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Evaluation of wheat varieties by the stability of grain yield in multienvironmental trails

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Abstract

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Changing grain yields as a result of growing conditions is the basis for assessing the stability of each variety. It determines the value of the genotype against the background of the other varieties in the group. The purpose of this study is to analyze and establish the effectiveness of various grain yield stability indexes in conditions where we have a strong interaction of a variety by environments.

A group of 40 winter wheat varieties have been tested with respect to grain yield at three locations of the country for two consecutive seasons. Against the background of the established genotype by environment interaction, eighteen statistical indices were determined and analyzed to determine the stability of genotypes. The correlation relationships between the ranks of all indices, including the grain yield, are analyzed. These are those which, together with grain yield, could independently characterize the value of each variety in relation to known check varieties, both in specific and in a wide range of environments.

The values of the calculated indices included in the study show significant differences between the stability of the varieties. This stability can be determined by several of the surveyed indices, such as $NP^{(3)}$, $NP^{(4)}$ and $S^{(6)}$, as well as the experimentally determined result index AR6. Several of the latest varieties such as (9) ARO Sankti, (17) ABC Veto, (31) Riana, (36) ABC Klausius, 38 ABC Zigmund and 40 ABC Navo have the rare ability to realize high and stable yields in the main wheat-growing regions of the country.

The measurement of variation in grain yield of the variety grown under different conditions is mandatory in determining its breeding value. The correlations between the ranks of the indices differ from grain yield, which indicates the need for careful analysis when interpreting them. The grain yield level after correction by its stability is the right approach for grouping varieties to target them in specific environmental conditions. The spatial location of the varieties studied through yield ranges and stability is an effective way of objectively comparing them with the standards. The grain yield stability of each variety can be assessed quickly, accurately and correctly by using modern statistical packages created for that purpose.

Keywords: wheat; grain yield; stability indexes; correlation rankings

Introduction

The analysis of the interaction of the genotype by environment (GEI) in recent years is indispensable in the effort to make an objective assessment of any variety of a given group of different crops such as barley (Kilic, et al., 2018; Vaezi et al., 2019), rice (Khumairoh et al., 2018), soybeans (El-Harty et al., 2018), cotton (Mukoyi et al., 2018), various beans crops (Georgieva & Kosev, 2018; Hossain et al., 2018; Mendes & Ramalho, 2018), peanuts (Dolinassou et al., 2016). Researchers are constantly looking for ways to simplify and effectively evaluate variance in various traits, against the backdrop of dynamically changing environmental conditions (Ceron-Rojas et al., 2016; Bornhofen et al., 2017; Doring & Reckling, 2018; Smith & Cullis, 2018). It is already very clear that in order to evaluate the appearance of the variety (grain yield), it is necessary to measure its variation, which in turn leads to a complication of its assessment in the arrangement of the group varieties involved (Yan & Frégeau -Reid , 2008).

In recent years, wheat researches has shown the strong influence of environmental factors on yield and its stability (Hristov et al., 2010; Fetahu et al., 2015; Racz et al., 2015; Tsenov & Atanasova, 2015; Gubatov et al. , 2016; Bedo et al., 2017; Ivanov et al., 2018; Mandea et al., 2019). The range of traits, properties and qualitative characters is increasingly being explored as the object of a study of stability in MET (Multi Environment Trails) (Brankovic et al., 2015; Khazratkulova et al., 2015; Grogan et al., 2016; Arshadi et al., 2018). The variation as a result of the interaction of the genotype by environment is the basis of the evaluation even for grain quality properties (Hristov et al., 2010; Kaya & Sahin, 2015; Prashant et al., 2015; Bornhofen et al., 2017), tolerance to stress (Mutwali et al., 2016; Prasad et al., 2016; Arshadi et al., 2018) and even to disease tolerance (Asmmawy et al., 2013; Akcura et al., 2017; Yan & Frégeau-Reid , 2018). Obviously, the measurement of variation in the performance of a given genotype in different environmental conditions should be taken into account in its final assessment. Classic approaches to using averages of data from different seasons or locations no longer give a correct estimate. The application of various methods of correction of the manifestation is already mandatory (Crespo-Herrera et al., 2016; Ferrante et al., 2017, Makinen et al., 2018). It applies both for assessment in specific conditions (locations) and for a wide range of environments to establish a "universal" stable type of variety. Kaya & Sahin (2015b) chose nonparametric patterns of grain in studying wheat grain quality because they believe it is a more appropriate approach to this. This group approach gives precedence over parametric because varieties of the same rank have a similar reaction to the conditions of the environments without analyzing the interaction of GEI.

