Evaluation of experimental corn hybrids on the development of morphometric parameters

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Abstract. The article presents the results of the study of new hybrid combinations of rediploid maize lines obtained by the diallelic scheme of crossing. The experiment involved simple hybrids of six homozygous lines. The degree of manifestation of heterosis according to the main morphometric parameters of the plant (stem length, ear height, panicle length, stem diameter), as well as the combinative ability of lines and components of genetic dispersion, was revealed. The ways of possible use of lines and hybrids in the breeding process are noted - for tall stature, resistance to lodging, manufacturability. The influence of overdominance in the manifestation of the length of the panicle and the diameter of the stem and the predominance of additive effects in the formation of the height of the ear were noted. Analysis of the components made it possible to identify the number of genes or groups of genes that influenced the manifestation of traits in 2021 (stem length - 1-2, cob height - 2-3, panicle length - 1-2, stem diameter - 2-3). A significant influence of cultivation conditions on the manifestation of the length of the stem, the height of the cob, the length of the panicle, and the diameter of the stem was noted.1.

1. Introduction

In corn breeding, a special role is given to morphometric parameters that show a correlation with the yield of grain and green mass, as well as affecting the manufacturability of cultivation. The effectiveness of the choice of parental lines and obtaining highly productive genotypes depends on the nature of the manifestation of traits. Many quantitative traits are characterized by complex polygenic control. Success in the selection improvement of such traits, including stem length, cob height, panicle length, and stem diameter, is largely due to the availability of information on the nature of inheritance and genetic control obtained under specific growing conditions [9]. An essential condition for selection for heterosis is the assessment of the source material not only for the economically valuable traits of the lines themselves, but also for their combinational value [4]. Analysis of the results of combining ability allows you to optimize the work with breeding material, select the best components for obtaining new highly heterotic hybrids. The most complete information about the combination ability of breeding forms is obtained in the system of diallel crosses [5;9].

The length of the stem determines the direction of use of the hybrid, the manufacturability of its cultivation. When creating a hybrid of the silage direction, it is desirable to use tall forms, which will
increase the yield by increasing the leaf mass. The model of a grain-oriented hybrid involves the use of relatively low-growing plants suitable for direct combine harvesting [7]. The height of the cob is also an important morphological feature that determines the manufacturability of corn harvesting. The threshold height of the cob when harvesting corn with minimal losses is considered to be 50 cm. However, too high cob placement is also undesirable, since losses increase due to the design features of corn harvesters [3]. The parameters of the grain hybrid idioype suggest the formation of low-growing plants with a relatively high cob initiation and a small panicle size [2]. In addition, when obtaining hybrids grown on a fertile basis with panicle clipping, it acquires the value of the panicle length, which to a certain extent affects the level of cut, and hence the quality of the set seeds.

2. Materials and methods
The aim of the research is to establish on a new source material (rediploid maize lines) the manifestation of the effects of combining ability, as well as some components of genetic dispersion by morphometric parameters.

Field experiments were carried out in 2021. on the experimental field of the Russian Research Institute for Sorghum and Maize "Rossorgo" (Saratov) in accordance with the methodology [1]. The climate of the region is characterized as sharply continental. The soil of the experimental plot is southern low-humus, medium-thick, heavy loamy chernozem. The density of the soil is 1.20 - 1.32 g/cm³, the lowest moisture capacity (LW) of the 0-30 cm layer is 101.1 mm, and the 0-100 cm layer is 295.6 mm. The experiment included simple hybrids (30 combinations) obtained by the full diallel scheme (method 1 Griffing B.) of six rediploid maize lines created by diploidization of haploid plants obtained using a haploinducer line [11]. The accounting area of the plot is 7.7 m². Plant density (55 thousand plants/ha). Agrotechnics in the experiment - zonal, developed at the Russian Research Institute for Sorghum and Maize "Rossorgo". Appropriate methods were used to carry out accounting and data processing [6;9]. The combination ability of the lines was determined by the first method of B. Griffing [11]. Genetic analysis of the components of the genetic dispersion was carried out according to B.I. Hayman [12].

3. Results

![Figure 1](image_url)

*Figure 1. Morphometric parameters of rediploid maize lines and average group values of hybrids, 2021. (* footnote: P – line average, F – average group value of hybrids).*
**Figure 2.** Effects of GCA in rediploid maize lines by morphometric parameters.

