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Genetics and Breeding

Comparison of statistical parameters for estimating the yield and stability of winter common wheat

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Abstract. *Data from different multi-environmental trails (MET) were analysed, including different number of varieties, number of locations and different research periods. The first experiment (24 PhD) included 24 wheat varieties that were studied in five locations of the country over a period of four years (2009-2012). The second field experiment (40 ABC) consists of 40 new advanced wheat lines and cultivars, which were studied in three locations over a three-year period (2017-2019). The grain yield datasets from the two experiments were used to make a direct comparison of various statistical parameters to assess the genotype stability against the background of significant growing conditions. The study involves the use of several statistical packages that are specialized for this purpose. Based on the ranking assessment of the values of each statistical parameter, a critical analysis was made of its relationship with the yield, for each dataset separately. For this purpose, the possibilities of correlation, principal component and cluster analyses were used. Parameters for which information differs between datasets or between statistical packages are removed from the analysis list. The final set of 31 parameters was analysed according to the set goal, after a statistically justified possibility to merge the two datasets. Most of the rank parameters do not show correlation with grain yield. The units are the parameters, the correlation of which is either positive (Pi, Ysi, TOP, λ) or, respectively, negative (DJi, NP(1), CVi]). The analysis of the data through different statistical approaches shows that the parameters correspond to the dynamic concept of stability assessment. Only one of the parameters (θi) is related to static stability assessment. In the presence of many more effective than it, it should not be applied because it is an exception from the analysed group. The groups of parameters of the regression coefficient (bi), the deviation from the regression line (s^2di), ecovalence (W^2i) and the stability variance (σ^2i), give objective information about the behaviour of the variety in environmental conditions and it is not influenced by software. Some of the non-parametric [S(i) NP(i)] assessment methods provide diametrically opposed information for stability because of differences arising from either the dataset or the software used. Suitable for stability assessment are non-parametric approaches - [S(1) and S(2)], which is fully confirmed by the three software packages. Each of the used software packages contains a set of parameters, the application of which as a set gives correct information about all aspects of the wheat stability*

Keywords: wheat, genotype x environment interaction, stability, parametric and nonparametric statistics

Introduction

In cereals, which are the subject of a large number of breeding studies worldwide, the genotype (G) corresponds to the manifestation of the phenotype. In turn, this manifestation is always updated with the direct effects that the state of the environment (E) has on it to be considered a phenotype. The combination of their effects is called a

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genotype by environment interaction (abbreviated G x E or GEI) (Dickerson, 1962). This affects the performance of the phenotype and is unique to each genotype (Kang, 1998). To get a real idea about the reaction of the variety under the specific environmental conditions, it is necessary to measure this interaction (Simmonds, 1981). According to Schlichting (1986), the GEI should not be confused with phenotypic plasticity, which is the reaction of one genotype under different environmental conditions. In essence, this interaction is different from the covariance (correlation) between genotype and conditions, because it changes the individual varieties, which we call the reaction to the environment, and which are in different directions. These are the reasons for the establishment of G x E (Kang, 1998). The performance of the phenotype is always the result of combining the genotype with the environment and the differential sensitivity in determining genotypes to different environments, which is known as the interaction of the genotype in the environments (G x E) (de Leon et al., 2016). G x E occurs when the reaction rate of different varieties is not average, i.e., they intersect, diverge or merge, with similar changes in conditions (van Eeuwijk et al., 2016).

This crossover interaction is consistent with the plasticity and productivity of the varieties (Cooper et al., 1999; Sadras and Rebetzke, 2013). The response of each genotype to a change in environmental conditions (season, location, or agronomical practices) is measured by the degree and direction of change that GxE causes in it (Singh et al., 1999). The genotype shows adaptability when its response rate, within the normal response of a given field experiment, is appropriate for that of the standard genotype or close to that of the ideotype (Van Oijen and Höglind, 2015). The stability that is being assessed is the ability of varieties to express their genetic potentials under a wide range of environments (Annicchiarico, 2002).

The parameters by which the stability of a given sample is evaluated are mainly for traits related to productivity and to a lesser extent to quality indicators or properties. The concept of stability, as a reaction to the genotype, in a sense overlaps with the concept of homeostasis, i.e. a return to the already disturbed balance between variability and sustainability (Sadras et al., 2009; Nicotra et al., 2010).

Varieties showing high adaptability at many locations have a wide adaptation, while those that show it in part of this network of conditions show specific adaptability (Sadras and Rebetzke, 2013). To determine GxE, it is mandatory to study groups of varieties in different environmental conditions, because only then the specific response of each of them could be measured (van Eewijk et al., 2016).

According to Kang (2020), the known and used popular methods for assessing the stability of the genotype in changing environmental conditions are based on two basic concepts of stability (adaptability): biological (static) and agronomic (dynamic). Some of the methods are related to one or the other or meet the requirements of both concepts (Vaezi et al., 2019; Brown et al., 2020; Rezende et al., 2021). According to long-term and systematic studies of the GxE interaction in plants Yan (2021) and Yan et al. (2021), the assessment of stability (GE) should always be combined with a parallel assessment of the level of genotype trait (G), which is at the heart of the state-of-the-art concept of measuring whole interaction (GGE).

This begs the reasonable question: which of the whole set of methods are suitable for application in this case? Many studies analyse a different set of methods by which an objective assessment of stability is made (Kang, 2020; Reckling et al., 2021; Pour-Aboughadareh et al., 2022). This assessment depends on the whole set of factors and their specific influence on the varieties, as well as on the number of varieties, years, and locations study (Brown et al., 2020; Yan et al., 2021).

Each of the statistical parameters (indices), calculated by a specific statistical model, provides some information about the behaviour (reaction) of the genotype. Therefore, many authors suggest using a group of parameters simultaneously (Flores et al., 1998; Verma et al., 2017; Balcha, 2020; Mohammadi et al., 2021). The use of one or two parameters to assess stability, at the current level of information and statistical approaches, is completely unacceptable.

The arrangement of varieties in each group is always inextricably linked to the basic concepts of evaluation with proven interaction of the genotype with the environment (Becker and Léon, 1988; Annicchiarico, 2002). Recently, it has been increasingly necessary to use parameters related to both the „static“ and the „dynamic“ concept for evaluation (Pacheco et al., 2015; Vaezi et al., 2019; Cheshkova et al., 2020). This is necessary because the information that each index carries in different experiments makes it extremely difficult to arrange the varieties. In order to be as objective as possible, the ranking of the varieties in terms of stability should be done from a small number of parameters or, if possible, from only one that is related to information from the other parameters. Some authors are looking for a way to use integral parameters such as KR (Pour-Aboughadareh et al., 2019, 2022), AR6 (Gubatov and Delibaltova, 2020), which are derivatives of a group of single parameters for stability assessment and show high correlations with both yield and stability.

According to a number of researchers (Cheshkova et al., 2020; Kang, 2020; Reckling et al., 2021), the problems associated with objective evaluation of the variety against the background of others in the group are as follows: *first*: each parameter follows a different statistical approach to assessing the change of the variety, compared to the others, which gives part of the complex picture of its variability; *second*: the rank of the variety for each parameter does not coincide or coincides to a different degree with its rank for the others, which creates extreme inconveniences for the interpretation of the results; *third*: the values of the parameters show different in strength and direction interdependence with the grain yield, which makes it complicated to choose objectively which to use for evaluation; *fourth*: the ranks of the individual parameters are differently informative about the actual differences between the studied varieties and *fifth*: the stability of a variety compared to others has different dimensions, directly depending on the choice of parameter or group of complementary parameters.