Georgieva & Kosev (2018) investigated the productivity of lupine and found that only the superiority index (Pi) had a correlation with the amount of plant seeds. All other parametric stability indices have had a positive but unproven high correlation with grain yield, which makes them inapplicable on their own. The results of the durum wheat study by Mohammadi & Amri (2008) are quite similar. Abate et al. (2015) investigate parametric and non-parametric stability indices for durum wheat and establish high ASV (AMMI Stability Value) indexes with oekovalence (W^2i) and σ^2i indices, as well as nonparametric indexes $S^{(1)}$, $S^{(2)}$. Kaya & Turkoz, (2016) found that out of the sixteen nonparametric indices for grain yield correlated to SD, Kang (*K*R), and an index called Percent of adaptability (PA). All others have marked strong negative correlations with grain yields and should not be used for selection of varieties with yield and high stability. The studies of Mustatea et al. (2009) and Tsenov & Atanasova, (2015) in wheat, and Vaezi et al. (2019) in barley, found that the coefficient of regression (bi) and grain yield had the strongest positive correlation, compared to the other indexes studied. In an analogous study, Gubatov et al. (2017) analyzed correlations between grain yield and several statistical stability indices. The yield ranking is strongly correlated with the parametric (KR, ASV) and nonparametric ($S^{(2)}$, $S^{(3)}$) indices. Each of them, according to the authors, could be used to assess the size and stability of the grain yield at the same time. From the analysis of the literature, it is clear that for each specific study various stability indices are informative. It is important in these studies to establish at least one index to distinguish the varieties according to their yield and stability in different growing conditions (Mustatea et al., 2009; Tsenov et al., 2017). Otherwise, differentiation of the valuable stable and high-yield varieties could not be successfully separated from the group of those surveyed.

Each of the statistical indices shows some information on the genotype stability, so almost all authors propose to use several of them for evaluation at the same time, which is logical (Verma et al., 2017). Changing the information that each index carries in a variety of experiments makes it extremely difficult to arrange, which should in principle be based on one of them in order to be effective from a breeding point of view. In principle, the approach to the sorting of varieties is directly related to the basic concepts (Becker & Léon, 1988; Annicchiarico, 2002) on the variability of culture grown under different environmental conditions. Whether the manifestation of the variety will be assessed by the "static" or "dynamic" concept makes the interpretation of the suitability of each index used different. Their effectiveness may change as a result of the factors of field experiments: the number of varieties, the weather and soil condition and the meteorological anomalies of the seasons. A primary criterion that determines whether an index is fit for complex grouping is the presence of a correlation between its ranking with a GY. As a benchmark, Kang's most popular approach (KR), which is included in the software used, is used.

The purpose of this study was to analyze and establish the effectiveness of various indices to measure the stability of grain yield under conditions of strong variety by environment interaction.

Materials and Methods

The study included 40 winter wheat varieties developed by Agronom 1 Holding, Dobrich during the period of the company's breeding activity. The group of varieties among which and two standard varieties were tested for two seasons 2017 and 2018 at three locations of the country, as follows: Paskalevo, Dobrich, marked with (A); Trastenik, Rousse region, with designation (C) and Straldzha, Yambol district, marked with (C).

The field experiments are set out in the same way, described in detail in a previous publication (Tsenov & Gubatov, 2018).

The grain yield database is analyzed using the most commonly used parametric and nonparametric methods for assessing grain stability. The evaluation of each distinct variety was made using the statistic package "Stability soft" (Pour-Aboughadareh et al., 2019) in which eighteen individual statistical indices were calculated for this. They are the most widely used criteria for assessing the stability of varieties and are applicable specifically to MET. Some of these indices and their relationship to grain yield have already collected data from previous analyses (Tsenov & Gubatov, 2018).

After calculating these indices, they have been found to give the most objective information about the sorting of varieties in the group. The correlation relationships between the rankings by individual indices and the rank of the GY as well as the principle component analysis (PCA) of their values were calculated using the XLStat 2014 statistical add-ins program.

Results and Discussion

The grain yield of each variety tested depends to a large extent on the particular environments (Table 1). Arrangement of varieties in this case is too difficult, especially if the classic way of calculating the means of the entire experiment is applied. It has been proven many times that this is the most ineffective way of dealing, as it is difficult to draw conclusions about grouping varieties in the absence of proper checks. The main reason for this is the interaction of the traits with the environments, which changes the manifestation of each variety in a different way as a result of different combinations of the environmental factors (Table 2).

