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CORRELATION BETWEEN THE RANKING OF WINTER WHEAT GENOTYPES BY GRAIN YIELD AND STABILITY THROUGH VARIOUS STATISTICAL APPROACHES

TODOR GUBATOV [1]; NIKOLAY TSENOV[*1]; IVAN YANCHEV[2]
[1] *Agronom I Holding Ltd, BG-9300 Dobrich, Bulgaria*
[2] *Agricultural University, BG-4000 Plovdiv, Bulgaria*

Abstract

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Setting and aim: The environmental conditions have a serious impact on grain yield of cereals. The change in the reaction of a variety yield is reason to look for ways for its evaluation despite his strong GE interaction. The aim of this study was to establish an effective model for the separation of varieties based on the magnitude of the yield and the stability in a wide range of environmental conditions.

Methods: In a typical country locations of testing (5) for four years 24 varieties of winter wheat, were studied. In the most detail the GE interaction by four statistical approaches that are current was analysed. The ranking approach in determining the yield stability and their interactions using the criteria “yield”, “stability” and “yield-stability” is attached. The possibilities of each method to evaluate the effect of GE for establishing the essential differences between varieties were analysed.

Key results: The GE interaction is essential and sets about 1/3 of the total variation of the trait. Its nature is complex and difficult to measure. A large share of the nonlinear interaction of the variety by environment is established. The most significant share of the interaction is between season * location (88 %), and the effect of genotype is about 10-12%. The arrangement of the tested varieties through various statistical methods is different, which is a prerequisite for a serious analysis of their grain yield behaviour.

Conclusions: The relationship between the three tested criteria of traits expressed by main types of correlations show that the “yield-stability” has a strong link with the other two criteria. This is reason to believe that each of applied statistical models for effective differentiation of behaviour of the variety in the group. The most relevant to achieving the objective are two commonly used model AMMI and GGE, due to the presence of software packages for their rapid implementation and visualization.

Key words: wheat; grain yield genotype* environment (GE); stability; AMMI and GGE
Abbreviations: GE – genotype* environment; GY – grain yield; YSi – Yield-Stability Index; AMMI – Additive Main effects and Multivariate Interaction; GGE – Genotype and Genotype* Environment; GY – grain yield; (stab) – stability and (yield-stab) – yield+ stability; NP – non parametric model; IPCA1..3 – Interaction of Principal Component Analysis

Introduction

Recently breeding evaluation of varieties is impossible without quantification of the genotype*environment interaction (GEI), (Gubatov et al., 2016; Golkari et al., 2016; Karimzadeh et al., 2016). The reasons for this are that each character in crops is strongly influenced by the environment. The term GE interaction is not new, but over the past several years has gained particular importance because of the presence already of effectively working statistical methods and models to assess it (Gauch and Zobel, 1996; Yan and Hunt, 2001; Kang, 2002).

**Corresponding author*: nick.tsenov@gmail.com

In cereals studies reached consensus on a number of researchers like Lin et al. (1986), Snape et al. (2007) and Najafian et al. (2010) that without quantitative evaluation of that interaction it is impossible to make a real arrangement of varieties in grain yield in a wide range of conditions. The basic premise and motive for such an assertion is based on the term "stability" through which the variety is measured not only by the level of character, but as the degree of variation in environmental conditions (Yan and Hunt, 2001; Annicciarico, 2002; Ayciccek and Yilderim, 2006).

The term "stable variety" in recent times is often used in the sense of variety that phenotypic expression of a trait is relatively the same regardless of the fluctuations of environmental conditions (Finlay and Wilkinson, 1963; Zobel et al., 1988). As a rule varieties with wide adaptation did not show cross-interaction with the environment. Very stable varieties are generally not highly productive and to that end it is imperative that the use of appropriate methods and approaches for combining a high productivity with a high stability (Fan et al., 2007)

According to Becker and Léon (1988) depending on the purpose and character at issue, there are two concepts of stability – "static" and "dynamic". In "static (biological)" concept stable variety does not change significantly at varying environmental conditions. The variation in traits in these genotypes is zero. Such characters are qualitative indications, for example resistance to certain diseases. While "dynamic (agronomic)" concept, stable genotype follow the dynamics of environmental conditions (temperature, rainfall, soil fertility, etc.). Dynamic concept refers to quantitative traits, such as grain yield.