**Figure 3.** SCA dispersion of rediploid maize lines by morphometric parameters.
Table 1. Effects of SCA ($\sigma_i$) and heterosis level (Hist) in corn hybrid combinations, 2021.

| Combination  | Stem length | Cob height | Panicle length | Stem diameter |
|--------------|-------------|------------|----------------|---------------|
|              | $\sigma_i$  | $G_{ist}$  | $\sigma_i$     | $G_{ist}$     |
| OG1/OG2      | -0.2        | -4.3       | 2.7            | -9.5          | 0.2           | 7.2           | -0.83         | 27.3          |
| OG1/OG3      | 2.0         | -5.3       | 0.7            | -8.1          | 2.3           | 9.9           | 3.19          | 23.6          |
| OG1/OG4      | 27.9        | 30.4       | 6.5            | -4.4          | 4.6           | 15.5          | 1.88          | 26.6          |
| OG1/OG5      | 0.3         | 5.1        | 2.0            | -0.7          | 0.5           | 5.5           | -0.24         | 12.8          |
| OG1/OG6      | 1.5         | -4.1       | 3.9            | -2.9          | 0.9           | 6.7           | 0.88          | -6.2          |
| OG2/OG3      | 11.8        | 14.6       | 13.2           | 35.9          | -6.0          | -12.2         | 4.44          | 28.8          |
| OG2/OG4      | -11.1       | 12.7       | -5.1           | 6.2           | 1.2           | 2.1           | 2.35          | 47.0          |
| OG2/OG5      | 14.7        | 29.7       | 4.9            | 20.5          | 2.4           | 8.1           | 7.08          | 42.2          |
| OG2/OG6      | 17.2        | 17.5       | 1.6            | 6.8           | 8.3           | 25.6          | 0.52          | 10.4          |
| OG3/OG4      | 11.1        | 14.3       | 5.3            | 17.1          | -0.1          | -0.1          | 3.20          | 52.3          |
| OG3/OG5      | 8.1         | 10.0       | 2.8            | 13.6          | 4.7           | 9.0           | 1.65          | 45.6          |
| OG3/OG6      | -14.7       | -7.3       | -9.4           | -5.2          | -0.3          | -8.0          | -2.48         | 15.5          |
| OG4/OG5      | 14.0        | 30.9       | 4.7            | 12.4          | 2.7           | 19.3          | 2.06          | 23.1          |
| OG4/OG6      | -1.2        | 6.8        | 1.2            | -3.6          | 2.0           | 1.0           | 1.81          | 24.5          |
| OG5/OG6      | 1.0         | 1.6        | 3.0            | 11.8          | -3.8          | -11.2         | -1.78         | -3.0          |

Table 2. Components of genetic dispersion by morphometric parameters of rediploid maize lines, 2021.

| Component    | Stem length, sm | Cob height, cm | Panicle length, sm | Stem diameter, mm |
|--------------|-----------------|----------------|---------------------|-------------------|
|              | $\bar{X}$±$S_{\bar{X}}$ | $\bar{X}$±$S_{\bar{X}}$ | $\bar{X}$±$S_{\bar{X}}$ | $\bar{X}$±$S_{\bar{X}}$ |
| D            | 73.5±49.9       | 365.1±17.1*    | 49.8±9.3*           | 3.6±1.4*          |
| F            | 177.1±128.1     | 85.0±42.8      | 17.1±22.8           | 2.6±3.4           |
| H₁           | 2008.4±145.0*   | 307.3±46.3*    | 110.1±23.7*         | 12.5±3.6*         |
| H₂           | 1612.1±133.8*   | 253.6±42.0*    | 96.6±21.1*          | 10.6±3.4*         |
| h            | 1949.5±90.8*    | 561.7±28.3*    | 165.2±14.2*         | 22.2±10.5*        |
| E            | 19.3±22.3*      | 7.4±7.0*       | 9.1±3.5*            | 2.8±0.5*          |
| m11-m10      | 22.2            | 11.9           | 6.5                 | 2.4               |
| $\sqrt{H_1/D}$ | 5.23           | 0.90           | 1.49                | 1.87              |
| H₂/4H₁       | 0.20            | 0.21           | 0.22                | 0.22              |
| h/ H₂        | 1.21            | 2.22           | 1.71                | 2.09              |
| r            | -0.84           | -0.90          | -0.32               | -0.79             |
| Fr 1         | эпистаз         | -558.6±58.3*   | 106.2±31.9*         | 2.4±4.7           |
| Fr 2         | -207.0±168.4    | эпистаз        | -56.8±31.9          | 10.2±4.7*         |
| Fr 3         | 702.1±168.4*    | 129.8±58.3*    | 77.3±31.9*          | 6.2±4.7           |
| Fr 4         | эпистаз         | 421.3±58.3*    | -97.8±31.9*         | 5.6±4.7           |
| Fr 5         | -524.8±168.4*   | 143.3±58.3*    | 56.2±31.9*          | -12.9±4.7*        |
| Fr 6         | 738.1±168.4*    | 289.0±58.3*    | 17.4±31.9           | 4.0±4.7           |
4. Discussion
The analysis of the data made it possible to reveal the significance of the morphometric parameters of new rediploid lines and the average group indicators of hybrids. (figure 1). At the same time, the variation of signs in the lines was revealed within the following limits: stem length - 126.6-186.0 cm; cob laying height - 34.0-84.0 cm; panicle length - 31.7-52.0 cm; stem diameter - 1.37-1.90 cm.

