Professional paper

DOI: /10.5513/JCEA01/21.4.2819

Journal of Central European Agriculture, 2020, 21(4), p.751-762

Effect of date of heading on variation of basic components of productivity of winter wheat

Ефект на дата на изкласяване върху варирането на основни компоненти на продуктивността на зимна пшеница

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Received: March 16, 2020; accepted: July 23, 2020

ABSTRACT

Ear emergence time (EED) in winter wheat directly affects its ability to adapt. Its change affects the grain yield similar to its components. The aim of the study was to analyze whether the change of date of ear heading has an effect on the elements of productivity and grain yield in contrast to the growing environments. Data were collected for analysis of test 30 varieties of winter wheat in the 4-years period in five locations of the country. The performance of individual traits is estimated by different statistical approaches to study the most detailed correlationships between them. The variation of the characteristics in terms of experience in these conditions characterized by contrast. Under normal and accidental changing growing conditions, resulting in season points and testing found positive influence on later date ear heading on the yield of grain. Between the EED and components of productivity there are positive correlations that are reliable even against the contrasting conditions. Changing this trait reflects fairly heavily on the characters associated with the number of grains in spike and per unit area, too. Characters that directly determine the level of productivity in winter wheat are strongly influenced by environmental conditions and genetics of participating in the experiment varieties.

Keywords: genotype x environment interaction, grain productivity, grain yield, wheat

РЕЗЮМЕ

Признакът дата на изкласяване (EED) на зимната пшеница пряко влияе върху нейната способност да се адаптира. Промяната му влияе на добива на зърното, подобно на неговите компоненти. Целта на изследването беше да се анализира дали промяната на датата на изкласяване влияе върху елементите на продуктивността и добива на зърно в контрастни условия за отглеждане. Данните са събрани за анализ и включват 30 сорта зимна пшеница, проучвани през четиригодишен период в пет пункта на страната. Проявата на всеки един признак е оценяван чрез различни статистически подходи за изследване на корелационните връзки между тях. Варирането на признаците по отношение на изследваните условия се характеризира с контрастни стойности. При нормални и случайни променящи се условия на отглеждане, в резултат на сезонните промени се установява положително влияние на по-късната дата на изкласяване върху добива на зърно. Между признака EED и компонентите на продуктивността има положителни корелации, които са надеждно доказани дори при контрастните условия на средата. Промяната на тази признак се отразява доста силно на признаците, свързани с броя на зърната в клас и на единица площ. Признаците, които пряко определят нивото на продуктивност при зимната пшеница, са силно повлияни от условията на околната среда и генетиката на участващите в експеримента сортове.

Ключови думи: взаимодействие на генотип х среда, продуктивност на зърно, добив на зърно, пшеница