The data show a reliable individual effect of each of the factors – location, season and variety, as well as interaction between the variety and the survey locations. Unreliable is the interaction of *season*genotype*. The change in the grain yield is also the result of the interaction *location*year* (Table 2). Against this background, it is clear that the variation in grain yield of each variety is an important element of its assessment. From the direction and magnitude of the variation depends on its manifestation on the grand mean of the MET and on the means of the check varieties. This is the basis for assessing the stability (variation) of each variety tested.

The substantial grain yield grading is a prerequisite for analyzing the stability of varieties in the experiment. The Stability soft software package provides values of eighteen indexes for assessing the stability of each test item. Which of them do we consider to be applicable after being so numerous? There is an abundance of studies in various basic directions of wheat breeding (quality, yield, stress tolerance) in which different parameters are effective for correcting the order of a given trait (Akcura et al., 2017; Bornhofen et al., 2017; Arshadi et al., 2018). If there is one whose values to correspond (correlate) to the grain yield would be very convenient for objective analysis. It is no accident that the ranks of two of the proposed statistical indices are derived from the others. These are the parameter SR = sum of the ranks of all calculated indices and AR = means of the ranks of all indices. Mathematically, in principle, they should be interchangeable, as they are the result of the same series of digits.

According to the Vaezi et al. (2019) research, the indices of ranging carry different information on the stability of the varieties studied. In order to determine which of these two indexes (their rank) is considered to be valid in order, the correlations between all ranges, including grain yield (Table 3) have been calculated.

The relationship between the ranks of SR and AR with the other ranks of the indices is high and reliable, without exception. The relationship between them is almost absolute (r = 0.96 ***). which means no matter which one will be used. At the same time, their correlation with grain yield is average but reliable (r = 0.58 *). This is a very "handy" result in terms of stability. Given that the relationship between yield and any index is strong (r > 0.65). it is believed that it evaluates correctly the variance, which should in principle show a negative correlation with the level of the trait. If the correlation is low (r < 0.25). there is a danger of a stronger assessment of the stability than the level of the character, which is the target. In this study. it is clear that the AR values are an effective instrument for correcting the rank of each variety in the group because the degree of bonding between grain yield is r = 0.58*.

The results of the analysis of the stability index values are not surprising in terms of their different informativeness (Table 4). The measurement of grain yield through its stability is possible in several of the indices. The strongest relationship between the ranks of GY have the $NP^{(3)}$ (r = 0.78. R2 = 0.62). $NP^{(4)}$ (r = 0.77. R2 = 0.59) and $S^{(6)}$ (r = 0.73. R2 = 0.54). Only the coefficient of determination is high enough to accept the relationship with the yield as proven. All other indices, although highly correlated, as ($S^{(3)}$ and *K*R). should not be used The correlation between GY and the resulting AR index is also from this last group.

After a careful analysis of the results it was logical to re-calculate the value of the AR index according to the credibility of the index correlations. Six of the indices that showed the strongest correlation with GY (Table 5) became the basis for calculating the adjusted average rank, denoted as (AR6*).

The correlation between this index and the yield was not only high but also the highest in comparison to each of the 6 indices, separately. The level of correlation determinations