According to the concept of Flores et al. (1998), the methods for assessing stability are divided into three main groups: *1)*-evaluate mainly yield and poor stability; *2)*-take into account to a similar extent both the yield and its stability and *3)* - highly express the stability of the variety, without being directly related to its yield. For these reasons, each researcher uses a different set of parameters, according to his chosen specific weight (criterion) for assessing the stability to yield.

There are many studies on this topic, the purpose of which is to compare the effectiveness of different sets of parameters (Mohammadi and Amri, 2008; Fasahat et al., 2015; Kaya and Turkoz, 2015; Vaezi et al., 2019; Cheshkova et al., 2020; Mohammadi et al., 2021). The criterion for comparing the methods is their relationship to yield, or the correlations between them. It is believed that the stronger the relationship with yield, the lower the assessment of stability and, conversely, in the absence of correlation, the two could be assessed independently (Flores et al., 1998; Cheshkova et al., 2020). In relation to this topic, the published information can be said to be quite contradictory (Kiliç, et al., 2010; Mohammadi et al., 2016; Vaezi et al., (2019). The authors examine a different set of parameters that they consider to be the right choice and the information about them is difficult to compare because it is diverse. Historically the oldest and naturally the most exploited evaluation parameters, such as the (bi)-regression coefficient (Eberhart and Russell, 1966); (W^2i)-ecovalence (Wricke, 1962); (s^2) -variance of variance (Shukla, 1972) and (Ysi) -stability index (Kang, 1993) are used in studies as a benchmark for comparison with different sets of parameters (Mohammadi and Amri, 2008; Mohammadi et al., 2010; Cheshkova et al., 2020). The direct comparison of the effectiveness of these parameters is also misleadingly different. The most popular are the two groups of well-known non-parametric statistics (S(1), S(2), S(3) and S(6)) (Nassar and Huehn, 1987) and NP(1),NP(2), NP(3), NP(4) (Thennarasu, 1995), the values of which are not influenced by statistical algorithms, but are related only to the rank of yield under different environmental conditions (Mohammadi et al., 2016; Verma et al., 2018; Vaezi et al., 2019). Information on their effectiveness against yield is contradictory (Kaya and Turkoz, 2015; Mohammadi et al., 2016; Vaezi et al., 2019; Lozada and Carter, 2020) and confuses the researchers‘ perception of the correctness of the analysis they would receive if they used it. A common comparison parameter in recent years is AMMI Stability Value (ASV) (Purchase et al., 2000). Its effectiveness for evaluation varies widely: from positive to negative (Gomez-Becerra et al., 2006; Khalili and Pour-Aboughadareh, 2016; Cheshkova et al., 2020). In each specific field experiment, various parameters are informative on the topic of stability. This is a prerequisite before their implementation is preceded by some verification of their effectiveness. In most studies, the emphasis is on the analysis and comparison of statistical parameters in terms of their ability to separate varieties by stability. There are only a few studies that critically assess the fundamental difference between them, which leads to the right set of them, according to the specific purpose of the development (Fasahat et al., 2015; Cheshkova et al., 2020).

The purpose of this study is to compare different methods for assessing the stability of grain yield of a group of varieties studied in proven different environmental conditions. Achieving this goal is related to solving the following main tasks: *1)* To compare established methods for stability assessment by their applicability for variety assessment, regardless of the specific field experiment, *2)* To identify those of them, which are effective for assessing the stability in its various aspects and *3)* To compare the effectiveness of the parameters analysed by different statistical programs.

Material and methods

Organization of the experiment

Two datasets of wheat varieties (*Triticum aestivum* L.) from field trials were analysed, including different growing locations and seasons (Table 1). The first experiment (dataset, labelled 24 PhD) included 24 wheat varieties studied in five locations of the country over four consecutive years. The data from it were analysed to study all aspects of the genotype x environment interaction, as well as the application of some statistical approaches to assess the change in yield and related quantitative characteristics of the studied varieties (Gubatov, 2020).

The second dataset (labelled 40 ABC) consists of forty wheat varieties and advanced breeding lines, developed by the Agronom Breeding Company. The field experiment was conducted in three locations of the country over a period of three consecutive years. The idea of this multifactorial field experiment is to investigate the stability of current cultivars and breeding lines under their most optimal conditions. The three locations are the same as in the first experiment, because significant differences in their soil and climatic conditions have already been identified, which is a good prerequisite for a correct assessment of the variety's stability (Gubatov, 2020, Gubatov and Delibaltova, 2020). The significant difference is in the set of varieties (completely different from the first) and in the years of study. Each field experiment is set in three repetitions with size of the experimental plot 10 m^2. The agricultural practice during the vegetation is absolutely the same for all varieties, at each location during each of the seasons of research.

Table 1. General information on the levels of the main factors - Location (A), Year of testing (B) and Genotype (C) of the conducted field experiments of both Datasets (24 PhD,40 ABC)

Location (A)	Coordinates		Altitude	Years (B)	Genotypes (C)
	N	E			
Data Base			24 PhD		
Dobrich (Paskalevo)*	43^{0}38'47"	27^{0}48'40"	248	2009	Varieties 22
Rousse (Trastenik)*	43^{0}37'40"	25^{0}51'37"	170	2010	Checks 2
Yambol (Straldja) *	42^{0}35'25"	26^{0}39'06"	150	2011	Total 24
VelikoTarnovo (Tsarevets) *	43^{0}36'30"	25^{0}30'02"	110	2012	
Experimental field, AU, Plovdiv *	42^{0}08'13"	24^{0}48'22"	155		
Data Base			40 ABC		
Dobrich (Paskalevo)	43038'47"	27048'40"	248	2017	Varieties 37
Rousse (Trastenik)	43037'40"	25051'37"	170	2018	Checks 3
Yambol (Straldja)	42035'25"	26039'06"	150	2019	Total 40

Legend: * - the exact location

Statistical analyses

The stability of the varieties from the groups was analysed by a total of 48 statistical parameters, described in detail in several studies or reviews (Vaezi et al., 2019; Kang, 2020; Temesgen et al., 2021). The values of each of them were calculated using some statistical computer programs that specialize in such analyses: *PBSTAT 2.9* (Suwarno et al., 2008), *GEA-R* (Pacheco et al., 2015), *Stabilitysoft* (Pour -Aboughadareh et al., 2019) and *META-R* (Alvarado et al., 2020).

Most of the statistical parameters (*bi, CV, σ2,* S^2d, W^2, *S (*), NP (*), α, λ*) are included in all three software packages, although the designation of some of them differs (Table 2). Each statistical package evaluates a different set of parameters, some of which are original to it. All of them, without exception, were analysed to determine whether there are fundamental differences in their effectiveness. Some of the parameters, although fundamentally analogous [*Bi, Di, NP(*)]* have shown different rank in direct comparison between individual datasets. Some of them showed significant differences in the correlation between their ranks and those of yield, which is why they were removed from the final set, which was practically analysed (Supplementary)

The applicability of each of the stability parameters has been studied with the intention of grouping them according to the approaches of Flores et al. (1998) and Annicciarico (2002). The grouping was performed according to the following several different approaches: *i)* by calculating the correlations between grain yield and their values (using SPSS, 19 or Past 4*), ii)* by principal component analysis (Alberts, 2004) based on Sperman' rank correlations between yield and their rankings (Piepho and Lotito, 1992) and *iii)* by cluster analysis according to the method described by Lin and Thompson (1975), according to the statistical model for Ward (1963) grouping. Combining the data from both field experiments was done after checking their similarity by analysing the canonical correlations between the two main factors of principal component analysis (PCA) from the two datasets.

