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GENETIC ANALYSIS FOR COMBINING ABILITY AND ESTIMATION OF SOME GENETIC PARAMETERS OF YIELD AND ITS COMPONENTS IN MAIZE USING HALF DIALLEL CROSS

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Abstract: A field experiment was carried out at the field crops research station of the Agricultural Research Abu-Ghraib during the season of 2014, in order to study the general and specific combining abilities and gene action heritability. As well as, the average degree of dominance for yield and its components within the method of the half diallel cross using the fixed model, among six inbred lines of maize: (Sy-2, Zm-9, AM-65, ART-A2, ART-C19, and Sy-35) to produce 15 hybrids. Seeds of genotypes (6 inbred lines + 15 hybrids). The results of the genetic analysis showed that there were highly significant differences for mean squares of general and specific combining abilities for all studied traits and the ratio of the variance component of σ2gca to the σ2sca was less than one for all studied traits. The effects of GCA were positive and negative among parents for all studied traits, where the inbred line (Sy-2) was shown a significantly superior GCA effect for ear length, number of rows per ear, number of grains per row, and 250-grain weight. The effects of SCA were positive and negative among crosses for all studied traits. The hybrid (Sy-2×ART-2) gave the highest SCA effect for ear length, number of rows per ear, number of grains per row and grain yield per plant, while the hybrid (AM-56×ART-2) gave the highest effect for 250-grain weight. The values of non-additive genetic variance (σ2D) were more than that of additive genetic variance (σ2A) for all studied traits. The values of the average degree of dominance (ā) were more than one for all studied traits, this indicated over-dominance control for these traits.

Keywords: Zea Mays L., GCA, SCA, Gene Action, Heritability.

1. Introduction

Yellow maize (Zea mays L.) ranks third after wheat and rice in terms of area and production in the world, including Iraq for its importance in human and animal feeding and in industrial and medical uses. In addition, it has a characteristic that distinguishes it from other cross-pollinated crops, since the tasseling is separate from silking in the plant, which facilitates the process of hybridization and the production of hybrids. Furthermore, plant breeders and geneticists make effort to develop new genotypes of yellow maize that have high productivity and good quality specifications, where sufficient information by analyzing the combining ability, the components of phenotypic variation, and some genetic parameters of the grain yield and its components required for achieving these goals. However, the diallel analysis con-siders as one of the most important systems that gives more information in this regard, which is the half diallel cross-system that widely used in plant breeding because it is one of the most efficient breeding systems in testing the general combining ability of inbred lines to diagnose the best and identify their weaknesses. As well as, their strengths in performance and use the best in educe hybrids, also in testing the specific combining ability of hybrids to determine the best hybrids that can contribute to increasing productivity.

Moreover, identifying its genetic behavior by estimating the additive genetic variance (σ2A) and the non-additive genetic variance (σ2D) and the average degree of dominance (ā) to identify the type of the most important gene action in inheriting the trait and determine the best breeding method to improve it. In addition, realizing the values of H2b.s% and H2n.s%, which means the amount of what the productive individuals in the trait convey to their offspring resulting from them in the first generation. Among the researchers who studied the combining abilities and the gene action of the yield and its components in the yellow maize by using half diallel cross between a number of pure inbred lines [1]–[3]. They found that there was a significant effect of the general and specific combining abilities and some of the studied traits were already governed by the non-additive gene action and some of the traits were already governed by the additive gene action.

Finally, the aim of this research is to elicit hybrids from pure inbred lines using half diallel cross and to conduct a genetic analysis of the general combining abilities for parents and specific combining abilities for hybrids. As well as, estimate some genetic parameters of the (σ2D) and (σ2A), the (ā), the values of H2 b.s% and H2n.s% to determine the best method of breeding and improvement that can be adopted to improve the yield of yellow maize.

