Estimation of Combining Ability, In F1 Hybrids for Yield and Yield Component in maize (Zea Mays L.) Using Half Diallie Design

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Abstract

This study was carried out in the experimental field the College of Agricultural Engineering Sciences, University of Duhok, in the autumn season of 2024. Five locally sourced inbred lines were planted, according to a half diallel design to produce 10 F_1 crosses. In the spring season of 2025, the parents, their crosses, and a commercial variety were designed in a complete block design with three replications. The result showed that height significant differences among genotypes for all studied traits. Cross (1×2) (HS×ZP-707) was superior in 500 grain weight (128.687g), number of grain per row (40.533), number of row per ear (16.533), yield per plant (171.397) and total grain yield ton per hectare (15.264 ton), both parent (HS and ZP-707) give positive general combining ability for the same traits followed by positive specific combining ability in the same cross (HS×ZP-707), the value of genetic parameters estimated showed that dominance variance exceeded additive variance for all traits except 500 grain weight, that means most traits were under the dominance gene effect The ratio between the general and specific ability components was less than one for all traits, mention that the crosses was the best for improving these traits broad-sense heritability was more than narrow-sense heritability and the value ranged between (51%) for number of row per ear and (94%) for yield per plant and total grain yield ton per hectare respectively, the average degree of dominance were greater than one for all traits indicated that the presence of over dominance. Expected genetic advance as a percentage of the mean was moderate for 500 grain weight, yield per plant and total grain yield ton per hectare and low for the rest traits.

Keywords: combining ability, heritability, half diallel design, maize.

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Introduction

Maize (Zea mays L.) represents an important source of direct food for humans and their livestock, as well as an important source of income for millions of people in countries around the world [39]. Its grains contain starch, protein, oil, vitamins, and minerals, in addition to its use as a source of biofuel such as ethanol production [6]. The effect of general combining ability (GCA) and specific combining abilities (SCA) are important indicators of potential value for

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inbred lines in hybrid combinations. The concept of GCA and SCA has become increasingly important to plant breeder because of the widespread use of hybrid cultivar in many crops such maize many researcher estimation the general and specific combining ability are related to the type for gene action effects [11,18,26]. Half diallel analysis provides a good information about the inheritance of traits among a set of genotype [11,28]. Combining ability analysis is an important tool for selecting parents with good general combining ability and these parents can be used for hybridization programs in order to produce superior hybrids. It also helps in understanding the nature of gene action of a particular character. General combining ability (GCA) is due to result of additive gene effects, while the specific combining ability (SCA) is due to result of non-allelic interactions [21]. The estimate of combining ability is useful to predict the relative performance of different lines in hybrid combinations. The information on the magnitude of gene action is important in understanding the genetic potential of a population and deciding the breeding procedure to be adopted in a given population. Combining ability analysis helps in the evaluation of inbreds in terms of their genetic value and in the selection of suitable parents for hybridization. It also helps in the identification of superior hybrid combinations which may be utilized for commercial exploitation the nature of gene action involved in the expression of characters and there by helps in formulating breeding methodology to be used for improvement of yield [33]. the information obtained about the heritability of the different traits, as well as the information about the relationship of these traits with the amount of yield, is very important in knowing how to practice methods of effective selection to obtain the best possible genetic improvement, heritability of maize yield and other traits have been studied by many researchers such as [29,37,42,36,35,30], and we can conclude from these studies that most traits have a higher heritability than the trait of the quantity of the yield .

This study aimed to estimate, general and specific combining ability and some genetic parameters in maize genotypes using half diallel cross.

Materials and Methods

A field experiment was located in the experimental area was chosen to layout the study specialized for conducting researches in the College of Agricultural Engineering Sciences, University of Duhok in Kurdistan Region-Iraq. Five inbred lines are involved in this study which presented (Table 1) in below, the land was plowed with plowing, smoothing and leveling before sowing date .