Table 2. Information on all the methods of stability analysis by statistical packages

№	Designation and name of parameters					
	GEA-R *		PBSTAT **		STABILITYSOFT ***	
1	bi	Regression coefficient	b_i	Regression coefficient	AR	Average Rang
2	B_i	Regression coefficient	Cv_i	Coefficient of variation	b_i	Regression coefficient
3	CV(%)	Coefficient of variation	D_i	Hanson's genotypic stability parameter	CVi	Coefficient of variation
4	DJ_i	Mean square deviation	$NP_i(1)$	Thennarasu's stability parameter-1	KR	Kang's rank-sum index
5	P_i	Superiority index	$NP_i(2)$	Thennarasu's stability parameter-2	$NP^{(1)}$	Thennarasu's stability parameter-1
6	S^2d	Deviation from regression	$NP_i(3)$	Thennarasu's stability parameter-3	$NP^{(2)}$	Thennarasu's stability parameter-2
7	Si(1)	Huehn's stability parameter-1	$NP_i(4)$	Thennarasu's stability parameter-4	$NP^{(3)}$	Thennarasu's stability parameter-3
8	Si(2)	Huehn's stability parameter-2	s^2d_i	Deviation from regression	$NP^{(4)}$	Thennarasu's parameter-4
9	R^2	Coefficient of determination of bi	$S_i(1)$	Huehn's stability parameter-1	$S^{(1)}$	Huehn's stability parameter-1
10	$s^2=\sigma^2_i$	Shukla's stability variance	$S_i(2)$	Huehn's stability parameter-2	$S^{(2)}$	Huehn's parameter-2
11	W_i	Wricke's ecovalence	$S_i(3)$	Huehn's stability parameter-3	$S^{(3)}$	Huehn's stability parameter-3
12	α (*alpha*)	Linear Response to environments	$S_i(6)$	Huehn's stability parameter-6	$S^{(6)}$	Huehn's stability parameter-6
13	λ (*lambda*)	Deviation from the linear response	StabVar= σ^2_i	Shukla's stability variance (σ^2)	S^2d_i	Deviation from regression
14	sd	Standard deviation of Yield	TOP	Fox's TOP	W_i^2	Wricke's ecovalence
15			W^2_i	Wricke's ecovalence	$\theta_{(i)}$	GE variance component
16			Ys_i	Kang's yield and stability index	θi	Mean variance component
17					σ^2_i (*sigma*)	Shukla's stability variance
18					SD	Standard Deviation AR

Legend: * (Pacheco et al., 2015), ** (Suwarno et al., 2008), *** (Pour-Aboughadareh et al., 2019)

Results

The three studied factors have a direct effect on grain yield (Table 3). The effect of each of these factors is combined with that of the genotype, which is an important factor in the field experiment. The only exception to the lack of interaction is between the „year x genotype", in the second dataset (40 ABC). Differences between the conditions of the locations and the seasons of the study affect the change in yield significantly, without exception. The influence of the location in both studied groups is the strongest, compared to the other two factors. It is further enhanced by the interaction with the years of study (A x C), which significantly and further causes a change in grain yield.

Table 3. Analysis of Variance for GY - Type III Sums of Squares (Statgraphics XVIII)

Source of variation	24 PhD *				40 ABC **			
	Df	Mean Square	F-Ratio	*p-value*	Df	Mean Square	F-Ratio	*p-value*
A:Location	4	276.904	1127.19	0.0000	2	360.53	1488.03	0.0000
B:Year	3	97.5548	397.11	0.0000	2	1.34285	5.54	0.0047
C:Genotype	23	0.979727	3.99	0.0000	39	2.06815	8.54	0.0000
A x B	12	45.4865	185.16	0.0000	4	1.69799	7.01	0.0000
A x C	92	0.289798	2.18	0.0156	78	1.15687	4.77	0.0000
B x C	69	0.61926	2.52	0.0000	78	0.248266	1.02	0.4420
RESIDUAL	276	0.24566			156	0.242288		
Total (corrected)	479				359			

Legend: *- 24 PhD Dataset; ** - 40 ABC Dataset

Table 4. Gollob's test of site regression analysis of Variances by GEA-R (Gollob, 1968)

Datasets		24 PhD				40 GY		
Source	DF	Percent*	Percenac**	Prob F***	DF	Percent*	Percenac**	Prob F***
ENV	4	81.37	81.37	0.0000	2	80.84	80.84	0.0000
GEN	23	5.31	86.68	0.0000	39	9.04	89.88	0.0000
GEN*ENV	92	13.32	100.00	0.0000	78	10.12	100.00	0.0000
PC1	26	48.27	48.27	0.0000	40	55.06	55.06	0.0000
PC2	24	21.29	69.56	0.0000	38	24.31	79.37	0.0000
PC3	22	14.10	83.66	0.0000	36	20.63	100.00	0.0000
PC4	20	9.51	93.17	0.0004				
PC5	18	6.83	100.00	0.0084				
Residuals	360	0	0		240	0	0	

Legend: * Percent-percent of the total variability explain, **Percent-percent of the total variability explain accumulative, *** Prob F-value of significance of the test (p<0.001)

The relative share of the effect of each factor in the experiments is presented in Table 4. The combination of the two factors „location x year“ is presented in general as „environments“. When choosing a method for estimating variants, the method of Gollob (1968) was chosen, which has advantages over the AMMI model because it is a combination of it and the statistical Factor analysis. The regression analysis (SREG) made on this model shows that the combined effect of the location and the year on the yield is huge and reaches about 80% of the total variation in the two groups (81.37 for 24 PhD and 80.84 for 40 ABC). The effect of genotype averaged between 5% (5.31 for 24 PhD) and 9% (9.04 for 40 ABC) of all variation. The interaction between them is between 10% (10.12 for 40 ABC) and 13% (13.32 for 24 PhD). Both types of interaction vary as follows: (PC1=48-55%) and (PC2 is 21-24%). The latter in the first group (24 PhD) reaches proven values of five components, and in the second group (40 ABC) the variation extends to three components.

Each variety displays itself differently against the background of the studied conditions, as the variation is a result of the above mentioned two types of genotype x environment interaction. Against the background of three to five proven principal components of variation (Table 4), the vectors of the studied locations are in different directions (Figure 1). This is true for both datasets and is direct evidence of the significant differences between the conditions in them.

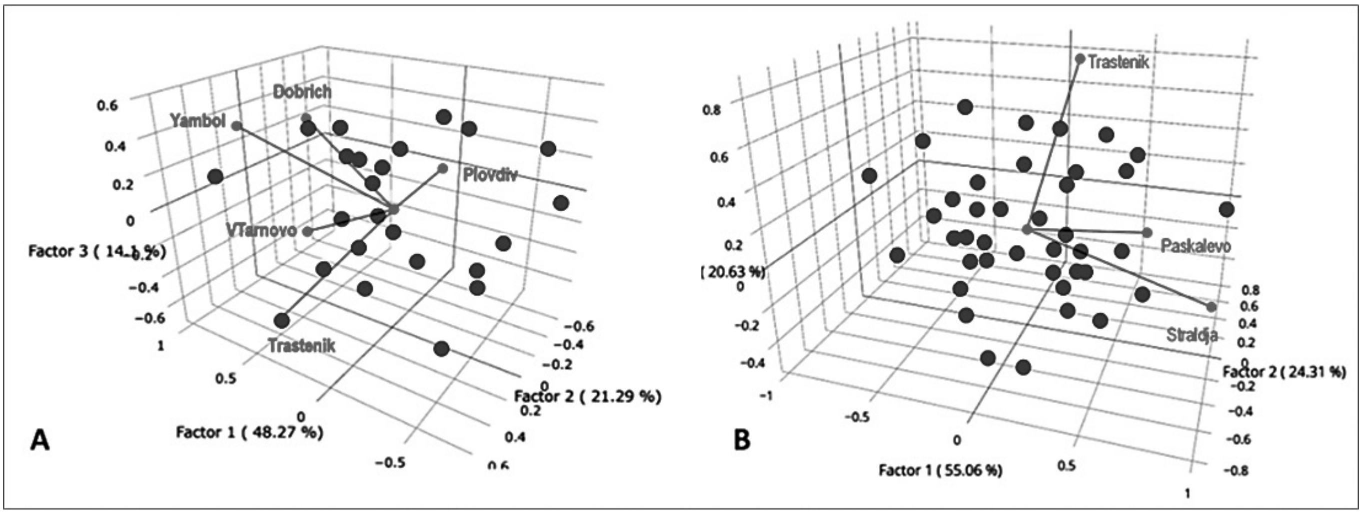

Figure 1. Spatial representation of Grain yield according to the crossover genotypes by location, (A) for 24 PhD and (B) for 40 ABC Datasets

