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Estimation of heterosis combining ability and some genetic parameters in sweet pepper

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Abstract

Four pure lines of pepper developing locally namely (S-1004, L-1008, K-1017 and E-1001) were used in a full diallel crossing program to evaluate the performance of those parents and their crosses, to estimate combining ability and genetic parameters for agronomic, fruit yield and its components traits. Crosses among parents were carried out in plastic house in fall season of 2012 using full diallel cross mating to produce 16 hybrids the parents, F1s and reciprocals hybrids plus hybrid check were sown in plastic house in fall season of 2013 using a R C B D design with four replicates. Data were recorded for plant height, branches number per plant, fruit number per plant, fruit diameter, fruit weight, fruit length and fruit yield per plant. The obtained results showed significant differences among the different genotypes for all traits under investigation. The hybrid (1×4) and the reciprocal hybrid (4×2) produced higher fruit number (73.90, 63.40) and fruit yield per plant (4.06, 3.28 Kg) while, the hybrid (1×3) and reciprocal hybrid (3×2) gave higher fruit length 8.02 cm. Positive and negative heterosis were found among the F1's and reciprocals. The hybrid (1×4) and reciprocal (4×2) produced higher heterosis in fruit number (88.85, 62.02%) and fruit yield per plant (79.64, 53.99%) respectively. Significant differences were revealed in general and specific combining abilities for all studied traits. Suggesting the presence of both additive and Non-additive gene effects in the inheritance of the various studied traits. The ratio of σ^2gca to σ^2sca was less than unity for all studied traits, expect for fruit weight, which showed pre dominant role of non-additive gene action in the inheritance. Estimates of GCA effects showed that the best combiner parents were found to these of P1 for plant height, fruit diameter and fruit weight, while P4 for branches number, fruit number, and for fruit yield per plant, and P2 for plant height and P3 for fruit length. Estimates of SCA effects showed that the hybrid 1×2 reflected the highest value in fruit diameter (0.56) and fruit weight (1.35) and the hybrid 1×4 in fruit number (10.02) and fruit yield per plant (0.54) and 2×3 in branches number per plant (0.81) and fruit weight (1.21), and 3×4 in plant height (19.30) and fruit length (0.38). Estimates of RCA effects showed that the reciprocal hybrid 3×1 was the best for fruit weight (8.09), while the reciprocal hybrid 4×1 was the best for branches number per plant (1), fruit number (16.13), fruit length (0.55) and for fruit yield per plant (0.91) where as 3×2 was the best for plant height branches number per plants (5.37) and fruit diameter, and 4×3 was the best for fruit number (6.03) and for fruit diameter (0.30). The values of σ^2 D and σ^2 D_r were more than that (σ^2 A) for all studied traits expect for fruit weight and fruit yield per plant, which were less than those for fruit diameter, fruit weight and fruit yield per plant, and this reflects the exceeded one for the value of average dominance degree for all studied traits in both diallel and reciprocal crosses expect for fruit diameter in reciprocal crosses which was less than one. As for broad sense heritability it was high for all studied traits in both diallel and reciprocal crosses, while, the values narrow of sense heritability were low in diallel and reciprocal crosses for all studied traits except for fruit weight, and fruit diameter were high value in reciprocal crosses (0.81) and (0.52) respectively. It was concluded that two inbred (p1 and p4) could be used in a breeding program to develop new versions of high fruit yield per plant and high SCA to produce better fruit yield hybrids and most studied traits were under over dominance gene action. This showed that developing elite hybrids, and most studied traits were under over dominance gene action. This showed that developing elite hybrids were the best method for improving pepper fruit yield per plant in pepper plant.

Keywords: Pepper, Diallel, Combining ability, Heterosis, Heritability.

