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Original article

Qualitative Assessment of Reaction Norm of New Cotton Lines (*G. hirsutum* L.) [1]

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Abstract

The qualitative side of reaction norm of eight promising cotton lines and of standard cultivar was studied. The lines were obtained by intra-specific and remote hybridization of the *G. hirsutum* L. species with some wild diploid species of the genus *Gossypium* L. The type of their dynamic regression (of their regression curve) and the structure of ecological environments in their dynamic rows were determined in order to characterize the reaction norm. The years of the study (2014-2017) appeared to be as different ecological environments. Four qualitative characters - seed cotton yield, boll weight, fiber length and fiber lint percentage were analyzed. It was found that in most cases the studied lines had reaction norm which considerably differed from that of the standard cultivar. The specificity of the lines reaction was less pronounced in its type (in ½ of cases) and stronger (in more than 7/8 of cases) in the structure of ecological environments in its dynamic row. By the index type of reaction line № 457 was closest to the standard cultivar, while line № 449 was furthest from it. For the individual characters, the line reaction norm was manifested to varying degrees, from very high - for the boll weight, where similarity with the standard cultivar was missing, to average - for the seed cotton yield, where for this character half of the lines were similar to the standard cultivar.

Keywords: Cotton, *G. hirsutum* L., Agronomic Traits, Regression Curves, Dynamic Rows.

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INTRODUCTION

Creation of stable varieties possessing high adaptive capability to the different ecological environments is one of the main objectives of the breeding programs.

Various methods and approaches are used to assess the stability of varieties, i.e. to evaluate their specific reaction to the environmental conditions (Plaisted and Peterson, 1959; Perkins and Jinks 1968; Francis and Kannenberg, 1978; Lin et al., 1986; Westcott, 1986; Becker and Leon 1988; Fasoula, 2013).

The most widely used methods are the classic regression methods of Finlay and Wilkinson (1963), Eberhart and Russell (1966) and the variance ones of Shukla (1972), the criterion of Kang (1993) for simultaneous estimation of yield and stability, AMMI (additive main effects and multiplicative interaction) and GGE biplot models (Gauch and Zobel, 1988; Yan et al., 2000).

All of them characterize the norm of genotype reaction in quantitative terms and were widely used in cotton (Xu et al., 2013; Singh et al., 2014; Balakrishna et al., 2016; Farias et al., 2016; Güvercİn et al., 2017; Maleia et al., 2017; Orawu et al., 2017; Greveniotis et al., 2018).

Examining the norm of genotypes response in a qualitative aspect is a different, nonparametric approach that complements quantitative methods. For qualitative assessment of this characteristic, two indexes are used **-** type of their dynamic regression (their dynamic curve) and structure of the ecological environments in their dynamic rows **(**Lidanski and Naydenova, 1993). According to the authors, qualitative assessments allow to reveal the specificity of genotypes, which in quantitative estimates is rarely possible.

The aim of this study was to assess the qualitative side (qualitative assessment) of the reaction norm (based on the proposed indexes) of new promising cotton lines obtained by applying of different selection methods in order to determine the selection strategy for their effective use in breeding programs.

Material and Methods

The lines Nos. 346, 426, 449, 457, 489, 535, 550 and 553 and the standard cultivar Chirpan-539 were included in the study. Lines 426, 449, 457, 550 and 553 were obtained by remote hybridization of *G. hirsutum* L. with the wild diploid species *G. thurberi* Tod., *G. raimondii* Ulbr. and *G. davidsinii* Kell., and saturating backcrosses with the species *G. hirsutum* L. Lines 346, 489 and 535 were obtained by intra-specific crosses (*G. hirsutum* L.).

The trial was carried out under dry conditions, by the standard method, in four replications, with the experimental plot of 20 m^2, during 2014-2017 at the Field Crops Institute in Chirpan. The following quantitative characters were analyzed: seed cotton yield; boll weight; fiber length measured by "butterflies" and fiber lint percentage. Measurements except the seed cotton yield were made on 40 plants (10 from each repetition).

In order to characterize the reaction norm in qualitative aspect of the genotypes studied the type of their dynamic regression (their dynamic curves) and the structure of ecological environments in their dynamic rows were determined **(**Lidanski and Naydenova, 1993).

The years of the investigation appeared to be as different ecological environments. In terms of temperature security the years were characterized as follows: 2014 was average (P%=55.17); 2015, 2016 and 2017 were warm (P%=6.90; 9.20; 8.05). About rainfall supply 2014 and 2015 were moderately humid (P%=21.84; 36.78); 2016 was dry (P%=91.29) and 2017 was average (P%=43.68).

(P% **-** coefficient of security respectively for temperature security and for rainfall supply).

Results and Discussion

The dynamic regression curves of the studied genotypes are given by traits on **Fig. 1**. Both similarity and difference were observed by the type of reaction norm between genotypes and characters.