INTRODUCTION

The character ear emergence date is a key in the breeding of wheat in Bulgaria in the last 50 years (Popov and Matsov, 1969; Boydjieva, 1976; Tsenov, 2009). This stems from its influence on the main traits that determine productivity and quality of grain in terms of continental climate of the Balkan Peninsula (Popov et al., 1969; Potocanac, 1973; Kazandjiev et al., 2011; Marinciu et al., 2013; Semenov et al., 2014). Time to ear heading is inextricably linked to the behaviour of varieties in different periods of its active growing season, which ultimately determined its flexibility and adaptability (Mersinkov, 2005; Mondal et al., 2013; Langer et al., 2014). The influence of EED on the growth and development of crop is very specific because of the huge variety of conditions in which it winter type wheat is grown (Slafer et al., 2014). The variability is the reason for the extensive genetic diversity of genes vernalization and photoperiod that exists in different parts of the world (Snape et al., 2001; Hu et al., 2005; Craufurd and Wheeler, 2009; Kolev et al., 2011). There are many specific Eps-gene and QTL-genes which, according to many authors determined the fine tuning of the date of ear heading, to maximize grain yield in specific environmental conditions (Bennett et al., 2012; Bogard et al., 2014; Zikhali and Griffiths, 2015). The effect of date of ear emergence or flawering are too specific to each geographical zone, which derives directly from the environmental conditions in it and must therefore be optimized by breeding (Mustatea et al., 2011; Tsenov and Tsenova, 2011; Jocković et al., 2014). Changing the date of ear emergence in the different seasons, affect differently the grain yield because it is directly dependent on the availability and duration of biotic or abiotic stress (Boyadjieva and Andonov, 2010; Kamran et al., 2014). In various studies a strong link between the time of ear heading and magnitude of yield in wheat are reported (Tao, 2015; Tsenov et al., 2005). The relationship that exists between the EED and grain yield varies in direct relation to the location and seasonal conditions of the study (Dodig, 2012; Kamran et al., 2014). In times of drought or high temperatures during grain filling the earlier date of ear emergence is a guarantee for obtaining higher grain yield (Mondal et al., 2013; Tsenov et al., 2009). Back, in favourable conditions, especially under irrigation prevail genotypes that emerge later (Griffits et al., 2009; Reynolds et al., 2012; Bustos et al., 2013). It has been found that the influence on the yield of the EED is depending on the type of wheat grown if it is winter or spring. Often conclusions about the impact of characters are directly dependent precisely on (Mondal et al., 2013; Tsenov and Gubatov, 2015). Therefore, the patterns associated with the date of the ear emergence in studies of spring wheat, could rarely be transferred as information for winter type of wheat. Against the background of different views on the impact of weather on yield of date of ear heading is almost impossible to give accurate and correct conclusions about it.

In most of the studies trait EED has been studied as secondary on background in yield or quality (Pinto et al., 2010; Subira et al., 2015). The information that its change would have any effect on the main components determining the direct grain production is limited. Variation, which establishes the date of ear heading due to environmental conditions is large and is associated with variation in grain yield (Kalariya and Monpara, 2014; Petrova and Penchev, 2014; Tsenov and Gubatov, 2015). What are the reasons for obtaining a higher yield when changing the date of ear emergence and whether this character affects the components of productivity are issues that almost no definite reply to date? The relationships between them are generally known (Kalariya and Monpara, 2014). According to Slafer et al. (2014) between the components of yield in specific conditions there is a balance that can be changed in favour of a further increase in yield. Can we change the characters through their relationship with EED? To get the answers we need to have information on the impact of traits on the main components of productivity given their real change as a result of their interaction with environmental conditions. Knowledge of this already exist, but they do not account for the influence of the environment on components of productivity, which in turn changes the balance between them and thus has a direct effect on the correlations between them (Bustos et al., 2013;

Keshavarzi et al., 2013).

The purpose of this study was to investigate the influence on the date of the ear heading on the elements of the productivity and the yield of grain in contrast growing conditions.

MATERIAL AND METHODS

Analyzed characters

They are examined key characters related to the productivity of winter wheat. Besides of grain yield (GY) in the study are included data on other several traits: number of productive stems per m^2 (NPT); number of grains per spike (NGS); thousand grain weight (TGW); number of grains per m^2 (NGM). The trait ear emergence date (EED) is reported as the number of days from January 1 in the corresponding season. The quantitative traits of productivity are determined based on the data of each replication of the field trials. The number of productive stems is measured by counting number of ears in ¼ m^2 areas in each plot at physiological maturity. Thousand grain weight as a trait was determined after harvest by direct counting of the two samples of 500 seeds from each harvested plot. The values of the traits number of grains per spike are calculated on the basis of their size and weight of the grain of the same spike. The number of grains per m^2 is calculated from the two main characters.

Field trials

In the five locations of the country, four consecutive years (2007-2010) 30 varieties grown in producing winter wheat, were tested. The design at any location is a Latin rectangle with a plot size of 10 m^2, in five replications. Each character has been studied on measurements of the 3 medium replications of field trials. Locations of research and participating in the trail varieties are presented in detail in the previous publications of Tsenov and Gubatov (2020) and Tsenov and Gubatov (2015).

