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Evaluation of rye specimens in maturity stage on the basis of mathematical – statistical analysis

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Abstract. *The aim of the study is to evaluate comprehensively the rye collection and the possibilities for the specimen usage in selection on the basis of mathematical approaches. The study was carried out during 2009-2012 in the experimental field of the Institute of Plant Genetic Resources (IPGR) – town of Sadovo on cinnamon-forest soils with 54 specimens collected (16 samples from expeditions in Bulgaria and 38 samples from abroad). As standard, the Bulgarian variety "Millennium" (current standard in IASAS) was used. The Danae variety has been used as a former 30-year standard for the country. Evaluation of the impact of the examined specimens was made on the basis of the following biometrical indicators: spike length (cm); tillering – productive and non-productive tillering; plant weight (g); ears weight (g); weight of the main spike(g); weight of the main ear`s grain (g); number of the spikelets in the spike; grain weight of the main spike (g); crop index (%). The correlation analysis made allows determination of the dependence of the complexity impact on the rye performance indicators. The established correlations show the degree of impact of each indicator in yield formation. Based on the correlation coefficients derived, the established dependencies between plant seed yield and maturation yield elements, a mathematical model of the plant with high productive potential was obtained. Rye specimens of the highest yield are characterized by high value of the crop index.*

Keywords: rye, correlation analysis, regression model

Introduction

Rye belongs to *Poaceae* family, *Pooideae* subfamily, *Secale* genus (Kiryakov, 1999). The significance of rye in Bulgarian agriculture is not appreciated properly and its resources are not used. This crop is cultivated more successfully than wheat in the low mountain regions, in more acid soils. Rye has good self-endurance and keeps down the weeds strongly.

Various plant resources are used as initial materials in the selection of the cultural plants: old and new varieties, populations, different forms and types of a given specimen, etc. They are carefully selected, maintained and preserved. Therefore, gene banks (like the Institute of Plant Genetic Resources in Sadovo) are of great importance for preserving the plant genetic resources, as well as for protecting the specimens threatened by extinction. The rye collection in IPGR – Sadovo ranks fourth in Europe. According to Knüpffer (2011), the Bulgarian collection ranks seventh in the world. The national basic rye collection includes around 1300 specimens and it is placed after the collections of Russia, Poland, Germany, the USA and Canada.

The contemporary selection is directed to creating economically advantageous varieties. The initial material is necessary to be of a wide genetic base. The constant expansion of the existent collections, as well as the accumulation, addition and systematizing of the received data help for higher effectiveness of the selective-improving activity. Rye *Millenium* variety is created on the basis of an inter-population changeability of a set of qualitative characteristics (Antonova, 2003; Mangova and Antonova, 2003). Such evaluation has been made for rye specimens in the phase of ear formation in the study (Kuneva and Valchinova, 2016).

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The current study aims to evaluate comprehensively the rye collection and the possibilities for the specimen usage in selection on the basis of mathematical approaches.

Material and methods

The scientific research was conducted in the period 2009-2012 in the experimental field of IPGR – Sadovo on cinnamon-forest soils with examined 54 specimens collected, of which 16 specimens collected from expeditions around the country and 38 specimens collected from abroad (Figure 1). The Bulgarian rye variety *Millenium* was used as a standard (a current standard in IASAS). *Danae* variety was used as a former 30-year-old standard for the country.

