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Ecological stability and plasticity of maize hybrids in different groups of ripeness

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Abstract. *Ecological stability and plasticity of maize hybrids in different groups of ripeness – Knezha 307, Knezha 435, Knezha 509 and Knezha M625 by the traits grain yield and length of the ear was evaluated. The ecological parameters were determined by using the method of Eberhart and Russell (1966) and of Pakudin and Lopatina (1984). In the period of study (2014-2017) the hybrids demonstrate different plasticity and stability by the examined traits. The results of the analysis of the variances demonstrate reliable differences of the hybrids and the conditions for the two traits and primarily reliable interaction genotype – environment. The variances of the regression Si^2 of all hybrids for the trait grain yield reliably differ from their theoretical value which determines them as plastic, i.e. responsive to more favourable conditions of growth. According to the values of bi the hybrid Knezha 435 (bi<1) is stable by the trait grain yield, the hybrids Knezha 307 and Knezha M625 are with values of bi close to one and have relatively medium stability and Knezha 509 with bi>1 is unstable. With reliable values of Si^2 for the trait length of the ear is only the hybrid Knezha M625. The ecological stability of the other hybrids was evaluated by the value of the coefficient of regression (bi). Increased stability by this trait is demonstrated by Knezha 435, followed by Knezha 509. Knezha 307 is with medium stability (bi=1.1) by the respective trait.*

Keywords: maize hybrids, ecological stability and plasticity, traits

Introduction

Maize is a main crop with high productive capabilities. By the cropped areas and as a feeding resource for the population of the Earth, it ranks third after wheat and rice (Tomov, 1997) and is first by production (Slavova, 2015). Its high and adaptive potential is a pre-condition for a broader area of spreading (Tomov, 1977). Maize is grown at higher variability of the environmental conditions, such as various soil types, temperature, rainfall, agrotechnique used, etc. The reaction of the different maize genotypes to the change of the environmental factors is of importance, i.e. the interaction genotype - environment. This aspect has been investigated by many researchers of genetics and selection of plants (Gatzovski, 1999; Vulchinkov, 2000; Vulchinkov and Vulchinkova, 2007; Vulchinkov et al., 2007; Ilchovska et al., 2016; etc.). A well-established method for evaluation of the ecological stability of the agricultural plants is the method of Eberhart and Russell (1966), applied at a later stage to maize by Pakudin and Lopatina (1984).

The purpose of this study is to perform an ecological evaluation of maize hybrids in different groups of ripeness by the traits grain yield and length of the ear in relation to the conditions of the year of growth and density of the crop.

Material and methods

The experimental work was conducted at the field of Maize Research Institute – Knezha in the period 2014-2017. In this study the productive capabilities and stability of the grain yield and the length of the ear of four maize hybrids in different groups of ripeness were defined: Knezha 307, FAO 300-399, Knezha 435, FAO 400-499, Knezha 509, FAO 500-599 and Knezha M625, FAO above 600. The hybrids were tested at the competitive varietal trails by a block method, at three repetitions, with a test plot of 20m^2 on typical black soil type, without irrigation, at six densities of the crops – 40000 pl/ha, 45000 pl/ha, 50000 pl/ha, 55000 pl/ha, 65000 pl/ha and 70000 pl/ha. The reaction of the hybrids by the traits grain yield and length of the ear was studied.

The statistical processing of the data obtained from the trails includes two-factored dispersion analysis with repetitions under the conditions and with parameters of stability and plasticity determined by Eberhart and Russell (1966) and Pakudin and Lopatina (1984).

Results and discussion

Meteorological reports for the period of the study and for 50 years' period (1920-1969) show significant variations of the average monthly temperature and rainfall sums during the vegetation period of the hybrids (April-September) (Figure 1).