2. Materials and Methods

The research was carried out in the spring and fall seasons of (2014) in the field crops research station of Agricultural Research Abu-Ghraib, where Six pure inbred lines of yellow maize: (Sy-2, Zm-9, AM-65, ART-A2, ART-C19 and Sy-35), obtained from the same station were used. The ground was well prepared from plowing, harrowing, leveling and fertilizing with compound fertilizer N: P (27:27) at a rate of 300 kg ha^{-1} mixed with the soil. Then, it is followed by dividing the field and opening the lines with a length of 5 m and a distance of 0.75 m between one line and another and by 8 lines for each inbred line. The inbred lines seeds were planted in mid-March in holes at a distance of 0.25 m between one hole and the other, with an average of two seeds in each hole; they were reduced to one plant in the 6-leaf stage. Furthermore, the crop service operations were performed from irrigation and fertilizing with urea fertilizer (N% 46) as a source of nitrogen by 300 kg ha^{-1}, was added in two batches the first when the plant height reached 30 cm and the second at the tasseling emergence.

The weed control operations were carried out with atrazine at a concentration of 85% after planting and before germination, at a rate of 3.25 kg ha^{-1}, Sesamia critica. As well as, the insect was controlled with diazinon 10% effective substance at a rate of 4 kg ha-1 by pruning the developing peak of plants twice, the first time when plants reached 5 leaves and the second after 20 days of the first control. Upon the emergence of silking in the plants of the inbred line and before the emergence of silking, they were bagged with paper bags to avoid open pollination and to ensure the required cross. As for the tasseling, they were wrapped in paper bags a day before the pollination procedure, after the pollen was released, all half diallel cross between inbred lines were conducted in one direction according to the second Griffing method to produce 15 hybrids, in addition to a self-pollination procedure for inbred lines to multiply their seeds. Upon complete maturing, the ears of inbred lines and hybrids were harvested separately, dried, then peel its grains, and preserved for the purpose of cultivating it in the comparison experiment in the next season. The seeds of six inbred lines and the 15 hybrids were planted in the same mentioned station on the twenty-fifth of July 2014 in lines with a length of 5 m and a distance of 0.75 m between the lines and 0.25 m between plants at a rate of 2 seeds for each hole.

They were reduced to one plant at the stage of six leaves according to the R.C.B.D with three replicates and by two lines for each genetic material. All agricultural operations were carried out from plowing, harrowing, fertilizing, dividing the field, planting, cultivating, irrigation, weed and Sesamia critica insect control and thinning and weeding according to what was mentioned in the previous season. Five plants were selected from each experimental unit, and the characteristics data of plant height and upper ear, ear length, number of row/ear, number of grains/ row, the weight of 250 grains, grain yield of the plant were recorded. The analysis of variance for each trait was conducted according to the design used to identify the significant differences in the mean squares of genotypes (inbred lines + hybrids). The genetic analysis of the general and specific combining abilities was conducted after identifying the significant differences in the mean squares of genotypes in each trait according to the second method, using the values of the averages parents and hybrids, and estimating the GCA for parents and SCA for hybrids. Their significance was tested by estimating the standard error of each and estimating some of the genetic parameters of phenotypic components (additive genetic variance (σ2A), non-additive genetic variance (σ2D) and environmental variance (σ2E)). Finally, the values of H2b.s% and H2n.s%, the (ā) for each studied trait using the second method of [4] using fixed model according to [5] mentioned, and as the following equations:

$$\hat{g}i = \frac{1}{p+2}\left[\sum (Yi.+Yii) - \frac{2}{p}Y..\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\hat{S}ij = Yij - \left[\frac{1}{p+2}Yi.+Yii+Y.j+Yjj\right] + \frac{2}{(P+1)(P+2)}(Y..) \ldots\ldots\ldots (2)$$

$$\sqrt{S.E_{(gi)} = \frac{[(p-1)\sigma^2 e]}{P(P+2)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$\sqrt{S.E_{(\hat{S}ij)} = \frac{[p(p-1)\sigma^2 e]}{(P+1)(P+2)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The components of the variance were calculated according to [4] procedure, the (σ^2A), (σ^2D) and (σ^2E) could be calculated from the expected mean squares (EMS) according to the following equations:

$$\sigma^2 gca = \frac{(MSgca - MSe)}{(P+1)} \quad ,$$

$$\sigma^2 sca = (MSsca - MSe),$$

$$\sigma^2 A = 2\sigma^2 gca$$

$$\sigma^2 D = \sigma^2 sca,$$

$$\sigma^2 E = MS\underline{e} = MSe/r,$$

3. Results and Discussion

Table 1 showed the results of the variance analysis of the genotypes and the general and specific combining abilities for the studied traits. It was observed the presence of highly significant differences for the mean square of variations of the genotypes (parents + hybrids) of all studied traits, and this indicates that there are genetic differences between them. Whereas requires conducting a genetic analysis of the GCA and SCA and studying its genetic behavior, in order to know the gene action that controls it to improve it. It is also noticed from the same Table that there are highly significant differences for the mean square of variations for the general and specific combining abilities for all studied traits. This indicates that all of these traits were under the control of the additive and non-additive effects of genes.

