD– from 5.8 to 35.3 g/m^2 in comparison to 153.5–244.1 g/m^2 of the weeded check.

Significant differences in the values determined for the index Y_0 after treatment with the herbicides during the two cropping seasons of cultivar Enola were not found (Table 5). They were within the limits from 0.75 to 0.83. The use of herbicides did not have negative effect on the active centers of PS_2.

Best results on the rate of the electron transport in cultivar Enola were determined after treatment with Granstar 75DF, Lintur 70VG and Husar Max OD (Fig. 2). This was due to presence of weed mass found after the application of the herbicide products. In the rest of the variants the values of the investigated index were lower. In cultivar Enola occurrence of phytotoxicity was also observed after treatment with

Таблица 4. Заплевеляване на посев пшеница сорт Енола преди и след внасяне на хербицидите „фаза 29 и 32“, по години

Table 4. Weed infestation in a crop of wheat cultivar Enola before and after application of herbicides at stages 29 and 32, over years

Варианти Variants	2013			2014		
	Преди/Before Plants/m^2	След/After Plants/m^2	Тегло/Weight g/m^2	Преди/Before Plants/m^2	След/After Plants/m^2	Тегло/Weight g/m^2
Дерби супер ВГ	*353	0	0	113	0	0
Derby super VG	**287	0	0	178	0	0
Гранстар 75ДФ	452	53	43,2	125	12	17,4
Granstar 75DF	296	59	56,6	173	27	52,0
Линтур 70ВГ	439	0	0	129	0	0
Lintur 70VG	322	0	0	140	0	0
Секатор ОД	367	0	0	117	0	0
Secator OD	313	0	0	173	0	0
Мустанг 306,25СК	403	0	0	138	0	0
Mustang 306,25CK	338	0	0	210	0	0
Палас 75ВГ + масло	370	47	25,6	99	25	16,3
Palace 75WG + oil	310	35	15,6	196	26	44,6
Хусар Макс ОД	355	28	5,8	180	15	8,6
Husar Max OD	278	31	9,6	194	24	35,3
Контрола заплевелена	405	374	244,1	228	183	179,4
Weeded check	330	313	242,8	170	150	153,5

*Легенда/Key: * - фаза/stage 29, ** - фаза/stage 32*

Таблица 5. Влияние на набор от хербициди върху максималната фотохимична ефективност на ФС2 в тъмнинно адаптирани листа при сорт Енола – „фаза 29 и 32”, по години

Table 5. Effect of a set of herbicides on the maximum photochemical efficiency of PS_2 in dark-adapted leaves of cultivar Enola – stages 29 and 32, over years

Варианти/Variants	Фаза 29/Stage 29		Фаза 32/Stage 32	
	2013	2014	2013	2014
Контрола чиста/Weed-free check	0,787	0,831	0,788	0,834
Дерби супер ВГ/Derby super VG	0,831	0,833	0,831	0,826
Гранстар 75ДФ/Granstar 75DF	0,831	0,832	0,830	0,836
Линтур 70ВГ/Lintur 70VG	0,827	0,832	0,824	0,833
Секатор ОД/Secator OD	0,801	0,833	0,815	0,831
Мустанг 306,25СК/Mustang 306,25CK	0,798	0,836	0,836	0,836
Палас 75ВГ + масло/Palace 75WG + oil	0,771	0,799	0,823	0,830
Хусар Макс ОД/Husar Max OD	0,784	0,827	0,826	0,841
Контрола заплевелена/Weeded check	0,820	0,825	0,776	0,830

Lintur 70VG and Mustang 306,25CK. The symptoms were less expressed in comparison to cultivar Aglika. The high ETR values in some of the variants resulted from the lack of weeds in them.

The ratio F_v/F_m or the index Y_0 reflects the maximum efficiency of capturing the excitation energy from the "open" (or oxidized and ready to accept electrons) reaction centers of PS_2. The decrease of this parameter indicates down regulation or photo inhibition (Öquist et al., 1992). In this investigation, treatment expectedly did not influence this parameter.

The decrease of Y is related to greater quenching (neutralization) of the excitation energy in PS_2 and is usually considered an indicator of down-regulation of the electron transport (Horton et al., 1996) due to disturbances in the antenna complexes or the Calvin cycle, and thence – lower consummation of ATP and NADPH, which are synthesized during electron transportation at light stage. Nogués and Baker (2000) pointed out that the decrease of Y in the respective variants can be considered an indicator of physiological regulation of electron transport by higher quenching of the excitation energy in the antenna complex of PS_2. This implies relatively higher rate of the non-cyclic electron transport than necessary for sustaining of CO_2 assimilation under the given conditions. Alternative acceptors of electrons can be photo transpiration and/or the Mehler reaction, through which the photosynthetic apparatus can be protected from photo oxidation.