Table 5. Genetic correlations between grain yield test locations (META-R)

Environment	Dobrich	Trastenik	V.Tarnovo	Plovdiv	Yambol
Trastenik	+0.53 (1)	***0.358 (2)***	***0.844***	***0.482***	***0.425***
V.Tarnovo	-0.12	+0.12	***0.846***	***0.299***	***0.559***
Plovdiv	-0.42	-0.59	+0.09	***0.880***	***0.560***
Yambol	+0.47	+0.35	+0.35	-0.35	***0.524***

Legend: (1) - below the diagonal - correlation coefficient,
(2) - **above the diagonal correlation reliability** (p <0.01)

The variation of the yield in each specific location is complicated in size and direction. Confirmation of this is the lack of reliable genetic correlations between the data from the different locations (Table 5). There are positive correlations between Dobrich and Yambol (r = + 0.47 ns), Yambol and V. Tarnovo (r = + 0.35 ns) and Yambol and Trastenik (r = + 0.35 ns), but as a result of the strong variation of the data in them by seasons, they are not statistically proven. The conditions for achieving the grain yield at the individual locations differ from one another, regardless of the studied different sets of years.

Table 6. Broad sense Heritability (H2) and variability (CV %) of grain yield by Location of testing (META-R)

Location	GY, t/ha	Genotype Variance	Environment Variance	CV %	Heritability (H^2)
			24 PhD dataset		
Dobrich	9.44	0.252	0.149	4.08	0.87
Plovdiv	4.03	0.034	0.186	10.70	0.42
Tarnovo	6.78	0.083	0.101	4.68	*0.77*
Trastenik	7.32	0.141	0.093	4.16	0.86
Yanbol	5.77	0.138	0.109	5.70	0.84
Combined	6.68	0.020	0.130	5.35	0.37
			40 ABC dataset		
Paskalevo	9.45	0.3903	0.1642	4.29	0.89
Trastenik	8.68	0.2668	0.1625	5.64	0.84
Straldja	6.14	0.5593	0.4061	10.37	0.80
Combined	8.10	0.1230	0.2450	6.11	0.48

These differences for the yield in the locations of the two datasets are presented in Table 6. In each of them the inheritance of the yield during the different seasons in it is high (H^2 = 0.77- 0.87). This implies a high degree of predictability of changes in yield at a given location, without significant impact on the years of research. This probability is over 75% (H^2> 0.77), which is a good reason to use these locations for a correct assessment of the yield and its stability for zoning purposes. An exception to this is the data at the Plovdiv location, where the yield can be predicted with a probability of only 42% (H^2 = 0.42). With almost twice as high variation of yields (CV = 10.7%) compared to the other locations in the group, they are significantly more affected than the seasons in it. All this against the background of the relatively lower mean value of grain yield (GY = 4.03 t / ha). These regularities for Plovdiv make it difficult to predict the evaluation of the variety, in strong dependence on the selected specific seasons in the experiment. The combined value of the inheritance coefficient in the different datasets is significantly lower: H^2 = 0.37 at (24 PhD) and H^2 = 0.48 at (40 ABC) and reflects the lack of relationship between yields from the studied locations (Table 5). Given these specific patterns, the assessment of the specific plasticity of the variety is preferable to its general adaptability to the whole set of items. In turn, this is an important prerequisite for the criterion of the magnitude of stability to be reduced when finding a compromise with the level of yield. In turn, this leads to a different attitude towards the set of parameters for assessing stability depending on their relationship to yield.

After calculating the values of each parameter, they are converted into a score. These ranks for each parameter are presented in several tables, grouped according to the software used. Due to their large volume, they are not included directly in the material, but are presented separately in the attached Supplementary.

In the process of data analysis, significant similarities, and significant differences in the ranks of the varieties of the individual parameters were found. There are two main reasons for this: either the differences in the software or the specific nature of the dataset. The complete coincidence of the ranks of the varieties for individual parameters included in the various statistical programs is not surprising. It is the result of the same statistical formulas by which they are calculated, although they are marked differently in different packages, such as (*bi-Bi, σ^2-StabVar, or s^2di-Di).* The significant differences between the same parameters are due to both the software and the specifics of the individual datasets. This necessitated further optimization of the set of parameters to be evaluated according to the aim set in the study. This additional analysis is based on each of the statistical packages separately, after which the information about the parameters is compared between them. The comparison of each parameter in the different datasets is based on the correlation with the yield it shows (Supplementary).

The parameters (Sd), CV (%) and (R2) are additionally excluded from the GEA-R package because they show radically opposite values of correlation with the yield in the individual datasets. (Table 4S). For this reason, they are inapplicable and are omitted for the following analysis.

The parameters (CVi) and (s2di) were excluded from the PBSTAT package, which also show opposite values of yield correlation (positive in one dataset and negative in the other) (Table 5S). These significant anomalies in the information are a good reason to exclude them from the group of parameters.

According to the correlations with the yield in the STABILITYSOFT software package, each parameter provides similar information for both datasets (Table 6S). There is no need to remove parameters from the group.

In the process of data analysis, it was found that some of the parameters calculated by the same statistical methods show different correlations with grain yield. A clear example of this are the non-parametric parameters NP(2), NP(3) and S(3), S(6), which were used in two of the three statistical programs (Supplementary). Both groups of similar parameters are additionally excluded from the comparison group. The reason is their completely opposite and significantly high correlation with yield: negative in (PBSTAT) and positive in (Stabilitysoft) after the parallel comparison between the two datasets. It is quite clear that in such a situation these parameters should not be included in the stability assessment analysis.

Table 7. Canonical correlations between the main factors of PCA in both datasets

Factors	Factor loading		Contribution of statistics (%)	
	$F1/_{24}$ [1]	$F2/_{40}$ [2]	$F1/_{24}$ [1]	$F2/_{40}$ [2]
$F2/_{24}$ [1]		0.47 *		0.67 **
$F1/_{40}$ [2]	0.93 ***		0.83 ***	
	Eigenvectors		Squared cosines of the variables	
$F2/_{24}$ [1]		0.47 *		0.67 **
$F1/_{40}$ [2]	0.93 ***		0.83 ***	

Legend: [1] - 24 PhD Dataset; [2] - 40 ABC Dataset

After the stages of „optimization“ and exclusion of parameters from their initial number of 48, it was reduced to 31 (Supplementary, 4S-7S). After removing the mentioned objective obstacles, this is the final set of parameters, the effectiveness of which must be subjected to critical evaluation. The applicability (effectiveness) of each parameter was analysed by combining the information from the two datasets. Such a combination is appropriate only if similarities between their data are demonstrated.