In connection with this problem and the term plasticity (durability, resistance) is introduced by Annicchiarico, (2002). According dynamic concept a variety shows flexibility if its behaviour is similar to the group of varieties when environmental conditions are changing.

In other words, the interaction of a variety of conditions creates "noise" on the level of the trait in each participating group surveyed variety. This "noise" represents its variation, which must be reported to a genotype can be correctly matched on the ground with other varieties or standards. For this purpose, identifiable and verifiable index set values and parameters, each of which provides information on all aspects of the variation of the trait (Kang, 2002; Grogan et al., 2016). Through each of them in a group to do "personal" in many aspects a comprehensive assessment of the variety on a trait, taking into account its variation (Alberts, 2004; Tazu, 2011).

Methods for assessing the stability of the variety can be grouped into parametric, non-parametric and multivariate as they divided a prominent theorists of the problem (Kang, 2002). Because the evaluation of any approach never gives complete information about the complex GE interaction around since 15 years many visual methods to evaluate genotypes which are referred to as multiple-choice methods for graphic presentation is the result of compromise between productivity and stability have been widely used (Yan et al., 2000; Namorato et al., 2009; Ahmadi et al., 2012).

In this regard the most effective for us are those of the approaches that have the strong relationship between the level of the trait and the degree of its stability, respectively plasticity. Nowadays it is Biplot-analysis because the information that allows the most complex one (Ding et al. 2008), (Malla et al. 2010) and (Abakemal et al., 2016). It is based on two models, which are widely used now days – AMMI and GGE (Ahmadi et al., 2012). According to recent studies of Roostaei et al. (2014), Golkari et al. (2016) and Karimzadeh et al. (2016) proved that it is through GGE and AMMI models can be made at an acceptable compromise between the level of the trait and stability in a huge number of testing locations (24). In research of Alberts (2004) and Tazu (2011) a thorough analysis of the opportunities that each of these methods provides for the evaluation of genotype. However, still little is known about the suitability of different models for compromise evaluate the productivity and stability of each variety in a group (Roostaei et al., 2014).

Aim of the study is to establish an effective model for the separation of varieties based on the magnitude of the yield and the stability in a wide range of environmental conditions.

Materials and Methods

Experimental design

Grain yield data are from a field trail of 24 varieties of winter wheat (20 varieties and 4 standard cultivars), which are grown in 5 locations in Bulgaria in four consecutive seasons (2009-2012). They are used to calculate the rank correlations as for this purpose two statistical methods (JRA and NP) and two models (AMMI, GGE biplot), which are commonly used for ranking the studied genotypes, according to the variation in yield in various environments have been used. In each location the varieties are bred in randomized block design of four replications. The size of the experimental plot was 10 m^2 (12 rows, 8 meters long with a distance between rows of 10.5 cm).

Statistical approaches

In order to establish the effects of genotype, of the environmental conditions and the interaction between them a combined analysis of variance which is included principal component analysis of AMMI-model is attached. It is made using the statistical packages IBM SPSS 23 and GenStat 15. The arrangement of the tested varieties for yield and stability of yield is done using 4 different statistical approaches. The rank for each of the varieties is based on three criteria: grain yield (Yield), stability (stab) and yield-stability as well. In each of the methods used this arrangement is made differently, according to the interpretation of the stability of the program. The criterion 'yield-stability" is obtained after adding up the values of the first two ranks, after which it was also subjected to ranking again.