Introduction

The pepper (*Capsicum annuum* L.) is the third important vegetable crop that is widely grown in Iraq after tomato and potato as well as in many other countries of the world belong to Solanaceae family. The middle region of south America, south of Mexico and Guantanamo were the original region for the sweet pepper. Yield increase in crops has occurred due to plant breeding and improved production and management techniques. In order to produce high yielding pepper varieties in Iraq, pepper improvement has been carried out by conventional breeding techniques for years Exploiting heterosis is one of the methods used to increase pepper yield that have stagnated in recent years. The success of the hybridization is largely dependent on the correct selection of parents. Estimates of genetic variation and combining ability are useful in determining the breeding value of some populations and the appropriate procedures to use in a breeding program. The general combining ability effects are important indicators of the value of genotypes in hybrid combinations. Differences in general combining ability effects have been attributed to additive interaction , whereas differences in specific combining ability effects have been attributed to non additive genetic variance (falconer, 1960). Genetic information was obtained by different quantitative genetic methods that full diallel cross analysis is a suitable and efficient method with eligible speed (Singh and chaudhary, 2007). Several studies have been conducted on heterosis in F1 hybrids of pepper for most studied quantitative traits by many researchers such as Thurya and Prtchya (2003), Geleta *et al.* (2004), Meyer *et al.* (2004) Sood and Kaul (2006), Hatem and salem (2009) and Sood and Kumar (2010). With regard to combining ability effects several studied have been conducted in diallel crosses for parents and hybrids of pepper for most studied quantitative traits by many researches such Legesse (2000) Zewdie *et al.* (2001), Farag (2003), Geleta and Labuschangne (2006), Fekadu *et al*. (2009) Huang *et al*. (2009) Kamble *et al.* (2009), Rego *et al.* (2009) Sarujpisit *et al.* (2012), Khalil and Hatem (2014) and Nasaimento *et al.* (2014). The aim of the present investigation was to estimate some important genetic parameters ie- general and specific combining abilities (GCA and SCA) heterosis relative to better parents for diallel crosses and reciprocal crosses to evaluate the most promising crosses an reciprocal effects between the hybrids of 4 parents of the sweet pepper.

Material and Methods

The trial was conducted in plastic house .seed parent which were developing locally were planted in first year of 1\10\ 2011 and the seedling were transplanted to the plastic house in summer season of 15\11\2011 and stay to 15\3\2012 to make crossing among the four parent using full diallel mating design to produce the required 12 F1s crosses (diallel and reciprocals). Crossing was done by following the conventional hand emasculation and pollination method developed. In the second season of 25\8\2012, seeds of parents, diallel hybrids and reciprocals were planted in plastic house to evaluate. A randomized complete blocks design with four replicates was used. The plants of each genotypes (Parents and F1 and reciprocals crosses)were distributed in plastic house which long 39M and width 5M. The other normal agricultural practices for pepper production i.e- irrigation, fertilization, plant protected against weeds and pests control were practice as recommended. Observations were recorded for average of plant height, average of branches number per plant, average of fruit weight, average of fruit diameter, average of fruit length, average of fruit number per plant and average of fruit yield per plant. The data of all parameters on 12 hybrids (diallel and reciprocal) and their four parental, genotypes were subjected to analysis of variance in order to test the significant of the differences among the various means of tested genotypes, according to Cochran and Cox (1957). Differences among means for all characters were tested for significant, according to the least significant differences (L.S.D) at 5% probability. Average degree of heterosis was estimated as a percent increase or decrease of F1 performance from the better parental (BP) values according to Sinha and Khanna (1975). GCA of parents and SCA variance of a full diallel mating design was used. The analysis was performed according to the Griffing method (1956) Method 1 model 1, which depended on the parents and their F1diallel and reciprocal crosses, by using the following formulae as outlined by Singh and Chaudhary (2007): $\sigma^2 gca = (MS\ gca - MSe)/ 2p$

$$\sigma^2 sca = MS\ sca - \overline{MS}e.$$

$$\sigma^2 rca = (MS\ rca - \overline{MS}e)/ 2$$

GCA, SCA and RCA effects were estimated by following formula (singh and chaudhary 2007):