For this purpose, PCA was performed on each of the two dataset groups. The relationship between the first ($F1/_{24}$ and $F1/_{40}$) and between the second ($F2/_{24}$ and $F2/_{40}$) factors on the components of PCA was established by applying the canonical correlation analysis (Table 7). The data show positive and reliable high correlations for some of PCA statistical traits (Factor loading, Eigenvectors, Contribution of statistics (%) and Squared cosines of the variables) in both groups of factors (r = 0.83 *** - 0.93 ***) and (r = 0.47 * - 0.67 **), respectively. Undoubtedly, the relationship between the two main components in the two data groups is completely similar and reflects similar information, which allows them to be combined in one matrix.

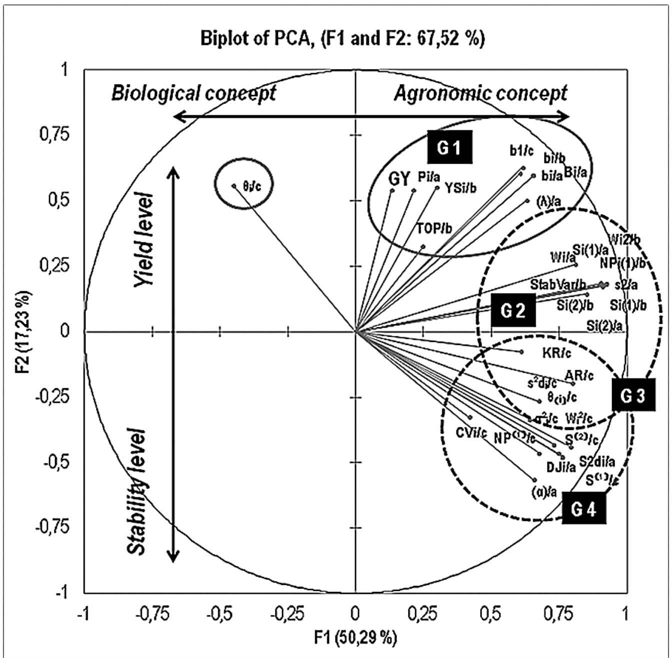

Figure 2. Biplot of Principal Component Analysis of 31 selected parameters of stability

The results of the graphical analysis of PCA, built on Sperman Rank correlations from the ranks of parameters and grain yield in combination of the two datasets are presented in Figure 2. The two main components: PC1 and PC2 reflect about 2/3 (PC1 + PC2 = 67.52) of all variation in rankings. According to the angle they make with the yield vector, their vectors form several basic groups in biplot. These regularities are valid for both directions of the yield vector. For an angle between vectors less than 45˚, the correlation between them is positive and reliable in value. At angles between 60-90˚ the correlation decreases to zero, and at increasing angles above 90˚, the correlation begins to increase in the negative direction. The more the angle exceeds 120˚, the more reliably negative the correlation becomes. An angle close to 180˚ means a 100 percent negative correlation.

The group of parameters (G1) that is most related to grain yield consists of the following parameters: *[(Pi/a), (Ysi/b), (TOP/b) (λ/a)]* and the parameters expressing the regression coefficient [*Bi/a), (bi/a), (bi/b), (bi/c)],* their vectors have an acute angle with that of the yield (<45˚). In the second group (G2), there are a total of 9 parameters, which are located in the range from >45 to <60˚, relative to the yield; as follows: [*(S(1)/a), (S (1)/b), (S(2)/a), (S(2)/b), (σ^2/a), (stabVar)/b, NP(1)/b), (Wi/a), (Wi^2/b)],* The third group (G3) consists of a total of 6 parameters, the vectors of which make an angle (>90 and <120 0) to the yield: σ^2/c), (Wi^2/c), (AR/c), (KR/c), (s^2di/c) and ($\theta_{(i)}$/c). This group can be considered intermediate because the parameters with similar vectors in space show a positive or negative correlation, the values of which are statistically insignificant. In practice, it can be assumed that they do not correlate with yield. The fourth group (G4) includes the other vectors whose angle is >120˚ with respect to the yield vector. Here are the parameters: *[(S(1)/c), (S(2)/c), (Dj/c), (NP(1)/c), (s^2di/a), (CVi/c) and α/a)].* The vector of the parameter (θi/c) forms an independent group to the left of the yield vector. Its location is at an acute angle, which means that in terms of its correlation with yield, it must be assigned to the second group of parameters (G2).

The location of the groups of vectors is in this part of the biplot (on the left along the axis of PCA1), which is related to the agronomic (dynamic) concept of evaluation. Only one parameter (θi/c) can be assigned to the biological (static) group. With respect to the horizontal axis of PCA2, the groups of vectors are arranged according to the strength of their positive correlation with yield (above the axis) or with that of stability (below the axis). This clarifies why the group of vectors (G3) can be called „intermediate“. It is in the „buffer“ zone between groups G2 and G4, which have already been described. The parameters surrounded by a red line are convenient for evaluation mainly of varieties with high yield and stability below the average for the group. These vectors, which are outlined with a black line, are for evaluating the varieties that have the best compromise between yield and stability. The third group, which is surrounded by a blue line, are the parameters that are used to evaluate mainly highly stable varieties (general stability), but with a lower level of productivity.