The results from the analysis of chlorophyll fluorescence showed that the treatment with the products did not have negative effect on the potential photosynthetic activity of PS_2 in all variants of the two cultivars at both dates of treatment. According to Schreiber et al. (1986), it is accepted that in dark-adapted leaves the potential photo chemical activity of PS_2 (Y_0) is normally within the range 0.75-0.85.

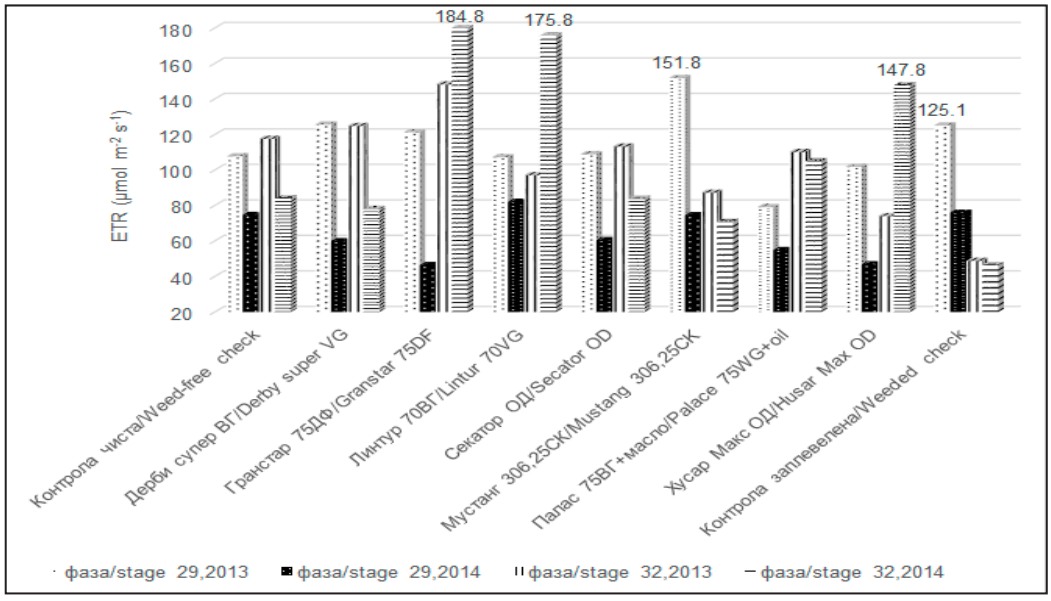
In cultivar Enola, the factor stage of treatment had good significance of the index ETR (Table 6). It was characterized with lower effect according to the index Y (0,096*). The effect of the factors herbicides and year conditions on the parameters of chlorophyll fluorescence was not significant.

CONCLUSIONS

1. The results from the analysis on the chlorophyll fluorescence showed that the treatment with the preparations did not have negative effect on the potential photosynthetic activity of PS_2 at both dates of application (stages 29 and 32) in dark-adapted leaves.

2. The treatment with the tested herbicides at stages 29 and 32 had negative effect on the crop. It was expressed in occurrence of hidden phytotoxicity in the two wheat cultivars – lower plant growth rate and decreased rate of electron transport in light-adapted leaves.

3. After using Lintur 70VG and Mustang 306,25CK at stage 32, symptoms of phytotoxicity were observed on wheat – anthocyanin coloration of leaves and spikes. These symptoms were more expressed in cultivar Aglika and less – in cultivar Enola. By the end of the growth season of wheat, partial to full sterility of spikes was found. It was better expressed after the use of Lintur 70VG and less - after Mustang 306,25CK.



Фиг. 2. *Влияние на набор от хербициди върху скоростта на електронния транспорт при сорт Енола „фаза 29 и 32", по години, (µmol $m^{-2}s^{-1}$)*

Fig. 2. *Effect of a set of herbicides on the rate of electron transport of cultivar Enola at stages 29 and 32, over years, (µmol $m^{-2}s^{-1}$)*

Таблица 6. Средно квадратично отклонение на параметрите на хлорофилната флуоресценция при сорт Енола, за периода 2013/2014 г.

Table 6. Mean square deviation of the parameters of chlorophyll fluorescence in cultivar Enola during 2013/2014

Параметри/ Parameters	Фактори/Factors			Грешка/ Error
	Хербициди/ Herbicides	Година/ Year	Фаза/ Stage	
Тъмнинно адаптирани листа/Dark-adapted leaves				
F_0	617,63	723917,4***	6448,5**	328,7
F_m	119437,9*	17404193***	212692,3*	43563,07
Y_0	0,0008*	0,003***	0,002**	0,0001
df	7	1	1	17
Светлинно адаптирани листа/Light-adapted leaves				
Y	0,014	0,031	0,096*	0,014
ETR	1872,6	4373,6	10526,4**	1019,4
df	7	1	1	17

**** P = 0,001; ** P = 0,01; * P = 0,05*

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