Statistical analysis

Variation, which causes the reaction of a different trait to the environmental conditions, is analyzed on the basis of each of the investigated factors in order to study the relationships between them. To identify changes caused by growing conditions on characters several statistical methods and software programs were used. The influence of different environments on the level and change of each trait is determined by analysis of variance from program Statgraphics Centurion XVI. Correlations between characters and environmental factors are analyzed by calculating the associations between them by the original statistical parameter eta^2 ($\dot{\eta}^2$) of software product IBM SPSS Statistics 23. With the module AMOS it calculated the indirect effects of the trait EED on grain yield through the values of the other studied characters. Special attention is paid to the correlation between the value on the date of ear emergence and components of productivity given their real change in the test environment.

RESULTS AND DISCUSSION

Analysis of the variation of the characters studied, according to the environmental factors is presented in Table 1. The conditions of the entire experiment are so varied the interaction of the genotype with the terms of the year and the location is present in each of the tested characters. The values of each of the trait change noticeable even in the complex interaction between every possible pair of the main factors in the test environment. Interaction (*p-value*) between the genotype and the location is found in four of these six traits, which indicates relatively less impact on traits from the point as a factor. Reaction has been found by the traits NGS and NGM even at the interaction of the three main factors (A*B*C), which is further evidence of appreciable change in any of the investigated characters as a result of the individual effects of the factors and their complex interactions of all possible levels. In EED, this is the basis of this study, the interaction with conditions not only proven by the combined effect of three factors, as already established and Tsenov and Gubatov (2015). Unproven interaction of factors (A*C) of trait NPT (B*C), and the number of grains per spike (NGS) and 1000 grain weight (TGW) are registered.

Table 1. Multivariate Analysis of Variance by Type III Sums of Squares for all the traits studied

Source	Significance	df	EED	GY	NPT	NGS	TGW	NGM
Intercept	F-Ratio	1	3360.178	60.956	211.509	73.837	434.586	71.848
	p-value		0.0000	0.0020	0.0010	0.0030	0.0000	0.0000
A:YEAR	F-Ratio	3	1451.99	1537.58	100.76	452.29	238.28	483.97
	p-value		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
B:LOC	F-Ratio	4	339.14	526.7	268.98	44.63	159.84	417.85
	p-value		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
C:GEN	F-Ratio	29	17.68	5.22	2.17	5.18	12.48	11.23
	p-value		0.0000	0.0000	0.0006	0.0000	0.0000	0.0000
A*B	F-Ratio	12	155.98	238.19	110.66	36	35.83	107.44
	p-value		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A*C	F-Ratio	87	2.72	2.64	0.9	1.48	2.37	1.78
	p-value		0.0000	0.0000	0.7106	0.0074	0.0000	0.0001
B*C	F-Ratio	116	1.38	1.82	1.35	1.06	1.08	1.65
	p-value		0.0138	0.0188	0.0191	0.3364	0.2899	0.0003
A*B*C	F-Ratio	348	1.89	1.11	0.936	2.665	0.897	5.765
	p-value		0.2340	0.2011	0.7410	0.0000	0.3590	0.0000

In general, all traits have changed significantly as a result of the change in conditions caused by each of the three factors and their combined impact. Similar information about the quantitative traits was established in studies for different effects of the environments and technology (Mursalova et al., 2015; Khazratkulova et al., 2015). These results are sufficient grounds for studying traits in terms of the objective in the study. In terms of the interaction between factors and characters it is interesting to ascertain the proportion of each factor on the occurrence and real change. Information for this to provide the data presented in Table 2.

Calculated links eta^2 (η^2) between the mean values of the characters on the basis of each of the factors used in the environment and genotype showed the strong dependence (association) on the conditions of the year followed by the location of the trail. The lowest dependencies have traits from genotype as a factor.