Ranking and evaluation of varieties by model YS (i)-statistic is done using a special computer program called (STABLE). The index of stability of grain yield (YSi) was calculated by the method of Kang (1993), in which a compromise between the high-yielding and stable varieties is made. The variety with the highest yield grain gets grading assessment (rank) of 24, while the lowest – 1. Ranks evaluate a variety was corrected by an assessment of its stability as follows: – 8 – 4 and – 2 measured significant stability at P <0.01, 0.05 and 0.10 respectively and 0 negligible stability of the variety. This rating of the stability is selected so as to change the rank of the genotype based solely on yield (Kang, 1988).

In this way a statistical corrected grain yield indicated by the author as (Ysi). The ratings for the stability of the varieties was prepared according to the variation of the Shukla's (σ2) parameter of Shukla (1972). The rank criterion 'yield-stability" for each variety is received again after ranking based on the sum of the first two ranks assessments (yield) and (stability).

The rated assessment as non-parametric model by Huehn (1990) are placed on each variety on similar criteria first. Stable high rank (24) are varieties whose variance rank (S^2i), to different locations test is the lowest or the sum of the absolute deviation from the maximum rank of each variety (S^3i) . The arrangement of varieties in yield and stability together is the sum of the first two ranks after a second has passed the average rank of the two criteria for the stability of this method.

Criteria by AMMI model were calculated using a computer program GenStat 15. This analysis combines additive components into a single model for the main effects of genotypes and environments, as well as multiplicative components on the effect of interaction. According to him genotypes (or conditions) with large IPC score (either positive or negative) showed strong interaction, while genotypes (or conditions) with IPC1 score near zero have lower interactions, i.e. low variation. To describe the "stability" in AMMI statistical factor (D), is used which is calculated according to the method of Zhang et al. (1998). The genotype with the lowest value of the parameter D were considered as the most stable (Zhang et al., 1998) and accordingly receives the highest (24) rank for criterion "stability".

The analysis of the model GGE biplot was obtained using software described by Yan, (2001). Through it each genotype group receives an assessment of the effect of genotype (G) and the GE interaction (Yan et al., 2000). Assessment of each variety, the main starting point is a small circle in the centre of biplot, which is the average "environmental" coordinate (AEC), which is an average from PC1 and PC2 of the environment (E) (Figure 3). About the origin (0,0) has several concentric circles (Figure 1). As a point of a variety is located in a concentric circle near the beginning, the variation in the conditions of the test is less. For example, variety № 18 has the least variation, variety № 3 has an average degree of variation, while variety № 2 varies most from the whole group (Yan, 2001, Yan and Kang, 2003). In terms of stability ranking depends on distance from the origin (0,0) to the dot of the variety with the highest ranks have these varieties with the shortest distance to that location. The parameter yield – stability is the result of the sum of the first two ranks, too.

To determine whether a particular method can be successfully divided varieties of the group according to their yield and stability (yield-stability) three main types of correlations (Pearson, Spearman and Kendall) between the ranks of the three criteria of each of the approaches used, have been calculated using the statistical package Unistat 6.

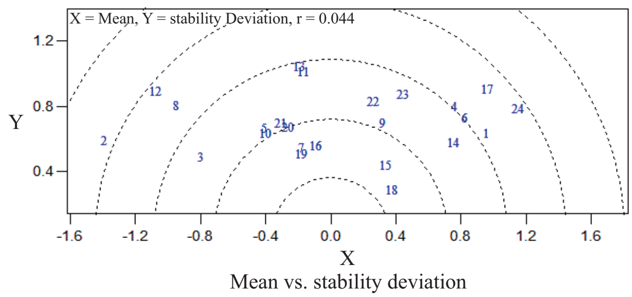

Fig. 1. GGE Biplot Ranking of cultivars based on their grain yield and stability deviations

Results

According to survey data, some of which have been published already (Gubatov et al., 2016) GE interaction is very significant. This is clearly seen from the data in Table 1, which is a compilation of two assay mentioned in the Materials and Methods section. According to them, almost all sources of variability are significant at high confidence level (*p-value*). Particularly strong interaction between environmental factors studied, which reaches 1/3 of the total variation of (31.94%). The strongest effect of the season (year), whose main effect is about 40%, and with test locations causing almost all variations of the interaction (88.72%). This is an extremely powerful effect on yield by environmental factors. The proportion of genotype is very low (1.17%), but it is involved in the interaction with the environment noticeably stronger (about 12%).