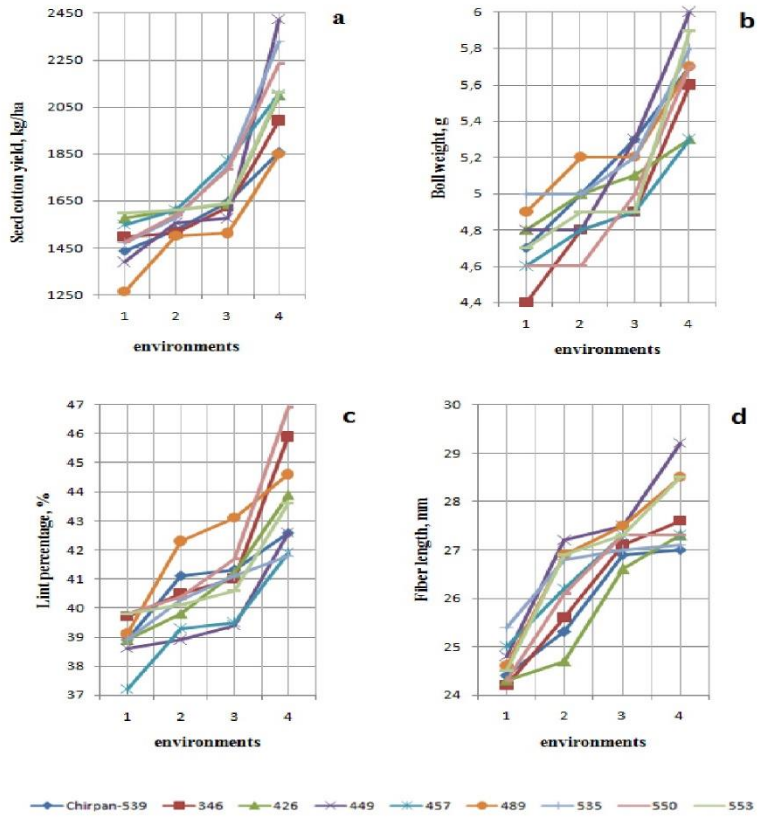

Figure 1. Dynamic regression lines of genotypes by traits a-d

Main types of regressions were the concave and combined, which took 80% (over ¾) of all regressions in the trial (Table 1). The predominant type of regression was concave, which took about half (44.4%) of the regressions. Combined regression was slightly lower (36.1%). Of the other two types of regressions, the convex regression showed a higher frequency (16.7%) and the linear one had the lowest frequency (2.8%).

The analysis of the results shows that about ½ of the genotypes reacted in the same way they had a similar reaction - weaker, when less unfavorable environments were changed with relatively more favorable ones and stronger, when the more favorable environments were changed with less favorable ones. The other main part of genotypes had a strong reaction to the change of favorable and unfavorable environments. The remaining genotypes showed a high adaptive ability and only a very small part of them exhibited a reaction that was adequate to the environmental conditions.

The concave regression dependence was observed for almost all genotypes (except for line No. 489) showing the highest frequency for line No. 550 and the lowest for the standard cultivar. Combined regression dependence was also observed for almost all lines (except for line No. 535) and predominated for line No. 489. The convex type regression occurred only in five of the genotypes studied (Nos. 346, 457, 535, 550 and the standard cultivar). The linear regression occurred only at the standard variety.

Table 1. Type of reaction of the lines studied

Lines	Types of regression curves				Characters similar to the standard type	
	Concave	Convex	Linear	Combined	Number	%
Chirpan-539	1	1	1	1	-	-
346	2	1	0	1	2	50.0
426	2	0	0	2	1	25.0
449	2	0	0	2	0	0.0
457	2	1	0	1	3	75.0
489	0	0	0	4	1	25.0
535	2	2	0	0	2	50.0
550	3	1	0	2	2	50.0
553	2	0	0	0	1	25.0
Total:	16	6	1	13	12	33.3
%	44.4	16.7	2.8	36.1		
Ratio:	16	6	1	13		

The distribution of the types of regression curves by characters (Table 2) showed that the prevailing type for the seed cotton yield and for the fiber lint percentage was the concave regression (7 and 5 numbers, respectively). For the boll weight the concave and the combined types showed equal frequency (4 numbers). For the fiber length the convex and the combined types had a near frequency (5 and 4 numbers).

The convex type regression occurred in three of the studied traits (4 to 7 numbers), the maximum number was observed for the seed cotton yield and the minimum number was observed for the boll weight. The combined type of regression was observed for all characters (2 to 4 numbers), the maximum number was typical for the boll weight and fiber length, and the minimum number - for the seed cotton yield. The convex type of regression (1 to 5 numbers) was observed for two of the characters - length (5 numbers) and lint percentage (1 number) of the fiber and the linear regression (1 number) was observed only for the boll weight.

Table 2. Distribution of regression type curves to the characters

Characters	Types of curves			
	Concave	Convex	Linear	Combined
Seed cotton yield	7	0	0	2
Boll weight	4	0	1	4
Fiber length	0	5	0	4
Lint percentage	5	1	0	3

The comparison of the studied lines regression type with that of the standard cultivar showed their similarity in 12/36 of the cases, i.e. 33.3% (Table 1). Coincidence according to the type of regression with the standard cultivar was observed in seven of the studied eight lines, for one to three characters, most often for two characters.