Seeds of five inbred lines sown autumn season 15th of July 2024. The seed of each inbred line planted in four rows and the long of row was 3m for each inbred lines, 0.75m between the rows and 0.25m between plants. We sprayed a insecticide when the plant reached 3 to 5 leaves SPEAR sp, a systemic insecticide, was sprayed on a plant. It was sprayed for two weeks. NPK fertilizer (20:20:18) was added according to recommendations (200kg/ha^{-1}) and urea fertilizer 46%, 400kg/ha^{-1} was added in to tow doses, the first dosage when plant height was 30cm the second dosage before flowering each inbred line, all agricultural service operation were followed during the growth period. When the tasseling and silking begin to appear, these tasseling and silking are covered by (paper bags) to prevent self-pollination, and Crosses between male and female lines were conducted according to a half diallel design (Table 2.(

In the spring season, the land preparation process included plowing, smoothing, and leveling. The experiment was planned, and arrangements were made for planting fifteen, genotypes (5 line+10 cross) with commercial variety on March 5, 2025. the length of the rows was 3 m, with 0.75 m between the rows and 0.25 m between plants to plant each genotype was sown in one row, using a Randomized Complete Block Design (RCBD) with three replications .

The service operation related to weeding was carried out, according to recommendations by applying 200kg/ha of Russian fertilizer (20:20:18) before planting on March 1, 2025. also, the Nitrogen fertilizer (urea 46%) was applied at a rate of 200kg/ha in two split doses: the first on April 5, 2025, when the plants reached 30 cm in height, and the second before flowering. A systemic insecticide (TRIXAN SC) was sprayed on the plants twice between April 4 and May 3, 2025, Thinning was done on April 5, 2025. Data were recorded on six plants from each experimental unit, taken randomly. and the data recorded on Number of grains per row, Number of ears per plant, Number of rows per ear, Yield per plant, 500-grain weight (g), Total grain yield per hectare (ton.(

The parameters were calculated by the following formulas:

Combining Ability

was carried out according to the procedure of [19] using second method fixed model. The (GCA) and (SCA) were estimated using the general linear model for the analysis which take the formula of, [40.[

$Y_{ijk} = \mu + g_i + g_j + s_{ij} + r_k + e_{ijk}$ i, j = 1, 2----- P

k= 1, 2-------- r

Where:

Y_{ijk}: observed value of the experimental unit .

μ: population mean.

g_i: general combining ability (GCA) effect for the (i) parent.

g_j: general combining ability for the (j) parent.

s_{ij}: specific combining ability (SCA) for the cross-involving parent (i) & (j.(

r_k: replication (block) effect.

e_{ijk}: experimental error effect.

Estimation of General and Specific Combining Ability Effects:

$\hat{g}_i = 1/r(n+2)\ (z_{i\ldots} - (z_{\ldots}/n($

$\hat{s}_{ij} = y_{ij.}/r - (z_{i..} + z_{j..})/r(n+2) + (2y_{\ldots})/r(n-1)(n+1($

Estimation of Components of Variance for both General and Specific Combining Abilities:

$\sigma^2 g = [1/r(p+2)][\ Ms(G.C.A) - Mse[$

$\sigma^2 s = (1/r)\ (Ms(S.C.A) - Mse\ ($

$\sigma^2 e = Mse$

Estimation of Components of Variance and Genetic Interpretation:

The Additive, Dominance and Environmental variances were estimated by using EMS from Griffing analysis. And their significance from zero were tested in the manner explained by [23.[

$\sigma^2 A = 2\ \sigma^2 g$

$\sigma^2 D = \sigma^2 s$

$\sigma^2 E = \sigma^2 e$

$\sigma^2 G = \sigma^2 A + \sigma^2 D$

$\sigma^2 P = \sigma^2 G + \sigma^2 E$

Where :

$\sigma^2 A$: additive genetic variance ,

$\sigma^2 D$: dominance genetic variance ,

$\sigma^2 g$: the variance of general combining ability,

$\sigma^2 s$: the variance of specific combining ability

$\sigma^2 E$: the variance of experimental error, i.e. environmental variance,

$\sigma^2 G$: total genetic variance ,

and $\sigma^2 P$: phenotypic variance (genetic and environmental variance.(

Heritability

Broad and narrow sense heritability was estimated depending on the mean square of general and specific combining abilities, and experimental error according to, [40.[

Broad sense heritability considered high when it is more than 60%, medium between 40% - 60% and low when it is less than 40%, [10.[