$\hat{g}i = 1/2\ p\ (Xi. + X.j) - (1/p^2)\ X..$

$\hat{S}ij = 1/2\ (Xij. + X.ji) - 1/2\ p\ (Xi. + X.i + Xj. + X.j) + 1/P^2\ X..$

$Rij = 1/2\ (Xij - Xji).$

Average degree of dominance for diallel $\overline{(a)}$ and for reciprocal crosses $\overline{(ar)}$ were estimated by using following formula :

$\overline{a} = (2\ \sigma^2 D / \sigma^2 A)^{1/2}$

$\overline{ar} = (2\sigma^2 Dr/ \sigma^2 A)^{1/2}$

Results and Discussion

The analysis of variance (Table 1) revealed that the mean squares of genotypes for all characters studied were significantly different (P ≤ 0.05) indicating the presence of variability among hybrids and their parents. The average performance of parents and hybrids (diallel and reciprocal) is listed in Table (1). Pepper parents were superior for the following traits plant height (P1 and P2) , branches number per plant (P3) fruit number per plant (P4), fruit diameter (p3 and p4), fruit weight (p1) , fruit length (P3) and for fruit yield per plant (P3 and P1). Pepper hybrids (diallel and reciprocal) were superior for the following traits: plant height (4×3) was the best (133.27cm). The hybrid 2×3 was found the best for branches number per plant (10.00), while the hybrid 1×4 was found the best for fruit number per plant (73.90) and for fruit yield per plant (4.06 kg). The hybrid 1×3 was found the best for fruit weight (61.73g), whereas the reciprocal hybrid was found the best for fruit length (8.20 cm) and the hybrids 3×4 and 2×1 were found the best for fruit diameter (4.60 and 4.56cm), respectively. These results are in agreement with the finding of Geleta and Labuschangne (2004a) Rego *et al.* (2009a) and Nascimento *et al.* (2014) who observed some parents and their some crosses exhibited higher mean values for some studied traits.

Table (1): Mean parental and F1 hybrids in studied traits.

Genotypes / Parents	Plant height (cm)	Branches number Per plant	Fruit Number Per plant	Fruit Diameter (cm)	Fruit Weight (g)	Fruit length (cm)	Fruit yield Yield Per Plant (kg)
1	108.97	7.23	37.60	4.20	54.63	7.60	2.26
2	105.13	7.30	36.67	3.27	48.77	7.16	1.78
3	89.67	7.42	43.49	4.43	52.37	7.80	2.27
4	82.77	7.23	39.13	4.33	52.80	6.56	2.13
Diallel crosses							
1×2	120.13	7.00	38.93	4.50	56.03	6.56	2.13
1×3	102.47	7.67	32.83	4.06	61.73	7.33	2.02
1×4	113.61	9.67	73.90	4.30	55.13	7.66	4.06
2×3	110.20	10.00	51.20	4.06	53.30	7.26	2.65
2×4	122.5	7.11	37.07	3.33	46.13	6.36	1.70
3×4	119.18	9.00	54.63	4.60	46.03	7.92	2.50
Reciprocal crosses							
2×1	118.51	9.33	52.50	4.56	53.32	7.10	2.81
3×1	110.89	6.97	39.78	3.63	45.54	6.70	1.80
4×1	112.77	7.67	41.63	4.40	53.89	6.56	2.23
3×2	99.46	8.00	43.33	3.56	50.58	8.20	2.16
4×2	116.06	9.00	63.40	3.93	51.97	7.20	3.28
4×3	133.27	8.57	42.57	4.00	52.19	7.7	2.17
Cont. hybmandra	116.43	9.10	66.53	4.36	56.13	7.40	3.71
mean	110.72	8.13	46.76	4.09	52.40	7.24	2.45
L.S.D (0.05)	9.21	1.85	8.09	0.30	5.13	0.83	0.26