Years 2015, 2016 and 2017 were drier than 2014. The sum of the rainfall during vegetation of maize in these years was between 291.2–397.1 l/m^2, and they were spread extremely irregularly month by month. The sum of the rainfall in 2015 and 2016 during the colder months April-June was higher compared to the critical for the growth of the maize in July

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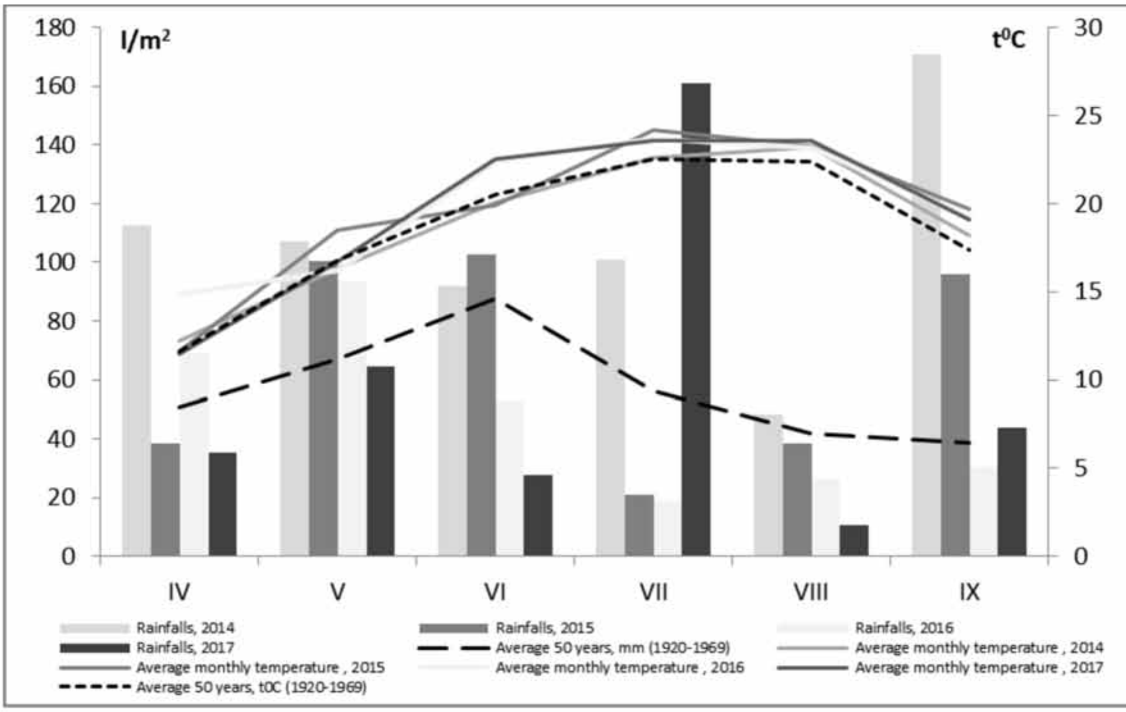

Figure 1. Sum of the rainfalls and average monthly temperatures during the vegetation of the maize in the period of the study

and August. This is very typical for 2016 (July – 18.7 l/m^2, August – 26.2 l/m^2). On the other hand, the deficit of rainfall in both years was combined with extremely high temperature.

The average values of the meteorological factors for 50 years' period (1920-1969) are closer to the ones in 2017 though with more irregular spreading of the rainfall and higher average monthly temperature. Only year 2014 appears to be more favorable for the growth of maize in the region, with enough and normally spread rainfall and lower average monthly temperature, which explains the better manifestations of the studied traits.

According to some scientists for more objective evaluation of the interaction 'genotype – environment' testing of the evaluated objects under a broader range of environmental conditions is needed (Gatzovski and Hristov, 1998; Gatzovski, 1999; Vulchinkova and Vulchinkov, 2002; Dimova et al., 2006; Zhuchenko, 2012; Dimitrova-Doneva et al., 2014; etc.).

In this study, some idea of the influence of the complex of the environmental conditions upon the studied traits of the hybrids is given through the influence of six densities of the crops and the reactions of the hybrids in case of change of the four consecutive crop years.

