International Journal of Environmental Studies and Researches (2024), 3(2):101-111

Genetic Studies on the Most Important Economic Traits for Some Inbred Lines of Watermelon

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Abstract

Six inbred lines of watermelon (*Citrullus lanatus.* thumb) were crossed to produce 15 F_1 hybrids through a half diallel design mating design. General combining ability (G.C.A.) estimates, specific combining ability (S.C.A.), and heterosis effects were studied for No. of days to maturity, No. of fruits per plant, total yield / plant, rind thickness, average fruit weight, fruit shape index and TSS. The analysis of variance of combining ability showed importance of both additive and non-additive gene influences in the inheritance of studied traits. Effects of GCA estimates revealed that inbred line P6 (3MWS53) had the lowest negative value with non-significant effect for No. of days to maturity, also, this inbred line had the highest positive values with significant effects for average fruit weight and total yield / plant. inbred lines P2 (3MWS55) and P5 (96604005) had significant positive values for TSS. The crosses (P1xP2, P1xP4, P3xP4 and P3xP6 had negative SCA values with significant effects for No. of days to maturity, cross P2xP4 had the highest significant value SCA for average of total yield /plant and fruit weight. Heterotic effect revealed different results for all studied traits and mostly better in cases of crossing. All crosses revealed the best heterotic effect for total yield / plant and No. of fruits / plant.

Keywords: GCA, SCA, Heterosis, Fruit traits, Watermelon.

Introduction

Watermelon is a member of the plant family Cucurbitaceae and one of the most popular and widely grown cucurbitaceous fruit vegetable crops in sub-tropical and tropical countries of the world. Its global consumption is greater than that of any other cucurbits (**Goreta et al., 2005**). World production is about

101634719 tons), whereas the productivity in Egypt is about 12.4 tons / Fadden (FAO, 2021). The problem of watermelon cultivation in Egypt is the insufficient local supply of watermelon seeds and low productivity from them. Therefore, Egypt imports annually in about 200 million pound and this constitutes a major burden on the Egyptian economy, therefore, we need to produce, locally, appropriate quantities of watermelon seeds that are highly productive with good quality. The general and specific combining ability enables the selection of highly productive parents with good quality traits. Therefore, developing inbred lines for commercial use in hybrid combinations is considered one of the most important breeding programs for watermelon. According to **Nascimento et al. (2018)** on watermelon crops, the ability to combine potential parents allows identifying the most suitable parents for in the production of commercial hybrids. According to **Afaf et al. (2009)** in watermelon crop the ratio of GCA/SCA mean squares for number of fruits per plant rind thickness and fruit weight pointed to the predominant role of additive gene action in the expression of these traits. Many researchers indicated in watermelon that GCA and SCA were significant for mean weight of fruits per plant and the additive gene influences were the most important in the inheritance of the trait (**Hassan et al., 2002; Ferreira et al., 2002; Rajan et al., 2002; El-Meghawry et al., 2002; Abd El-Salam and EL-Ghareeb, 2007 and Khereba et al., 2007).**They also reported partial and complete dominance for the high yield. According to **Singh et al. (2022),** the combining ability analysis revealed that GCA effects and SCA effects were significant for the same studied traits. The ratio of SCA/ GCA indicated the dominance of non-additive gene influences for number of fruits/ plants, yield/ plant, rind thickness, average fruit weight and TSS. In general, studying of general, specific combining ability effects, heterosis and type of gene action, introduce provide a useful improve agronomic and quality traits. The aim of this work was to study the combining ability effects, heterosis, and other genetic parameters in the crosses between six inbred lines of watermelon (*Citrullus lanatus. thumb*). Crosses in a half-diallel fashion.

Materials and methods.

The genetic materials used in the present study included six inbred lines of watermelon (*Citrullus lanatus.* Thumb), Viz., (3MWS 48(P1), 3MWS 55(P2), 3MWS 54(P3), 3MWS 49(P4), (96604005) (P5), and 3MWS 53(P6) (obtained from **Prof. Dr. Mohamed Abd El-Salam**, Head of Research, Department of vegetable breeding Research, Horticultural Research Institute), All inbred lines were a high degree of homozygosity since they were selfed for five successive generations.