Table 1
Combined ANOVA and AMMI analysis of variances and GE interaction during the four-year period of investigation

Source of variation	SS %	df	MS	F-stat	p-value	η^{2**}
Main effect	64.55	30	41.45	168.72	0.0000	0.911
Year	43.12	3	276.904	1127.18	0.0090	0.598
Location	20.26	4	97.555	397.11	0.1380	0.416
Genotype	1.17	23	0.98	3.99	0.1110	0.340
Interaction	31.94	173	3.56	14.47	0.0000	
Year * Location	88.72	12	45.486	185.161	0.0000	0.890
Year * Genotype	6.95	69	0.619	2.521	0.0000	0.387
Location * Genotype	4.33	92	0.290	1.18	0.1560	0.282
Adjusted model	3.52	203	9.156	37.72	0.0000	0.908
Error	67.82	276	0.246			
Total	1926.49	479	4.022			
Regression	22.20	23	0.123	3.12	0.00000	
Deviation	77.80	276	0.435	2.55	0.00000	
IPCA1	58.8	25	0.99	3.86	0.00000	
IPCA2	12.6	23	0.57	2.23	0.00112	
IPCA3	11.2	21	0.23	0.90	0.59706	
Residuals	10.0	0	0.333	2.78	0.00012	

Table 2
Ranking of 24 genotypes by estimating of yield-stability index (YS_i), according to the model of Kang (1993)

№	Genotype	Mean GY	Yield Rank	Adjustment to R.	Adjusted	Stability rating	YS (i)
1	Tervel	6.87	22	1	23	-8	15
2	A 15/89	6.15	1	-1	0	-4	-4
3	Iveta	6.38	4	1	5	-8	-3
4	Apogej	6.83	19	-1	18	-4	14
5	Laska	6.48	7	1	8	-8	0
6	Dageya	6.87	21	-1	20	-2	18
7	Samuil	6.58	13	-2	11	0	11
8	Bilyana	6.34	3	1	4	-2	2
9	Neven	6.73	16	-1	15	-4	11
10	Faktor	6.47	6	-1	5	-8	-3
11	Presyana	6.55	10	-1	9	-8	1
12	Ralitsa	6.22	2	-2	0	0	0
13	Riana	6.46	5	-1	4	0	4
14	Topolitsa	6.84	20	1	19	-4	15
15	Ognyana	6.72	14	2	25	-2	23
16	Enola	6.57	12	1	13	0	13
17	Alexa	6.90	23	1	22	-4	18
18	Alisa	6.73	15	1	16	-2	14
19	AP Velika	6.56	11	-1	10	-8	2
20	Bul Aneta	6.48	8	-1	7	-2	5
21	Vyara	6.52	9	1	10	0	10
22	Svilena	6.74	17	1	18	-4	14
23	Hela	6.79	18	1	19	-2	17
24	Pryaspa	6.98	24	2	26	0	26

