INHERITANCE AND NATURE OF RESISTANCE TO FUSARIUM WILT IN WATERMELON

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ABSTRACT

Two crosses were made between different watermelon cultivars, i.e. Charleston Gray X Baby Sugar and Crimson Sweet X Baby Sugar as well as there reciprocal crosses, in order to study the inheritance and nature of resistance to fusarium wilt disease. The F_1 hybrid showed high resistance to the disease. The ratios of resistant to susceptible plants in the F_2 and Bc_1 populations (backcross to the susceptible parent) were 3 : 1 and 1: 1, respectively . The earliness and total yield/plant were inherited quantitatively. The nature of dominance for earliness and total yield/plant ranged from partial to over dominance in both crosses. The estimates of broad sense heritability for earliness and total yield/ plant ranged from intermediate to above intermediate, while those of the narrow sense heritability ranged from low to intermediate. With regard to number of gene pairs differentiating the two parental cultivars for earliness ranged from 1 to 3 and for total yield/plant from 1 to 5 pairs. Plant reaction to fusarium wilt disease were negatively correlated with each of earliness, fruit length, diameter and weight and total yield/plant, Moreover, there were highly significant positive correlations between plant reaction to fusarium wilt disease and each of reducing, non-reducing and total sugars. Also, negative correlation with each of total, free and congested phenols in the cross Crimson Sweet X Sugar Baby was found. The combined effect of plant disease reaction, number of branches/plant, fruit set percentage and fruit length, diameter and weight on total yield/plant was highly significant.

INTRODUCTION

Fusarium wilt disease of watermelon caused by *Fusarium oxysporum* f. sp. *niveum* (**E. F. Sm**.) **Snyd**.& **Hans**., is one of the most serious production problems confronting watermelon growers throughout the world. Once a field is infested, the fusarium wilt pathogen may survive for many years and seriously limit watermelon production in those fields. Resistant varieties and long rotation are the only control methods now used by watermelon growers. Genetic resistance has consistently proven to be the most effective and efficient means of control (**ELmstrom** and **Hopkins, 1981; Hopkins** and **ELmstrom, 1984**).

ELmstrom and Hopkins (1981); Martyn and Netzer (1991); Zhang *et al* (1995); Zhou and Zhou (1995); Gu *et al* (1996); Fenny *et al* (1998); Young *et al* (1998); Xiao *et al* (1999); Yucel *et al* (1999); Xiao *et al* (2000); Hawkins *et al* (2001); Zhang *et al* (2002 a); Zhang *et al* (2002 b); Swiader *et al.* (2002); Michail *et al*. (2003) and **Zhou and Everts (2003)** mentioned that highly genetic differences were observed between the different *Citrullus lenatus* genotypes concerning resistance to fusarium wilt disease.

Xiao *et al* (2000) made intergeneic crosses between lines D3-1 and D3-2 of bottle gourd (*Lagenaria siceraria*) which are highly resistant to wilt disease of watermelon caused by *Fusarium oxysporum* and watermelon cultivar Sugar Baby which is susceptible. The F_1 hybrid showed high resistance to the disease. The ratios of resistance to susceptibility the Bc_1 (backcross to the susceptible parent-Sugar Baby) and the F_2 populations were 1: 1 and 3:1, respectively.

Yu *et al* (1995) showed that the inheritance of resistance fitted the additive-dominance model, whereas the additive effect was major and the susceptibility was partially dominant. On the other hand, **Xiao *et al* (2000)** mentioned that resistance to fusarium wilt was dominant and simply inherited which was controlled by a mono-gene or mono-segment DNA.

Chemical constituents of watermelon plants, *i.e.*, total phenols and sugars (reducing, non-reducing and total) varies between resistant and susceptible plants concerning on powdery mildew of melon (**Merghany**, **1989)**; fusarium wilt and downy mildew of cucumber **(Abd El Hafez** *et al.*, **1990**; **Fang** *et al.*, **1994**). In addition **Abd El Hafez** *et al*. (**1990**) found a negative strong correlation between the degree of susceptibility and total phenols and strong positive correlation between the degree of infection and soluble and non-soluble sugars in their study on the inheritance of downy mildew resistance in cucumber. **Badr** and **Mohamed** (**1998**) found that, leaves of resistant male parent of cucumber contained higher phenols and lower sugars contents than any of the susceptible female parents.