The results of the analysis of the variances of the hybrids confirm the difference in the environmental conditions during the years of the study. The values of the variances of the factors hybrids and the conditions for both traits are reliable, provided that the environmental conditions as an absolute value dominate the rest. The most important relation – the interaction 'hybrid' x 'environmental conditions' for both traits is also reliable. After proving its reliability, the behavior of the hybrids is determined by the parameters of stability: coefficient of regression - bi and its variance - Si^2 (Table 1).

Table 1. Analysis of variance for the characters studied

Source of variation	df	SS	MS	F
Hybrids	3	1) 856803.9 2) 317.7	285601.3^{++} 105.9^{++}	207.9 205.2
Environmental conditions	23	1) 7863056.5 2) 110.8	341872.0^{++} 4.8^{++}	248.9 9.3
Hybrids x Environmental conditions	69	1) 1559216.2 2) 99.0	22597.3^{++} 1.4^{++}	16.5 2.8
Replications in the environmental conditions	8	1) 15956.6 2) 5.3	1994.6 0.7	1.5 1.3
Errors	184	1) 252739.2 2) 94.9	1373.6 0.5	
Total	287	1) 10547772.4 2) 627.7		

*1) Grain yield, kg/ha; 2) Length of the ear, cm; $^{++}$Significance of P=1%

According to Pakudin and Lopatina (1984) the first parameter describes the linear behavior of each hybrid in case of a change of the environmental conditions, and the second one shows the extent to which the empirical and theoretical meanings correspond to the trait, located at the line of regression. When the values of bi are below 1 (bi<1), the hybrids show increased stability to the environmental conditions and if they are above 1 (bi>1) – increased responsiveness (plasticity) to the changes of these conditions. When the values of Si^2 do not differ reliably from 0, a good coincidence of the empirical and theoretical results is ascertained on the line of regression, and when $Si^2 \neq 0$ the behavior of the studied trait is more complex; the ecological instability increases.

The average values of the studied traits and the parameters of the ecological stability and plasticity are presented in Table 2. Upon comparison of the hybrids, the medium early hybrid Knezha 435 has the highest grain yield, followed by the late hybrid Knezha M625 and the early hybrid Knezha 307. This tendency was kept in the four years of the study but the stability of the grain yields was different.

Table 2. Average values of grain yield and length of the ear, and parameters of ecological stability and plasticity of the studied maize hybrids traits

Hybrids	Traits	$\bar{x}$	bi	Si^2
Knezha 307	1) Grain yield, kg/ha	8083.0	1.0	4497141.9
	2) Length of the ear, cm	20.6	1.1	0.6
Knezha 435	1) Grain yield, kg/ha	9161.3	0.7	1628337.2
	2) Length of the ear, cm	20.3	0.5	0.3
Knezha 509	1) Grain yield, kg/ha	7666.8	1.4	871525.3
	2) Length of the ear, cm	22.7	0.9	0.7
Knezha 625M	1) Grain yield, kg/ha	8316.8	0.9	774841.9
	2) Length of the ear, cm	21.7	1.6	1.1
		8307.1	1.0	
$\bar{x}$		21.3	1.0	

In regard to the trait length of the ear, Knezha 509 has the longest ears, the rest of the hybrids have relatively close length but different stability. According to the data from Table 2, the variances of regression of all hybrids for the trait grain of yield are with values reliably different from 0. In this case, the hybrids are considered unstable under the unfavorable conditions of 2015, 2016 and 2017 and responsive to change of the conditions of growth.

For the trait length of the ear, with reliable values of Si^2 is only the hybrid Knezha M625. All other genotypes do not differ reliably by this parameter from their theoretical values and their ecological stability is judged by the coefficient of regression (bi). The early hybrid Knezha 307 is characterized by the so called "medium stability". The other two hybrids are stable by this trait under the growth conditions.