Analysis of variance by AMMI-model establishes a fairly high share of the regression (22.20%) and deviations from it (77.80%). In practice. the variation in the experiment expressed by the interaction reaches 82.6% and about of 10% residual variation. The presence of the three components (IPC_1, IPC_2, IPC_3) by reacting of the conditions with the character is indicative of its complex nature. Indeed, the third component PC_3 is not fairly high, but it is an indication of the presence of the nonlinear interaction of grain yield with environmental conditions. According to Gubatov et al. (2016) The share of non-linear interaction is of the order of about 35% at 50% share of PC_1, which is really significant. Highly nonlinear interaction already a regularity in grain yield is reported in studies of major crops, wheat (Bose et al., 2014; Golkari et al., 2016; Karimzadeh et al., 2016; Dyulgerova and Dyulgerov, 2016; Ramazani et al., 2016) and legumes (Asfaw et al., 2009; Sabaghpour et al., 2012) and reaches PC_9, which is unique information. These facts speak volumes about the complex nature of the response of genotype grain yield in different growing conditions. Under these circumstances, it is clear why most of the indices and parameters for evaluation of the GE interaction in different models give different information (Kaya and Turkoz, 2016; Storck et al., 2016) in terms of accuracy assessment of the variety to others in the study group.

The different arrangement of varieties on the yield level and its stability at different approaches is the reason to apply rank evaluation, as in our study. First rank is based on the approach of Kang (1993) (Table 2). Clearly and distinctly visible way of formation evaluation scores and the difference in rank yield (GY) and adjusted yield (YSi). More greater the difference in the evaluation of genotype after rectification of the rank according to the parameter "yield – stability" (Table 3).

This arrangement according to the not parametric approaches (YSi) and (NP) differs greatly if we focus on specific varieties. There are two main comparison groups: a group of varieties, which have similar ranks (1, 8, 15, 23) and a group that have contrasting ranks in both methods (2, 4, 10, 19). The arrangement of varieties in yield and stability by AMMI analysis is presented in Table 4. According to the principals of analysis at high yield varieties have about the origin of coordinate system (9, 10, 17). According to the program GGE highest rank varieties are 1, 4, 17, 24, that is, other than those of the previous analysis. After correction of ranks to the stability evaluation of varieties of the picture changes dramatically in some cases (Table 4).

Table 3

Rank estimates of grain yield and its correction by criterions by index for variance stability (YSi) and Nonparametric analysis of GE interactions by ranks (NP)

Variety	Ranks by YSi			Ranks by non-parametric (NP)		
	Yield	Stab	Yield-Stab	Yield	Stab	Yield-stab
1	22	23	15	22	22	20
2	1	0	-4	1	5	1
3	4	5	-3	4	21	9
4	19	18	14	19	18	18
5	7	8	0	8	6	5
6	21	20	18	21	19	19
7	13	11	11	13	11	10
8	3	4	2	3	20	9
9	16	15	11	16	14	14
10	6	5	-3	6	8	4
11	10	9	1	10	9	6
12	2	0	0	2	10	4
13	5	4	4	5	3	2
14	20	19	15	20	15	16
15	14	25	23	14	23	17
16	12	13	13	12	16	12
17	23	22	18	23	24	21
18	15	16	14	15	7	8
19	11	10	2	11	4	3
20	8	7	5	7	1	3
21	9	10	10	9	17	11
22	17	18	14	17	12	13
23	18	19	17	18	2	7
24	24	26	26	24	13	15

Table 4
Rank estimates of grain yield and its correction by criterions connected by *AMMI-model and software program GGE Biplot (GGE)**

Variety	AMMI*			GGE**		
	Yield	Stab	Yield-Stab	Yield	Stab	Yield-stab
1	22	11	20	22	11	14
2	1	1	1	1	1	1
3	7	21	16	7	21	11
4	20	12	18	20	12	13
5	8	15	10	8	15	7
6	13	10	9	13	10	7
7	9	22	15	9	22	11
8	4	16	7	4	16	5
9	17	13	17	17	13	12
10	10	8	5	10	8	4
11	16	17	19	16	17	14
12	2	6	3	2	6	2
13	3	5	2	3	5	2
14	19	7	13	19	7	9
15	14	24	22	14	24	15
16	15	23	21	15	23	15
17	23	19	24	23	19	17
18	11	14	12	11	14	8
19	12	9	8	12	9	6
20	6	3	4	6	3	3
21	5	20	11	5	20	8
22	21	18	23	21	18	16
23	18	2	6	18	2	5
24	24	4	14	24	4	10