In the first season of 2022, after planting inside an agricultural greenhouse, a crossing was made among the six parents without reciprocals to produce 15 F1 hybrids According to **Griffing (1956)** method II design and the following equation n(n-1)/2.

The genetic materials (21 genotypes) which included six parental inbreds and 15 F_1's were in the second summer season of 2023.

The experiment was conducted in the farm of the institute of Environmental studies and Research, Sadat City University, Egypt. The experimental design was a randomized complete block with three replications. All genotypes were randomly distributed in each replicate; that consisted of 21 plots (six inbred lines and 15 F1hybrids). The plot was 12 plants with 1.0 m between hills.

All agricultural practices were conducted in accordance with the recommendations of the Egyptian Ministry of Agriculture. Five plants were randomly selected from each plot in each replicate and labeled in order to estimate the number of days to maturity, number of fruits per plant, rind thickness (in centimeters), total yield per plant (in kilograms), fruit shape index, average fruit weight and total soluble solids (TSS).

Statistical analysis

Analysis of variance was conducted to test for significant differences between the means of the different populations in a completely randomized block design, as reported by **Cochran and Cox (1957)**.

Estimates of general and specific combining ability

A half-diallel mating design was constructed from the six inbred lines and the analysis of half-diallel crosses was used to estimate general combining ability (G.C.A.) and specific combining ability (S.C.A.) according to **Griffing (1956)** method II, model II as outlined by **Singh and Chaudhary (1985)**.

Heterosis

The amount of heterosis percentage was estimated as the deviation of the F1 mean over the average of the two parents (M.P.) or above the higher parent (H.P.) as described by **Mather and Jinks (1971)** formulas as follows:

$$H\ (M.P)\ \% = \frac{\overline{F1} - \overline{M.P}}{\overline{M.P}} \times 100$$

$$H\ (H.P)\ \% = \frac{\overline{F1} - \overline{H.P}}{\overline{H.P}} \times 100$$

$$T\ (M.P) = (\bar{F1} - \bar{P}) \Big/ \sqrt{\frac{3}{8} \times m.s.e} \quad T\ (H.P) = (\bar{F1} - H.P) \Big/ \sqrt{\frac{2}{bc} \times m.s.e}$$

m.s.e : the mean square of the error.

b: Number of plants within the sample.

C: Number of Replications.

3/8: fixed. $\bar{P}$: the average of the two parents. H.P: the higher parent.

Degree of dominance

This parameter was determined by estimating the potence ratio value (P), according to **Mather and Jinks (1971)** as the following equation:

$$P=\frac{\overline{F1}-\overline{M.P}}{1/2(\overline{P2}-\overline{P1})}$$

P1 :the mean of lower parent
P2 : the mean higher parent.

Absence of dominance is considered when (P) is equal zero, partial dominance is assumed when (p) is between 1+ > P>-1 but not equal zero. Complete dominance is present when the (p) equals either +1.0 or -1.0 (+1.0 = p = -1.0) and Over dominance is considered when the (p) exceeds either +1.0 or -1.0 (-1.0 < P > +1.0).

Results and Discussion

Genetic analysis

The differences between all genotypes were highly significant at 0.01% level of probability as shown from the analysis of variance (Table 1), except average of fruit weight which showed significant only at 0.05% level of probability differences.

Table 1. Analysis of variance and mean squares for studied economic traits in watermelon.

S.O.V.	d.f	M.S						
		No. of days to maturity	Average of fruit weight (kg)	No. of fruits/ plant	Total yield /plant (kg)	Rind thickness (cm)	Fruit shape index.	Total soluble solids TSS %
Replication (Rep)	2	3.388	0.081	0.638*	5.312*	0.07*	0.001	0.016
Treatments (T)	20	9.77**	0.245*	1.535**	27.983**	0.076**	0.017**	1.357**
Error	40	2.914	0.124	0.176	1.04	0.014	0.002	0.114

*Significant at 0.05% level of probability and **Highly Significant 0.01% level of probability

General and Specific combining ability effects

The results showed that number of days to maturity, number of fruits/ plants, total yield /plant and (T.S.S.), recorded significant GCA and SCA effects (Table 2), indicating that these traits were affected by both additive and non-additive gene action. Only, GCA was significant for fruit shape index indicating the prevalence of additive gene action. On the contrary, only SCA was significant for average fruit weight and rind thickness, this means that non-additive genes action controlled these traits. The ratio of GCA/SCA for number of days to maturity and fruit shape index, exceeded one, indicated the importance of additive gene effects. While it was less than one for the other traits, indicating more importance of SCA than GCA, and the non-additive gene influences are more important in the inheritance of these traits. These findings are partially in agreement with those reported by **Abd El-Salam and El-Ghareeb (2007)**; **Afaf *et al*. (2009); Bahari *et al*. (2012); Santos et al. (2017) and Nascimento et al. (2019)** in watermelon and **El- Shoura et al. (2023)** in melon.