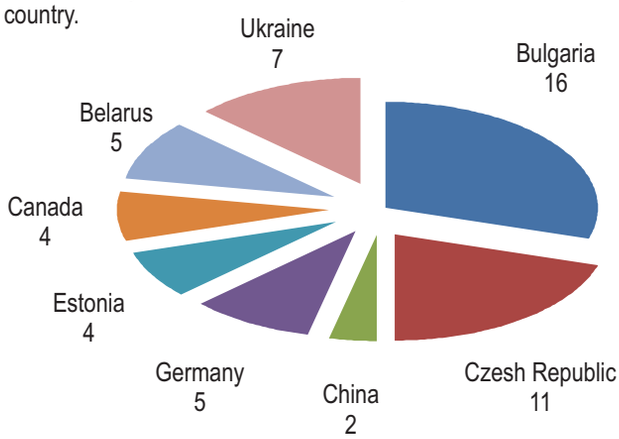


Figure 1. Collection of rye by countries

The experiment was set in a block method at 1.2 m^2 area under review, in three repetitions. The sowing norm was calculated at 500 horse power/m^2. In maturity phase 10 specimens were marked in advance and were measured in three repetitions. Evaluation of the impact of the examined specimens was made on the basis of the following biometrical indicators: ear length (cm); awn length (cm); tillering – productive and non-productive tillering; plant weight (g); ears weight (g); weight of the main ear (g); mass of the main ear`s grain (g); number of spikelets in the spike; number of grains in the main ear; grain weight of the spike (g); crop index (%).

The mathematical processing of data was conducted with the help of a mathematical software SPSS 13.0. The results of the morphological and some biological indicators were processed under a correlation analysis, according to Genchev et al. (1975) for establishing the relation between the measured indicators and the seed yield from one plant.

The elements, which led to a high yield of a plant, were processed through the method of step regression. The model of the plant with high yield potential (Stamatov and Deshev, 2010) was built up with the help of the statistical software SPSS 13.0 for Windows (Manov, 2001).

Results and discussion

Correlation between investigated indicators

The correlation dependences between indicators in maturity phase are presented in Table 1. The calculated correlation coefficients between most of the elements of the yield and the grain yield of one plant are positive. The following indicators have a high value of coefficients: the dependence between yield and the number of fruit tillers (r=0.432**), the weight of one plant and spikes (r=0.467**), the spikes weight of one plant (r=0.885**), the weight of the main spike (r=0.369**), the number of grains in the spike (r=0.470**), the crop index (r=0.856**). The spike length also has positive effect on yield quantity, but with a lower degree of reliability (r=0.326*). The be- optional grid shows the dependences between the examined elements without giving a concrete idea for their combination in the genome. Their combination in the plant genome is defined by the heredity of the used parent forms. Therefore, the correlation analysis is not precise enough. A regression model is needed to receive a real vision for the perfect plant architecture. It combines skillfully the correlated indicators.

Table 1. Correlation dependences between the morphological characteristics of rye

	Yield	Ear length, cm	Awns length, cm	Number of productive tillers	Number of non-productive tillers	Weight of one plant, g	Weight of ears in one plant, g	Weight of main ear, g	Number of ears in a main ear	Number of grains in a main ear	Mass of grains in a main ear, g	Crop index, %
Yield	1.000	-0.046	0.326*	0.432**	0.132	0.467**	0.885**	0.369**	0.260	0.702**	0.470**	0.856**
Ear length, cm		1.000	0.583**	-0.467**	-0.398**	0.120	0.038	0.551**	0.276*	-0.122	0.448**	-0.182
Awns length, cm			1.000	-0.293*	-0.331*	0.152	0.354**	0.776**	0.062	0.254	0.636**	0.281*
Number of productive tillers				1.000	0.297*	0.258	0.391**	-0.324*	-0.199	0.192	-0.288*	0.373**
Number of non-productive tillers					1.000	0.246	0.052	-0.384**	0.160	0.054	-0.287*	0.000
Weight of one plant, g						1.000	0.427**	0.198	0.230	0.164	0.194	0.000
Weight of ears in one plant, g							1.000	0.418**	0.273*	0.620**	0.447**	0.760**
Weight of main ear, g								1.000	0.137	0.361**	0.891**	0.298*
Number of ears in a main ear									1.000	0.464**	0.336*	0.146
Number of grains in a main ear										1.000	0.614**	0.684**
Weight of grains in a main ear, g											1.000	0.406**
Crop index,%												1.000