Compared to the previous two models in these ranks assess the variety has a similar behaviour. It is clear that in any statistical evaluation approach of the variety after subtracting the „noise“ which is caused by its interaction with the ambient conditions vary. Therefore in recent years both cutting-edge of this methodical AMMI and GGE is widely used (Asfaw et al., 2009; Sabaghnia et al., 2013). The main reason for this interest is the ability to have both a visual representation of each variety as dots against the whole picture of the experiment. Logically occur question whether it meets the objective truth about the relationship between the level of yield and its change in the conditions of the particular experiment.

Answer to this question give correlations between ranks evaluation of criteria to assess the yield and stability of the variety (Table 5). The data indicate that between these two criteria is a positive connection, but is not strong enough. There are strong

Table 5
Rank correlations between the ctiterions "Yield" and "Stability" by models of adjusted yield (Ys), Nonparametric analysis (N), AMMI (A) and GGE (G) by the ranked scores of grain yield, stability of yield

Variables	Ys(Yield)	Ys(STAB)	N(Yield)	N(STAB)	A(Yield)	A(STAB)	G(Yield)	G(STAB)
Ys(Yield)	1	0.8871**	0.2414	0.1085	0.1052	0.1043	0.1052	0.1043
Ys(STAB)	0.031*	**1**	0.9743	0.8150	0.2731	0.9903	0.2731	0.9903
N(Yield)	0.249	-0.007	**1**	0.0941	**< 0.0001**	0.9229	**< 0.0001**	0.9229
N(STAB)	0.336	0.050	0.350	**1**	0.0748	**0.0016**	0.0748	**0.0016**
A(Yield)	0.339	0.233	**0.852**	0.370	**1**	0.5905	**< 0.0001**	0.5905
A(STAB)	0.440	-0.003	0.021	**0.609**	0.116	**1**	0.5905	**< 0.0001**
G(Yield)	0.339	0.233	**0.877**	0.370	**0.998**	0.126	**1**	0.5905
G(STAB)	0.540	-0.003	0.021	**0.611**	0.116	**0,999**	0.133	1

** – Correlation coefficients – below diagonal, ** -significance (p-value) – above the diagonal*

Table 6
Rank correlations between the ranking of varieties by models of adjusted yield (Ys*), Nonparametric analysis (NP), AMMI and GGE by the ranked scores of grain yield, stability of yield and corrected by its yield-stability**

Method	Index, score	Type of correlation	Correlation	*2-tail p*	Correlation	*2-tail p*
			Yield		Stability	
*Ys_i	Yield-Stab	Pearson	**0.741**	0.0000	**0.621**	0.0000
		Spearman	**0.741**	0.0000	**0.604**	0.0018
		Kendall	**0.537**	0.0003	**0.464**	0.0016
			Yield		Stability	
**NP	Yield-Stab	Pearson	**0.802**	0.0000	**0.800**	0.0000
		Spearman	**0.792**	0.0000	**0.811**	0.0000
		Kendall	**0.616**	0.0000	**0.623**	0.0000
			Yield		Stability	
AMMI	Yield-Stab	Pearson	**0.738**	0.0000	**0.713**	0.0000
		Spearman	**0.731**	0.0000	**0.718**	0.0001
		Kendall	**0.562**	0.0001	**0.532**	0.0003
			Yield		Stability	
GGE	Yield-Stab	Pearson	**0.745**	0.0000	**0.728**	0.0000
		Spearman	**0.755**	0.0000	**0.733**	0.0001
		Kendall	**0.593**	0.0001	**0.544**	0.0003

*Values in **bold** are different from 0 with a significance level alpha = 0,05;*

correlations between the ranks after applying non-parametric model and both modern methods. The lack of a strong enough correlation between ranks of yield and stability be adopted in case of normal, because they have a completely different characteristics for a variety. The fact the non-parametric model shows a high correlation is due more to the manner in which it is evaluated in stability (by ranking only). On the other hand the strong and reliable correlations between yield estimate at AMMI and GGE (reaching almost to the unit) are visual evidence of monotonous assessment that both models provide.

