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DETERMINATION OF ECOLOGICAL PLASTICITY AND STABILITY FOR FEMALE COMPONENTS OF MAIZE HYBRIDS

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Topicality. *In Ukraine, a sharp manifestation of unfavourable climate elements for growing hybrid maize seeds, brought to the fore the tolerance of the female components of hybrids to environmental factors limiting the formation of potential yield. Therefore, the study and evaluation of the ecological plasticity and stability of female components are an urgent issue of the modern seed production of maize hybrids.* ***Purpose.*** *To determine the requirements of the female components of maize hybrids to environmental conditions.* ***Materials and Methods.*** *During the research, 20 female components of maize hybrids bred by the SE Institute of Grain Crops of NAAS were used. The female components were single-cross sterile hybrids. The methodology of S. A. Eberhart, V. A. Russell, edited by A. Zykin and others, was used. The methodology is based on the calculation of two parameters: the linear regression coefficient b_i (ecological plasticity) and the dispersion σ_d^2 (ecological stability).* ***Results.*** *The grain yield of the female components was determined in five years of the research. The influence of environmental conditions on the yield of female components of maize hybrids was determined. The female components were distributed according to the requirements for growing conditions.* ***Conclusions.*** *The most valuable, highly intensive female components include sister hybrids Kros253C, Kros256C, Kros247C and Kros238C with high ecological plasticity and stability. To realize the potential yield, they need a high agrophone under favourable weather conditions. Female components Kros364M and Kros368M with high regression coefficient and root mean square deviation are less valuable because their high plasticity is combined with low yield stability. It is desirable to grow these female components only on a high agrophone under favourable climatic conditions to get the maximum yield. Hybrids Kros254M, Kros255M, Kros266S, Kros277M, Kros301M, etc., have low ecological plasticity and high yield stability. These hybrids will give maximum returns for minimum costs in extensive cultivation.*

Key words: *female component, yield, hybrid, adaptation, regression coefficient, root mean square deviation, stability, plasticity*

Introduction. Adaptation is the ability of biological systems to optimally adjust to environmental changes. The biological potential realisation within a particular agrophytogeocenosis created by human technological methods depends entirely on the genetic system of the variety. Therefore, the profitability of a variety (hybrid) depends on its adaptability, and in a broad sense, the feasibility of technological and ameliorative practices for plant habitat management [1].

Modern maize seed production is based on the use of heterosis in hybrids. Heterosis in certain traits is manifested when parental components are crossed, which may have different degrees of relationship with each other. The parental components of hybrids are mainly self-pollinated maize lines or single-cross and sister hybrids.

The use of single-cross or sister hybrids as the female component for the F_1 seed production of three-way and single-cross modified hybrid types is one of the options to reduce the costs of seed production and increase the yield of the main product [2]. Most domestic hybrids are produced according to this scheme, and therefore it is important to identify variations in seed yields of female components at hybridisation plots under different environmental conditions.

One of the requirements for the parental components of hybrids is resistance to environmental factors that limit the formation of potential yields, which is especially important in areas with a sharp manifestation of climate elements unfavourable to plants. For this reason,

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the study and assessment of their ecological plasticity and stability is an urgent issue in the modern agricultural production [3, 4].

Ecological plasticity is the level of adaptability of a variety to environmental conditions. The wide range of adaptability defines the high ecological plasticity. According to S. A. Eberhart and W. A. Russell [5], ecological plasticity of a genotype is the ability to change, which ensures the adaptability of the organism to environmental changes. *Ecological stability* is the ability of a variety to preserve its structure and functions under the influence of internal and external environmental factors [6].

The problem of correlation between potential productivity and ecological stability of varieties is becoming increasingly important in theory and practice. Knowledge of the variety's requirements to environmental conditions and its ability to respond to their improvement is now becoming crucial, as the market for seed varieties depends on the economic situation of farms.

Purpose. To determine the ecological plasticity and stability for the female components of maize hybrids in terms of seed yield under different weather conditions**.**

Materials and Methods. In 2015–2019, the experimental work was carried out in a special breeding crop rotation at SE Institute of Grain Crops of NAAS. Over the years of research, the weather conditions during the maize growing season were diverse. The year 2016 was relatively rainy (270.6 mm), and the driest years were 2015 (164.2 mm) and 2017 (149.4 mm). The air temperature also changed, exceeding the norm by 1.1 to 4.4 °C. In general, the weather conditions during the research were characterised by an alternation of both favourable and unfavourable environmental factors for plant growth and development.