Table 2. Analysis of variance of combining ability effects and the mean squares (M.S) for some economic traits of the six inbred lines and their 15 F1 crosses.

S. O. V.	**d.f**	**M.S**						
		No. of days to maturity	**Average fruit weight (kg)**	**No. of fruits/ plant**	**Total yield /plant (kg)**	**Rind thickness (cm)**	**Fruit shape index**	**Total soluble solids TSS %**
GCA	5	3.463**	0.053	0.147*	2.781**	0.007	0.019**	0.295**
SCA	15	3.188**	0.091*	0.633**	11.51**	0.032**	0.001	0.505**
ERROR	40	0.971	0.041	0.058	0.347	0.004	0.001	0.038
GCA/SCA		1.086	0.582	0.232	0.242	0.219	19	0.584

*Significant at 0.05% level of probability and **Highly Significant 0.01% level of probability.

As shown in Tables 3 and 4, all inbred lines showed negative and non-significant GCA values for number of days to maturity, except inbred line P2 (3 MWS 55), indicating these inbred lines may be early production, inbred line P6 (3 MWS 53) was the good combiner parent for total yield / plant and average fruit weight which recorded positive significant values, inbred line P2 (3 MWS 55) and P5 (96604005) showed positive and significant GCA values for TSS trait, these results are partially in agreement with those reported by **Shaban and Abd El-Salam (2009); Gvozdanovic-varga *et al*. (2011); Bahari**

***et al*. (2012); Ahmed *et al*. (2012); Omran *et al*. (2012); Nascimento *et al*. (2019) and Singh *et al*. (2022).**

Table 3. General and Specific combining ability for No. of days to maturity, Average fruit weight, No. of fruits/ plant, and Total yield /plant (kg) in watermelon plants grown in the summer season of 2023.

Parents	**No. of days to maturity**	**Average fruit weight (kg)**	**No. of fruits/ plant**	**Total yield /plant (kg)**
1-3MWS 48	-0.468	0.03	-0.026	-0.087
2-3MWS 55	1.307**	-0.09	-0.256**	-1.069**
3-3MWS 54	-0.235	-0.014	0.011	-0.066
4-3MWS 49	-0.318	-0.048	0.065	0.214
5-(96604005)	-0.285	-0.024	0.115	0.38
6-3MWS 53	-0.001	0.147*	0.09	0.627**
L.S.D.05(gi)	0.643	0.133	0.158	0.384
L.S.D.01(gi)	0.86	0.178	0.211	0.514
Crosses				
P1×P2	-1.917*	0.301	0.618**	2.307**
P1×P3	0.558	-0.108	0.218	0.604
P1×P4	-2.358*	-0.007	0.264	1.224*
P1×P5	1.008	-0.098	0.481*	1.491**
P1×P6	0.058	-0.185	0.439*	1.444**
P2×P3	-0.55	-0.105	0.581**	1.652**
P2×P4	-0.467	0.68**	0.593**	4.405**
P2×P5	-1.033	0.022	0.377	1.373*
P2×P6	-1.117	0.351	0.135	1.559**
P3×P4	-2.058*	-0.196	0.193	-0.165
P3×P5	-1.092	-0.071	0.543*	1.856**
P3×P6	-2.308*	0.109	0.902**	4.389**
P4×P5	0.525	0.147	0.423	2.123**
P4×P6	0.442	-0.29	0.248	0.236
P5×P6	1.742	-0.048	0.098	0.51
L.S.D.05(sij)	1.766	0.365	0.434	1.055
L.S.D.01(sij)	2.362	0.488	0.58	1.411

*Significant at 0.05% level of probability and **Highly Significant 0.01% level of probability.
GCA: General combining ability and SCA: Specific combining ability.