Our efforts are aimed to find out whether the transformation to assessment ranks at “yield-stability” corresponds to the level of yield and its stability at different models. Each of the models applied to evaluate the variety can be properly used for that purpose. (Table 6). High and reliable at the highest statistical level are the three types of correlations between criterion “yield-stability” and the other two. In general criterion “yield” shows little stronger link with “yield-stability” as the criterion of “stability”, when comparing each method separately.

A comparison between the methods the strongest are correlations in non-parametric approach to analysis (r = 0.802). It is followed with fully comparable and high correlations between the studied parameters and modern two methods AMMI and GGE. By no means negligible and already outdated approach of Kang (1988), which successfully separates the most successful varieties based on strong interaction with environmental conditions. Completely according to our expectations, the correlation value is highest in the algorithm of Pearson, followed by that of Spearman and the lowest are those according to Kendall, irrespective of the method used for forming the three criteria. The types of correlations were analysed to determine whether there are indeed objectively determined links between the studied variables.

In conclusion it can be said this approach applied provide us with information on the use of various statistical patterns to assess the specific variety of the background of the group (Malla et al., 2010; Roostaei et al., 2014). It became clear each of the models used can be grouped according to yield and its stability successfully. Biplot like approach in this respect is the most appropriate and this is the main reason to be widely used for breeding purposes (Ding et al, 2008; Bose et al., 2014).

Once ranked assessments of each variety received specific information (Table 3 and 4) for arranging the varieties according to three criteria are examined. Then we decided to check whether the graphic module of the two most used software products GenStat 15 (AMMI) GGEbiplot 6.3, will group the varieties in a similar way as more researchers consider (Sabaghnia et al., 2013; Bose et al., 2014).

AMMI analysis of the data from our experiment score each variety being assessed in a manner shown in Figure 2. According to their available varieties designation 9 (Neven),

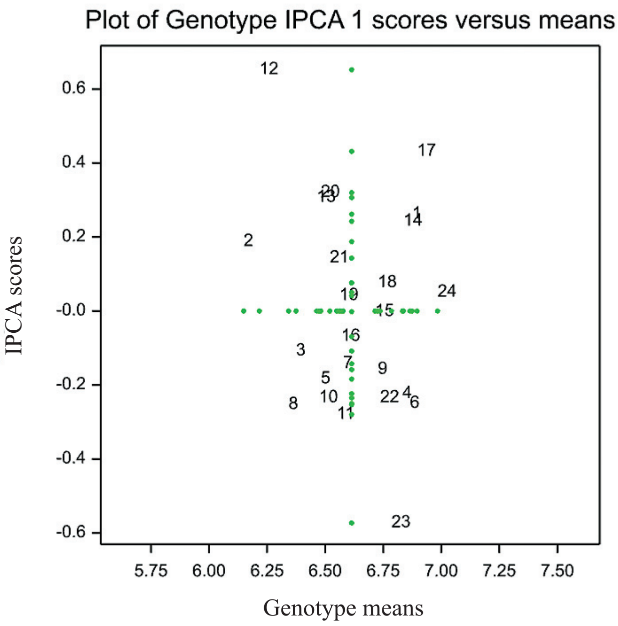

Fig. 2. AMMI Biplot of IPCA scores vs. genotypic and environmental mean grain yields for the group of genotypes across the locations

15 (Ognyana) 18 (Alisa), 22 (Svilena), 4 (Apogej) and 6 (Dageya) showed the best combination of yield and general stability. These are varieties that have demonstrated a slightly lower yield than the reference variety Pryaspa (24), but are considerably more stable than it. The usefull 4 (Apogej), and 6 (Dageya) showed their excellent stability under adverse environmental conditions in southern Bulgaria (Yambol and Plovdiv locations).

