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Original article

Evaluation of New Cotton Lines in View of Selection [1]

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Abstract

The selection value of 8 new cotton lines and the standard variety was studied on the base of significant differences between the most important agronomic characters and their phenotypic stability, over a four-year period 2014-2017. The years of the investigation appeared to be as different ecological environments. Four stability parameters - b_i (Finlay and Wilkinson, 1963), σ^2_i and S^2_i (Shukla, 1972) and YS_i (Kang, 1993) were used. It was found that the studied cotton lines interacted significantly with the environmental conditions (years) in terms of total yield, boll weigt, fiber length and lint persentage. All lines had bigger breeding value than the standard cultivar Chirpan-539 exceeding it by one or more traits. In a complex assessment as best line for the studied period outlined No. 550 distinguished by 9.7% higher yield than the standard, 0.4 mm longer fiber and 1.2% higher lint percentage. This line showed stability for the ball weight and fiber length, and responsiveness above the average to the environmental conditions for the seed cotton yield and lint percentage, but both traits were with low stability. Lines Nos. 553 and 426 showed a high average level and high stability for yield, Nos. 489 and 535 – for ball weight, No. 553 – for fiber lint percentage and No. 489 – for fiber length, which makes them very valuable for the selection of these traits. A complex breeding value (average level and stability) for all studied traits was found for line No. 553.

Keywords: *G. hirsutum L.,* genotype-inveronment interaction, phenotypic stability, agronomic traits.

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INTRODUCTION

An important prerequisite for the success of the breeding programs is the creation and evaluation of genetic diversity and its most effective use in order to develop better varieties than existing ones. There are many and effective methods for assessing genotypes and genetic diversity.

In recent years, in the selection of cotton in Bulgaria, in order to create greater genetic diversity, remote hybridization of *G. hirsutum* L. with some wild diploid species of the genus *Gossypium* L. was used (Stoilova and Saldzhiev, 2015). The inclusion of foreign germpalsm and the interaction of genotypes with the environment, determined the need to study their behaviour under different environmental conditions.

The phenotypic stability of genotypes is part of the problem associated with the genotype-environment interaction, i.e. with different varieties reaction when changing environments. Many parameters and concepts have been developed to assess the stability of genotypes (Lin et al., 1986; Westcott, 1986; Becker and Leon 1988). The most widely used methods are the regression methods of Finlay and Wilkinson (1963), Eberhart and Russell (1966), the variance method of Shukla (1972) and the criterion of Kang (1993) for simultaneous estimation of yield and stability. Fasoulas (1988) proposed the ratio between mean and standard deviation for stability estimations and later Fasoula (2013) used the squared form as a stability criterion (Greveniotis et al., 2017).

Recent methods include the AMMI (additive main effects and multiplicative interaction) model (Gauch and Zobel, 1988), which is a statistical method for understanding the structure of interactions between genotypes and environments, and the GGE biplot model (Yan et al., 2000), which considers the sum of the genotype main effects and the genotype and environment interaction (Farias et al., 2016).

Ecological stability was the subject of intensive studies in genetic and breeding research on cotton. Stability estimits were based on regression and variance methods (Killi and Harem, 2006; Singh et al., 2014, Balakrishna et al., 2016; Güvercİn et al., 2017; Greveniotis et al., 2018), as welle as on AMMI and GGE biplot models (Baxevanos et al., 2008; Xu et al., 2013; Farias et al., 2016; Maleia et al., 2017; Orawu et al., 2017; Greveniotis et al., 2018).

The aim of the study was to investigate the productive and qualitative potential of new cotton lines and evaluate their phenotypic stability in terms of seed cotton yield and most important qualitative fiber properties with a view to their most effective use in selection programs.

Material and Methods

The study included the standard cultivar Chirpan-539 (*G. hirsutum* L.) and eight new promising cotton lines obtained by applying of different breeding methods - remote hybridization of *G. hirsutum* L. (5 lines), intra-specific (diallel and line × tester) crosses (3 lines).