The maximum similarity was observed for line 457 (for three characters), and the minimum similarity was observed for lines 426, 489 and 553 (for one character). Line No. 449 showed no similarity to the standard cultivar. This indicates that about the type of regression line No. 457 was relatively closest to the standard cultivar, while line No. 449 was the most distant from it. The coincident cases by characters were from 0 to 4, i.e. from a lack (for the boll weight) to ½ (half of the lines) coincidence for the fiber length (Table 3).

Table 3. Distribution of lines similar to the standard cultivar according to indexes for the individual characters

Characters	Types of regression curves		Sequence of the dynamic row		Simultaneously by both indexes	
	Number	Line No.	Number	Line No.	Number	Line No.
Seed cotton yield	6	346, 426, 457, 535, 550, 553	0	0	0	-
Ball weight	0	-	1	449	0	-
Fiber length	4	346, 457, 535, 550	1	457	1	457
Lint percentage	2	457, 489	2	457, 489	2	457, 489

According to the structure of the dynamic row formed based on the environments (the years), the genotypes studied grouped into eight classes (denoted by the letters A to H) and their distribution by characters ranged from three (fiber length) to five (seed cotton yield and boll weight) classes, including and the standard cultivar (Table 4).

Compared to the standard cultivar, most of the lines about the studied characters had another structure of the dynamic row. The distribution of the analyzed characters according to the number of lines whose structure of dynamic row was similar to the standard cultivar showed that for the seed cotton yield coincidence with the standard cultivar did not occur in any of the lines. With respect to the other characters, the coincidence with the standard structure was observed in one (for the boll weight and fiber length) up to two (for the lint percentage) of the lines.

Table 4. Sequence of dynamic row by lines and characters

Lines	Seed cotton yield	Boll weight	Fiber length	Lint percentage
		Groups		
Chirpan-539	4, 2, 3, 1 A	4, 3, 2, 1 D	4, 2, 1, 3 H	3, 2, 4, 1 E
364	2, 3, 4, 1 B	2, 1, 4, 3 F	4, 2, 3, 1 A	3, 4, 2, 1 G
426	2, 4, 3, 1 C	4, 2, 3, 1 A	4, 2, 3, 1 A	4, 3, 2, 1 D
449	4, 3, 2, 1 D	4, 3, 2, 1 D	4, 2, 3, 1 A	4, 2, 3, 1 A
457	2, 4, 3, 1 C	4, 2, 3, 1 A	4, 2, 1, 3 H	3, 2, 4, 1 E
489	3, 2, 4, 1 E	4, 2, 3, 1 A	4, 2, 3, 1 A	3, 2, 4, 1 E
535	2, 4, 3, 1 C	2, 4, 3, 1 C	4, 3, 2, 1 D	3, 4, 2, 1 G
550	3, 2, 4, 1 E	3, 4, 2, 1 G	4, 2, 3, 1 A	4, 3, 2, 1 D
553	4, 3, 2, 1 D	4, 2, 1, 3 H	4, 2, 3, 1 A	3, 4, 2, 1 G

Of the generally possible 36 cases, only 4 of them (11.1%) showed coincidence with the standard cultivar. This indicates that in most cases the studied lines had other structure of their dynamic row compared to the standard cultivar, i.e. they had a norm of reaction strongly distinguishing from that of the standard cultivar, expressed by this metric.

Comparison the genotypes (lines) with the standard cultivar simultaneously by the reaction determined using the two metrics showed that according to the first metric their specificity occurred in 1/3 of the cases (Table 1) and according to the second one it was much higher - in nearly 7/8 of the cases.

The results obtained showed that the studied lines had a different norm of reaction under different environmental conditions and differed significantly from the standard cultivar. In order to be effectively used in future breeding programs, the selection strategy should be based on their specific norm of reaction across the variation of environments. Based on the results obtained 16.7% of studied lines were considered as most adoptable across the three years and they might be exploited in future breeding programs to improve the adoptability of new cotton varieties.

Conclusions

In most cases the studied lines had other norm of reaction which differed considerably from that of the standard cultivar.

The specificity of lines reaction norm was less pronounced according to the type of their reaction (in 1/3 of the cases) and stronger (up to 7/8 of the cases) according to the structure of ecological environments in their dynamic row.

As regards the type of reaction line 457 was relatively closest to the standard cultivar, while line 449 was furthest from it.

For the individual characters the specificity of lines reaction norm was manifested to varying degrees, from very high for the boll weight, where there was no coincidence with the standard cultivar, to average – for the seed cotton yield, where half of the lines were similar to the standard cultivar by the type of their reaction.

In view of effective use of the studed lines in the future breeding programs, the selection strategy should be complied with their specific reaction norm across the three years. The most adoptable lines with a convex type of regression could be used in future breeding programs to improve the adaptability of new varieties.

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