Table 1. Grain yield (t ha^{-1}) of each variety at the three test locations

№	Variety	*A17	A18**	B17	B18	C17	C18
1	LG Anapurna	7.52	9.18	9.37	8.79	5.57	5.92
2	A 38/64	8.62	8.83	8.42	7.90	6.50	4.56
3	A 48/617	7.29	8.82	9.20	9.01	5.94	5.88
4	A 18/74	8.29	9.37	9.17	7.78	7.25	5.26
5	R1-4-5	7.84	8.82	8.89	9.57	5.70	5.38
6	ACR 48/615	7.54	8.82	9.32	8.50	6.15	5.18
7	06/198-21	7.54	8.82	9.32	8.50	6.15	5.18
8	A 27/320	7.92	9.10	7.42	8.46	5.07	5.85
9	ABC 27/512	8.28	9.95	9.08	9.71	6.53	6.56
10	ABC 28/313	7.97	8.94	8.65	8.38	6.28	5.48
11	Pryaspa***	7.46	8.63	9.16	7.99	6.05	6.37
12	A 37/215	8.07	9.01	7.91	8.25	6.66	5.78
13	06N137-22	8.73	10.11	9.48	8.57	7.89	6.44
14	01/54-84	7.85	9.68	7.77	8.51	5.95	6.83
15	04/255-92-2-1	8.28	9.01	8.85	8.58	6.14	6.52
16	ABC 48/716	8.98	10.80	8.89	9.42	7.35	7.82
17	A 47/415	7.95	9.36	9.27	9.38	6.51	6.77
18	ABC 37/716	7.92	8.43	9.12	7.93	6.18	7.05
19	05N48-22-1	8.00	9.29	8.72	8.70	6.34	6.78
20	05N48-22-8	8.31	9.64	9.08	8.32	6.02	6.71
21	LG Avenue***	7.76	9.73	10.43	9.55	5.92	5.41
22	Aneta	8.36	8.18	10.30	9.26	5.41	5.68
23	Apogej	7.60	8.49	8.69	8.58	5.47	4.16
24	Presyana	7.87	10.16	9.47	9.08	5.87	5.06
25	Ognyana	8.14	9.61	9.30	8.53	6.55	4.97
26	Alisa	8.17	10.64	9.00	8.99	5.72	5.45
27	Bilyana	8.06	10.02	8.57	8.67	5.68	5.72
28	Vyara	7.99	10.30	7.51	8.16	5.57	5.89
29	Neven	8.24	8.24	9.05	8.94	5.49	6.28
30	Ralitsa	8.53	9.33	9.33	9.67	5.83	6.43
31	Riana	8.41	10.12	8.80	8.63	5.65	6.12
32	Tervel	8.43	9.36	9.07	8.22	6.02	5.64
33	Faktor	8.77	9.56	8.82	8.19	6.24	6.92
34	ABC Alfio	8.06	9.74	8.25	8.53	5.37	6.89
35	ABC Lombardia	8.34	10.61	8.01	8.37	6.19	7.12
36	ABC Klauzius	7.79	9.70	7.69	9.68	5.58	7.27
37	ABC Speri	8.02	9.94	9.27	8.14	5.76	7.11
38	ABC Zigmund	8.12	9.37	8.46	9.56	6.31	7.42
39	ABC Kolino	8.05	9.19	8.39	7.65	5.50	6.80
40	ABC Navo	8.20	10.54	9.10	8.66	6.06	6.72

* A – Dobrich, B – Rousse and S-Yambol; ** – 17-season 2017 and 18 – season 2018, *** – standard variety

($R^2 = 0.78$) is significantly higher than the highest value of the $NP^{(3)}$ index ($R^2 = 0.62$). Therefore, the rank of this model could be considered as determining the stability of the variety and used to rank the varieties with a view to any comparison between them. These regularities allow for an index to be used with a high degree of certainty, not to be interpreted according to the values of several of them. The use of a corrected index in this case (AR6 *) significantly facilitates the comparison of varieties in the group. It stems mainly from two moments: *i*) the stability of each variety is expressed by the value of an index, and *ii*) the value of this index is mainly due to nonparametric indexing (5 out of the 6).

Table 2.Analysis of variances for grain yield

Source	df	MS	F	p-value
Main effect of the factors				
A:location	2	360.53	1488.03	0.0000
B:season	39	2.06815	8.54	0.0000
C:genotype	78	1.34285	5.54	0.0047
Interaction between the factors				
A*B	2	1.15687	4.77	0.0000
A*C	78	1.69799	7.01	0.0000
B*C	39	0.248266	1.02	0.4420

Table 3. Pearson correlations between the grain yield index ranks, the rank of the SR (SR) and the adjusted mean rank (AR)

Index	AR	p-value	R^2	SR	p-value	R^2
GY	0.58	0.0001	0.34	0.55	0.0002	0.30
$S^{(1)}$	0.77	< 0.0001	0.60	0.80	< 0.0001	0.64
$S^{(2)}$	0.81	< 0.0001	0.66	0.83	< 0.0001	0.69
$S^{(3)}$	0.93	< 0.0001	0.87	0.94	< 0.0001	0.89
$S^{(6)}$	0.92	< 0.0001	0.85	0.93	< 0.0001	0.86
$NP^{(1)}$	0.77	< 0.0001	0.60	0.78	< 0.0001	0.62
$NP^{(2)}$	0.79	< 0.0001	0.62	0.79	< 0.0001	0.63
$NP^{(3)}$	0.90	< 0.0001	0.81	0.89	< 0.0001	0.80
$NP^{(4)}$	0.92	< 0.0001	0.85	0.91	< 0.0001	0.83
W_i^2	0.79	< 0.0001	0.63	0.79	< 0.0001	0.62
σ^2_i	0.79	< 0.0001	0.63	0.78	< 0.0001	0.62
s^2d_i	0.76	< 0.0001	0.57	0.75	< 0.0001	0.56
CVi	0.48	0.0015	0.23	0.48	0.0014	0.23
KR	0.86	< 0.0001	0.74	0.84	< 0.0001	0.70
$\theta_{(i)}$	0.79	< 0.0001	0.63	0.77	< 0.0001	0.59
θ_i	-0.79	< 0.0001	0.62	-0.72	< 0.0001	0.52
SR	0.96	< 0.0001	0.92			
AR				0.96	< 0.0001	0.92