Variety trial was carried out by the standard method in four replications and a harvest plot of 20 m^2 in the experimental field of the Field Crops Institute in Chirpan during the period 2014-2017. Different environmental conditions occurred in the separate years. In Bulgaria, the cotton-growing regions usually do not differ significantly in soil and climate. The climatic factors, however, during the cotton vegetation period in the separate years of study prove to be very different and sometimes contrasting.

The following characters were analyzed: seed cotton yield; boll weight; fibre length and fiber lint percentage. The fibre length was determined by the "butterfly" method on 40 individual plants (10 of replication), and the fibre lint percentage was calculated on average sample for each replication. A two-factor dispersion analysis of the data was performed using ANOVA 123 statistical program. The program STABLE (Kang and Magari, 1995) was used to estimate stability parameters σ^2_i and S^2_i (Shukla, 1972) as well as Kang's YS_i parameter (Kang 1993). Statistics 8 was used to estimate the regression coefficient b_i (Finlay and Wilkinson, 1963).

The study period included years of different temperature and rainfall supply: 2014 was moderately warm and moderately humid; 2015 - warm and moderately humid; 2016 - warm and dry; 2017 - warm and moderately dry.

Results and Discussion

The averaged results for four years (Table 1) show that six lines had a significant higher seed cotton yield than the standard cultivar exceeding it by 7.2 - 11.1 %, seven lines had a longer fiber by 0.4-1.2 mm, and three lines had a higher fiber lint percentage by 0.8-1.3 %.

In a complex assessment, for the studied period, line No. 550 ($F_{10}BC_3$) originating [F_3BC_1 (C_1 413 × *G. davidsinii*) × Chirpan-603] × Chirpan-603 × Chirpan-603 was the best, exceeding the standard cultivar in seed cotton yield by 9.7%, in fibre length by 0.4 mm and in fibre lint percentage by 1.2 %.

Line No. 553 - $F_{10}BC_1$ [(F_7 *G. turberi* × *G. raimondii*) × Darmi] × Darmi exceeded the standard cultivar in seed cotton yield by 7.8 %, in fiber length by 0.9 mm, while in fiber lint percentage was equal to it.

Lines Nos. 449, 457 and 535 exceeded the standard Chirpan-539 in seed cotton yield by 7.4%, 9.7% and 11.1%, respectively and had longer fiber by 1.2 mm, 0.5 mm and 0.7 mm, but they were inferior to it in fiber lint percentage. Lines Nos. 449 and 457 originated [(*G. turberi* × *G. raimondii*) × Darmi] × Darmi. Line No. 535 was obtained from the crossing of line 37 × Dorina. The pedigree of line 37 included Pearla-267 variety possessing germpalsme of the *G. barbadense* L. species.

Table 1. Economic qualities of studied lines included in a competition variety test in the period 2014-2017 (Average for 4 years)

Line No.	**Seed cotton yield** *kg/ha*	**In % to Chirpan-539**	**Boll weight** *g*	**Fiber length** *mm*	**Lint percentage** %
Chirpan-539	1615	100.0	5.2	25.9	41.0
346	1656	102.5	4.9^{000}	26.2^{+++}	41.8^{++}
426	1731	107.2^{++}	5.1	25.7	40.9
449	1735	107.4^{++}	5.2	27.1^{+++}	39.9^{000}
457	1771	109.7^{+++}	4.9^{00}	26.4^{++}	39.5^{000}
489	1531	94.8^{0}	5.2	26.9^{+++}	42.3^{+++}
535	1794	111.1^{++}	5.2	26.6^{+++}	40.5^{0}
550	1771	109.7^{++}	5.0^{0}	26.3^{+}	42.2^{+++}
553	1741	107.8++	5.1	26.8^{+++}	41.0
GD 5.0 %	81	5.0	0.2	0.3	0.5
GD 1.0 %	107	6.6	0.3	0.5	0.7
GD 0.1 %	138	8.5	0.4	0.6	0.9

Selection value was found for line No. 489, which combined longer fiber and higher fiber lint percentage. Its lower productivity was due to the smaller number of plants in the experimental parcel in 2014 as a result of irregular sprouting. Line No. 489 originated from Chirpan 539 × 713. The pedigree of line No. 713 included line 268 with the *G. barbadense* L. germplasme.