Hetrosis: The results of Table (2) showed positive heterosis over better parent, where the reciprocal 4×3 and diallel hybrid 3×4 in plant height reflected highly positive heterosis 48.62 and 32.90% respectively for plant height, whereas the diallel hybrids 2×3 and 1×4 were gave highly positive heterosis 34.77 and 33.74% respectively for branches number per plant. While, diallel 1×4 and reciprocal 4×2 hybrids revealed positive significant over the better parents 88.85 and 62.02% respectively for fruit number per plant. The reciprocal 2×1 and diallel 1×2 hybrids revealed positive increase over better parent 8.57 and 7.14% respectively for the fruit diameter. While the diallel hybrids 1×3 and 1×2 showed positive significant heterosis over better parents 12.99 and 2.56% respectively, for the mean weight of fruit with regards to fruit length, the reciprocal 3×2 and diallel 3×4 hybrids gave positive heterosis over better parent 5.12 and 1.66% respectively, while in the fruit yield per plant the diallel hybrid 1×4 and reciprocals hybrid 4×2 showed and higher positive heterosis over the better parent value 79.64 and 53.97% respectively, these results are in agreement with finding of Pandey *et al.* (2002), Farage (2003), Geleta and Labuschagne (2004a) Sood and Kaul (2006), Fekadu *et al.* (2009), Sarujpisit *et al.* (2012) and Khalil and Hatem (2014) who found that some cross gave high over better parents heterosis value for all studies traits.

Table (2): Heterosis relative to the better parents for the studied traits.

Hybrids	Plant height (cm)	Branches Number per plant	Fruit Number per plant	Fruit diameter (cm)	Fruit weight (g)	Fruit Length (cm)	Fruit yield per plant
1×2	10.40	-4.10	3.53	7.14	2.56	-13.68	-5.75
1×3	-5.96	3.36	-24.51	-8.35	12.99	-6.02	-11.01
1×4	4.25	33.74	88.85	-0.69	0.91	0.78	79.64
2×3	4.82	34.77	17.72	-8.35	1.77	-6.92	16.74
2×4	16.50	-2.60	-5.26	-23.09	-12.63	-11.17	-20.18
3×4	32.50	21.29	25.61	3.83	-12.82	1.66	10.13
2×1	8.75	27.80	39.62	8.57	-2.39	-6.57	24.33
3×1	1.76	-6.06	-8.53	-18.05	-16.63	-14.10	-20.70
4×1	3.48	6.08	6.38	1.61	-1.35	-13.68	-1.32
3×2	-5.39	7.81	-0.36	-19.63	-3.41	5.12	-4.84
4×2	10.39	23.28	62.02	-9.23	-1.57	0.55	53.99
4×3	48.62	15.49	-2.11	-9.70	-1.15	-1.28	-4.40

Combining ability: The analysis of variance in the Table (3) revealed the mean squares of genotypes for all characters studied were significantly different 0.05 indicating the presence of variability among hybrids and their parents General combining ability mean squares were significant of probability of 5% for all traits. Mean square of diallel SCA and reciprocal RCA were significant of level 5% for all traits, suggesting that both additive and non-additive gene effects are involved in their genetic mechanism. These results showed concordance with finding of Pandy *et al.* (2002), Farag (2003), Geleta and Labuschagne (2006) Kamble *et al.* (2009) Rego *et al.* (2009) Sarujpisit *et al.* (2012), Khalil and Hatem (2014) and Nascimento *et al.* (2014) for these traits. On the other hand, The ratio between variance of general and specific combining ability was found to be less than one for all traits, except the fruit weight which was found to be larger than one. This is in conformity with the finding of Rego *et al.* (2009a) and Nacimento *et al.* (2014). To evaluate the parents according to their combining ability, the effect of general combining was estimated for each parent as shown in Table (3). Obvious that parent 1 was a good combiner for plant height 1.70, fruit diameter 15% and fruit weight 2.21. On the other hand parent 4 was significantly a good combiner in the desirable direction with the tiller number 0.11, fruit number per plant 3.39 and with total yield fruit per plant. While the parent 2 was significantly a good combiner for plant height. As for parent 3 was significantly a good combiner only with fruit length 0.35. These parents showed the highest GCA effects values. This result is agree with that reported by Samashekhar and Salimath (2008), Sarujpisit *et al.* (2012) Khalil and Hatem (2014) and Nascimento *et al.* (2014).