*-proved at a degree of freedom 0.05 **- proved at a degree of freedom 0.01

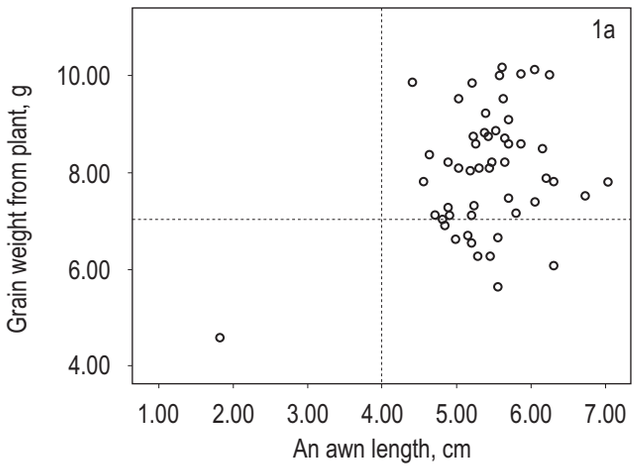
A model of the rye plant according to yield parameters

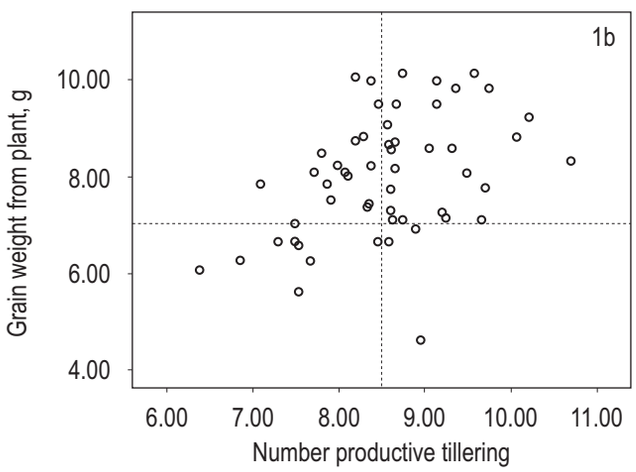
The analyzed characteristics correlate with the yield at this stage of rye growth. They form the following regression model of the plant, which has a high yield potential:

$$Y = -8.011 + 0.0018*X_1 + 0.00078*X_2 + 0.229*X_3 + 0.116*X_4 - 0.175*X_5 + 0.00094*X_6 + 0.280*X_7 + 26.249*X_8,$$

where: Y- grain yield from one plant; X_1– spike length, cm; X_2 – number of productive tillers; X_3– weight of one plant, g; X_4 – weight of spikes of one plant, g; X_5 – weight of a main spike, g; X_6– number of grains in a main spike; X_7 –weight of grains in a main spike, g; X_8– crop index, %.

The mathematical model is presented graphically. There is a weak dependence between the grain yield of one plant and the awns length which is presented in Figure 1a. It is obvious that the plants with a higher yield potential have longer spikes. The increase of the number of fruit tillers leads to the increase of the yield of one plant. This tendency is presented in Figure 1b. The weak exclusions on the right or on the left of the ordinate do not alter the total dependence. The weight of the plant and its ears affects the grain yield of one plant identically with the previous indicator. Figure 1c demonstrates this dependence. Specimens with a total weight from 32 g to 36 g comprised the highest grain yield of one plant.