Line No. 346 combined length and lint percentage of the fiber and in seed cotton yield it was insignificantly superior to the standard cultivar by 2.5%. This line was obtained from the crossing of Natalia variety × Millennium (Greek cultivar).

Line No. 426 - $F_{11}BC_2$ [(C_6 9736 × *G. thurberi*) × 413] × T-073 was significantly superior to the standard by 7.2%, in length and lint percentage of the fiber it was equal to the standard.

In the total variation of all the studied traits, the years had the highest relative share: 66.66 % for the seed cotton yield; 51.57 % for the boll weight; 59.63 % for the fibre lint percentage and 71.96 % for the fibre length (Table 2). For the seed cotton yield and boll weight, after years, the interaction genotype × years was of importance, conditioned by different response of genotypes to environmental changes. Concerning the fibre lint percentage, the participation of lines was 17.38 %, indicating that their genotypes were also important for the formation of this property.

The interaction genotype-environment was statistically significant for all the traits tested, indicating that the lines reacted specifically to the environmental conditions for each one.

Table 2. Two-factor dispersion analysis of line traits in competition variety test in the period 2014 – 2107

Sources on variation	Degrees on freedom	Sum of squares	Correlation ratio (Average square %)	Dispersion	F-exp.
	Seed cotton yield, *kg/ha*				
Total	143	1206605	100.0	-	-
Repetitions	3	11515	0.95	3838.33	2.98
Variants	35	1059565	87.81	30273.29	23.45^{+++}
Line-A	8	96190	7.97	12023.75	9.32^{+++}
Years-B	3	792210	65.66	264070	204.59^{+++}
Line×years (A×B)	24	171165	14.19	7131.87	5.53^{+++}
Errors	105	135525	11.23	1290.71	-
	Boll weight, *g*				
Total	143	32.739	100.00	-	-
Repetitions	3	0.101	0.31	0.034	0.37
Variants	35	22.959	70.13	0.656	7.12^{+++}
Line-A	8	2.330	7.12	0.291	3.16^{++}
Years-B	3	16.884	51.57	5.628	61.05^{+++}
Line×years (A×B)	24	3.745	11.44	0.156	1.69^{++++}
Errors	105	9.679	29.57	0.092	-
	Lint percentage, %				
Total	143	693.625	100.00	-	-
Repetitions	3	0.281	4.05	0.937	0.161
Variants	35	362.391	91.17	18.068	31.12^{+++}
Line-A	8	120.562	17.38	15.070	25.96^{+++}
Years-B	3	413.625	59.63	137.875	237.51^{+++}
Line×years (A×B)	24	98.203	14.16	4.092	7.04^{+++}
Errors	105	60.953	8.79	0.581	-
	Fiber length, *mm*				
Total	143	283.273	100.00	-	-
Repetitions	3	2.063	0.73	0.687	2.86^{+}
Variants	35	255.953	90.35	7.313	30.40^{+++}
Line-A	8	28.219	9.96	3.527	14.66^{+++}
Years-B	3	203.843	71.96	67.948	282.45^{+++}
Line×years (A×B)	24	23.891	8.43	0.995	4.14^{+++}
Errors	105	25.258	8.92	0.241	-

Mean values and results obtained from the phenotypic stability analysis of studied traits showing significant genotype-environment interaction are present in Table 3.

Seed cotton yield. Assessment of stability using the b_i-regression coefficient depends on the adopted stability concept (Becker, Leon, 1988). According to the biological concept, genotypes having a regression coefficient $b_i=0$ or near 0 are the most stable. According to the agronomic concept, genotypes having $b_i=1.0$ are accepted as the most stable. In this case, lines No. 426 ($b_i=0.914$), No. 550 ($b_i=1.133$) and No. 553 ($b_i=0.905$) had high stability. Concerning seed cotton yield, the agronomic concept is more important, because genotypes that are above average for experience are considered to be more valuable. High responsiveness $b_i>1.0$ was found for lines Nos. 449 and 535, but the variance parameters (σ^2_i and S^2_i) defined the two lines as very unstable.