$h^2.b.s = (\sigma^2 G)/(\sigma^2 P) = (\sigma^2 A + \sigma^2 D)/(\sigma^2 A + \sigma^2 D + \sigma^2 e($

$2]\!])=\sigma]\!]^2 \; gca + \sigma^2 sca)/(2\sigma^2 \; gca + \sigma^2 \; sca + \sigma^2 e($

Narrow sense heritability is considered high when it is more than 50%, medium in the range 20% - 50% and low when less than 20%, [7.[

$h^2.n.s = (\sigma^2 A)/(\sigma^2 P) = (\sigma^2 A)/(\sigma^2 A + \sigma^2 D + \sigma^2 e($

$2 = \sigma^2 gca/(2\sigma^2 \; gca + \sigma^2 \; sca + \sigma^2 e($

Where:

$h^2 b.s$ = heritability in broad sense. $h^2 n.s$ = heritability in narrow sense.

σ^2 gca = The variance of general combining ability.

σ^2 sca = The variance of the effect of specific combining ability.

$\sigma^2 e$ = The variance of the effect of experimental error i.e. environmental variance.

σ^2 A = additive genetic variance.

σ^2 D = non-additive genetic variance.

$\sigma^2 G$ = total genetic variance.

σ^2 P = phenotypic variance (genetic and environmental variance.(

Expected Genetic Advance

The expected genetic advance in the next generation for studied traits was estimated according to the following formula.

$EGA = h^2.n.s. \times I \times \sigma P$

Where:

GA= genetic advance .

I= Selection intensity is equal to 1.75 when 10% of the plants are selected.

σP = standard variance of phenotypes

Then expected genetic advance as percent % for character mean ($\bar{y}$...) estimated according to the following equation.

$EGA\% = GA/(y\hat{}-\ldots) \times 100$

Where:

$\bar{y}$ ... = General mean.

The value of expected genetic advance is considered high when it is more than 30%, medium between 10-30% and low when less than 10% [5.[

All statistical and genetic analyses were performed according to the experimental design by [15], Statistical Analysis System (SAS), and Microsoft Office Excel 2003 programs.

Table 1. Inbred lines used in the study

No.	Inbred lines	Source
1	HS	Locally devised
2	ZP-707	Locally devised
3	Maximo	Locally devised
4	DKCC6418	Locally devised
5	H-4	Locally devised

Table 2.A crosses according to half diallel design.

	1	2	3	4	5
1	Ọ	1×2	1×3	1×4	1×5
2		Ọ	2×3	2×4	2×5
3			Ọ	3×4	3×5
4				Ọ	4×5
5					Ọ

Results and Discussion

The analysis of variance according to second method by [19]. for yield and yield components was showed in table (3). The mean square due to genotypes was greatly significant for all studied traits. It specified that significant genetic variability is displayed among genotypes (Parents and Crosses). Moreover, the mean square for general combining ability was significant for all studied traits except number of ear per plant, Whilst the mean square of specific combining ability was highly significant for all studied traits. The significant mean square for general and specific combining abilities for the generality traits signifies the importance of additive and dominance gene action in controlling inheritance the same result was reported by [20,38,9,1,41,43.[

Table 3. Analysis of variance for genotype, and combining ability (GCA and SCA) for studied traits in maize.

	M.S for Traits						
Source of variation	**d.f**	500 grains weight(g)	No. of ear per plant	No. of grains per row	No. of row per ear	yields per plant(g)	Total grains yields ton per hectare
Replication	2	6.084	0.182	15.734	1.398	392.854	3.178
Genotypes	14	** 849.629	** 0.074	** 58.805	** 2.376	** 3694.183	** 29.297
GCA	4	** 1760.251	0.020	** 67.750	** 2.781	** 5213.637	** 41.431
SCA	10	** 485.380	** 0.095	** 55.227	** 2.214	** 3086.402	** 24.444
Error	28	40.600	0.018	5.966	0.677	82.382	0.645
σ2 GCA/ σ2SCA		0.552	0.003	0.179	0.196	0.244	0.245

(**)and (*) Significant at 1% and 5% probability level respectively.

