Analysis and Assessment of Yield Ranking Models in Triticale (x*Triticosecale* Wittm.) in Contrasting Environmental Conditions

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The analysis and evaluation of yield is an important stage of the breeding process in cereals. There are various methods for grouping and ranking of the tested genotypes by their yield, which allows for a correct interpretation of the interaction of the environment with the genotype. Triticale as a product of wide hybridization is characterized by certain features, which requires the applicable models for yield evaluation in other cereals to be analyzed in this crop. For this purpose five yield ranking models were assessed in 16 triticale varieties for a three-year period. The three monitored periods were characterized by contrasting agro-climatic conditions of the environment. With the highest efficiency was the model using average standard value formed by values of check varieties in the experiment. With a good performance for yield evaluation are also models in which the yield is adjusted by the variation caused by different environmental conditions – heritability adjusted (HA) model and Hi-model. In spite of this fact, HA-grouping is very similar to the grouping of the varieties by their absolute yield. This is related to the absence of many locations of the study, regardless of the contrasting agro-climatic conditions. On the other hand, the Hi-model enables interpretation of yield and grouping of yield reaction in different varieties without multilocation trials. Despite some of their disadvantages, each of the used models could be applied to the analysis of the yield in periods of different conditions, depending on the specific purpose of the breeding program.

Keywords: Contrasting conditions, environment, triticale, yield model

Introduction

The development of new crop plant cultivars is a complex task rather than a one-sided process and involves finding solutions for multiple problems. One of the most significant factors seriously limiting the yield from the cereals is the influence of the environment. In this respect, contemporary breeding is trying to develop genotypes that can be simultaneously very stable under contrasting environments and highly productive. There are various investigations, which point out that the ecological plasticity of a given genotype is in negative correlation with its potential for yield (Lozano del Rio et al., 2009; Becker and Leon, 1988). On the other hand, Tsenov et al. (2013) have reported a good combination of high stability and high productivity.

As a product of wide hybridization, triticale possesses stability, which is closely related to the investigated genotype (Baychev, 2013; Stoyanov and Baychev, 2016b). Different studies on the crop (Stoyanov and Baychev, 2016b; Dhindsa et al., 2002) have reported that the interaction of the factors environment x genotype determines about 10-15 % of the total variation. In comparison to other cereals (Tsenov et al., 2014), such reaction is very high. Therefore the investigated cultivars and breeding materials have to be ranked by their yield and its stability.

There are different methods for ranking of the investigated genotypes (Tsenov et al., 2014). Some of them are based on the conventional statistical procedures and models - PCA, ANOVA, Duncan test, etc. (Gabriel, 1971; Zobel et al., 1988). Other approaches are related to the use of models developed especially for the evaluation of the effect of the environment on the genotype - AMMI, GGE, HARV, Hi (Yan and Kang, 2003; Karimzadeh, 2012; Farshadfar and Farhadi, 2002). Last but not least are the methods for analysis of the genotype's stability and plasticity (Becker and Leon, 1988).

The use of all these models allows grouping (ranking) of a given set of investigated genotypes according to the phenotypic reaction of the yield. The efficiency of each of the applied approaches is directly related to both the involved genotypes and the conditions of the environment (Tsenov et al., 2014). Therefore careful analysis and evaluation of each approach is necessary when applying it to a certain crop. The specific peculiarities of triticale with regard to the stability of its yield have been subject of a limited number of investigations (Stoyanov and Baychev, 2016b; Alljarah et al., 2014; Dhindsa et al., 2002; Goyal et al., 2011; Goyali and Dhindsa, 2003; Motzo et al., 2001). This is the reason why ranking models of the cultivars should be applied very carefully, analyzing in detail the respective models to be applied (Stoyanov and Baychev, 2016b). Such a necessity arises from the fact that sharp deviations from the normal meteorological conditions cause distortion of the results from certain statistical approaches (Tsenov et al., 2013). Since triticale is considered a crop with enhanced tolerance to abiotic stress (Baychev, 2013), the ranking of the specific genotypes according to their yield and stability can be of high practical value.

The aim of this investigation was to analyze the yield of Bulgarian triticale cultivars through various approaches for ranking and to assess their applicability under contrasting environments.

Materials and Methods

In order to realize the above aim, 11 Bulgarian cultivars (Kolorit, Atila, Akord, Respekt, Bumerang, Irnik, Dobrudzhanets, Lovchanets, Doni 52, Blagovest, Borislav) were used.