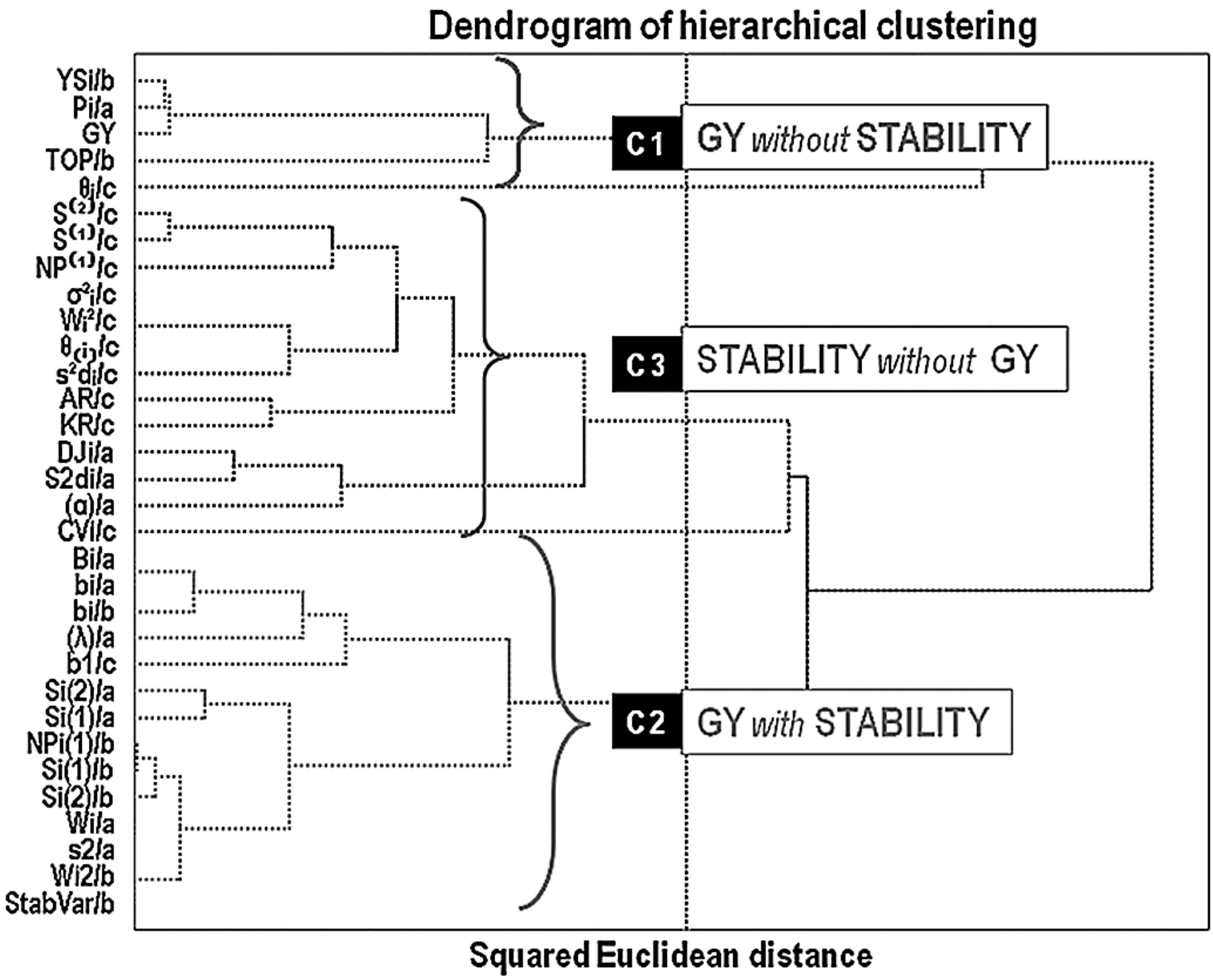

Figure 3. Cluster analysis of yield and selected stability parameters by Squared Euclidean distance (XLSTAT 2014)

The information on the effectiveness of the parameters was also analysed by cluster analysis (Figure 3) to confirm its correctness regarding the grouping of the parameters. Their location in clusters relative to yield, in principle, almost repeats that of the groups shown in Figure 2. In a yield group there are only four parameters: (Pi/a), (Ysi/b), (TOP/b) (C1). Thirteen parameters [*(S(1)/c), (S(2)/c), (NP(1)/c), (σ²/c), (Wi²/c), (θ(i)/c), (s²di/c), (AR/c), (KR/c), (Dj/c), (s²di/a), (α/a) and CVi/c]* form a second group (C2). Group (C3) consists of the remaining fourteen parameters, arranged in Figure 3 from top to bottom, as follows*: [(Bi/a), (bi/a), (bi/b), (bi/c), (λ/a), (S(2)/a), (S(1)/a), (NP(1)/b), (S(1)/b), (S(2)/b), Wi/a), (σ²/a (Wi²/b) and (stabVar)/b*].

Table 8. Spearman Rank correlations (*rho*) between yield and finally selected stability statistics by groups, according to the concept of Flores et al. (1998)

GY–STAB**	rho	Probability	GY+STAB**	rho	Probability	STAB-GY**	rho	Probability
Pi/a*	0.98	0.000	(α)/a	-0.04	0.725	DJi/a	-0.24	0.079
YSi/b	0.97	0.000	(λ)/a	+0.19	0.130	NP(1)/b	-0.25	0.063
TOP/b	0.69	0.000	s^2/a	+0.07	0.559	CVi/b	-0.39	0.002
KR/c	0.56	0.000	σ^2_i/b	-0.02	0.886			
AR/c	0.37	0.003	StabVar/c	+0.07	0.559			
			$\theta_{(i)}$/b	-0.02	0.886			
bi/a	0.24	0.053	Si(1)/a	+0.13	0.303			
Bi/a	0.24	0.053	Si(1)/c	+0.10	0.421			
bi/b	0.18	0.157	$S^{(1)}$/b	-0.04	0.750			
b1/c	0.19	0.156	Si(2)/a	+0.10	0.439			
θi/c	0.21	0.097	Si(2)/b	+0.08	0.523			
			$S^{(2)}$/c	-0.01	0.917			
			Wi/a	+0.07	0.559			
			Wi^2/b	+0.07	0.559			
			Wi^2/c	-0.02	0.886			
			S^2di/a	-0.08	0.551			
			NPi(1)/c	+0.09	0.456			

Legend: * The letter after the slash in the designation of each parameter indicates the software in which it is included, as follows: (A-GEA-R, B-PBSTAT, C-STABILITYSOFT), ** - grouping of parameters according to their correlation with yield according to the approach of Flores et al., (1998): GY - STAB - strong positive relationship [Pi/a-"Superiority measure (index)", YSi/b-"Kang's yield and stability index", TOP/b- "Fox's TOP", KR/c-"Kang's rank-sum index", AR/c-average rank, bi/a, (B/a, bi/b, b1/c)-"Regression coefficient", $\theta_{(i)}$/c - "Mean variance component"]; GY + STAB - without any correlation: [(α/a-"Linear Response to environments", λ/a-"Deviation from the linear response", S^2d/a-"Deviation from regression", σ^2=(sigma)/b- Shukla's stability variance, StabVar/b- Shukla's stability variance (σ^2), $\theta_{(i)}$/c-"GE variance component", Si(1)/a, Si(1)/c, $S^{(1)}$/b, Si(2)/a, Si(2)/b, $S^{(2)}$/c-"Huehn's non-parametric statistics"; Wi/a, Wi^2/b,Wi^2/c-"Wricke's ecovalence", S^2di/a-"Deviation from regression", NPi(1)/c-"Thennarasu's nonparametric stability parameter]; STAB-GY - with negative correlation [Dj_i/a-"Mean square deviation"; NP(1)/b-"Thennarasu's nonparametric stability parameters; CVi/b-"Coefficient of variation"].

The difference between the grouping in the two types of visualization is that the parameters of the regression coefficient [*(Bi/a), (bi/a), (bi/b), (bi/c)]* are in one cluster together with those of group (G2), (Figure 2). This location does not significantly change the relationship between rankings for yield stability. On the contrary, grouping the parameters into clusters confirms the spatial arrangement of the vectors shown in Figure 2.

The designation of the groups in the cluster analysis (C-cluster) largely corresponds to the groups of vectors in Figure 2. This comparison (G1 with C1; G2 with C2, G4 with C3) is reflected by the designation of the groups according to the trade-off between yield and stability, which they possess as a criterion. The only difference in this analysis compared to PCA is the classification of the parameters expressing the regression coefficient [*(Bi/a), (bi/a), (bi/b), (bi/c)*] to group C2, which is equivalent to G2, if they were in G1 (Figure 2). In practice, here they appear as an intermediate group by analogy with the G3 group.

The search for interdependencies between the parameters through different analyses was done to establish their level of efficiency in their combination with grain yield. The stronger the association with it, the lower the degree of genotype stability. The data in Table 8 show that several parameters: (DJi/a, (NP(1)/b), (CVi/b), have a significant negative correlation with the yield, but at a lower level of reliability ($p <0.010$) Their joint assessment with the combined yield will identify the varieties with slightly higher overall stability under the two field trials. Parameters *(Pi/a), (Ysi/b), (TOP/b) , (AR/c), (KR/c),* show a positive correlation with the level of yield, which makes them suitable for identifying such varieties with a combination of high yield (higher than the group average) and low stability (lower than the group average) A small group of parameters (bi/a, Bi/a, bi/b, b1/c, θi/c) show a weak positive correlation with yield, in three of them (bi/a, Bi/a and θi/c) the positive correlations could be accepted at a lower level of reliability ($p <0.010$), and in the other two - practically no correlation.