Table (4) exhibited the yield and yield components for all genotypes Among the parents, for 500 grain weight line 1 exhibit the highest value (115.183g) while the lowest value (90.187g) recorded by line 5. For the result in the same table the line 5 recorded the minimum value for number of ear per plant (1.367) while the lines 2,3,4 gave the maximum number of ears per plant with value (1.633). Regarding the number of grains per row line 3 recorded the maximum value (38.500) and minimum value (33.533) obtained by line 5.

For number of rows per ear the minimum value was (14.900) obtained by line 5 and maximum value (16.733) exhibited by line 3. For yield per plant line 3 exhibited highest value (126.030g) and lowest value (90.607g) recorded by line 5. For total grain yield ton per hectare line 3 recorded the highest value (11.202) and lowest value (8.054) exhibited by line 5.

From the result of table (4) the line 3 superior in number of ears per plant, number of grains per row, number of rows per ear, yield per plant, total yield this line considers the best line in this study followed by line 1 was superior in 500 grain weight and line 2 for number of ears per plant. The same result was reported by [4,14,17,30,2.[

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Table 4. Mean performance of parents for studied traits in maize

Parents	500 grains weight(g)	No. of ear per plant	No. of grains per row	No. of row per ear	yields per plant(g)	Total grains yield ton per hectare
1	115.183 b	1.433 bcde	34.933 def	15.433 abcd	123.897 cd	11.013 cd
2	100.167 de	1.633 abc	37.700 bcde	15.767 abc	118.860 de	10.565 de
3	97.547 def	1.633 abc	38.500 bcd	16.733 a	126.030 cd	11.202 cd
4	103.273 cd	1.633 abc	34.700 defg	15.000 bcd	107.080 e	9.492 e
5	90.187 ef	1.367 cde	33.533 efg	14.900 bcd	90.607 f	8.054 f

The values followed by the same latter for each trait are not significant differences for each other.

The general combining ability of parents for different traits of maize is presented in table (5).for 500 grain weight two parents showed undesirable and negative significant for GCA effect with value(-2.763g and -9.745g) and one parent showed desirable and positive significant for GCA with value 15.103g. Frome results within the same table, the number of ear per plant, the rest parent exhibited positive and negative is non-significant for this trait. For number of grains per row, three parents showed desirable and positive significant number with value,(0.934, 1.658 and 1.249) in parent 1,2 and 3,while the two parents showed undesirable and negative significant with values,(-2.337 and -1.504.) For number of row per ear one parent displayed desirable and positive significant GCA effects with value (0.404), whereas the two parents displayed undesirable and negative significant GCA with value(-0.325 and -0.434.(

Concincing to yield per plant only two parents showed desirable and positive significant with values (21.420g and 7.655g) in parent 1 and 2, while the two parents showed undesirable and negative significant with values(-13.817g and -16.803g) in parent 4 and 5. Regarding to total grain yield ton per hectare only two parents displayed desirable and positive significant effects of GCA with value (1.909 and 0.683) in parent 1 and 2,while the two parents displayed undesirable and negative significant with value (-1.235 and -1.495). This result corroborates with finding by [27,17,25,31,2[

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Table 5. General combining ability effect on studied traits of parents

Parents	500 grains weight(g)	No. of ear per plant	No. of grains per row	No. of row per ear	yields per plant(g)	Total grains yields ton per hectare
1	**15.103** *	**-0.001**	**0.934** *	**0.247**	**21.420** *	**1.909** *
2	**-0.522**	**0.032**	**1.658** *	**0.404** *	**7.655** *	**0.683** *
3	**-2.763** *	**0.028**	**1.249** *	**0.109**	**1.544**	**0.138**
4	**-2.073**	**-0.039**	**-2.337** *	**-0.325** *	**-13.817** *	**-1.235** *
5	**-9.745** *	**-0.020**	**-1.504** *	**-0.434** *	**-16.803** *	**-1.495** *
$S.E.(\hat{g_i})$	2.154	0.046	0.826	0.278	3.068	0.271

(**)and (*) Significant at 1% and 5% probability level respectively.