These results are consistent with [3], [6], [7] findings. The ratio between the components of the σ^2gca that represented the additive variation of the genes to the σ^2sca that represented the non-additive variation of the genes was less than one in all studied traits; this indicates the importance of the non-additive gene action in the genetic behavior of the studied traits. These results were consistent with [2], [7], [8] findings, which showed the superior dominance of genes over these traits.

Table 1. Results of the variance analysis of the genotypes and the general and specific combining abilities by the second method of Griffing according to the fixed model of the yield traits and its components in the yellow maize.

S.O.V	DF	Plant height cm	Ear height cm	Ear length cm	Number of rows/ear	Number of grains/row	Weight of 250 grains g	Gains yield g
Geno.	20	**517	**444.8	**13.88	**55.04	**17.62	**42.72	**1404
Error	40	6.49	8.58	2.32	3.30	0.830	2.57	17.18
GCA.	5	**93.56	**28.18	**5.28	**19.04	**6.27	**18.20	**320.5
SCA.	15	**198.6	**188.2	**4.41	**18.17	**5.94	**12.92	**517.5
Error	40	2.31	2.86	0.774	1.43	0.276	0.856	5.73
gca/sca		0.058	0.017	0.155	0.132	0.180	0.180	0.077

Table 2 showed the estimating of the effect of GCA $\hat{g}i$ or each parent and the effect of SCA $\hat{S}ig$ for each hybrid of the half crosses. It was observed that there are a wide range of differences in the effects of GCA between the inbred lines, as inbred line (1) showed the highest positive and a significant effect of combining abilities to the ear length, the number of rows /ear, the number of grains /row and the weight of 250 grains. The inbred line (3) showed the highest positive and significant effect of combining abilities to the ear height and the grains yield, which reached 6.74. As for the inbred line (4), it showed the highest positive and significant effect of combining abilities to the plant height. It was observed from the same Table of the effect estimating of SCA for each hybrid, a wide range of differences between these effects of the cross in all studied traits. As the hybrid (4 × 1) showed the highest positive and significant effect of SCA to the ear length and the number of grains /row and the grains yield (37.55), and the hybrid (4x3) showed the highest positive and significant effect of SCA for the number of rows /ear and the weight of 250 grains (6.55). While the hybrid (5 × 4) showed the highest positive and significant effect of SCA of plant height and upper ear height. These results are consistent with [9], [10], [8], [7], [11] findings.

Table 2. the effect of GCA for each parent and for each hybrid by the second method of Griffing and the fixed model in the studied traits of the yellow maize.

Traits Parents and hybrids	Plant height (cm)	Ear height (cm)	Ear length cm	Number of rows/ear	Number of grains /row	Weight of 250 grains (g)	Gains yield (g)
1	2.83	0.097	1.26	2.29	0.903	1.26	3.74
2	-1.88	-1.44	0.341	1.13	0.468	0.222	5.86
3	2.58	2.60	0.264	0.333	0.736	0.806	6.74
4	3.42	1.72	0.319-	-0.625	0.028	2.86-	2.02-
5	2.00	-0.653	0.778-	-1.58	1.01-	0.889	6.93-
6	4.96	-2.32	0.861-	-1.54	1.14-	0.319-	7.39-
$SE_{(gi)}$	0.491	0.546	0.284	0.386	0.170	0.299	0.773
2×1	7.33	-0.161	2.32	4.49	3.26	0.006	23.67
3×1	5.20	-1.20	1.85-	-2.72	1.32-	0.423	14.87-
4×1	2.04	-1.66	3.07	5.24	4.05	3.09	37.55
5×1	-7.22	-2.29	2.14-	3.80-	1.91-	0.339	16.87-
6×1	11.41	19.38	0.387-	0.155	1.11-	3.88	1.74-