According to the analysis of the program GGE Biplot, location of dots in the said varieties is completely analogous. We note a significant difference only in the position of variety Hella (23), which according to the graphic analysis is an excellent combination of yield and stability. In AMMI this variety has shown very high volatility by its strong variation (Figure 2). Such differences arising from the analysis are common and have been noted by many authors (Malla et al., 2010; Roostaei et al., 2014; Agyeman et al., 2015). It should be noted that much of the information that various statistical models allow for varieties is similar (Table 2). Proof of this assertion is almost the similar position of studied varieties in terms of their criteria yield-stability which Kang approach (1993) provides such information (Figure 4). A similar arrangement of varieties through the rang their assessments regardless of the method in which they are placed, is very appropriate. It provides visual information on the characteristics of each variety in terms of its yield and stability in environmental conditions.

The attached arrangement of the studied varieties through their rank assessments regardless of the method in which they are placed is very appropriate. The results will be similar because the ranking approach is objective and is recommended by many authors as Huehn, (1990), Kang, (2002) and Kaya and Turkoz, (2016). The results that we brought here indicate the approach to creating term 'yield-stability" to correct the grain yield is very proper and does not depend on the particular method of its calculation.

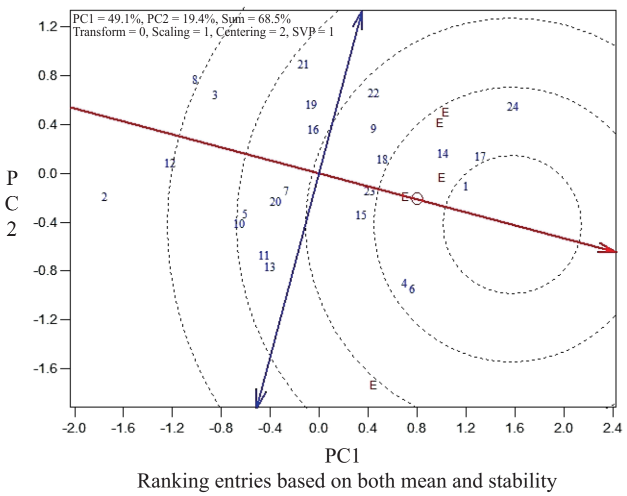

Fig. 3. GGE Biplot Ranking of cultivars based on their mean yield and stability across the four seasons

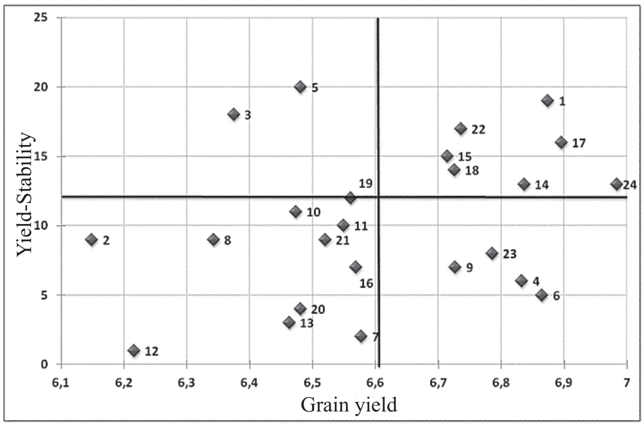

Fig. 4. Scatter plot of yield-stability of cultivars by Ys_i ranking approach

Conclusions

Ranks evaluation of varieties can be successfully used to identify those in the group with the desired high yield and adaptation to various environmental conditions.

Different approaches to assess the level and stability of yield provides similar information when arranging varieties of the study group, among them no fundamental difference.

All applied modern methods of analysis of the GE interaction are sufficiently informative, so they are effective in differentiating the behaviour of varieties in a wide range of growing conditions.

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