The investigated 11 cultivars were grown as a whole-surface crop in trial plots of 10 m^2, in four replications according to a standard block design within a competitive varietal trial. The trial was carried out in 3 successive cropping seasons: 2013/2014, 2014/2015, and 2015/2016. Planting was done using mechanical equipment within the standard dates (10th – 15th October) at density 550 seeds per m^2. Besides the above cultivars, the standard triticale varieties AD-7291, Vihren and Rakita, as well as the world standards Lasko and Presto were involved in the investigation.

The yield data (Y) were summarized by calculating the mean values according to cultivar and year. Each genotype was ranked on the basis of five different models:

1. RY-model. It is based on the ranking of cultivars by their relative yield according to the accepted mean standard between check varieties Vihren and Rakita.

2. RV-model. This model is based on the ranking of the cultivars by their relative value between the absolute yield from each cultivar and the mean yield from all cultivars (Yan and Holland, 2010).

3. RE-model. The cultivars are ranked on the basis of their score by the relative value of the yield as follows: below 90% (1); 90-94% (2); 95-100% (4); 101-105% (6); 106-110% (8); 111— 115% (10), and above 116% (12), according to Tsenov et al. (2014).

4. HA-model. The cultivars are ranked on the basis of the corrected relative value of yield according to the conditions of the environment. The HARV parameter is calculated according to Yan and Holland (2010).

5. Hi-model. The model is based on the Hi parameter according to Martynov (1990) and gives idea about the stability of the absolute yield according to the direct effect of the growing year.

Each model was assessed on the basis of the correlation between its values and the values of the absolute yield. To analyze the efficiency of the models, cluster and regression analyses and Duncan test were carried out. For data processing, the software Microsoft Excel 2003 was used, and for correlation analysis, cluster analysis, regression analysis and Duncan test – IBM SPSS Statistics 19.

Results and Discussion

The investigated periods differed significantly with regard to the weather (Table 1). This was valid both for the average monthly temperatures and the rainfalls. The data from the three investigated periods allowed evaluating the cultivars by their stability due to the rather contrasting conditions of the environment. The great variations during the growing period strongly changed the values of the yield components because the weather had direct effect on them. Especially high was this effect on the weight parameters because proper development of the plants was necessary for the formation of high values (Baychev, 2013).

The results from the ANOVA (Table 2) unequivocally emphasized the serious influence of the interaction of the environment with the genotype on the variation as a result from the contrasting conditions. The environment x genotype interaction accounted for 14 % of the total variation. Such high values are related to a wide genetic basis of adaptability of the yield components, which implies different mechanisms with regard to the values of productive tillering, number of grains in spike and absolute weight of grain (Tsenov et al., 2013).

In fact, the investigated cultivars formed their productivity in different ways. Previous investigations indicate that such cultivars as Atila and Borislav form their yields mainly from the productive tillering and the thousand kernel weight (Stoyanov and Baychev, 2016a). The other cultivars formed their yield mainly from the number of grains per spike and the productive tillering (Stoyanov and Baychev, 2016a).

Table 1. Meteorological data during the period of investigation

Parameter/Months		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
AMT, °C	2013/2014	10.9	9.0	1.1	2.4	4.0	7.7	10.7	15.2	18.8	21.7
	2014/2015	11.2	5.6	3.1	1.4	2.0	5.0	10.1	16.4	19.4	22.4
	2015/2016	10.9	9.3	3.4	-0.8	7.3	6.8	13.2	14.7	20.9	22.8
TMP, mm	2013/2014	156.3	18.6	9.2	94.8	6.9	37.7	29.6	78.2	192.5	50.9
	2014/2015	57.9	33.2	87.0	33.2	79.5	67.7	8.5	12.9	31.3	27.2
	2015/2016	78.3	55.1	0.4	86.3	40.7	52.7	20.8	117.1	55.7	2.8

AMT – average monthly temperatures; TMP – total monthly precipitation

Table 2. Two way ANOVA of the yield from the investigated triticale cultivars

Parameter	SS	df	MS	F	Sig.	F%
Total	3883247,250	191	20331,137	-	-	-
Genotypes (G)	432112,917	15	28807,528	6,197	0,000	11,13
Environments (E)	2191414,781	2	1095707,391	235,694	0,000	56,43
G x E	543684,552	30	18122,818	3,898	0,000	14,00
Blocks	60545,750	3	20181,917	4,341	0,006	1,56
Err	655489,250	141	4648,860	-	-	-