The crosses combination P1xP2, P1xP5, P1xP6, P2xP3, P2xP4, P3xP5 and P3xP6 showed positive significant values for SCA effects for number of fruits / plants and total yield /plant, although, these crosses involved poor general combiner parents; P1xP2, P1xP3, P1xP5, P1xP6, P2xP4, P2xP5, and P3xP6 showed positive and highly significant SCA effects for TSS trait. Furthermore, the crosses P1xP2, P1xP4, P3xP4 and P3xP6 had negative significant values for number of days to maturity; this means that they are the earliest crosses. **El-Meghawry *et al*. (2001); Rajan *et al*. (2002)** and **Nascimento *et al*. (2019)** recorded similar trend of results on watermelon**.**

Table 4. General and Specific combining ability for Rind thickness (cm), Fruit shape index, and Total soluble solids (TSS %) in watermelon plants grown in the summer season of 2023.

Parents	**Rind thickness (cm)**	**Fruit shape index**	**Total soluble solids TSS %**
1-3MWS 48	0	-0.018*	0.022
2-3MWS 55	-0.042	-0.024**	0.172**
3-3MWS 54	0	-0.029**	-0.086
4-3MWS 49	-0.021	0.098**	-0.34**
5(96604005)	0.021	-0.007	0.16*
6-3MWS 53	0.042	-0.02*	0.072
L.S.D.05(gi)	0.044	0.016	0.127
L.S.D.01(gi)	0.059	0.022	0.17
Crosses			
P1×P2	0.256**	0.001	0.802**
P1×P3	0.214**	0.022	0.794**
P1×P4	0.068	0.027	-0.118
P1×P5	-0.14*	-0.015	0.382*
P1×P6	-0.161*	0.019	0.636**
P2×P3	-0.077	0.037	0.244
P2×P4	-0.057	-0.043	0.632**
P2×P5	-0.098	0.012	0.465*
P2×P6	0.048	0.005	0.152
P3×P4	-0.098	0.017	0.157
P3×P5	0.027	-0.017	0.323
P3×P6	0.173**	-0.003	0.544**
P4×P5	0.214**	0.06**	-0.289
P4×P6	0.027	0.041	-0.202
P5×P6	0.318**	0.01	0.032
L.S.D.05(sij)	0.122	0.044	0.35
L.S.D.01(sij)	0.163	0.06	0.468

*Significant at 0.05% level of probability and **Highly Significant 0.01% level of probability.
GCA is General combining ability and SCA is Specific combining ability.

Heterosis and Degree of dominance

We found positive significant values for all crosses for number of fruits/plants and total yield/plant, over both mid and better parent (Tables 5 and 6), indicating that over dominance gene effect was present in controlling these traits same results were obtained for TSS trait, except for P4xP5, P4xP6 crosses. Crosses which showed negative and zero values indicated the predominance of additive gene action in controlling the inheritance of these traits. Negative significant values for number of days to maturity are desired. The heterosis for all studied traits are partially in agreement with **Rajan *et al.* (2002); Hatem (2009); Afaf *et al*. (2009); Bahari *et al.* (2012) and Nascimento *et al*. (2018).**

Table 5. Average degree of heterosis (ADH), based on high parent (H.P) and mid parents (M.P.), as well as potence ratio (P) for No. of days to maturity,Average fruit weight (kg), No. of fruits/ plant, and Total yield /plant (kg) in watermelon plants grown in the summer season of 2023.