These 5 parameters are statistically completely analogous and this small contradiction calls into question which of the three groups to be assigned to. Positive correlations with yield are the reason to be treated as parameters of the first group. For all others (17 in number) of the groups G2 (Figure 2) and C2 (Figure 3), the yield ranks and those of the parameters have no correlation with each other. Therefore, they are an appropriate choice for establishing a variety whose yield and stability are „independent" values. Most of the parameters here are completely similar, which means that they could be interchangeable. When arranged, according to their statistical meanings, they form several basic sets: 1) those expressing in principle - „Deviation from regression", *[(λ)/a, s^2/a, σ^2_i/b, StabVar/b, $\theta_{(i)}$/b), S^2d_i/a]*, 2) those expressing Huhn's non-parametric statistics" [*Si(1)/a, Si(1)/c, $S^{(1)}$/b, Si(2)/a, Si(2)/b, $S^{(2)}$/c*)], 3) „Wricke's ecovalence" [*Wi/a,* *Wi2/b, W_i^2/c]* and 4) several independent parameters - [(α/a- „Linear Response to environments“ and NPi(1)/c -“ Thennarasu‘s non parametric stability parameter. In practice, it can be assumed that the parameters of this group are five in number - three sets plus two single parameters.

Discussion

Under the conditions of the two field trials, without exception, grain yield is strongly influenced by the type of variety and growing conditions, with the highest statistical level of reliability (Tables 3 and 4). The complex of environmental conditions is the main reason for the variance of the yield (80.8%). The change in the trait is because of the variety of (5-9%), as well as the interaction of the two main factors (A x B = 10.2-13.3%). Against the background of the established significant differences between the meteorological indicators and their influence on the grain yield, it is logical that the share of the conditions on the variation is so large. The effect of the variety on yield is completely analogous in terms of share when compared to data from other previous studies (Tsenov and Atanasova, 2015; Gubatov et al., 2016; Gubatov and Delibaltova, 2020). It can be assumed that the genotype alone and in interaction with the conditions (G + GxE) causes almost 1/5 of the variation in yield (18.6-19.3%). This interaction affects specifically each studied variety, whose variation is unique in direction and magnitude in the specific environmental factors (Figure 1).

The joint analysis of the yield and its stability against the background of the established variation is obligatory in case the most objective assessment of the variety is sought. That is why the research offers already established methods and new ones are constantly sought, the effectiveness of which is subject to verification (Kang, 2020). The availability of many methods for assessing stability is an indication that each of them, if used alone, provides information on some aspect of the complex picture of stability studies. For this reason, they need to be applied in groups (Flores et al., 1998; Balcha, 2020). Here the question arises: exactly which of the whole set of methods are suitable for application in this case? Many studies indicate a different set of statistics by which an objective assessment of stability is made (Mohammadi et al., 2016; Kang, 2020.) This assessment depends on the whole set of factors and their specific impact on varieties, on their specific number and a set of years and locations of study (Brown et al., 2020; Yan et al., 2021). Before proceeding to the application of any of the whole range of methods, the fundamental question must be decided: which high criterion of stability must the high-yielding genotype meet? In this regard, there is already a specific proposal from Olivoto et al. (2019), who discuss a compromise model for assessing stability, using an index that considers the weight of yield and stability, such as the most working relationship between these is 65/35 (yield/stability), but the approach allows this to be changed.

The significant differences in the conditions of the locations in both studies (Table 5) and the high degree of repeatability of the data in each of them (excluding Plovdiv) suggest the need to assess the specific stability of the variety before its general one. A prerequisite for this is the low degree of yield prediction (H^2 = 0.37-0.48), on average from all locations (Table 6). Therefore, the choice of evaluation parameters should fall on those that have a positive or no correlation with the yield (Table 8). Those that show a negative correlation with yield [*DJi/a,NP(1)/b, CVi/b]* are not preferable in the specific conditions studied. On the contrary, parameters from groups G1, G2 and G3 (Figure 2) or C1 and C2 from Figure 3 must be applied.

The parameters with designations (*Pi/a), (Ys_i/b), (TOP/b) (λ/a*) and those expressing the regression coefficient for the individual statistical packages [*(Bi/a), (bi/a), (bi/b), (bi/c)]*, are most applicable for the detection of high-yielding varieties with stability around the average for the whole group. Evaluated by some of these parameters the variety will be suitable for some of the locations, for others not. In this way, each variety could be properly zoned. Particularly valuable in this regard is the information provided by the parameters (*Pi/a), (TOP/b),* because the way they are calculated is directly related to the size of the yield and its change in locations relative to others. These parameters are desirable for evaluation, in wheat according to the research of Cheshkova et al. (2020), as well as in other cereals - corn (Fan et al., 2007), durum wheat (Mohammadi and Amri, 2008) and barley (Vaezi et al., 2019). In their study, Kiliç et al. (2010) expressed the exactly opposite view that the parameters (Pi) and (Ysi) are mainly related to stability (have a negative correlation with yield) and should not be used to assess stability along with grain yield.

The values of (Ysi/b) are essentially a compromise assessment of yield + stability, in which yield is predominant (Kang, 1993; Kaya and Turkoz, 2015), which makes this parameter extremely applicable to such estimates, to the extent to become a benchmark for comparison (Mohammadi et al., 2016; Wardofa et al., 2019; Gubatov and Delibaltova, 2020). This study confirms the high efficiency of this index in both datasets, without exception. The assessment of Mohammadi et al. (2010), who studied this parameter in durum wheat, is similar. Contradictory are the studies of Kiliç et al. (2010) and Khaki et al. (2021), according to which this parameter shows a strong negative correlation with grain yield and should not be used for evaluation of stability

The regression coefficient parameter is included in all software packages, and in the GEA-R package it has two variants of calculations: bi/a (according to Eberhart and Russell, 1966) and Bi/a (according to Perkins and

Jinks, 1973). This does not change its nature of stability assessment at all. Regardless of the software used or the method of calculation, it shows a positive relationship with grain yield (Figure 2, Table 8). According to Pacheco et al. (2015), who are the authors of the software, both variants of the regression coefficient are assigned by effect to the dynamic concept of evaluation, which makes them very convenient to use. The regression coefficient is the most exploited indicator for assessing stability (Cheshkova et al., 2020; Kang, 2020; Mohammadi et al., 2021). Some authors use it as a stand-alone criterion for assessing stability, together with the deviation from regression (S^2d) (Georgieva and Kirchev, 2020; Stoyanov and Baychev, 2021). A number of other models that are most relevant now are based on the idea of regression: additive main effect and multiple interaction (AMMI) (Gauch, 1988), Factorial Regression (FR), (Denis, 1988) and partial least square regression (PLS) (Vargas et al., 1998) The main reason for looking for new interpretations of the regression model is that the most valuable for the performance of a variety is the assessment, whose main starting point for comparison is the performance of the group in which it is studied.

According to the way in which the variation of the variety is analysed, individually or in relation to the group, the methods are divided into two concepts of stability (adaptability): biological (static) - the variety is stable, when changing slightly in different environments and agronomic (dynamic) - the variety shows a group-like change in different environments (Kang, 2020). The value of the regression coefficient also shows what conditions the variety is suitable for. The higher its value, the higher the yield will be in favourable conditions and vice versa. The regression coefficient is inextricably linked to the parameters that consider the deviation (variation) of the variety from the regression line (S^2di/a, Dj_i/a, S^2di/c), which reflects the difference from the group in variation in direction and magnitude. The application of both parameters as a tandem is highly recommended because (bi) shows how adaptable the genotype is (adaptive) and (s^2di) measures its stability (Pacheco et al., 2015). The evaluation of the variety by the parameters (α)/a) (adaptability) and (λ)/a) (stability) is completely analogous, according to the methodology of Tai (1971) and Pacheco et al. (2015). Both provide information on the variety, regardless of the level of its yield (Figure 2, Table 8) and should also be applied similarly as a tandem: (bi)-(s^2di.). They are a very suitable tool for a comprehensive assessment of the yield variety, along with its adaptability and stability (Pacheco et al., 2015).