The objectives of this research were to study the inheritance of resistance to fusarium wilt disease in watermelon plants and reveal the nature of resistance. Such information is important when designing a breeding program for developing new watermelon cultivars that are resistant to fusarium wilt disease.

MATERIAL AND METHODS

This research was conducted in the experimental field and greenhouse of the Department of Horticulture, College of Agriculture-Moshtohor, Zagazig University, Benha Branch, during the summer seasons of 2000, 2001 and 2002.

Individual plants of cultivars Crimson Sweet, Sugar Baby and Charleston Gray, which belong to *Citrullus lanatus*, were selfed for two generations during summer seasons before staring this research. Watermelon cultivars Charleston Gray and Crimson Sweet are known to be resistant to the fusarium wilt disease, while, Sugar Baby is known to be susceptible (**ELmstrom** and **Hopkins**, **1981**). Seeds of these cultivars were obtained from the germplasm preservation laboratory, Faculty of Agriculture-Moshtohor, Department of Horticulture, Moshtohor, Kalubia, Egypt. The following crosses were made between the different parental germplasm in the summer season of 2000: Crimson Sweet X Sugar Baby, Charleston Gray X Sugar Baby, Sugar Baby X Crimson Sweet and Sugar Baby X Charleston Gray.

Seeds of the parental genotypes and F_1's were planted on March 25, 2001 in the field. Plants of the F_1 populations were selfed to obtain F_2 seeds and the crosses between the different parental genotypes were repeated, as the previous year, to obtain enough seeds for the different F_1 populations. In addition, the backcross populations i.e., Bc_1 and Bc_2, were obtained by crossing plants of each F_1 hybrid with its respective parents. Seeds of the parental genotypes, F_1, F_2 and backcrosses were kept until the next season to evaluate the different populations in the field.

Seeds of the different populations of each cross were planted in the field on March 28, 2002, for evaluating the plants of each population individually. The experimental design used was randomized complete block design with three replications. Each replicate contained one ridge for each of the parental genotypes and their F_1 plants, four ridges for F_2 plants and two ridges for plants of each backcross populations. Seeds were sown in hills on one side of each ridge of four-mater length and 2.0 maters wide, with two seeds per hill at 40 cm apart. All other agriculture practices, i.e., irrigation, fertilization, weed control, …*etc*., were followed as in the district.

Wilt disease studies:

Samples of naturally infected of plants collected from the Exp. Farm, Fac. Agric., Moshtohor, Zagazig Univ., were used for isolation. Infected plants were surface sterilized with 5% sodium hypochloride solution for 2 minutes, re-washed several time in sterilized distilled water, and then dried between sterilized filter papers. Small portions of infected tissues were cut, plated on potato dextrose agar medium (PDA) and incubated at 25 °C for 3-5 days. The resultant fungus was isolated and purified using the hyphal tip and/or the single spore methods (**Hawker**, **1950**). The obtained fungus was identified as *Fusarium oxysporum* according to **Barnett** & **Hunter** (**1972**) and confirmed by Fungal Taxonomy Dept., Plant Pathology Institute, ARC, Egypt. The pathogenicity of the obtained fungus was verified on number of inbred lines, *i.e*., (susceptible to fusarium wilt disease) and plants under greenhouse conditions.

Greenhouse experiment:

Plastic pots (20 cm dim) each containing 3 Kg sterilized clay loamy soil (1 sand: 2 clay (w:w) were used in this study. The potted soil was infested at the rate of 3 % (w/w) by 2-weeks old cultures of *Fusarium oxysporum* grown for 2 weeks on corn meal-sand medium at 25°C (**Riker** and **Riker 1936**), thoroughly mixed, watered and left for two weeks under the greenhouse conditions. Untreated natural soil as well as un-infested sterilized soil were served as controls. Pots were planted with healthy surface sterilized watermelon seeds of an inbred lines using 3 seeds per pot. Three pots were used for each particular treatment.

Percentage of pre-emergence damping-off was calculated 15 days after sowing while % post-emergence damping-off and % healthy survived seedlings were also determined after 45 days.

Field experiment:

Watermelon germplasm were tested in field soil naturally infested with the watermelon fusarium wilt fungus.