Crosses	No. ofdays tomaturity			Average fruitweight (kg)			No. offruits/plant			Total yield/plant(kg)		
	ADH%		p	ADH%		p	ADH%		p	ADH%		p
	MP	HP		MP	HP		MP	HP		MP	HP	
P1×P2	-4.01**	-6.39**	-1.58	16.5**	3.2	1.29	89.5**	63.6**	5.66	98.5**	53.7**	3.38
P1×P3	-1.51	-2.60**	-1.47	-5.4	-6.1*	-8.8	62.7**	57.5**	19	51.0**	46.0**	15.3
P1×P4	-4.31**	-4.82**	-8	1.56	-3.22	0.33	51.2**	41.1**	7.33	54.0**	52.2**	12.6
P1×P5	0.71	-0.108	-0.93	-3.2	-4.96	-2	62.2**	51.3**	8.90	53.7**	47.5**	13
P1×P6	-0.97	-1.08	-9	-5.5	-8**	-2	59.7**	49.0**	8.54	55.0**	48.0**	1.17
P2×P3	-3.24**	-4.74**	-2.13	3.9	-7.9*	0.31	96.7**	74.7**	7.69	97.0**	56.2**	3.73
P2×P4	-2.83*	-4.74**	-1.42	31.5**	21.8**	3.96	78.1**	45.0**	3.46	129**	76.0**	4.27
P2×P5	-2.18	-5.36**	-0.65	9.1	-1.79	0.82	69.9**	38.3**	3.09	81.3**	36.3**	2.47
P2×P6	-2.85*	-5.15**	-1.17	17.6**	1.8	1.16	56.7**	27.6**	2.51	86.2**	39.5**	2.58
P3×P4	-4.27**	-5.20**	-9.77	-5.42	-10.2**	-1	54.1**	39.5**	5.27	43.5**	37.1**	9.69
P3×P5	-2.38*	-4.14**	-1.29	-4.5	-6.6*	-2	71.6**	55.3**	6.97	63.2**	51.7**	8.34
P3×P6	-4.18**	-5.10**	-4.58	0.024	-1.97	0.01	86.0**	68.3**	8.38	92.6**	78.2**	11.5
P4×P5	-0.10	-1.50*	-0.08	5.79	2.56	1.83	52.5**	52.5**	1.33	61.4**	56.6**	20.9
P4×P6	-0.86	-1.28	-2	-5.49	-12.1**	-0.74	45.0**	45.0**	1.14	43.8**	38.9**	12.75
P5×P6	1.96	0.97	-2.11	-1.71	-5.8*	-0.4	41.1**	41.1**	1.04	43.7**	43.0**	86.4

*Significant at 0.05% level of probability and **Highly Significant 0.01% level of probability.

Table 6. Average degree of heterosis (ADH), based on high parent (H.P) and mid parents (M.P.), as well as potence ratio (P) for Rind thickness (cm), Fruit shape index, and Total Soluble Solids (TSS %) in watermelon plants grown in the summer season of 2023.

Crosses	Rind thickness (cm)			Fruit shape index			Total Soluble Solids (TSS %)		
	ADH%		p	ADH%		p	ADH%		p
	MP	HP		MP	HP		MP	HP	
P1×P2	33**	33**	0.33	1.92	0.95	4	21.59**	19.0**	10
P1×P3	33**	33**	0.33	4.90	2.88	3.33	21.4**	21.4**	1.94
P1×P4	17*	17**	0.17	6.14*	-2.41	0.7	5.92**	3.47**	2.5
P1×P5	0	0	0	0.95	0	1	12.8**	6.91**	2.29
P1×P6	0	0	0	4.85	3.84*	5	16.5**	11.9**	4.05
P2×P3	0	0	0	4.5	2.85	2.5	14.4**	12.0**	6.7
P2×P4	0	0	0	-0.87	-8.87**	-0.10	13.1**	12.9**	61
P2×P5	0	0	0	2.85	1.88	0.03	12.9**	9.18**	3.79
P2×P6	16*	16**	0.16	2.91	0.95	3	10.9**	8.44**	5.25
P3×P4	0	0	0	5.35*	-4.83**	0.54	7.75**	5.26**	3.27
P3×P5	16*	16**	0.16	0.97	-1.88	0.5	11.1**	5.23**	2
P3×P6	33**	33**	0.33	3.96	2.94	0.04	14.2**	9.86**	3.50
P4×P5	33**	33**	0.33	8.69**	0.80	1.11	-0.10	-3.28**	-0.03
P4×P6	16*	16**	0.16	7.96**	1.61	0.81	1.44	-0.30	0.84
P5×P6	50**	50**	0.5	3.84	1.88	2	5.51*	3.91*	3.46

*Significant at 0.05% level of probability and **Highly Significant 0.01% level of probability.

Conclusion

The crosses P1xP2 and P3xP6 showed consistency in values of SCA effects and heterosis, therefore, we recommend their inclusion in hybrid vigor evaluation programs.

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