Table (3): Analysis of variance of genotypes ,general, specific and reciprocal combining ability for studied traits.

SOV	df	Plant height (cm)	Branches Number per plant	Fruit Number per plant	Fruit diameter (cm)	Fruit weight (g)	Fruit Length (cm)	Fruit yield per plant (kg)
Genotype	16	472.76	3.17	362.52	0.55	51.90	0.94	1.09
GCA	3	4.81	0.03	4.26	0.03	1.83	0.04	0.01
SCA	6	322.76	0.65	91.45	0.21	1.70	0.16	0.26
Reciprocal	6	12.54	0.52	86.46	0.04	12.94	0.10	0.27
Error	31	10.74	0.42	8.26	0.01	3.32	0.08	0.001
σ^2gca / σ^2sca		0.01	0.04	0.04	0.15	1.07	0.27	0.06
σ^2gca / σ^2rca		0.05	0.05	0.04	0.74	12.94	0.45	0.06

Effect of SCA: The same Table (3) showed estimation on SCA effect for each hybrid in the studied traits. It was observed that the hybrid 1×2 had a SCA effect in desirable direction for fruit diameter and fruit weight (0.56) and (1.35) respectively ,the hybrid 1×4 revealed SCA effect in the desirable direction for fruit number per plant and fruit yield per plant (10.02) and (0.54) respectively. As for the hybrid 2×3, it had a desirable SCA effect for branches number plant (0.81) and for fruit weight (1.21). The hybrid 3×4 recorded a SCA effect in the desirable direction for plant height (19.36) and for fruit length 0.38. Whereas, the hybrid 2×1 had desirable SCA effect for plant height (7.10). Reciprocal effect: Also the same table showed the estimation reciprocal effects for each reciprocal hybrid in the studied traits. It was observed that the reciprocal direction for fruit diameter (0.21), for fruit weight (8.09) and for fruit length (0.31) while the reciprocal hybrid 4×1 had RCA effect in desirable direction for branches number per plant (1.00), for fruit number per plant (16.13) for fruit length (0.55) and for fruit yield per plant (0.91). As the reciprocal hybrid 3×2 showed RCA effect in desirable direction for plant height 5.37, for branches number per plant (1.0), for fruit diameter 0.25 and for fruit yield per plant (0.24). The reciprocal hybrid 4×3 had RCA effect in desirable direction for fruit number per plant (6.03) and for fruit diameter (0.30). Whereas the reciprocal hybrid 4×2 showed desirable direction only for plant height trait (3.20). These finding were similar to those obtained by Rego *et al.* (2009a), Khalil and Hatem (2014) and Nascimento *et al.* (2014).

Table (4): Estimate of general, specific and reciprocal combining ability effects for each parent and hybrid in studied traits.