In order to maximally verify such an approach a parallel check of the results of Table 4 was performed using the PCA (Figure 1). This approach has recently been used to spatially present correlations between different traits or parameters (Vaezi et al., 2017). It is clear that the index (AR6) and the others have a strong correlation with the yield level, as evidenced by the localization of their vectors with that of GY. The lower the values of the angle between the grain yield vector and the other indices, the more correlation between them is higher and more reliable. The vector location fully confirms the correlation data in Table 4 including their grouping by magnitude.

According to some authors (Kaya & Sahin, 2015b; Vaezi et al., 2019) this group of approaches gives priority over parametric, because varieties with a similar reaction to the environment conditions get a similar rank without considering or analyzing the interaction of the genotype by environment. On the other hand, these indices take into account the stability according to the “static” concept (Becker & Léo, 1988). This is the reason to interpret the “stability” of the variety rather than “plasticity” (Annicchiarico, 2002). From the point of view of assessing the variety against the background of random environmental factors, it is considerably more convenient to look for genotypes that exhibit the least possible variation, i. e. the “static” type of assessment.

Table 4. Pearson correlations between grain yield (GY) and the ranks of the indices studied

№	Index	GY	p-value	R^2
1	$S^{(1)}$	0.17	0.2806	0.03
2	$S^{(2)}$	0.23	0.1585	0.05
*3	$S^{(3)}$	0.60	< 0.0001	0.36
*4	$S^{(6)}$	0.73	< 0.0001	0.54
5	$NP^{(1)}$	0.13	0.4204	0.02
*6	$NP^{(2)}$	0.75	< 0.0001	0.56
*7	$NP^{(3)}$	0.78	< 0.0001	0.61
*8	$NP^{(4)}$	0.77	< 0.0001	0.59
9	W_i^2	0.10	0.5577	0.01
10	σ^2_i	0.10	0.5577	0.01
11	s^2d_i	0.17	0.3033	0.03
12	CVi	0.33	0.0347	0.11
*13	KR	0.64	< 0.0001	0.40
14	$\theta_{(i)}$	0.10	0.5577	0.01
15	θ_i	-0.10	0.5347	0.01
16	AR	0.58	< 0.0001	0.34
	AR6 **	0.88	< 0.0001	0.78

* – the indices involved in calculating the resulting average rank
** – Average rank derived from the values of the six indices

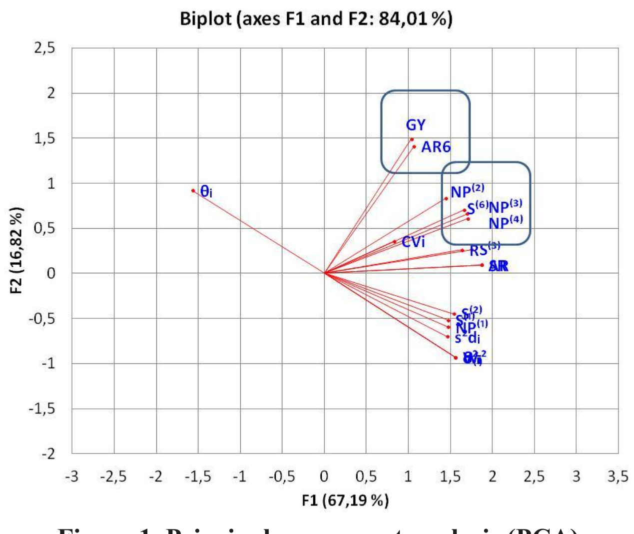

Figure 1. Principal component analysis (PCA) of the indices related to grain yield and grain stability

Table 5. Ranking of varieties by GY and selected stability indices according to their relationship to the AR6