The information about the parameters from the group of „stability variance" (s^2/a, σ^2_i/b, StabVar/c) (according to Shukla, 1972) is contradictory in various studies. Verma et al. (2018), Vaezi et al. (2019), and Mohammadi et al. (2021) reported no correlation between yield and this parameter. According to other studies by Mohammadi and Amri (2008) in durum and Cheshkova et al. (2020) in bread wheat, the parameter shows a strong negative correlation with yield. The significant difference between the data from similar studies on the topic is a signal for need of preliminary verification of each parameter before proceeding to a specific use. Preliminary information should not be taken lightly, as can be seen to be quite misleading. This was the reason why many parameters were included in this study. Their set is specific to each software, but is determined by professional statisticians, which in this case completely excludes personal choice for specific parameters by the user.

An analysis of the parameters of the Wricke's ecovalence group (Wi/a, Wi^2/b, W_i^2/c) (according to Wricke, 1962) found that all without exception are effective in assessing stability, regardless of yield level. There is practically no correlation between this parameter and the yield (Table 8). This coincides completely with the research of Verma et al. (2018), Vaezi et al. (2019) and Mohammadi et al. (2021), but completely contradicts the opinion of Cheshkova et al. (2020), who report a strong negative relationship with yield. Here again, the opinion of a critical assessment of the effectiveness of this parameter is needed before proceeding to the analysis of specific data.

The information about the correlation with the yield of the parameters from the group of "non-parametric stability" [*(Si(1)/a, Si(1)/c, $S^{(1)}$/b, Si(2)/a, Si(2)/b, $S^{(2)}$/c)]* (according to Nassar and Huehn, 1987) is completely contradictory. The whole set of non-parametric methods is included in two of the packages, and some of them in all three software (Table 2). It was found that the two parameters S(1) and S(2) in all three software packages provide completely identical information about their relationship with the yield (Table 8). The data are consistent with those from studies on different crops (Segherloo et al., 2008; Kaya and Turkoz, 2015; Verma et al., 2018). Therefore, they could be safely used to assess stability with full conviction. The information on the other two parameters S(3) and S(6) is diametrically opposed and contradictory (Supplementary) The positive correlation by Stabilitysoft and the negative correlation by PBSTAT have become a reason for them to be removed from the set of comparison parameters in the process of work.

The results have been highlighted by various authors in similar studies: lack of significant correlation (Mohammadi et al., 2016), high positive correlation (Kiliç, et al., 2010; Vaezi et al., 2019) and a strong negative correlation (Kaya and Turkoz, 2015; Verma et al., 2018). The differences in this study with the same data from the two experiments give the impression that the opposite data is due to a possible error in some of the two software packages in which they were analysed. It is not possible to say in which of them the information can be considered reliable.

The results for the group of "non-parametric stability parameters" [NP(1); NP(2); NP(3); NP(4)] (according to Thennarasu, 1995) are contradictory. Only one of them (NP(1)/b) and (NPi(1)/c) can be used to assess stability (Table 8). The reason the rest of the whole group (NP(2); NP(3); NP(4)] to be eliminated for comparison is the contrast between the data from the two software in which they are included. Such contradictions are found in the review of publications on the topic, which are not due to differences of this nature. In the studies of Mohammadi and Amri (2008) and Kaya and Turkoz (2015) these three parameters show a negative correlation with yield, Mohammadi et al. (2016) reported a lack of reliable correlation, and Vaezi et al. (2019) found a positive correlation of each of them with yield.

All these inconsistencies in the information on the applicability of non-parametric groups of parameters call into question their objective applicability. The probable reasons for such diametrically opposed information about them in relation to the yield are found in the specific combinations of the studied factors: varieties and conditions (combination location x year). Even if one does not have in-depth knowledge on these laws, one should be able to make an adequate assessment of the group of varieties that interest him. In this regard, the existence of different statistical programs for this purpose is a prerequisite for avoiding these contradictions.

Conclusion

In conclusion, the information in this study can be summarized in several main areas that are related to the tasks set out in it.

The set of parameters in each of the software packages used is sufficient in number to provide objective information according to the goal set in the study. At the discretion of their authors, they include popular and unique parameters, the combination of which further enriches the information about the variety when used in combination.

Similar parameters provide either analogous or diametrically opposed information about yield. The popular parameters of the regression coefficient (bi), ecovalence (W^2i) and stability variance ($σ^2_i$) are completely similar for stability assessment. All of them provide information that is completely correct to previous research, and it is independent of the software with which they are calculated.

All parameters in this study, apart from (θi/c), can be attributed to the „dynamic" concept of evaluation, which is a guarantee of high accuracy of the results, according to the goal of the study. Over 90% of the analysed parameters have different strengths with the yield, which makes them applicable to different aspects of stability - general and specific one.

In this study, opposite results were found only in the now popular non-parametric evaluation methods. Only in one part of their group [S(1), S(2) and NP(1)] the information between the datasets is one-way, which makes them effective for evaluation.

Before making final conclusions about the varieties in a specific field experiment, it is advisable to do so after a preliminary critical check of the similarity of the information about the group of parameters to be analysed. This can be done in two main ways: by comparing data from different experiments or by parallel data analysis with several different software programs. For the first: researchers do not often have a comparable dataset. The second one is easy to apply because there are specialized packages that are easy to use, completely free and available directly through the global network (PBSTAT, Stabilitysoft). Such a quick check is completely reasonable since there are discrepancies between the information between these software products between completely similar parameters.

Before proceeding with genotype assessment, it is necessary to „clarify" the basic criterion (weight) for stability assessment. It is extremely dependent on the specific characteristics of the field trail. The ability of individual parameters to assess stability unequivocally identifies as the most effective for this purpose those of them in which there is no relationship with the value of yield. In this way, the greatest compromise option possible for a complex assessment between general and specific stability is achieved. In this regard, the specific choice of parameters will approximate the assessment in one direction or another according to the specific goal.

The obtained information about the efficiency of the parameters is both basic and specific for the considered data. When choosing the software packages, it is important to choose different performance parameters. For the assessment to be as objective as possible, those that are mainly related to the dynamic concept of genotype assessment should be applied. There must also be differences between them in terms of the intention to assess stability. The basic concept of the relationship between the parameter and the magnitude of the yield should not be ignored. The most valuable are those parameters, the ranks of which do not correlate with yield and provide unique information about the genotype according to the group of varieties in which it is evaluated.

The studied three separate sets of parameters in the individual software ("GEA-R", "PBSTAT" and "Stabilitysoft") can be used to assess the variation of the variety completely independently of each other. Their application is easy and fully accessible, and the information after analysis is well illustrated with tables and figures. The final set of parameters in this study is 31. According to the final number of parameters studied, the most desirable should be the "GEA-R" package, in which 11 of the 14 are compared. The parameters in it are selected to provide the most objective information about the level of yield, adaptability, and stability of each studied genotype.

In it you can choose from several specific modules for analysis, which are tailored to the nature of specific data or goals of the field trial. The "Stabilitysoft" package proved to be the most inefficient, in which only 9 out of a total of 18 parameters were analysed. However, there were no discrepancies between the data on the parameters obtained from the two datasets. All parameters in it (18) are selected so that their values give a different rank for a variety. Therefore, if used alone, this package has enough parameters to obtain objective information for each group of studied varieties. The "PBSTAT" statistical package has a wide selection of tables and figures that provide the most comprehensive information on all aspects of adaptability and stability.

The compilation of parameters calculated from different packages is a non-standard research approach that is applied only for direct comparison between similar and different in nature statistical parameters. „Removing" parameters due to conflicting data is the only possible way to provide an objective analysis of each parameter, no matter how or where it is calculated.

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