Table 2. Associations (*trait* factor*) between the source of variation and the traits by software Statgrapics#

Trait	Measures of Association by Eta Squared		
	* Year	* Loc	* Gen
EED	.493	.153	.058
GY	.441	.201	.014
NTP	.090	.321	.019
NGS	.253	.226	.128
TGW	.499	.066	.055
NGM	.270	.320	.057

Interpret η^2 as for r^2 or R^2; a rule of thumb (Cohen): 0.05 ~ small; 0.20 ~ medium; 0.30 ~ large

The latter is connected reliably with trait NGS, only. In three of the characters: EED, GY, TGW conditions of the year are the factor that changes the most of traits. Location conditions also have decisive influence on the manifestation of characters associated with crop density-

NPT and NGM. The number of grains per spike is the trait only influenced almost equally on three factors. It is noteworthy that the environment has a similar influence on the appearance of the trait EED and grain yield. In this case the values of the parameter estimates η2 are important because they show the magnitude of the influence of factors on each trait. Naturally "genotype" (as factor) has the slightest association with environmental conditions, and the factor "year" the strongest one. Intricate and complex environmental cause severe change in each of the characters therefore could be expected significant change and the relationships between them. Each of the investigated traits is strongly influenced by the change of each of the factors to varying degrees (Table 3).

Table 3. Variance Components Analysis (%) of main environmental factors for all traits

Variation	Year	Location	Variety
EED	51.48	40.92	7.61
GY	48.58	38.78	12.64
NTP	59.40	22.13	18.47
NGS	52.26	23.26	24.48
TGW	22.38	42.45	35.17
NGM	20.09	61.91	18.00

According to the magnitude of the influence of factors are emerging signs two groups: one strongly influences the conditions of the year (EED, GY, NTP, NGS) and two strongly influence the environments of location. The influence of variety genetics on several traits vary – from 7.61 % at EED, to 35.17 % at TGW. The low proportion of genotype variability of characters is reported repeatedly by Fatemeh et al., (2015) and Ivanova and Tsenov, (2014). In traits NTP and NGS the "variety" effect is close to that of locations (24.48 % and 35.17 %), respectively, which is a bit unusual. On the other side, there is information on the relevance of the two factors on grain yield, in different environments (Subira et al., 2015) There are significant differences in each of the characters under the influence of the conditions of the studied factors (Table 4 and 5). The data in these tables are grouped by traits, according to the magnitude of influence of factors on them. Variation in EED is so great that between seasons significant difference of almost a full 10 days exist (124.2 days to 133.8 days). Practically in each season, the mean value is significantly different from the others on the level of 5%. When analyzing the data оди grain yield and weight of 1000 grains, we observe completely analogous picture where the differences reach up to 55% (GY) and 43% in (NGS). These differences in the background of normal variation of any quantitative traits are indeed unusually high (Tsenov et al., 2013; Chamurliyski et al., 2015). The NTP has similar values in 2009 and 2010, while in other seasons the difference is significant, especially in 2007. The variation caused by factors in the trail already described by Tsenov et al. (2014). The remaining two traits, which are influenced mainly by "location", variation is also high for their normal means (16% at TGW and 36% in NGM). So, we distinguish three groups of reliability of differences in the 5 locations. This information is very important because it shows significance of changing as a result of growing conditions, which is characteristic of many contrasting environments. In that case is important the variation depends much stronger on degree of environmental conditions than by genetic potentialities of a variety. Similar results were reported by (Mohammad et al., 2005; Erayman et al., 2016). High grain yield is a result of the possible compromise combination of high values of the components of productivity (Yao et al., 2014; Mesele et al., 2016). Given that each of these key components varies so much whether it is possible to perform a breeding balance between them in a dynamically changing weather conditions? Whether established correlations between them will be valid in the future under similar conditions to those? It is known that under stress conditions the correlations between the quantitative traits of productivity change as a rule, compared to the favourable conditions for cultivation of the same genotypes (Singh et al., 2010; Ivanova and Tsenov, 2012). These results assume a prerequisite for a thorough examination of the correlations between the traits associated with grain productivity.