Genotype	GY	$S^{(3)}$	$S^{(6)}$	$NP^{(2)}$	$NP^{(3)}$	$NP^{(4)}$	KR	AR	AR6
LG Anapurna	27	28	27	25	22	30	18	21	33
A 38/64	38	40	40	39	36	40	40	40	36
A 48/617	30	26	25	26	27	29	21	23	23
A 18/74	20	33	24	17	25	28	33	35	17
R1-4-5	29	30	29	34	29	26	30	29	30
ACR 48/615	35	34	34	36	31	34	28	32	39
06/198-21	35	34	34	36	31	34	1	28	28
A 27/320	39	15	30	38	39	25	35	25	38
ABC 27/512	3	2	2	6	1	3	2	1	2
ABC 28/313	31	9	11	30	16	10	17	8	35
Pryaspa***	33	32	37	31	38	33	24	27	32
A 37/215	32	24	21	28	23	24	27	19	34
06N137-22	2	6	6	11	6	4	13	11	3
01/54-84	26	18	18	19	21	20	28	17	25
04/255-92-2-1	18	3	5	1	7	5	7	2	18
ABC 48/716	1	4	3	7	3	2	9	7	1
A 47/415	6	7	7	3	8	7	3	6	6
ABC 37/716	25	36	32	27	30	31	35	33	31
05N48-22-1	14	8	8	4	4	8	6	4	13
05N48-22-8	12	5	4	2	2	6	5	3	11
LG Avenue***	8	27	23	24	24	21	23	34	15
Aneta	19	39	38	29	35	38	37	39	24
Apogej	40	23	39	40	40	39	39	36	40
Presyana	17	29	28	23	20	22	24	30	20
Ognyana	21	20	14	8	14	17	24	20	26
Alisa	13	16	15	10	17	16	19	16	12
Bilyana	24	11	16	13	9	13	13	13	19
Vyara	37	37	31	35	33	36	38	37	37
Neven	28	22	26	20	28	23	30	26	29
Ralitsa	7	10	12	5	10	9	7	9	4
Riana	15	14	13	15	11	12	9	12	14
Tervel	23	12	9	9	15	14	12	10	27
Faktor	10	17	17	12	12	15	9	14	10
ABC Alfio	22	25	22	18	26	27	19	22	21
ABC Lombardia	9	21	19	16	18	18	22	24	9
ABC Klauzius	16	38	36	32	34	32	32	38	16
ABC Speri	11	19	20	14	19	19	13	18	8
ABC Zigmund	5	13	10	22	13	11	16	15	5
ABC Kolino	34	31	32	32	37	37	33	31	22
ABC Navo	4	1	1	21	5	1	4	5	7

The sampling of six indices from the others and their presentation gives a much clearer picture in terms of the ranging of varieties in the group (Table 5). If we compare the resultant indexes (AR) and (AR6), which we may need to sort the varieties of grain yield and stability, we will see a large discrepancy. The correlation between the two indices is (r = 0.58. R2 = 0.34) and is similar to the strength of the relationship between GY and AR. which is practically unproven.

Table 6. Pearson correlations between the ranks of the indexes (AR) and (AR6) in the different survey locations

Index	Location	AR	p-value	R^2
AR6	A	0.91	< 0.0001	0.83
	B	0.99	< 0.0001	0.99
	C	0.96	< 0.0001	0.92

Information on the behaviour of varieties in a region is interesting for the correct zoning of each variety. This is particularly true for new varieties, whose appearance must be compared to those already living. The efforts of the breeding are constantly aimed at creating both stable and at the same time high-yielding varieties. Location-level variation is significantly lower than that of the entire experience, making the use of the adjusted index (AR6) unnecessary, as evidenced by the data in Table 6. The correlations between the both are extremely high for the location A (r = 0.91. R^2 = 0.83). for location B (r = 0.99. R^2 = 0.99) and for location C (r = 0.96. R^2 = 0.92). Accordingly, the ranking of the varieties of stability at individual points is done with the program-calculated index (AR) (Table 7).

Table 7. Ranking of varieties of according to the yield (GYR) at each location and the average rank (AR) for the whole experiment (* – standard variety)