During the research programme, 20 female components of maize hybrids bred by the SE Institute of Grain Crops of NAAS were used with their official and working names.

The female components were studied in different years, which allowed us to obtain information on environmental plasticity and peculiarities of the genotype's response to environmental changes. Differences in the female component yield from year to year identify that there is an interaction between variety and weather conditions, the effect of which should be analysed as a variance complex.

The methodology developed by S. A. Eberhart, W. A. Russell in the edition of A. Zykin et al. was used in the research [7, 8]. The methodology is based on the calculation of two parameters: the linear regression coefficient b_i (ecological plasticity) and the variance σ_d^2 (ecological stability).

For calculation of ecological plasticity, we used the average yield of female component (Y_i) on each year of research (Y_j). Average yield in the experiment (Y) was calculated by the formula 1:

$$Y = \Sigma Y_{ij} / v \times n, (1)$$

where ΣY_{ij} – sum of the yield of female components over the years of testing; v – number of female components; n – number of years.

Linear regression coefficient bi (ecological plasticity) was calculated using the following formula 2:

$$I_j = \Sigma Y_{ij} / v - \Sigma\ \Sigma Y_{ij} / v \times n, (2)$$

where ΣY_{ij} – sum of yield on all female components in certain year; $\Sigma\ \Sigma Y_{ij}$ – sum of yield for all female components for all years; v – number of female components; n – number of years.

Then, for each female component, the regression coefficient characterising ecological plasticity was calculated using the formula 3:

$$b_i = \Sigma Y_{ij} I_j / \Sigma I_j^2, (3)$$

where $\Sigma Y_{ij} I_j$ – sum of products of the certain female component yield for a certain year and the corresponding index of environmental effects; ΣI_j^2 – sum of squares for indices of environmental effects.

Theoretical yield for each female component was first calculated separately to determine the yield stability using formula 4:

$$Y_{ij} = x_i + b_i \times I_j, (4)$$

where x_i – average yield of the i^{th} female component for the years of testing, t/ha (i.e., x_i is equal to Y_i); $b_i \times I_j$ – product of the regression coefficient of the i^{th} female component on index of environmental effects.

Deviation of the actual yield of female component from the theoretical yield was determined by the formula 5:

$$\sigma_{ij} = Y_{ij} - x_i, (5)$$

where Y_{ij} - actual yield of a certain female component for a certain year, c/ha;
x_i – theoretical yield of a certain female component for a certain year, c/ha.

Root mean square deviation (ecological

stability) was calculated using the formula 6:

$$\sigma_d^2 = \Sigma\sigma_{ij}^2 / (n - 2), (6)$$

where $\Sigma\sigma_{ij}^2$ – sum of squares of deviations between actual and theoretical yields;
n – number of years.

Results. In 2015–2019, we studied the grain yield of 20 sterile female components (single-cross and sister hybrids), which averaged 4.24 t/ha (Table 1). The yield varied significantly, with a coefficient of variation over the years from 10.9 % to 15.6 % (Table 2). The minimum yield was 2.85 t/ha (Kros268C) in 2016, and the maximum yield was 6.74 t/ha (Kros368M) in 2019. The most significant yield fluctuations were observed in 2019 (V=15.6 %), 2018 (V=15.2 %) and 2015 (V=15.1 %). Thus, the influence of environmental effects on the female component yield of maize hybrids is evident.

We have calculated the indices Ij, the totality of which characterizes the variability of the growing conditions of female components. The indices of environmental effects (I_j) can be both positive and negative. The best conditions for the genotype development are formed when the environment index is positive, and the worst - when it is negative. According to our data, the most favourable years of testing were 2019 (I_j = 0.9837) and 2015 (I_j = 0.0427); the worst conditions for testing were in 2017 (I_j = -0.5273), 2018 (I_j = -0.4008) and 2016 (I_j = -0.0983).

Over the years of research, the most productive hybrids were Kros238C (4.81 t/ha), Kros256C (4.95 t/ha), Kros364M (4.75 t/ha), Kros368M (5.05 t/ha), Kros253C (4.87 t/ha), Kros247C (4.99 t/ha), Kros244M (4.60 t/ha). The lowest yield was in hybrids Kros222C (3.87 t/ha), Kros160C (3.68 t/ha), Kros266C (3.56 t/ha), Kros301M (3.70 t/ha), Kros197C (3.56 t/ha) and Kros268C (3.66 t/ha). (Table 1).