Table 4. Environment means of four traits and scores of years and multiple pairwise comparisons using the Dunn's procedure*

Trait	Year	2007	2008	2009	2010	Grand mean
Ear emergence date	Mean	124.2	129.5	133.8	132.5	129.9
	LSD *	a	b	d	c	
Grain yield	Mean	4.47	8.04	6.65	7.47	6.66
	LSD	a	d	b	c	
Number of productive tillers	Mean	756	677	635	631	674.8
	LSD	c	b	a	a	
Number of grains per spike	Mean	16.5	28.1	27.5	28,5	25.13
	LSD *	a	bc	b	c	

* Method: 95.0 percent LSD

Table 5. Environment means of some traits and scores of locations and Multiple pairwise comparisons using the Dunn's procedure*

Trait	TGW		NGM	
Location	Mean	LSD	Mean	LSD
Selanovtsi	38.2	a	15963.5	b
Gorski Izvor	44.2	c	15152.2	b
Radnevo	42.8	b	14083.2	a
Pordim	38.9	a	15463.9	b
Chepintsi	38.1	a	21927.4	c
Grand mean	40.5		16518.0	

* Method: 95.0 percent LSD

The ear emergence date has similar variability in different environmental conditions, as the grain yield (Tables 2, 3 and 4), which is sufficient reason to suppose that it affects not only directly to grain yield (Tsenov and Gubatov, 2016). Given that these traits occur before all else, we assume that it has any effect on the characters directly related to grain productivity.

The verification of this hypothesis began with an analysis of variance of participating in the experiment traits using AMMI model (Table 6). The reason for this was to determine whether there is a nonlinear interaction with environments. Such interaction exists right for characters EED and GY (IPCA2 have reliable means). In all other traits interaction with conditions causes a linear change in their means of traits. Similar results in a study of productivity in contrasting environmental conditions in durum wheat are received by Hassam et al. (2013) and Sabaghnia et al. (2013). This suggests a high probability of maintaining the correlation values amid the diverse growing conditions, although for some crops have information to the contrary (Ruzdik et al., 2015). Unpredictable changes in the direction of the date of ear heading is happening against the background of foreseeable changes in the components of productivity

Generally, the date of ear emergence has fairly strong correlation with the yield grain to drought conditions in 2007 and partially in 2008 was unexpectedly high (Table 7). Its value is as a link to the trait NGM, which is an integral of the characters that should in most strongly determine yield in terms of the country (Tsenov et al., 2008; Dyulgerova, 2012). This direct connection is too variable in different seasons, what the background of their high variability, we can accept as normal. Strong change is even with traits NGS, which largely determined grain yield (Tsenov et al., 2008; Gaju et al., 2009; Fetahu et al., 2015).

The most stable is link of EED with NGM, which is fully in line of the figures for the relatively low impact of the "year" on trait (Table 3). Many variable (-0,349 ÷ 0,385) compared to the other traits of the correlation with TGW traits. Although the correlation with the size of the grain is very low (r = 0.131) its change from a positive to a negative value is signal for serious effect on the date of ear heading on the TGW. Correlations between the characters change materially and grouping traits by locations (Figure 1).

Changing the value of the correlation coefficients between the traits and date of ear emergence is a significant on the level of "location". In two of the locations (Chepintsi and Selanovtsi) there are mostly positive correlations with EED and traits, determining grain yield. Strong changes in the correlations observed in locations Pordim and Gorski Izvor.