Such type of genetic basis allows clearly differentiating the separate genotypes according to their adaptability to specific contrasting environments, and ranking them by their productivity. Depending on their origin, the set of genotypes involved in a certain trial, demonstrated different reactions, as indicated by the greater part of the investigations on triticale (Alljarah et al., 2014; Dhindsa et al., 2002; Goyal et al., 2011; Goyali and Dhindsa, 2003) and common winter wheat (Banjack et al., 2014; Tsenov et al., 2013). The 8 groups formed according to the Duncan test additionally confirmed the differences in the response of the genotypes.

Table 3. Yield values and numerical parameters of the applied ranking models

Cultivar	Y, kg/dca	RY, %	RV, %	RE	HARV	H_i
AD-7291	572^{bcd}	103,4	102,5	6	98,2	0,16
Vihren	548^{abc}	98,9	97,9	4	93,8	-0,75
Rakita	570^{bcd}	101,1	99,3	4	95,2	-0,37
Lasko	548^{abc}	96,2	94,0	2	90,2	-1,38
Presto	537^{ab}	94,0	91,7	2	87,9	-1,94
Kolorit	580^{bcd}	103,6	102,1	6	97,9	0,40
Atila	609^{cde}	107,7	106,0	8	101,8	0,74
Akord	611^{cde}	108,6	106,7	8	102,3	1,61
Respekt	490^{a}	86,3	84,0	1	80,4	-3,20
Bumerang	550^{abc}	96,5	94,1	4	90,2	-1,10
Irnik	602^{bcde}	106,3	104,2	6	99,9	1,11
Dobrudzhanets	538^{ab}	96,3	94,7	4	90,7	-1,16
Lovchanets	494^{a}	88,0	86,3	1	82,6	-2,91
Doni 52	661^{e}	117,8	116,0	12	111,2	3,88
Blagovest	616^{de}	110,0	108,2	8	103,7	2,18
Borislav	646^{e}	114,2	112,1	10	107,6	2,73

Table 3 shows the data by cultivars obtained as a result from the application of the above ranking models. In all calculated parameters, a clear tendency was outlined toward forming of groups which included genotypes with identical productivity. In spite of the different methodologies used in each model, the results clearly emphasized their similar ranking under the specific growing conditions. The present high effect of the environment x genotype interaction implies variable stability and ecological plasticity. From this point of view, the conditions of the environment allowed following the genotypes with highest interaction with the sharp changes during the growth period with regard to total productivity. This information is being visualized through the parameters HARV and Hi. Their values corrected the absolute yield according to the expression of the cultivars during the investigated period and provided practical data on the behavior of the complex index yield-stability. On the other hand, the presence of an identical tendency of HARV and Hi with the rest of the models underlined the fact that a negative correlation between the productive potential and the genotype's stability was not observed. This fact is also confirmed by previous investigations on the same cultivars (Stoyanov and Baychev, 2016b), in which it was found on the basis of different methods that the most productive cultivars (Akord, Doni 52, Blagovest and Borislav) possessed highest stability. The different ways for formation of productivity of the individual genotypes, however, were difficult to differentiate. This is so because the stability of the separate yield components does not follow the stability of the yield itself (Tsenov et al., 2014).