Table 1. Indicators of grain yield, ecological plasticity and stability in female components of maize hybrids

No	Female component	2015	2016	2017	2018	2019	$\sum Y_i$	Y_i	b_i	σ_d^2
		Yield, t/ha								
1	Kros222C	3.98	4.06	3.59	3.01	4.69	19.33	**3.87**	**0.906**	**0.12**
2	Kros159C	4.29	4.02	3.83	3.29	5.01	20.44	**4.09**	**0.972**	**0.09**
3	Kros160C	3.86	3.62	3.45	2.96	4.51	18.40	**3.68**	**0.875**	**0.07**
4	Kros254M	4.51	4.68	3.99	4.08	4.75	22.01	**4.40**	**0.470**	**0.06**
5	Kros255M	3.85	4.20	3.36	3.95	4.56	19.92	**3.98**	**0.622**	**0.08**
6	Kros266C	3.56	3.85	3.02	3.41	3.98	17.82	**3.56**	**0.515**	**0.07**
7	Kros277M	4.29	3.65	3.91	3.88	5.05	20.78	**4.16**	**0.829**	**0.08**
8	Kros301M	3.56	3.85	3.27	3.25	4.56	18.49	**3.70**	**0.869**	**0.03**
9	Kros238C	5.02	4.29	4.52	4.21	6.01	24.05	**4.81**	**1.152**	**0.11**
10	Kros256C	4.95	4.82	4.62	4.13	6.25	24.77	**4.95**	**1.265**	**0.07**
11	Kros364M	4.59	4.21	3.69	4.98	6.28	23.75	**4.75**	**1.423**	**0.32**
12	Kros288C	3.78	4.15	3.26	3.86	5.01	20.06	**4.01**	**0.999**	**0.08**
13	Kros197C	3.56	3.84	3.21	2.98	4.23	17.82	**3.56**	**0.740**	**0.07**
14	Kros245M	4.24	4.53	3.51	3.69	4.89	20.86	**4.17**	**0.858**	**0.09**
15	Kros250M	3.98	4.26	3.35	3.68	4.87	20.14	**4.03**	**0.917**	**0.05**
16	Kros368M	5.24	4.59	3.68	5.01	6.74	25.26	**5.05**	**1.731**	**0.25**
17	Kros268C	3.02	2.85	3.59	4.19	4.65	18.30	**3.66**	**0.600**	**0.61**
18	Kros253C	5.01	4.52	3.85	4.64	6.34	24.36	**4.87**	**1.493**	**0.08**
19	Kros247C	5.45	4.69	4.26	4.01	6.52	24.93	**4.99**	**1.645**	**0.10**
20	Kros244M	5.01	4.25	4.39	3.67	5.67	22.99	**4.60**	**1.120**	**0.19**
	$\sum Y_j$	85.75	82.93	74.35	76.88	104.57	**424.48**	-	-	-
	Y_j	4.29	4.15	3.72	3.84	5.23	**4.24**	**-**	-	-

We calculated the linear regression coefficient of the female component yields b_i to determine the response of female components to environmental changes. In this case, the regression coefficient can be a measure of the degree of response of the genotype to environmental changes. Thus, the regression coefficient estimates plasticity in the genetic sense and stability in the broader sense, i.e., an indicator of the stability of the phenotypic values of a trait under different environmental effects. It can be greater than or less than 1, and can also be equal to 1.

The higher the value of the coefficient (b_i>1), it means that the female component is more sensitive. In the case of b_i<1, the female component responds less strongly to environmental changes than the entire hybrid set on average. When b_i=1, there is a complete response of the female component yield to fluctuations in growing conditions.

Table 2. Variation parameters of grain yield in female components of maize hybrids

Indicators	2015	2016	2017	2018	2019	Average
Average	4.29±0.31	4.15±0.21	3.72±0.21	3.84±0.28	5.23±0.39	4.24±0.24
Coefficient of variation (V), %	15.1	10.9	11.9	15.2	15.6	11.8
Lim	3.02÷5.45	2.85÷4.82	3.02÷4.62	2.96÷5.01	3.98÷6.74	3.56÷5.05
n	20	20	20	20	20	20

The parameters of plasticity (regression coefficient) and stability (root mean square deviation from the regression line) make it possible to predict the behaviour of the female component in production conditions. According to our results, the hybrids Kros254M (bi=0.470), Kros255M (b_i=0.622), Kros266S (b_i=0.515) (Table 1) are the least sensitive to the improvement of growing conditions. Hybrids with regression coefficients significantly below 1 are of the extensive type (with low environmental plasticity). They respond poorly to environmental changes, are unable to provide high yields under intensive farming, but under adverse conditions they reduce yield less than intensive hybrids.