The means performance of the crosses presented in Table (6). Regarding to 500 grain weight the height weight was in cross (1×3) by (134.460g), while the lowest weight in cross (3×5) by (87.953g). Concerning the number of ear per plant the minimum value recorded in cross (3×4) with (1.233), while the maximum was in cross (3×5) with value (1.733). for number of grain per row the highest mean recorded in cross (2×3) with value (44.300), while the lowest value was in cross (1×4) with (30.000). Also the number of row per ear the maximum value was in cross (1×2) by (16.533), but the minimum was recorded in cross (3×4) with value (13.967). For yield per plant the highest value was in cross (1×5) with (189.857g), while the lowest was recorded in cross (4×5) with value (82.830g). Regarding the total grains yield ton per hectare the highest value was recorded in cross (1×5) with (16.878), while the lowest was recorded in cross (4×5) with value (7.362). From the result of table (6), the cross (1×5) showed superiority in yield per plant, total grain yield ton per hectare, this cross consider the best cross in this study followed by cross (3×5) was superiority in number of ear per plant followed by (1×3) in 500 grain weight and cross (2×3) in number of grain per row , the same result were prepared by [20,32,13,25,2.[

Table (6). Mean performance of crosses for studied traits in maize

Crosses	500 grains weight (g)	No. of ear per plant	No. of grains per row	No. of row per ear	Yield per plant (g)	Total grains yield ton per hectare
1×2	128.687 a	1.700 ab	40.533 ab	16.533 ab	171.397 b	15.264 b
1×3	134.460 a	1.633 abc	39.800 abc	15.067 abcd	160.603 b	14.275 b
1×4	126.297 a	1.667 ab	30.000 g	15.533 abcd	118.060 de	10.494 de
1×5	133.090 a	1.500 Abcd	43.767 a	16.300 ab	189.857 a	16.878 a
2×3	113.087 bc	1.700 ab	44.300 a	16.367 ab	162.953 b	14.484 b
2×4	113.227 bc	1.300 de	36.733 bcdef	16.400 ab	136.117 c	12.099 c
2×5	88.187 f	1.633 abc	32.067 fg	14.567 cd	83.167 f	7.372 f
3×4	97.240 def	1.233 e	33.000 efg	13.967 d	89.880 f	7.989 f
3×5	87.953 f	1.733 a	32.067 fg	14.467 cd	83.080 f	7.384 f
4×5	89.357 ef	1.633 abc	31.933 fg	14.400 cd	82.830 f	7.362 f
Commercial variety	125.710 a	1.633 abc	35.600 cdef	14.233 cd	126.127 cd	11.211 cd

The values followed by the same latter for each trait are not significant differences for each other

The estimation of specific combining ability effects of the crosses are presented in table (7). Concerning 500 grain weight six crosses had positive significant SCA effect and cross (1×5) obtained the highest value (19.403g) and the cross (1×4) recorded the lowest value (5.403g). for the same traits were as four cross gave desirable negative value. In the same table for number of ear per plant the result showed six crosses had positive significant SCA effect and the largest value (0.163) recorded by cross (3×5) and lowest value (0.059) recorded by cross (2×5), while two crosses had negative significant SCA effect and the rest crosses exhibited non-significant positive or negative SCA effect. Concerning number of grain per row five crosses had positive significant SCA effect and the cross (1×5) obtained the maximum value (8.098) and cross (2×4) recorded the minimum value (1.175) for the same trait, whereas four cross gave significant negative value SCA effect ranged between (-4.835) in cross (1×4) and (-2.149) in cross (3×4), the other crosses showed non-significant positive or negative SCA effect for the same trait. Regarding number of row per ear, four cross gave positive significant SCA effect the maximum value (1.059) in cross (1×5) and the minimum value (0.425) in cross (2×3), while four cross showed significant negative value SCA effect ranged between (-1.246) in cross (3×4) and (-0.637) in cross (3×5), the other crosses non-significant positive or negative SCA effect. Concerning to yield per plant, five cross showed positive significant SCA effect the highest value (62.278g) in cross (1×5) and lowest value (14.677g) in cross (1×3), while

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five cross showed significant negative value SCA effect ranged between (-30.647g) in cross (2×5) and (-9.511g) in cross (4×5). For total grain yield ton per hectare, five cross displayed positive significant SCA effect the highest value (5.536) in cross (1×5) and lowest value (1.299) in cross (1×3), while five cross significant negative value SCA effect ranged between (-2.744) in cross (2×5) and (-0.836) in cross (4×5). The results showed that the cross (2×3) and (1×2) was surpassed in 6 traits while the (1×5) in 4 traits respectively indicating that the parent 1,2,3 had a good general combiner indicating that both additive and non-additive gene action were important for inheritance of these traits. the result of specific combining ability were supported by the results of [24,44,34,2 .[

Table 7. Specific combining ability for studied traits in crosses.