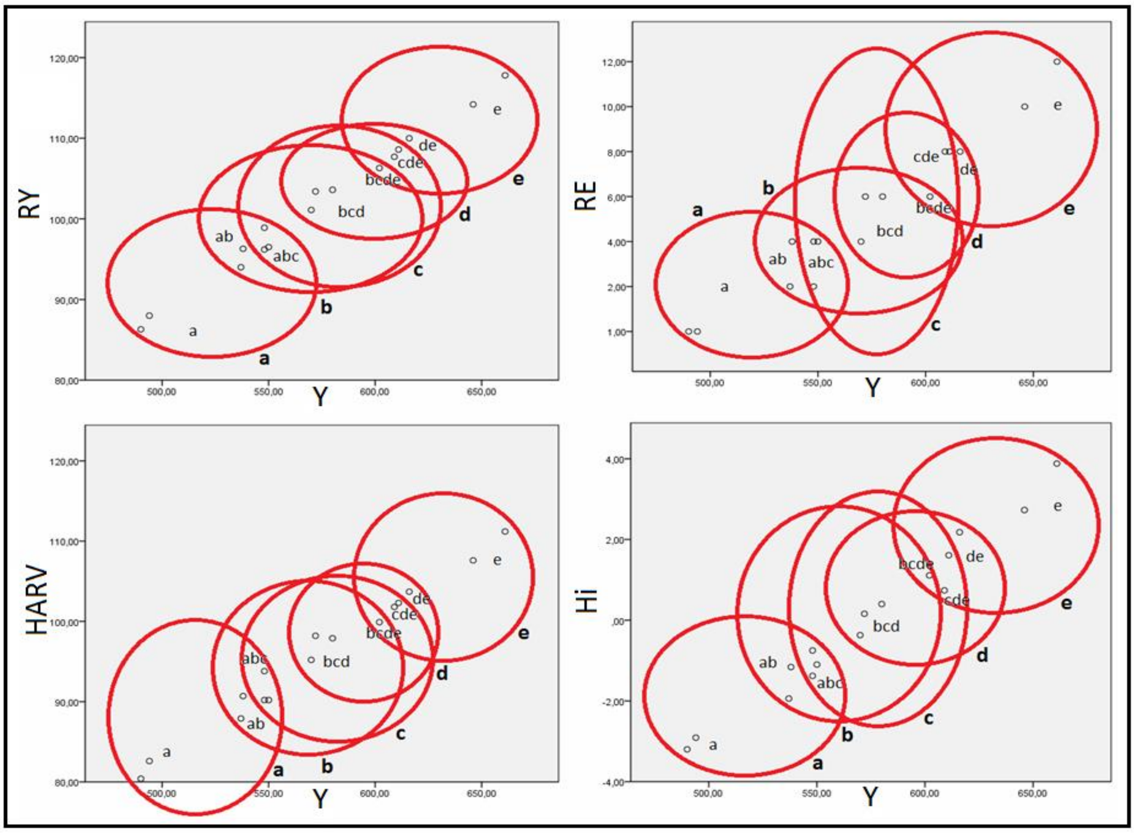

Figure 1. Regression between yield and the applied ranking models

The high correlation observed between the yield and the values of the respective models (Table 4) emphasized the applicability of each of them. The RY-model was with the highest correlation coefficient, and the RE-model – with the lowest. The parameters RV, HARV and Hi had similar values. The parameter HARV was with the highest coefficient of determination, which emphasized its practical applicability because apart from yield, it was also taking into account the effect of the environment. Tsenov et al., (2014) have pointed out that in experiments with multiple locations, the applicability of Hi significantly decreased. Since this parameter is aimed at trials carried out in a single location (Martynov, 1990), its high correlation and applicability for ranking of the investigated genotypes is in accordance with such investigations.

Table 4. Correlation of yield with the numerical parameters of the applied ranking models

Parameter	Y, kg/dca		
	r	sig	R^2
RY, %	0,994	0,000	0,989
RV, %	0,989	0,000	0,977
RE	0,964	0,000	0,929
HARV	0,989	0,000	0,978
H_i	0,986	0,000	0,973

A confirmation for the high applicability of all models is the graphic presentation of the linear regression of each of them with the yield. Such type of correlation is related to the efficiency of the used ranking models in the investigated set of genotypes. Figure 1 allows clearly following the regression lines and the slight deviations from the main tendency. Nevertheless, it was observed when using the RE-model that the ranking was less precise. It can be claimed that the coefficient of determination also confirm that, this model was less efficient than the rest. In these models the groups can be easily distinguished as a result from the Dunkan test, while in the RE-model certain values can not be clearly differentiated due to the discrete nature of the index. Concerning the two models related to the effect of the environmental conditions, the HA-model gave better ranking than the Hi-model. Nevertheless, the absence of multiple locations in the HA-model is related to higher identity of the environmental conditions regardless of the presence of contrasting environments (Yan and Holland, 2010). On the other hand the high correlation with the absolute yield makes it suitable for ranking since it takes into account the actual variation of the yield within the entire investigated set of cultivars.