3×2	-1.42	8.01	1.32	2.78	3.10	4.46	20.34
4×2	3.74	6.88	1.10-	3.60-	2.20-	1.87-	22.91-
5×2	3.16	11.26	2.36	4.70	0.845	0.381	17.67
6×2	-1.55	0.077	0.780	2.32	0.970	2.26	16.80
4×3	2.62	1.84	2.74	5.20	2.55	6.55	26.55
5×3	12.70	9.55	2.20	4.16	0.929	0.202-	18.46
6×3	18.66	15.88	0.613	2.11	1.05	3.01	12.59
5×4	24.87	20.42	0.220	0.780	0.637	0.869-	1.55
6×4	9.83	3.09	1.14-	3.93-	0.905-	1.33-	10.66-
6×5	-4.76	0.131	0.655	2.03	0.804	3.08-	1.59
SE_{Sij}	1.11	1.24	0.644	0.875	0.385	0.677	1.75

Table 3 showed the estimation of (σ^2A), (σ^2D) and (σ^2E), values of H^2b.s% and H^2n.s% and average degree of dominance (ā) for the studied traits, where the estimation of (σ^2A) and (σ^2D) differed from zero, and the values of (σ^2D) were greater than the values of (σ^2A) for all traits studied. The non-additive genetic effects were more important than the additive genetic effects for all the traits, this is reflected in increasing the (ā) from one for all studied traits, due to increase the (σ^2D) and decrease the (σ^2A), which indicates the presence of superior dominance that controls the inheriting these traits, so the traits can be improved by hybridization. These results are consistent with [10] findings. As for the values of H^2b.s% and H^2n.s% according to the ranges mentioned by [3], it was high for all traits and ranged between (86.01%) for the ear length and (99.04%) for the grains yield. These results are consistent with [2], [12]. The H^2n.s% was low in the plant height and the upper ear, the number of rows/ear and the grains yield (13.20%), this indicates a decrease in the value of (σ^2A). Whereas it was medium for the ear length, the number of grains/row and the weight of 250 grains (25.12%), this means that elections can be held in early isolated generations. These results are consistent with [13], [14]. It can be concluded from this that all the traits were under the influence of the superior dominance of genes, where the evidence for this being the ratio of the σ2gca to the σ2sca were less than one, and the (ā) greater than one and the H2b.s% were high.

Table 3. The estimation of (σ^2A), (σ^2D), and (σ^2E), values of H^2b.s% and H^2n.s% and average degree of dominance (ā) for the studied traits.

Traits Parents and hybrids	Plant height (cm)	Ear height (cm)	Ear length (cm)	Number of rows/ear	Number of grains/row	Weight of 250 grains (g)	Gains yield (g)
σ^2gca	11.41	3.17	0.563	2.20	0.749	2.17	39.36
σ^2sca	196.3	185.4	3.63	16.68	5.46	12.07	511.7
σ^2A	22.81	6.33	1.13	4.40	1.50	4.34	78.72
σ^2D	196.3	185.4	3.63	16.68	5.46	12.07	511.7
σ^2E	2.31	2.86	0.774	1.43	0.276	0.856	5.73
H^2b.s%	99.0	98.53	86.01	93.63	96.19	95.04	99.04
H^2n.s%	10.30	3.25	20.35	19.55	20.71	25.12	13.20
ā	4.15	7.65	2.54	2.75	2.70	2.36	3.61

4. Conclusion

In conclusion, through research, it was found that there were highly significant differences for mean squares of genotypes in all studied traits, and the results also showed highly significant differences for the average squares of general and specific combining abilities for all the studied traits. The ratio of the variance component of σ2 GCA to the σ2 SCA was few in all studied traits. It can be concluded from this that all the traits were under the influence of the superior dominance of genes, where the evidence for this being the ratio of the σ2gca to the σ2sca were less than one, and the (ā) greater than one in all studied traits. Which showed the superior dominance of genes over these traits.

Supplementary Materials:

No Supplementary Materials.

Author Contributions:

A. H. Suwaid and M. A. Rashid; methodology, writing—original draft preparation M. M. Taha and S. A. Rashid; writing—review and editing, M. A. Rashid; paraphrasing. All authors have read and agreed to the published version of the manuscript.

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The authors declare no conflict of interest.

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