Table 6. Multivariate ANOVA table for AMMI model of all characters

Trait	Parameter	Years	Genotypes	Locations	Interactions	$IPCA_1$	$IPCA_2$	Residuals
	df	119	29	3	87	31	29	27
EED	F	39.41	16.15	7.25	2.48	4.17	2.35	0.69
	p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.8798
GY	F	38.88	4.84	4.96	2.45	4.16	1.95	1.01
	p-value	0.0010	0.0010	0.0021	0.0010	0.0010	0.0026	0.4538
NPT	F	8.87	2.22	2.48	1.38	2.27	1.36	0.86
	p-value	0.0001	0.0001	0.0437	0.0114	0.0001	0.0981	0.7426
NGS	F	2.82	4.82	0.38	0.99	1.56	1.22	0.52
	p-value	0.0001	0.0001	0.8226	0.5168	0.0289	0.1982	0.9979
TGW	F	5.94	9.8	2.09	0.85	1.57	0.8	0.46
	p-value	0.0001	0.0001	0.0808	0.8508	0.0265	0.7715	0.9997
NGM	F	14.65	10.61	2.32	1.14	2.3	0.91	0.58
	p-value	0.0001	0.0001	0.0566	0.1779	0.0001	0.6002	0.9927

Table 7. Spearman correlations between EED and traits by year environments

Variables	Parameters	2007	2008	2009	2010	Entire trail
GY	r	0.352	0.441	0.014	0.059	0.564
	p-values	< 0.0001	< 0.0001	0.8682	0.4760	< 0.0000
NPT	r	0.337	0.462	0.101	0.178	0.107
	p-values	< 0.0001	< 0.0001	0.2176	0.0293	0.0130
NGS	r	-0.323	0.378	-0.445	-0.092	0.459
	p-values	< 0.0001	< 0.0001	< 0.0001	0.2622	< 0.0001
TGW	r	0.385	-0.250	-0.165	-0.349	0.131
	p-values	< 0.0001	0.0021	0.0434	< 0.0001	0.1072
NGM	r	0.548	0.228	0.436	0.512	0.567
	p-values	< 0.0001	0.0051	< 0.0001	< 0.0001	< 0.0000

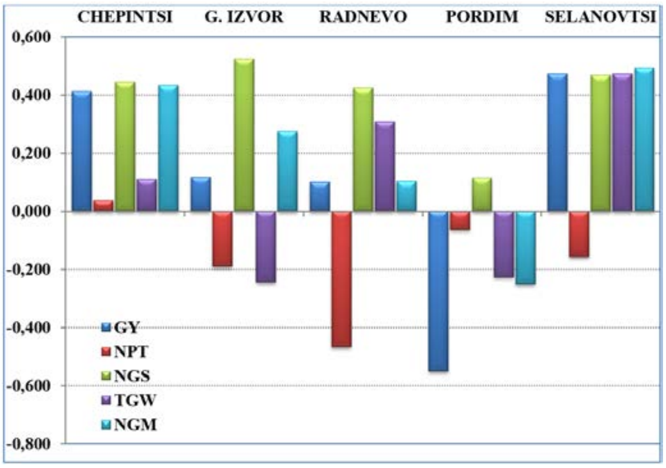

Figure 1. Spearman Correlationships between EED and traits studied by location environments

The strongest is the change in direction of the correlations under traits number of productive tillers and size of the grain (TGW). Both characters have a significant impact on grain yield (Tsenov et al., 2008; Tsenov et al., 2014). Their change, according to the location of testing was prompted by the considerable influence of the date of ear formation on each of the studied traits. This causes a change in the relationships between them, which is the reason for changing the correlation in mean and direction. On the other hand, both traits are associated with the amount of the grains (NGS, NGM) and show relatively stable and positive correlations with the date of the ear emergence. The only exception is the correlation in Pordim for the NGM.