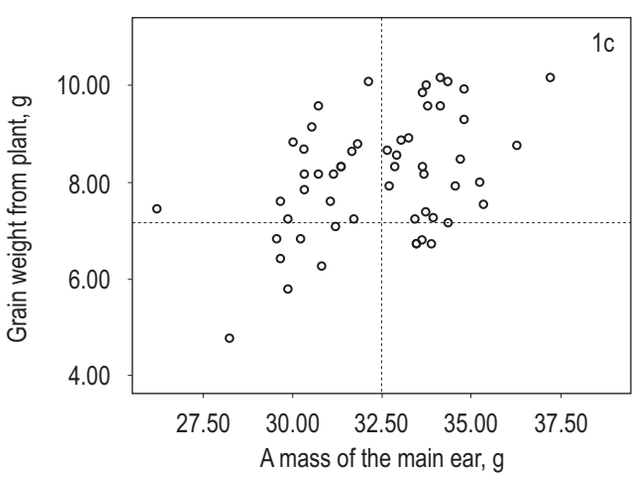
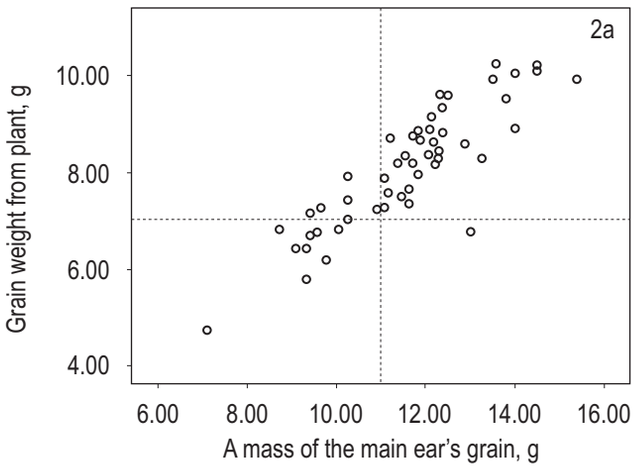
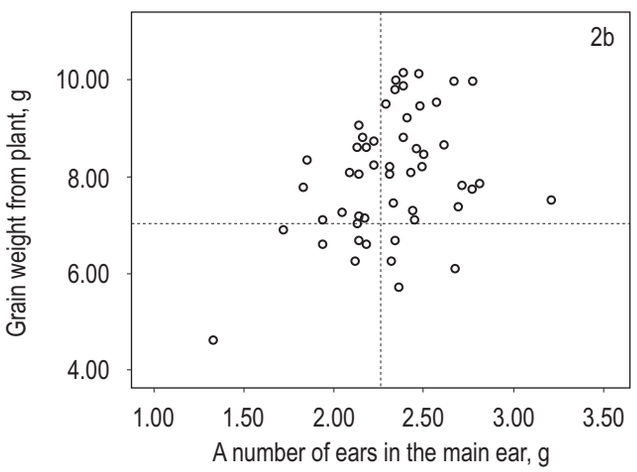


Figure 1 a, b, c. An image of the correlation dependence between: 1a – the grain yield of one plant and the spikes length; 1b – the grain yield of one plant and the number of productive tillers; 1c – the grain yield of one plant and the mass of one plant and its spikes





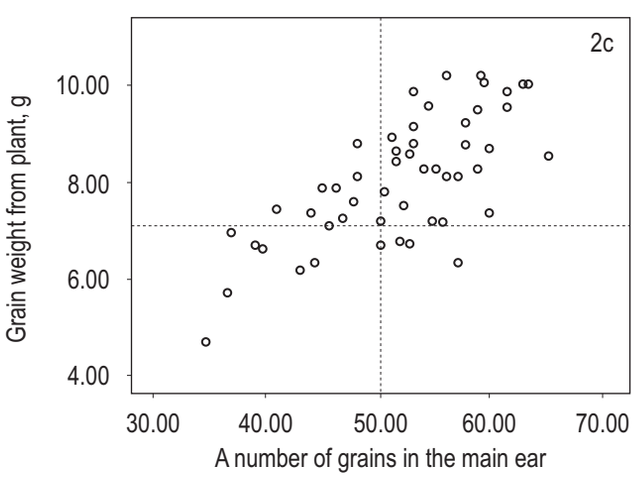


Figure 2 a, b, c. Correlation dependence between: 2a – the yield of one plant grain and the weight of plant ears; 2b - the yield of one plant grain and the weight of the main ear; 2c - the yield of one plant grain and the number of grains in the main ear