The stability variances σ^2_i and S^2_i (Shukla, 1972), estimating the linear and non-linear interactions, respectively give a one-way assessment of phenotypic stability. Genotypes showing lower values are considered more stable for their weaker environmental interactions. Negative values of σ^2_i and S^2_i are assumed to be 0. At significantly high values of any of the two parameters σ^2_i or S^2_i genotypes are considered unstable. On this basis, lines Nos. 346, 426 and 553 were most stable for seed cotton yield. Line No. 457 and the standard cultivar had average stability. The remaining lines were very unstable.

Very useful information about the breeding value of genotypes gives the YS_i parameter (Kang, 1993) for simultaneous assessment of yield and stability on the basis of the statistical significance of differences (the genetic effects) and the variance of environmental interaction. By this parameter, lines Nos. 553 and 426 were the most valuable, followed by Nos. 535, 457, 550 and 346.

From the analysis of the results it can be noted that lines Nos. 426 and 553 had high stability based on the evaluations of all the stability parameters and had the highest breeding value in terms of seed cotton yield and its stability. Lines Nos. 449 and 535 ($b_i=1.681$ and $b_i=1.345$) were found to be most responsive to the environment, but they were very unstable showing significant high values of the variance parameters σ^2_i and S^2_i.

Table 3. Average data for the seed cotton yield and boll weight for four years (2014-2017) and stability parameters by Finlay and Wilkinson (1963) (b_i), Shukla (1972) (σ^2_i, S^2_i) and Kang (1993) (YS_i) for 9 cotton genotypes

Genotypes	**Mean value**	**b**	**σ^2_i**	**S^2_i**	**Y_{Si}**
	Total yield, kg/ha				
Chirpan-539-St.	1615	0.598	8309.52++	4089.84+	-8
346	1656	0.826	1715.37ns	1558.58ns	0+
426	1731	0.914	-698.36ns	-763.06ns	5+
449	1735	1.681	20863.64++	5924.45+	-2
457	1771	0.840	5427.40++	7400.37++	1+
489	1531	0.755	9286.76++	11251.71++	-10
535	1794	1.345	10177.88++	9234.17++	3+
550	1771	1.133	9180.69++	13457.05++	0+
553	1741	0.905	-156.68ns	-31.84ns	7+
	Boll wight, g				
Chirpan-539-St.	5.2	0.960	0.113ns	0.181ns	5+
346	4.9	1.000	0.131++	0.596++	-7
426	5.1	0.440	0.233ns	0.038ns	1
449	5.2	1.340	0.2661+	0.247ns	4+
457	4.9	0.680	0.064ns	0.017ns	-3
489	5.2	0.780	0.023ns	0.011ns	9+
535	5.2	0.880	0.0339ns	0.063ns	10+
550	5.0	1.240	0.147ns	0.150ns	0
553	5.1	1.320	0.097ns	-5.618ns	4+

Boll weight. Lines had close values for the boll weight (4.9 to 5.2 *g*). Lines Nos. 550 and 553 showed responsiveness above the mean $b_i>1.0$ and high stability expressed by the variance parameters (σ^2_i and S^2_i). Based on the variance parameters (σ^2_i, S^2_i) only two lines were unstable one of which (No. 449) demonstrated a good responsiveness. The YS_i parameter estimated as the most valuable lines Nos. 535 and 489 followed by the standard cultivar and lines Nos. 449 and 553.

Lint percentage. Based on the b_i-regression coefficient and according to the biological concept, line No. 535 ($b_i=0.557$) and the standard cultivar ($b_i=0.697$) outlined as most stable, but they were unstable on the basis of variance parameters (σ^2_i and S^2_i). Lines Nos. 550 ($b_i=1.566$) and 346 ($b_i=1.400$) were responsive to the environment, but they also were unstable based on the variances σ^2_i and S^2_i.

Biological stability is more important for the fiber length and fiber lint percentage, but the regression coefficient security can reduce in the presence of significant non-linear interactions (heterogeneity). In such cases, the variance methods, including the Kang's method, are more secure.

Line No. 553 was most stable on the basis of the estimates using the variances parameters (σ^2_i, S^2_i). The same line was also most valuable when the YSi parameter was used. This line was followed by lines Nos. 489 and 550. Both lines were unstable when the variance parameters were used, but they had a very high fiber lint percentage (42.2-42.3%) and respectively highly significant genetic effects to the standard cultivar.