All these considerations lead to several hypotheses. First: date of ear heading has tangible influence on each component of productivity; Second: the relationship with each one of the characters is affected by changing of conditions ("year" or "location"); Third, change the trait EED causes a change of correlations between them. Whether all these changes, which are essential in studies traits are due to change of date of ear emergence? However, a positive correlation with the yield components, it was found that they are changing relative to the environmental conditions, which is unavoidable. Against the background of these changes every trait that we can predict what changes in the components of productivity would change the very grain yield. For this purpose, were checked all possible regression models for the relationship between the ear emergence and every one of the traits (Table 8). After comparison of the coefficients of determination (R^2) of each model a type of cubic nonlinear type of regression for all examined characteristics was selected. According to observed values of two characters TGW and NPT cannot be provided at all by the date of ear heading due to lack of reliable relationship with it. The numbers of grains per spike and grain yield are influenced by the date of ear emergence, but not so strong as to be fully provided by regression with it. These data indicate that the EED is strongly associated with the NGM number than with grain yield itself. After only one trait could be directly linked to the EED, despite high and reliable correlations, how to accept that its occurrence and causes an effect on grain yield. Influence of NGM is clear from the study of Sancez-Garcia et al. (2013), according to which progress in grain yield in Spain in the 20th century, is due mainly to its breeding improvement. Contrary to this statement is the opinion of Aisawi et al. (2015), based on the yield of grain in Mexico increased by the trait weight of grains per spike, not by the NGS and or NGM. The contradiction in various posts stems from the climate and strategy breeding of productivity accordingly. Therefore, any information about these patterns in real-time weather anomalies is very important for the breeding of winter wheat.

In order to go deeper into the intricate and complex interrelationships between traits each to another, subjected the entire database to the path-analysis (Table 9). For a more detailed comparison between different assessments parameters are placed in the table and correlations between each pair of traits. The mean of Estimate# represents how many changes each surveyed trait at the first trait of change. Changing the date of ear heading up to one day have a direct effect on every trait, as follows: the NTP increases by about 3.5 spikes; the TGW increases by about 0.14 grams; the number of grains per spike in the range of about 0.65 grains and the NGM increases with 548 spikes per m^2.

Table 8. Equations of the regression model according to the EED trait

Trait	Cubic Regression Model (Y = pr1+pr2*X1+pr3*X1^2)	R^2
NGM =	389066-6331*EED+26,61051*EED^2	0.4529
GY =	37,16022-0,69729*EED+0,00355*EED^2	0.4207
NGS =	-301,36398+4,42630*EED-0,01471*EED^2	0.2173
TGW =	-712,85085+11,54317*EED-0,04415*EED^2	0.0945
NPT =	16419-247,57655*EED+0,97126*EED^2	0.0501

Table 9. Spearman correlations (r) and path analysis of direct① and indirect② effects EED trait on components of productivity, and their effects on GY

Reason trait①	Caused trait	Estimate #	S.E.	*p-value*	r	*p-value*
EED	NTP	3.4545	1.3039	.0081	.1076	0.0130
EED	TGW	.1345	.0417	.0013	.1307	0.1072
EED	NGS	.6264	.0495	***	.4596	***
EED	NGM	547.7111	32.5025	***	.5671	***
NTP	GY	.0001	.0001	.6188	.3191	0.013
NGS	GY	.0109	.0042	*	.6333	***
TGW	GY	.1494	.0017	***	.3496	***
NGM	GY	.0004	.0000	***	.9143	***
EED ②	GY	.2278	.0012	***	.4732	***

Estimate = Regression Weights by AMOS module of IBM SPSS 23

Of all these positive effects two are proven - NGS and NGM, on the highest statistical level. Strong effects on grain yield have three of four surveyed traits - NGS (.0109), TGW (.1494) and NGM (.0004). On the background of the data on their correlations that are fairly high, it is quite logical and expected. The impact of two of these three is influenced positively by EED, as already noted above. This suggests the positive impact of the change of date of ear emergence on them will have a positive effect on grain yield. Proof of this is significant high indirect (mediated) EED effect on grain yield of 0.2278. This value of the assessment means that a change in the date by one day ear heading causes an increase in grain yield of 227.8 kg/ha.

Further evidence of this positive effect is the tendency to increase grain production, presented in Figure 2.