No	Variety	A		B		C		ABC
		GYR	AR	GYR	AR	GYR	AR	AR6
1	LG Anapurna	31	30	10	12	28	17	33
2	A 38/64	23	37	35	21	37	39	36
3	A 48/617	38	28	9	1	22	5	23
4	A 18/74	18	12	32	39	16	37	17
5	R1-4-5	32	16	7	28	36	21	30
6	ACR 48/615	35	15	16	27	32	34	39
7	06/198-21	35	14	16	22	32	30	28
8	A 27/320	29	11	39	36	39	33	38
9	ABC 27/512	9	9	4	19	9	7	2
10	ABC 28/313	30	18	30	7	25	27	35
11	Pryaspa*	*39*	***22***	*28*	37	*18*	***1***	32
12	A 37/215	28	21	37	23	17	26	34
13	06N137-22	3	3	11	29	2	25	3
14	01/54-84	19	29	36	34	13	22	25
15	04/255-92-2-1	25	31	19	2	15	2	18
16	ABC 48/716	1	7	8	20	1	4	1
17	A 47/415	24	10	5	3	5	3	6
18	ABC 37/716	37	36	29	38	6	16	31
19	05N48-22-1	26	2	21	13	8	6	13
20	05N48-22-8	13	6	23	25	14	14	11
21	LG Avenue*	20	38	1	14	31	24	15
22	Aneta	33	40	2	15	35	23	24
23	Apogej	40	24	26	11	40	31	40
24	Presyana	11	35	6	6	38	32	20
25	Ognyana	17	1	15	16	27	40	26
26	Alisa	4	32	14	9	34	12	12
27	Bilyana	10	23	27	17	30	8	19
28	Vyara	8	34	40	30	29	13	37
29	Neven	34	39	13	4	24	28	29
30	Ralitsa	14	26	3	8	21	11	4
31	Riana	6	4	20	10	23	18	14
32	Tervel	16	17	25	31	26	15	27
33	Faktor	7	19	31	18	7	9	10
34	ABC Alfio	15	13	33	24	20	38	21
35	ABC Lombardia	2	20	34	26	4	20	9
36	ABC Klauzius	22	33	24	40	11	36	16
37	ABC Speri	12	27	22	33	10	29	8
38	ABC Zigmund	21	5	12	35	3	19	5
39	ABC Kolino	27	8	38	32	19	35	22
40	ABC Navo	5	25	18	5	12	10	7

In this way the rank of each variety can be determined in the specific conditions of the locations. Naturally, this arrangement is made to establish variety (yield and stability) in comparison with the rest of the variety and the standard varieties too. If we accept the range of < 20 for a criterion in determining the most suitable varieties for the regions we will get the following picture, presented in Figure 2. The ABC Veto (17) variety, which has a very high ranking at the three test sites, stands out against the background of the other varieties. High grain yields were shown of varieties 16. 9. 19. 31 and 33 in all the three places. From this group, only one 33 (Faktor) is from the regionally varied varieties. A group of seven varieties have a high rank in two of the three locations. These are the varieties with numbers 15. 26. 27. 30. 35. 38 and 40. The third group includes varieties showing a high rank at one of the three locations 36 and 37.

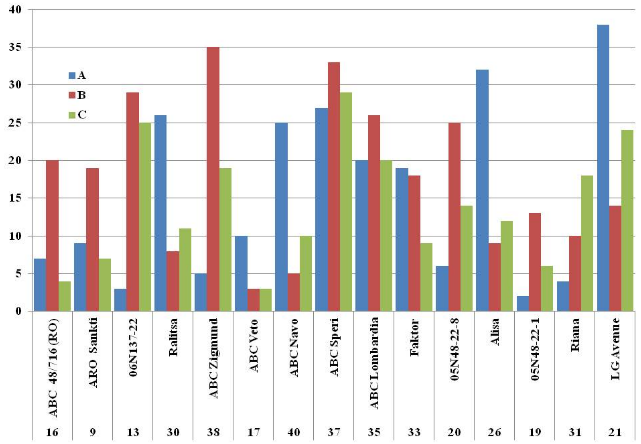

Figure 2. Arrangement of the varieties by their mean grain yield and by the AR6 index values at the test locations (ABC)

After all these results it is logical to reach the culmination point of the study, consisting of an arrangement of varieties of yield and yield stability (Figure 3). The scatter plot of the xlstat 2014 statistical packet is used, which means "scattered stack". The term fully corresponds to the purpose with which it is applied. Grain yields (GY) and average grade of stability (AR6) were used for the grading. In the quadrant in red, the varieties are ranked, having the two above-average values for the whole group (20). In the top right square are positioned varieties, with a low and highly variable grain yield, which is to avoid zoning.

The varieties found in the red quadrant could also be grouped according to the crossing of the two ranks. The most valuable are the varieties No 9. 13 and 16. followed by 38 and 40, where the grain yield is kept high, but its stability is reduced. If we compromise on stability, the next value varieties are 17. 30. 33 and 35, the standard LG Avenue is right in this last group. In contrast to its position in terms of stability, but with somewhat lower relative yields (> 95%) it is the varieties with No 19. 20. 26 and 37. Therefore all new varieties with numbers 33. 35. 36. 37. 38 and 40 fall into the group of the most valuable and thus spatial representation.