Percentage of disease incidence was recorded five times starting 15 days from sowing periodically every 3 days and calculated as disease index. The final one was recorded in the results using a scale containing 6 grades suggested by **Perry** (**1962**) to illustrate the differences between the various grades of susceptibility:

Grade: 0 : Apparently healthy plants.
1 : Plants with net chlorosis of cotyleonary leaves.
2 : Plants with yellowing and browning of cotyledonary leaves.
3 : Plants with yellowing, browning and chlorosis of the first true leaf.

4 : Plants with dropping of cotyledonary leaves and yellowing in the first foliage leaves with slight brown colour.

5 : Plants with complete death of all leaves whether dropped or not and had the black colour.

The equation used for estimating disease incidence was as follows:

$$\text{Disease index} = \frac{(n0 \times X0 + (n1 \times 1) \ldots + (n5 \times 5)}{n \times c} \times 100$$

Where:

n = No of plants in each grade.

c = number of grade as modified from **Perry** (**1962**).

The following characters affected by the degree of resistance to wilt disease were recorded for the individual plants of the different populations of each crosse: Earliness of flowering, fruit set percentage, number of branches, fruit weight, total yield/plant and fruit length and diameter.

Total phenols present in plant leaves were estimated and presented as ml/100 gm fresh weight according to the method described by **Snell** and **Snell** (**1953**).

Total sugars content of leaves of individual plants was determined using the method described by **Flood** and **Priesty** (**1973**).

Genetic statistical analysis:

The frequency distribution for the different characters in the F2 population of the different crosses was used to determine the mode of the inheritance according to the method suggested by **Briggs** and **Knowles** (**1977**).

Analysis of variance and calculations of the mean and its standard error, total variance and correlation coefficients were performed according to the methods described by **Briggs** and **Knowles** (**1977**). The chi- square test was applied to reveal the mode of inheritance of the qualitative characters according to the method described by **Strickberger** (**1976**).

The nature of dominance for the studied quantitative characteristics was determined by the value of the potence ratio of gene set (P) calculated by the formula reported by **Smith** (**1952**)

Potence ratio (P) =

Where:

F_1 = F1mean., M. P. = Mid-parent mean., P_1 = the smaller parent mean. And P_2 = the larger parent mean.

The following formula suggested by **Allard** (**1960**) was used to calculate the broad sense heritability (BSH) estimate for the different quantitative characters.

BSH =

Narrow sense heritability (NSH) was estimated using the formula described by **Mather** and **Jinkes** (**1971**):

NSH =

Whereas:

VF1 = variance of the first generation, VF2 = variance of the second generation, VP1 = variance of the first parent, VP2 = variance of the second parent, VBc1 = variance of the first backcross and VBc2 = variance of the second backcross.

The minimum number of gene pairs differentiating the two parents was estimated using the following method given by **Castle** and **Wright** (**1921**):

$$N = \quad N = \frac{D^2}{8(VF_2 - VF_1)}$$

Where:

N =minimum number of gene pairs by which the parental differ, D = Mean of larger parent-Mean of smaller parent, VF_2 = variance of F_2 population and VF_1 = variance of F_1 population.

RESULTS AND DISCUSSION

Greenhouse experiment:

The parental cultivars Charleston Gray and Crimson Sweet were highly resistant to fusarium wilt disease, While Sugar Baby showed high susceptibility (**Table**, 1). The F_1 hybrids for all crosses were highly resistant. The differences between plant reaction means of each P_1, P_2 and F_1 of both crosses in the field and greenhouse experiments were not significant. This means that evaluation of different populations for fusarium wilt disease in the greenhouse is a dependable method for evaluation. These results indicate that this parental germplasm possess different gene for resistance to fusarium wilt disease. In this regard, **Barnes** (**1972**) in field and greenhouse studies determined that field and greenhouse resistance was categorized as follows: highly resistance, moderately resistance, slightly resistance and susceptible.

Table (1): Mean values of wilt disease index, estimates for some watermelon crosses under greenhouse and field conditions.