Crosses	500 grains weight(g)	No. of ear per plant	No. of grains per row	No. of row per ear	yields per plant(g)	Total grains yields ton per hectare
1×2	**6.243***	**0.106***	**1.703***	**0.454***	**19.360***	**1.744***
1×3	**14.257***	**0.044**	**1.379***	**-0.717***	**14.677***	**1.299***
1×4	**5.403***	**0.144***	**-4.835***	**0.183**	**-12.504***	**-1.109***
1×5	**19.869***	**-0.041**	**8.098***	**1.059***	**62.278***	**5.536***
2×3	**8.510***	**0.078***	**5.156***	**0.425***	**30.793***	**2.735***
2×4	**7.959***	**-0.256***	**1.175***	**0.892***	**19.317***	**1.722***
2×5	**-9.409***	**0.059***	**-4.325***	**-0.832***	**-30.647***	**-2.744***
3×4	**-5.787***	**-0.317***	**-2.149***	**-1.246***	**-20.808***	**-1.843***
3×5	**-7.401***	**0.163***	**-3.916***	**-0.637***	**-24.623***	**-2.187***
4×5	**-6.688***	**0.130***	**-0.463**	**-0.270**	**-9.511***	**-0.836***

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$S.E.(\hat{S}_{ij})$	2.781	0.059	1.066	0.359	3.961	0.350

(**) and (*) Significant at 1% and 5% probability level respectively.

The data in table (8). Indicated that the result of genetic parameters for yield and yield component traits it's clear that the additive and dominance genetic variance were significant from zero showing the importance genetic control the inheritance of these traits explain that the values of dominance variance was more than the additive variance for all studied traits except 500 grain weight indicating that the dominance genetic effects were more important in the inheritance of these traits, according to the same reason it's clear that the values in narrow-sense heritability was less than the heritability in broad-sense for these traits the value of narrow-sense heritability was range between (0.003) for number of ear per plant which was low and Modred for 500 grain weight (0.464g), while the highest value broad-sense heritability was found in yield per plant and total grain yield ton per hectare (94%) moderate for number of row per ear (51%). Indicating that the crosses is the best to improve these traits, the same table explain the result of average degree of dominance is more than one for all traits, indicated that the presence of over dominance which may be attributed the distribution of linked genes between parents, concerning to expected genetic advance in next generation which was low for number of ear per plant, number of grain per row and number of row per ear, while moderate for 500 grain weight, yield per plant and total grain yield ton per hectare the result are similar to those of [12,22,3,8,2.[

Table 8. Heritability and genetic parameters for studied traits in maize genotypes.

Genetic Parameters	500 grains weight(g)	Ear per plant	grains per row	row per ear	yields per plant(g)	Total grains yields ton per hectare
$\sigma^2 E$	40.600 ± 10.483	0.018 ± 0.005	5.966 ± 1.540	0.677 ± 0.175	82.382 ± 21.271	0.645 ± 0.166
$\sigma^2 A$	163.776 ± 96.794	0.000 ± 0.001	5.884 ± 3.728	0.200 ± 0.154	488.691 ± 286.683	3.884 ± 2.278
$\sigma^2 D$	148.260 ± 66.144	0.026 ± 0.013	16.420 ± 7.533	0.512 ± 0.307	1001.340 ± 420.066	7.933 ± 3.327
$\sigma^2 G$	312.036	0.026	22.305	0.713	1490.031	11.818
$\sigma^2 P$	352.636	0.044	28.271	1.390	1572.413	12.462

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H^2B.S	0.885	0.587	0.789	0.513	0.948	0.948
H^2N.S	0.464	0.003	0.208	0.144	0.311	0.312
$\bar{a}$	1.346	19.666	2.362	2.261	2.024	2.021
EGA	15.263	0.001	1.937	0.298	21.567	1.926
EGA%	14.150	0.071	5.344	1.928	17.540	17.620

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