Among the whole set of female components, the most sensitive to changes in the testing years were Kros368M (b_i=1.731), Kros247S (b_i=1.645), Kros253S (b_i=1.493), Kros364M (b_i=1.423) (with an increase in the average yield by 1 t/ha, it increased by 1.731–1.423 t/ha). Female components with a regression coefficient significantly higher than 1 are of the intensive type, and they respond well to improvement of growing conditions. However, under unfavourable weather conditions of the year, as well as on a low agrophone, they are sharply reduced in productivity.

Hybrids Kros222S (b_i=0.906), Kros159S (b_i=0.972), Kros288S (b_i=0.999), Kros250M (b_i=0.917) have the regression coefficient (b_i) closest to 1, so they respond correspondingly to changes in growing conditions.

Subsequently, we determined the stability parameters σ_d^2 (root mean square deviation from the regression line) (Table 1). The smaller the root mean square deviation of the actual values from the theoretically expected ones (stability coefficient), the more stable the parental component is. In our experiment, the most stable hybrids were Kros301M (σ_d^2=0.03) and Kros250M (σ_d^2=0.05); and less stable were Kros268C (σ_d^2=0.61) and Kros364M (σ_d^2=0.32).

As follows from the model of S. A. Eberhart and W. A. Russell [5], the most valuable female components are those that have b_i>1 and σ_d^2 is close to zero. In this case, these are the hybrids Kros253C (b_i=1.493; σ_d^2=0.08), Kros256C (b_i=1.265; σ_d^2=0.07), Kros247C (b_i=1.645; σ_d^2=0.10) and Kros238C (b_i=1.152; σ_d^2=0.11). These hybrids are classified as high-intensity. They are responsive to improvement of growing conditions and are characterised by stable yield. Female components Kros364M (b_i=1.423; σ_d^2=0.32) and Kros368M (b_i=1.731; σ_d^2=0.25) with high regression coefficient (b_i) and root mean square deviation (σ_d^2) are less valuable, as their high sensitivity is combined with low yield stability. Hybrids Kros254M (b_i=0.470; σ_d^2=0.06), Kros255M (b_i=0.622; σ_d^2=0.08), Kros266S (b_i=0.515; σ_d^2=0.07), Kros277M (b_i=0.829; σ_d^2=0.08), Kros301M (b_i=0.869; σ_d^2=0.03), etc. with b_i<1 and close to zero σ_d^2 weakly respond to the improvement of external conditions (semi-intensive), but have a fairly high yield stability.

Conclusions

During the testing period, the yield of 65 %

of female components was more than 4 t/ha. The most high yielding hybrids were Kros238S (4.81 t/ha), Kros256S (4.95 t/ha), Kros364M (4.75 t/ha), Kros368M (5.05 t/ha), Kros253S (4.87 t/ha), Kros247S (4.99 t/ha), Kros244M (4.60 t/ha).

The most valuable, high-intensity, female components of Kros253C (b_i=1.493; σ_d^2=0.08), Kros256C (b_i=1.265; σ_d^2=0.07), Kros247C (b_i=1.645; σ_d^2=0.10) and Kros238C (b_i=1.152; σ_d^2=0.11) were identified. They have high ecological plasticity and stability and can be grown in different environmental conditions, but will provide maximum yield on a high agrophone under favourable weather conditions.

The parental components Kros364M (b_i=1.423; σ_d^2=0.32) and Kros368M (b_i=1.731; σ_d^2=0.25) with high regression coefficient (b_i) and root mean square deviation (σ_d^2) are less valuable, as their high plasticity is combined with low yield stability. These female components should be grown only on a high agrophone under favourable weather conditions, when they will give the maximum yield.

The hybrids Kros254M (b_i=0.470; σ_d^2=0.06), Kros255M (b_i=0.622; σ_d^2=0.08), Kros266C (b_i=0.515; σ_d^2=0.07), Kros277M (b_i=0.829; σ_d^2=0.08), Kros301M (b_i=0.869; σ_d^2=0.03), etc, have low ecological plasticity (b_i) and high yield stability (σ_d^2). They are most suitable for use on extensive agrophone, where they will give maximum return at minimum cost.

Studying the reaction of parental components to environmental changes will allow to select elements of cultivation technology and obtain the optimal amount of high-quality seeds of maize hybrids.