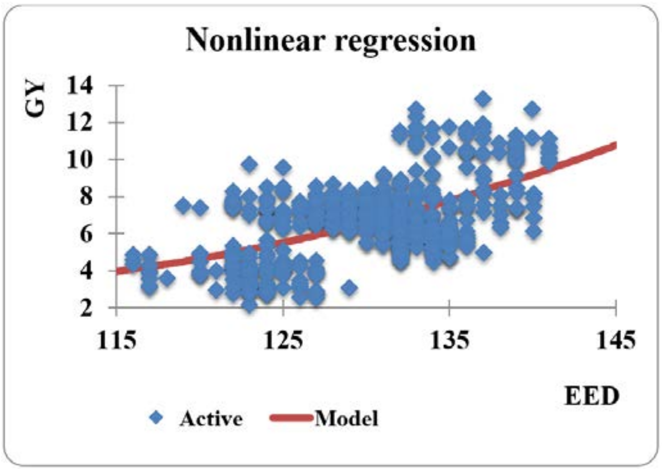

Figure 2. Cubic nonlinear regression of GY as the dependant from EED

Careful analysis of the position measurements of the figure (active points) shows that spot for high grain yield is about 132-133 days after the date of ear heading and reaches its maximum values around 136-137 days. Given that in means of EED = 130 days of the experiment, it can be expected seriously increasing the yield of grain if by breeding prolong to ear emergence by several days. In confirmation of this thesis is the data on Figure 3. The data shows that NGM changes to the ear emergence date, completely analogous to the changes in grain yield.

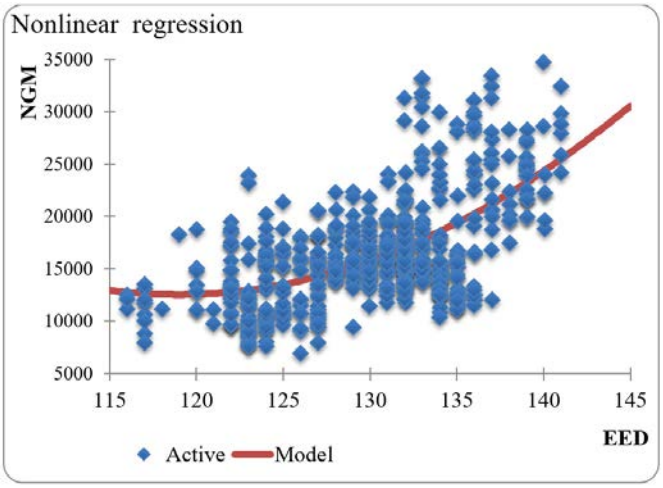

Figure 3. Cubic nonlinear regression of NGM trait as the dependant from EED

The results presented in this study greatly change our ideas about the relationship between grain yield and its basic components that are associated with it (Boyadjieva, 1976; Tsenov et al. 2005; Tsenov et al., 2013). In terms of the dynamic change of growing conditions resulting in season and location we found advantage of the later dates of ear emergence on the yield of grain. In critical for productivity 2007, which had a long and severe winter spring drought, these data are extremely important for conclusions regarding the breeding of precocity. On the other hand, these results are in the opposite direction at the conclusions of Boydjieva and Andonov (2010), Marinciu et al. (2013), Tsenov et al. (2015), which point out the advantage of the earlier lines for obtaining a high yield grain in abiotic stress conditions. Data obtained from complex research for productivity in environmental experiments in Bulgaria helped us to establish patterns between traits, basic for grain yield based on environmentns (Tsenov et al., 2011; Tsenov et al., 2014; Tsenov et al., 2015).

This was a prerequisite for studying the interaction of genotype with the environment in all of these details. Detailed analysis of the direction and magnitude of the variation of any trait against the others provide us with exclusive information about the correlations between them under the dynamically changing environmental conditions typical of the country climate. Established regularities between the date of ear emergence and basic characters that determine grain yield is extremely important to build a breeding strategy in a changing climate in the Balkans.

CONCLUSIONS

Traits, that directly determine grain yield in winter wheat are strongly influenced by environmental conditions and genetics of participating in trail varieties. Between the ear emergence date and basic traits of productivity there are positive correlations that are significant even under strong interaction with growing conditions. The date of ear heading has a significant influence on the components of productivity in the direction of increasing the yield of grain. Its impact on traits related to the number of grains are a prerequisite for obtaining high and stable grain yield in contrasting conditions.

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