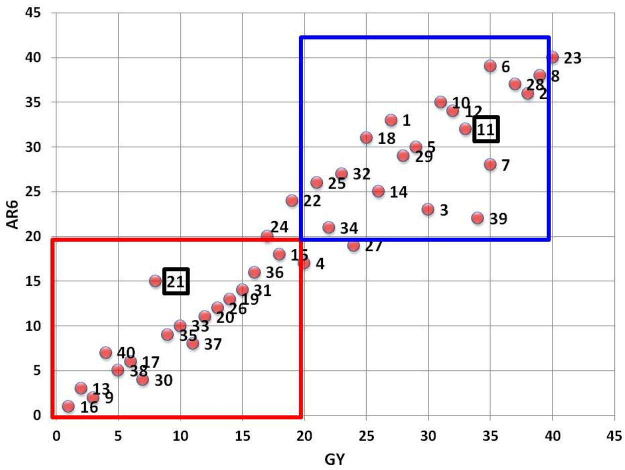

Figure 3. Spatial grouping of the varieties tested according to their grain yield (GY) and the adjusted average rank of stability (AR6)

The two standard varieties are situated in the different quadrants. Pryaspa variety is of low grade and yield and stability of yield compared to LG Avenue. The location of the latter shows high yields and stability above the average for the group, making it a high standard of comparison. If that is the case, if we assume a rank of up to 20 in terms of GY and STAB, we obtain a group of fifteen varieties (40% of all) that are similar to the French variety-standard, rank. Seven of them exceeded both criteria, representing 18% of all varieties studied.

In the other group of varieties twenty three in number (60%) with low ranks are mainly high grain qualitative varieties with № 10. 23. 25. 32. 34 and 39, which against the background of the high standard for GY is completely logical. Many other varieties like No 22. 27. 28. 29 are already cultivated varieties to be replaced in practice. This is recommended against the background of the excellent results that new varieties and candidate varieties show.

Because of doubts about the complete objectivity of such spatial representation, the data were further analyzed with the GGE biplot program, 6.3, which is currently the most widely used in the world for this purpose (Neisse et al., 2018; Quintero et al., 2018; Verma et al., 2019).

Figure 4 shows the spatial points of all the varieties studied at all points and seasons of the field experiment. The red circle, located on the red (somewhat parallel to the abscissa) line, is the place of the "ideal" variety in terms of yield and stability. The nearest varieties are the same No – 9, 13, 16, 38 and 40. At the opposite end are the points of the same varieties 8, 23 and 28, with low and variable yields, totally similar to their position in the previous Figure 3. Therefore, the spatial representation of the ranks in the way presented in that Figure 4 reflects objectively the relationship between the varieties of yield and the stability of the background of the group.

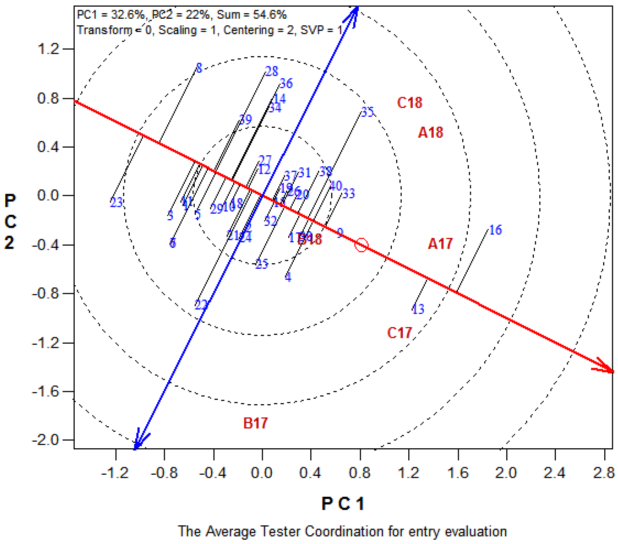

Figure 4. Spatial points of all the varieties and seasons of the field experiment

Conclusions

The measurement of the variation in yield grain of varieties grown in different conditions is an action that is binding on its objective evaluation, compared to the other group

The values of the calculated indices included in the study show significant differences between the stability of the varieties of the test group

The stability assessment of the individual varieties is most objective using the adjusted average index (AR6)

The level of grain yield after correction of stability is the right approach for grouping varieties in their zoning in specific environmental conditions.

The arrangement of the tested varieties through spatial representation of the ranks of mining and its stability is an effective way for a comprehensive assessment of every genotype.

The grain yield stability of each variety can be assessed quickly, accurately and correctly using modern statistical packages created for that purpose.

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