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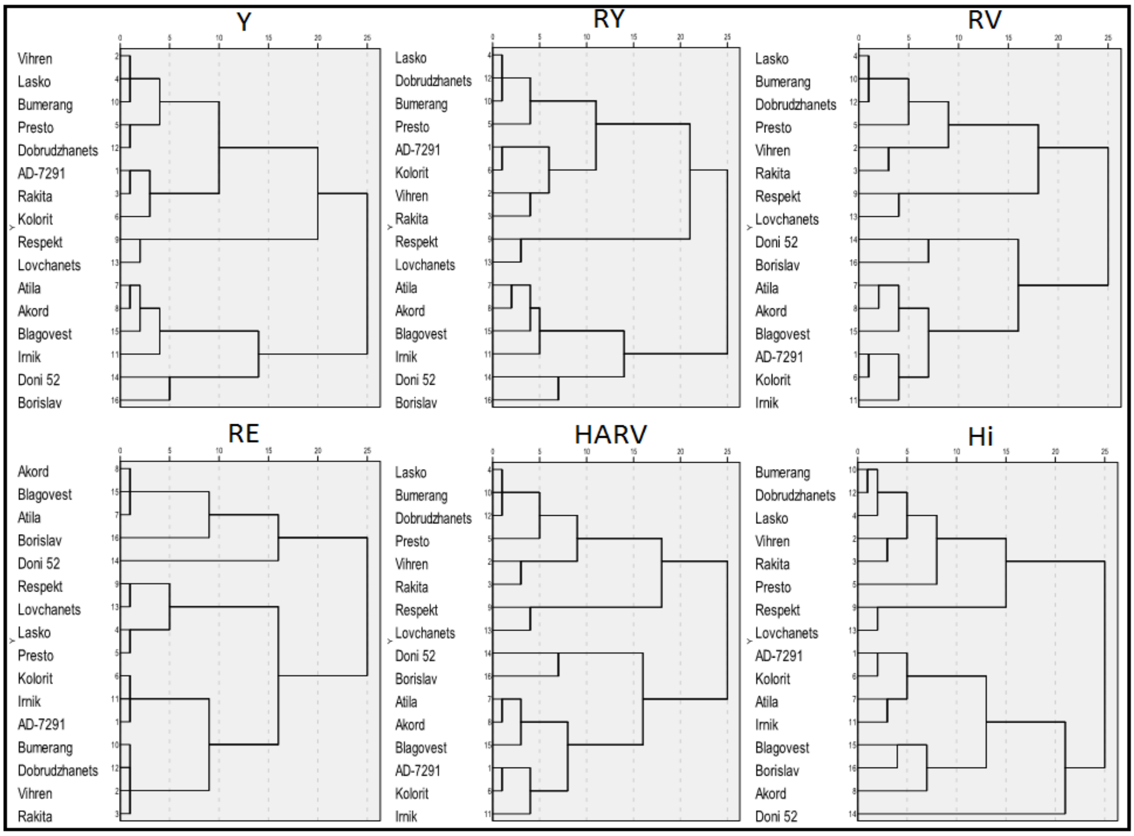

Figure 2. Cluster analysis by yield and parameters of the applied ranking models

Figure 2 presents dendrograms from the cluster analysis by values of each applied model. This analysis gives a real idea about the ranking of the genotypes taking into account the similarities between them. It is worth mentioning that the high-yielding and stable varieties ranked in identical clusters regardless of the method used. Cultivars Doni 52 and Borislav comprised a separate cluster in each of the applied models. This emphasized their unique productivity and high ecological plasticity.

In triticale, such ranking is essential due to the complexity in the response of the genotypes to the environment. The investigated genotypes allowed, even under very contrasting environments, the forming of groups which combined certain productivity with stability. All applied models are in this respect suitable for identification of this ranking and can be efficiently used in the breeding of triticale.

Conclusions

Most efficient was the model using the mean standard from the check varieties in the trial. The models, in which the yield was being corrected with the variation caused by the variable environment (HA and Hi models), were also with good efficiency for yield evaluation. Nevertheless, the HA-model was very similar to the ranking of the cultivars by their absolute yield. This was related to the single location of investigation regardless of the contrasting agro-climatic conditions. On the other hand, the Hi-model allowed interpreting the yield and ranking the response of the yield from the different cultivars. The score based on the relative yield according to the mean of the trial turned out to be with lowest efficiency because the ranking of the cultivars was too subjective according to the accepted scale and did not correctly take into account the effect of the contrasting conditions. In spite of some disadvantages, however, each model can be successfully used for analysis of the yield during periods of strongly contrasting conditions depending on the specific purpose of the breeding program.

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