Parents	Plant height (cm)	Branches Number per plant	Fruit Number per plant	Fruit diameter (cm)	Fruit weight (g)	Fruit Length (cm)	Fruit yield per plant
1	1.70	-0.22	-1.19	0.15	2.21	-0.09	0.07
2	1.80	0.05	-0.57	-0.26	-1.04	-0.10	-0.08
3	-3.50	0.05	-1.62	0.02	-0.38	0.35	-0.14
4	0.01	0.11	3.39	0.07	-0.68	-0.16	0.15
SEg hybrids	1.01	0.04	0.77	0.01	0.31	0.01	0.01
1×2	5.54	0.26	1.94	0.56	1.35	-0.20	010.
1×3	-1.87	-0.58	-6.41	-0.40	-0.34	-0.48	-0.39
1×4	1.12	-0.70	10.02	0.03	0.92	0.13	0.54
2×3	-3.82	0.81	3.92	0.02	1.21	0.24	0.26
2×4	7.10	-0.18	1.87	-0.25	-1.27	0.18	0.04
3×4	19.30	0.54	1.29	0.12	-1.87	0.38	-0.04
SES_{ij} reciprocal	6.05	0.23	4.64	0.01	1.86	0.04	0.01
2×1	0.90	-1.16	-6.78	-0.03	1.35	-0.26	-0.34
3×1	-4.21	0.35	-3.47	0.21	8.09	0.31	0.11
4×1	0.42	1.00	16.13	-0.05	0.62	0.55	0.91
3×2	5.37	1.000	3.93	0.25	1.36	-0.46	0.24
4×2	3.20	-0.94	-13.16	-0.30	-2.91	-0.41	-0.78
4×3	-7.04	0.21	6.03	0.30	-3.08	0.11	0.16
SE_{Rij}	5.37	0.21	4.13	0.01	1.66	0.04	0.01

Genetic Parameters: The additive and non-additive effects influenced the hybrids performance, as indicated by the σ^2gca and σ^2 Sca (Table 5). The highest σ^2gca value indicates that additive effects, played a more significant role than non-additive effects in the control of all studied traits expect branches number per plant, this indicates that non-additive gene action was dominance in the controle these traits. Similar results were obtained by Geleta and Labuschane (2004a), Reg *et al.* (2009) and Nascimento *et al.* (2014). The values of σ^2 D and σ^2 D_r were more than that (σ^2 A) for all studied traits expect for fruit weight and fruit yield per plant, which were less than those for fruit diameter, fruit weight and fruit yield per plant, and this reflects the exceeded one for the value of average dominance degree for all studied traits in both diallel and reciprocal crosses expect for fruit diameter in reciprocal crosses which was less than one. As for broad sense heritability it was high for all studied traits in both diallel and reciprocal crosses, while, the values narrow of sense heritability were low in diallel and reciprocal crosses for all studied traits expect for fruit weight, and fruit diameter were high value in reciprocal crosses (0.81) and (0.52) respectively, It was concluded that two inbred (P1 and P4) could be used in a breeding program to develop new versions of high fruit yield per plant and high SCA to produce better fruit yield hybrids ,and most studied traits were under over dominance gene action. This showed that developing elite hybrids. And most studied traits were under over dominance gene action. This showed that developing elite hybrids were the best method for improving pepper fruit yield per plant .

Table (5): Estimates of some genetic parameters for studied characters.

Genetic parameters	Plant Height (cm)	Branches Number/ plant	Fruit Number/ plant	Fruit Diameter (cm)	Fruit Weight (g)	Fruit Length (cm)	Fruit yield Per plant
σ^2gca	332.38	0.59	99.98	0.72	5.37	0.26	0.30
σ^2 sca	322.76	0.65	91.45	0.21	1.70	0.16	0.26
σ^2 rca	12.54	0.52	86.46	0.04	12.94	0.10	0.27
σ^2A	9.62	0.05	8.52	0.06	3.66	0.09	0.35
σ^2 D^2	322.76	0.65	91.45	0.21	1.70	0.16	0.26
a	5.79	5.92	3.27	1.82	3.66	1.33	2.75
H^{2}bs	0.96	0.58	0.92	0.96	0.61	0.75	0.97
H^{2}ns	0.02	0.05	0.07	0.22	0.42	0.26	0.11
σ^2 D^{2}r	12.54	0.52	86.46	0.04	12.94	0.10	0.27
a-r	1.14	4.56	3.18	0.82	1.87	1.04	2.79
H^{2}bs.r	0.67	0.52	0.92	0.90	0.83	0.69	0.97
H^{2}ns.r	0.29	0.06	0.08	0.54	0.81	0.33	0.11

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