References

1. Lytun, P. P., Kyrychenko, V. V., Petrenkova, V. P., Kolomatskaia, V. P. (2007). *Adaptivnaya selektsyya: teoriya i tekhnolohiya na sovremennom etape* [Adaptive breeding: theory and technology at the current stage]. Kharkiv: N. p. [in Russian]
2. Dziubetskyi, B. V., Cherchel, V. Yu., Kyrpa, M. Ya., Aldoshyn, A. V., Satarova, T. M., Cherenkov, A. V., Liashenko, N. O., Bodenko, N. A..(2019). *Nasinnytstvo kukurudzy: navchalnyi posibnyk* [Corn seed production: a study guide] Kyiv: Agrarian science. [In Ukrainian].
3. Korzun, O. S., Bruylo, A. S. (2011). *Adaptivnye osobennosti selektsyi i semenovodstva selskokhozyaystvennykh rasteniy: posobiye* [Adaptive features of selection and seed breeding of agricultural plants: manual]. Hrodno: HHAU. [in Russian]
4. Zhuchenko, A. A. (1980). *Ekolohycheskaya genetika kulturnykh rasteniy* [Ecological genetics of cultivated plants]. Kyshynev: Shtyyntsa. [in Russian]
5. Eberhart, S. A., Russell, W. A. (1966). Stability parameters for comparing varieties. *Crop Science, 6 (1),* 36–40. http://dx.doi.org/10.2135/cropsci1966.0011183X000600010011x
6. Detsyna, A. A., Illarionova, Y. V., Shcherbinina, V. O.. (2019). Estimation of environmental plasticity and stability of confectionary sunflower varieties. *Maslichnyye kultury* [Oil crops], *3* (179). 35–39. DOI: 10.25230/2412–608X–2019–3–179–35–39. [in Russian]
7. Zykin, V. A., Meshkov, V. V., Sapega, V. A. (1984). *Parametry ekologicheskoy plastichnosti selskokhozyaystvennykh rasteniy, ikh raschet (metodicheskiye rekomendatsyy).* [Parameters of ecological plasticity of agricultural plants, their calculation (guidelines)]. Novosibirsk: VASKhNIL, SO. [in Russian]
8. Hudz, Yu. V., Lavrinenko, Yu. A. (1997). *Teoriya i praktika adaptivnoy selektsyi kukuruzy* [Theory and practice of adaptive selection of corn]. Kherson, BORYSFEN-polyhrafservys. [in Russian]

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Черчель В. Ю., Алдошин А. В., Свініцький Л. М. Визначення екологічної пластичності та стабільності жіночих компонентів гібридів кукурудзи. *Зернові культури. 2022. 6 (2). 31–36.*

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Актуальність. В стресових погодних умовах, при вирощуванні гібридного насіння кукурудзи, на перший план виходить стійкість жіночих компонентів гібридів до екологічних факторів середовища, що лімітують формування потенційно можливої урожайності. Тому, вивчення та оцінка екологічної пластичності та стабільності жіночих компонентів відносно врожайності насіння є актуальним питанням сучасного процесу виробництва насіння гібридів кукурудзи. **Мета дослідження** – визначити екологічну пластичність і стабільність жіночих компонентів гібридів кукурудзи відносно врожайності насіння за різних погодних умов**. Матеріали і методи.** При виконанні досліджень використано 20 дволінійних стерильних гібридів жіночих компонентів селекції ДУ ІЗК НААН. Застосовували методику, розроблену Eberhart S. A., Russel W. A., яка ґрунтується на обчисленні двох параметрів: коефіцієнта лінійної регресії b_i (екологічна пластичність) та дисперсії σ_d^2 (екологічна стабільність). **Результати.** Визначили урожайність зерна жіночих компонентів за п'ять років дослідження та встановили вплив умов середовища на цей показник. **Висновки.** До найбільш цінних, високоінтенсивних жіночих компонентів віднесені сестринські гібриди Крос253С, Крос256С, Крос247С та Крос238С, з високою екологічною пластичністю і стабільністю. Свою потенціальну урожайність вони реалізують на високому агрофоні при сприятливих погодних умовах. Гібриди Крос364М і Крос368М з високими показниками коефіцієнта регресії та середньоквадратичного відхилення бажано вирощувати тільки на високому агрофоні при сприятливих кліматичних умовах. Виділено гібриди Крос254М, Крос255М, Крос266С, Крос277М, Крос301М, та ін., з низькою екологічною пластичністю і високою стабільністю врожайності, які краще використовувати на екстенсивному фоні.

Ключові слова: *жіночий компонент, урожайність, гібрид, адаптація, коефіцієнт регресії, середньоквадратичне відхилення, стабільність, пластичність*