The variability of the average group indicators of hybrids ranged from 176.9-204.0 cm along the length of the stem, 67.5-88.3 cm along the height of the cob, 46.3-56.1 cm along the length of the panicle, 1.81-2.10 cm in stem diameter.

The general combination ability (GCA) expresses the average value of a line in hybrid combinations with its use and is measured by the average value of the deviation of the trait in all its $F_1$ hybrids from the general average for all forms of the diallel scheme. The results of the analysis of the combination ability of maize lines indicate high effects of GCA along the length of the stem in the lines OG 2, OG 3, OG 4, OG 5 (figure 2). At the same time, line OG 5 was characterized by a low value of SCA dispersion, which indicates that hybrids with the participation of this line have approximately the same trait expression (figure 3). The high level of the GCA effect in the lines OG 2 and OG 4 is combined with a significant contribution of the SCA dispersion, from which it can be concluded that the high GCA of these lines is the result of the existence of individual combinations that significantly exceed the average value and hybrids with a low stem length.

Differences in the studied material in terms of general and specific combining ability turned out to be highly significant in terms of the height of the cob, the length of the panicle, and the diameter of the stem. A high GCA effect was observed in lines OG 2, OG 3, OG 4 in terms of cob height, lines OG 1, OG 2, OG 6 in panicle length, and lines OG 2 in stem diameter. The low values of the GCA effect and the dispersion of the SCA of the lines OG 1 and OG 6 in terms of the height of the cob indicate that these lines are undesirable for use in breeding for trait enhancement. Since the stem thickness indices may indicate the resistance of plants to lodging, special attention should be paid to the OG 2 line, which is characterized by a high GCA effect and an average SCA variance.

When analyzing the data, the effects of SCA hybrid combinations and the degree were revealed. When analyzing the data, the effects of SCA hybrid combinations and the degree of manifestation of heterosis were revealed (table 1). Heterosis true (Hist.) characterizes a stronger manifestation of the trait in $F_1$ compared to the best parental form. For the evaluation, the method of calculating the coefficients of true heterosis was used: $\text{Hist} = \frac{(F_1 - P_{\text{best}})}{P_{\text{best}}} \times 100\%$. At the same time, it was found that the degree of correlation between the indicators of the effect of SCA and heterosis is 0.46**. Thus, a high degree of manifestation of true heterosis suggests the presence of a high SCA effect.

The method of diallel crosses also makes it possible to establish the nature of the inheritance of quantitative traits, to obtain information about other genetic properties of the analyzed forms. The depth of the obtained genetic conclusions and the relatively low requirements for the volume and structure of the experiment allow the Hayman method to remain relevant in selection and genetic studies [8]. The analysis of variance of the Wr-Vr values showed that the additive-dominant model is adequate: according to the length of the stem, with the exclusion of the lines OG 1, OG 4; according to the height of the cob, the lines OG 2. No epistatic effects of genes were found in determining the length of the panicle and stem diameter.

In the experiment, there is a negative correlation between the severity of the trait and dominance in parental lines: -0.84 (stem length), -0.90 (cob height), -0.32 (panicle length), -0.79 (stem diameter). Significantly significant indicators of the dominance components ($H_1, H_2$), in absolute value, exceed the values of the D component, which characterizes the additive effect of genes on stem length, panicle length, and stem diameter. Dominance according to the studied parameters is directed towards parental forms with a greater severity of the trait ($m_{11}-m_{10} > 0$). The ratio $\sqrt{H_1/D}$ along the panicle length and stem diameter is greater than 1, which indicates a positive effect of overdominance in the manifestation of these parameters. A significant excess of the value of the "D" component over the components of the dominant action ($H_1, H_2$) indicates the predominance of the effects of the additive action in the formation of the height of the cob.
A significant influence in 2021 on the manifestation of such parameters as stem length, cob height, panicle length, stem diameter was exerted by the paratypical component of the dispersion of cultivation conditions (E). The values of the H2/4H1 ratio are less than the theoretical value (0.25), which indicates an uneven distribution of alleles with positive and negative effects. The analysis of the components indicates that, depending on the growing conditions, 1-2 genes or groups of genes affect the manifestation of the stem length, 2-3 cob height, 1-2 panicle length, 2-3 stem diameter.

The relative contribution of genes with additive and dominant effects in the development of a trait characterizes the significance of the genetic component Fr. Individual lines are characterized by significantly significant indicators of this component. Fr values for plant height are positive and significant in lines OG 3 OG 6, which indicates a positive direction of dominance in these lines. According to the height of cob attachment, positive Fr values were noted in lines OG 3, OG 4, OG 5, OG 6.

5. Conclusion
Evaluation of the combination ability of rediploid lines by morphometric parameters suggests that the lines OG 2, OG 3, OG 4 can be used to obtain hybrids that form a long stem and a high distance from the soil to the cob. Particular attention should be paid to the OG 2 line, which is characterized by a high GCA effect and an average value of the SCA dispersion along the stem diameter, which can be used in breeding for resistance to lodging.

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