Figures 2 and 3 graphically present the distribution of the hybrids by grain yield and length of the ear referred to the average values of the tests and of the values of bi referred to the theoretical value of bi=1. According to Figure 2, under the line of bi=1 are hybrid Knezha 435 and hybrid Knezha M625, relatively stable at high level of grain yield.

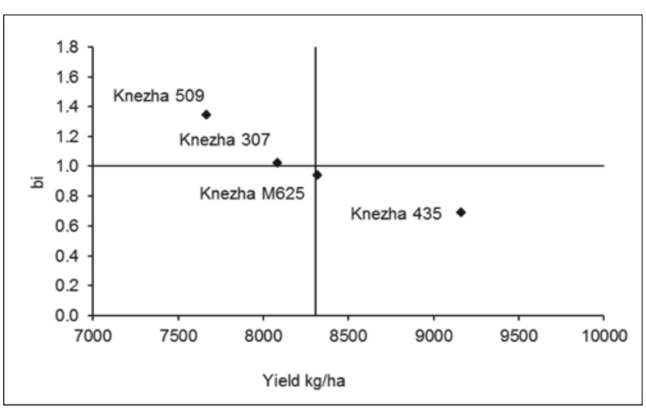

Figure 2. Distribution of the hybrids referred to the average values of the trait and bi

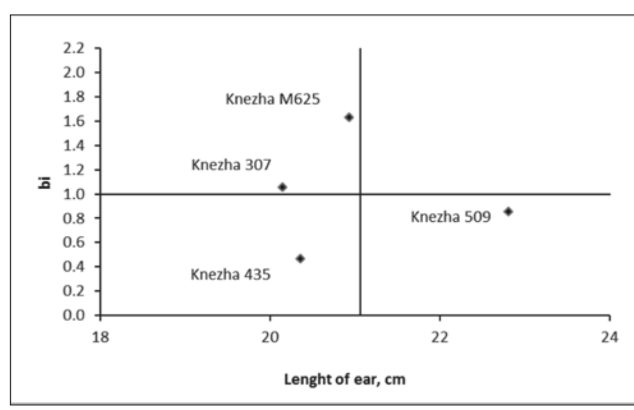

Figure 3. Distribution of the hybrids referred to the average values of the trait and bi

The yield of Knezha M625 as well as that of the hybrid Knezha 307, positioned above the line of bi=1, are with medium stability because their values of bi are closer to the theoretical model. Instability and plasticity at better growth conditions are demonstrated on this trait by Knezha 509.

Regarding the second trait (Figure 3) with a stable length of the ear are distinguished the hybrids Knezha 435 and Knezha 509 being under the line of bi=1. In addition, Knezha 509 has also the highest average value of the length of the ear. A medium stability by this trait is demonstrated by the early hybrid Knezha 307 with bi=1.1. The late hybrid Knezha M625 is with bi>1 (1.6) which confirms its relative instability under unfavorable conditions.

Conclusion

From the performed evaluation of the studied genotypes by both traits the following conclusions can be made: (a) For the studied period (2014-2017) the hybrids Knezha 307, Knezha 435, Knezha 509 and Knezha M625 demonstrate different stability and plasticity by the traits grain yield and length of the ear; (b) The results of the analysis of the variances of the studied hybrids demonstrate reliable differences of the variances of the factors hybrids and the conditions and, mostly, a reliable interaction genotype – environment; (c) For the trait grain yield the variances of the regression Si^2 of all hybrids reliably differ from their theoretical value which determines them as plastic, i.e. responsive to better conditions of growth. According to the values of bi, the hybrid Knezha 435 (bi<1) is stable by the trait grain yield, the hybrids Knezha 307 and Knezha M625 demonstrate medium stability with values of bi close to one and Knezha 509 is unstable (bi>1). With reliable values of Si^2 for the trait length of the ear is the hybrid Knezha M625. Ecological stability of the other hybrids is evaluated by the value of the coefficient of regression (bi). Increased stability by the trait demonstrates Knezha 435, followed by Knezha 509, while Knezha 307 is with medium stability (bi=1.1) for the respective trait.

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