The analysis of the results showed that the highest breeding value for the fiber lint percentage (average level and stability) was found for line No. 553, followed by lines Nos. 489 and 550. These lines showed significantly high values of parameters σ^2_i and S^2_i, which means unstable, but they had very high fiber lint percentage. Line Nos. 346 (b_i=1.400) and 550 (b_i=1.566) were distinguished as responsive to the favorable conditions, while line No. 535 and the standard outlined themselves as the most stable in adverse conditions (bi=0.557 and 0.695).

Table 4. Average data for lint percentage and length of the fiber for four years (2014-2017) and stability parameters by Finlay and Wilkinson (1963) (b_i), Shukla (1972) (σ^2_i, S^2_i) and Kang (1993) (YS_i) for 9 cotton genotypes

Genotypes	Mean value	b	σ^2_i	S^2_i	Y_{Si}
	Lint percentage - %				
Chirpan-539-St.	41.0	0.695	4.248++	3.554++	-5
346	41.8^{00}	1.400	3.929++	1.157ns	1+
426	40.9	1.015	3.330++	5.314++	-4
449	39.9^{000}	0.893	1.247ns	1.922+	-3
457	39.5^{000}	0.927	1.038ns	1.803+	-4
489	42.3^{+++}	0.983	7.300++	11.288++	4+
535	40.5^{0}	0.557	4.569++	1.811+	-7
550	42.2^{+++}	1.566	10.764++	6.526++	3+
553	41.0	0.870	0.234ns	0.270ns	7+
	Fiber length - mm				
Chirpan-539-St.	25.9	0.868	0.727+	0.995+	-4
346	26.2^{+++}	1.084	0.049ns	-0.002ns	2+
426	25.7	0.966	1.461++	2.280++	-10
449	27.1^{+++}	1.254	1.619++	1.330++	4+
457	26.4^{++}	0.771	0.499ns	0.202ns	4+
489	26.9^{+++}	1.169	0.488ns	0.248ns	8+
535	26.6^{+++}	0.497	2.735++	0.864+	-1
550	26.3^{+}	0.996	0.198ns	0.384ns	1
553	26.8^{+++}	1.175	0.754+	0.607ns	5+

Fiber length. The stability expressed by the b_i-regression coefficient indicates that the lowest regression coefficient and therefore the highest stability according to the biological concept was found for line No. 535 (b_i=0.497). The variance parameters (s^2_i, S^2_i) defined this line as very unstable. Lines Nos. 449 (b_i=1.254), 489 (b_i=1.169) and 553 (b_i=1.175) showed responsiveness above the mean level. Lines Nos. 346, 457, 489 and 550 were stable on the basis of the variance parameters (s^2_i, S^2_i). Based on the YS_i parameter line No. 489 was the most valuable, followed by lines Nos. 553, 449, 457 and 346, the genetic effects were more important for the first two lines (553 and 449), for line No. 449 the variances s^2_i and S^2_i had significantly high values.

Summarized results showed that in terms of trait average level and stability, lines Nos. 553 and 426 were most valuable for the seed cotton yield, lines Nos. 489 and 535 for the boll weight and line No. 489 for the fiber lint percentage.

Line No. 553 possessed complex breeding value for all tested characters (average level and stability). Line No. 489 showed high stability for the boll weight and fiber length.

The method supposed by Kang (1973) assessing genotypes simultaneously on their average level and stability was particularly valuable in terms of selection.

Conclusions

All lines had bigger breeding value than the standard cultivar Chirpan-539 exceeding it by one or more characters.

In a complex evaluation of economic traits, for the period 2014-2017, line No. 550 was the best having 9.7% higher yield than the standard, 0.4mm longer fiber, and 1.2% higher fiber lint percentage, and useful stability for boll weight and fiber length, and responsiveness above the average for the seed cotton yield and fiber lint percentage.

Lines Nos. 553 and 426 were found to have high seed cotton yield and high yield stability, line No. 553 had high lint percentage and line No. 489 combined fiber length and stability, which makes them very valuable for the selection of these traits.

Complex breeding value (average level and stability) for all studied characters was found for line 553.

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