The weight of the plant ears confirms that high-yield plants are characterized by higher biomass. Figure 2a shows that the yield of plant grains increases with the growth of the weight of the plant ears. The dependence of the weight of the main ear to the yield of the plant grains is weak. The impact of this indicator is even negative towards the yield. This can be seen from the mathematical model and is presented in Figure 2b. The number of grains in the spike does not determine its weight and it can be seen on Figure 2c. It presents the strong positive dependence between their number and the grains weight in a plant.

The bigger weight of grains in the main ear has a positive effect on the quantity of one plant yield. Specimens of the highest yield are those with grains weight in the main ear over 2g. There is a controversy between the indicators mass of the main ear and grain

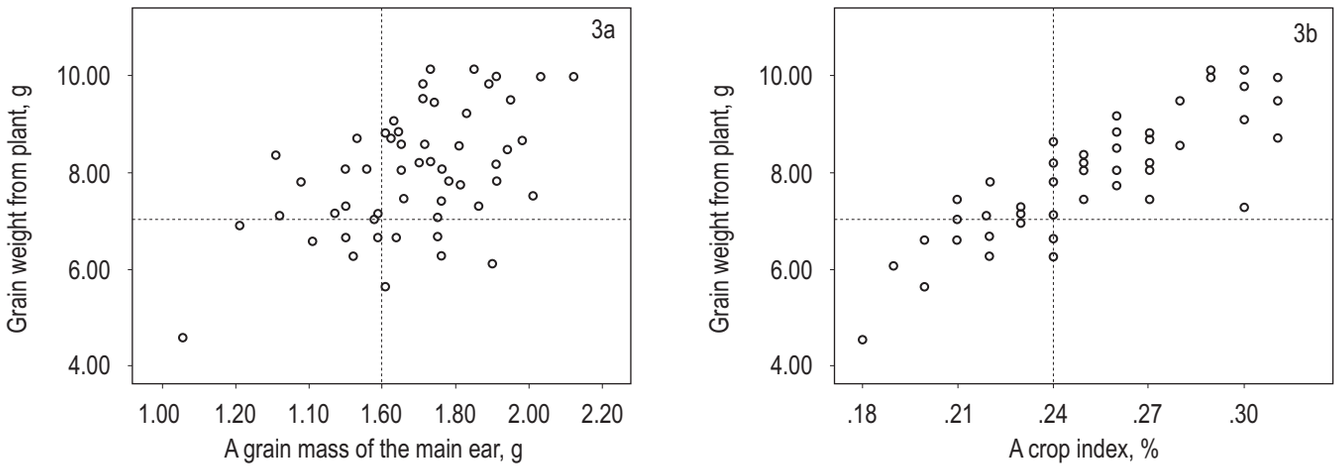


Figure 3 a, b. Correlation dependence between: 3a - the yield of a one plant grain and the mass of grains in the main ear; 3b - the grain yield of one plant and the crop index

weight in the main ear and their relation to the yield quantity. It can be explained with the crop index.

It is obvious that the main ear of rye is the biggest one and it forms the greatest number of ears and seeds. They determine the yield quantity according to their fertility. Figure 3a presented the correlation dependence between the yield of one plant grain and the mass of grains in the main ear. Rye specimens of the highest yield are characterized by a high value of the crop index. In the examined correlation the crop index over 0.30 leads to a high yield of grains in one plant Figure 3b.

Conclusion

The correlation analysis made allows determination of the dependence of the complexity impact on the rye performance indicators. The established correlations show the degree of impact of each indicator in yield formation. A mathematical model of the plant has been obtained on the basis of the studied correlation coefficients and the proved dependences between the grain yield of a plant and the yield elements in the maturity stage. The plant is characterized by high productive possibilities. The results could be used as a basis for determining more perspective rye specimens.

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