Cross	Population	Wilt disease index %		T. Test
		Green-house	Field	
Charleston Gray X Sugar Baby	P_1	8.30	4.83	0.302
	P_2	100.0	86.67	0.817
	F_1	9.3	7.33	0.158
Sugar Baby X Charleston Gray	P_1	100.0	86.67	0.817
	P_2	8.30	4.83	0.302
	F_1	10.67	9.50	0.049
Crimson Sweet X Sugar Baby	P_1	11.0	6.50	0.305
	P_2	100.0	86.67	0.817
	F_1	13.7	10.83	0.223
Sugar Baby X Crimson Sweet	P_1	100.0	86.67	0.817
	P_2	11.0	6.50	0.305
	F_1	15.3	15.00	0.028

Field experiment:

Fusarium wilt disease reaction:

Data presented in **Table** (**2**) show that, plants of Charleston Gray and Crimson Sweet were resistance to fusarium wilt disease, while plants of Sugar Baby were highly susceptible. Differences among *Citrullus lanatus* germplasm concerning their resistance to fusarium wilt disease have been reported by **El mstrom** and **Hopkins (1981); Martyn** and **Netzer (1991); Zhang *et al* (1995); Zhou** and **Zhou (1995); Gu *et al* (1996); Fenny *et al* (1998); Young *et al* (1998); Xiao *et al* (1999); Yucel *et al* (1999); Xiao *et al* (2000); Hawkins *et*** al (2001); Zhang et al (2002 a); Zhang et al (2002 b); Swiader et al. (2002); Michail et al. (2003) and Zhou and Everts (2003). All F1 plants were high resistant to the disease indicating the dominance of resistance plants. The results are in agreement with those obtained by Xiao et al (2000); Swiader et al. (2002) and Zhang et al. (2002 a) they found that F1 hybrid had high resistance to the disease. F2 populations segregated according to 3 resistant to 1 susceptible. When F1 plants were backcrossed to the susceptible parent, the progeny segregated to the ratio of 1 resistant to 1 susceptible, while when backcrossed to resistant parent, the progeny exhibited resistance. These results showed that resistance to fusarium wilt disease was a kind of dominant inheritance controlled by a single gene pair. These results are in accordance with those reported by Xiao et al (2000) who found that the ratios of resistance to susceptibility of the Bc1, which F1 was backcrossed with the susceptible parent-Sugar Baby, and the F2, populations were 1 : 1 and 3 :1, respectively. Also, Yu et al (1995) showed that the inheritance of resistance confirmed the additive-dominance model. The additive effect was major and the susceptibility was partially dominant. Moreover, Xiao et al (2000) mentioned that resistance to fusarium wilt was a kind of dominant inheritance controlled by a mono-gene or mono-segment DNA.

Table (2): Frequency distribution and segregation for plant reaction to Fusarium wilt in parents, F_1, F_2, BC_1, BC_2 generations in some watermelon crosses.

Generations	Frequency distribution and segregation for plant reaction (%)					Total No. of plants	R	S	Ratio	X^2
	20	40	60	80	100					
Charleston Gray (P_1)	27	3	-	-	-	30	30	-		
Sugar Baby (P_2)	-	-	-	-	30	30	-	30		
F_1	28	2	-	-	-	30	30	-		
F_2	34	19	17	14	36	120	84	36	3:1	1.6 n.s.*
BC_1 (F_1 x P_1)	47	13	-	-	-	60	60	-		
BC_2 (F_1 x P_2)	21	8	-	-	31	60	29	31	1:1	0.06 n.s.
Sugar Baby (P_1)	-	-	-	-	30	30	-	30		
Charleston Gray (P_2)	27	3	-	-	-	30	30	-		
F_1	26	3	1	-	-	30	30	-		
F_2	35	24	13	19	29	120	91	29	3:1	0.04 n.s.
BC_1 (F_1 x P_1)	17	14	3	-	26	60	34	26	1:1	1.06 n.s.
BC_2 (F_1 x P_2)	55	5	-	-	-	60	60	-		
Crimson Sweet (P_1)	24	6	-	-	-	30	30	-		
Sugar Baby (P2)	-	-	-	-	30	30	-	30		
F_1	22	7	1	-	-	30	30	-		
F_2	35	19	21	18	27	120	93	27	3:1	0.4 n.s.
BC_1 (F_1 x P_1)	48	12	-	-	-	60	60	-		
BC_2 (F_1 x P_2)	26	4	-	1	29	60	31	29	1:1	0.06 n.s.
Sugar Baby (P_1)	-	-	-	-	30	30	-	30		
Crimson Sweet (P_2)	24	6	-	-	-	30	30	-		
F_1	27	3	-	-	-	30	30	-		
F_2	68	10	3	5	34	120	86	34	3:1	0.71 n.s.
BC_1 (F_1 x P_1)	14	13	8	-	25	60	35	25	1:1	1.66 n.s.
BC_2 (F_1 x P_2)	52	8	-	-	-	60	60	-		

n.s.: not significant

Earliness of flowering:

Differences in earliness were detected among the parental watermelon cultivars (**Table**, **3**). The cultivar Baby Sugar had the highest number of days to the first flower anthisis (82.47 day), followed by cv. Charleston Gray (73.70 day) and cv. Crimson Sweet (54.30 day). The variability in number of days to the first flower anthesis observed among the different parental watermelon germplasm could be very useful in breeding programs for watermelon earliness.

Table (3): Frequency distribution for earliness in different population for some watermelon crosses.

Population	Upper class limits (days)								Total No. of plants	Mean ± SE	Variance
	50	60	70	80	90	100	110	120			
Charleston Gray (P_1)	-	-	11	7	12	-	-	-	30	73.70 ± 1.73	142.99
Sugar Baby (P_2)	-	-	-	8	23	-	-	-	30	82.47 ± 1.73	32.04
F_1	-	-	6	7	17	-	-	-	30	78.23 ± 1.73	54.91
F_2	1	8	4	20	47	28	10	2	120	85.51 ± 0.86	110.67
BC1 (F_1 x P_1)	-	-	2	16	24	17	1	-	60	84.37 ± 1.22	96.22
BC2 (F_1 x P_2)	-	-	-	15	22	15	8	-	60	86.97 ± 1.22	94.28
L.S.D. 0.05 0.01										13.36 20.24	
Sugar Baby (P_1)	-	-	-	8	23	-	-	-	30	82.47 ± 1.55	32.04
Charleston Gray (P_2)	-	-	11	7	12	-	-	-	30	73.70 ± 1.55	142.99
F_1	-	-	13	10	7	-	-	-	30	72.73 ± 1.55	70.56
F_2	-	-	3	30	60	24	1	2	120	83.64 ± 0.78	157.00
BC1 (F_1 x P_1)	-	1	9	19	13	15	3	-	60	81.03 ± 1.10	134.56
BC2 (F_1 x P_2)	-	-	1	28	26	5	-	-	60	80.17 ± 1.10	136.24
L.S.D. 0.05 0.01										9.01 15.19	
Crimson Sweet (P_1)	4	26	-	-	-	-	-	-	30	54.30 ± 1.75	21.34
Sugar Baby (P_2)	-	-	-	8	23	-	-	-	30	82.47 ± 1.75	32.06
F_1	-	-	6	8	16	-	-	-	30	79.00 ± 1.75	102.21
F_2	2	1	4	24	49	17	16	7	120	87.23 ± 0.87	141.61
BC1 (F_1 x P_1)	-	-	8	6	20	22	4	-	60	86.13 ± 1.23	120.56
BC2 (F_1 x P_2)	-	-	-	9	43	8	-	-	60	84.58 ± 1.23	119.62
L.S.D. 0.05 0.01										13.51 20.47	
Sugar Baby (P_1)	-	-	-	8	23	-	-	-	30	82.47 ± 1.49	32.04
Crimson Sweet (P_2)	4	26	-	-	-	-	-	-	30	54.30 ± 1.49	21.34
F_1	-	-	-	-	19	11	-	-	30	87.70 ± 1.49	24.90
F_2	5	4	25	42	31	9	3	1	120	76.13 ± 0.75	100.0
BC1 (F_1 x P_1)	-	-	5	26	15	14	-	-	60	80.17 ± 1.06	89.06
BC2 (F_1 x P_2)	-	-	5	24	23	8	-	-	60	79.60 ± 1.06	88.2
L.S.D. 0.05 0.01										11.56 17.51	

The frequency distribution of the F_1, F_2, Bc_1 and Bc_2 plants shown in **Table (**3) indicated quantitative inheritance pattern for earliness in the crosses Charleston Gray X Baby Sugar, Baby Sugar X Charleston Gray, Crimson Sweet X Baby Sugar and Baby Sugar X Crimson Sweet.

Concerning nature of dominance, earliness showed partial dominance (p=0.03 and 0.75) in the crosses Charleston Gray X Baby Sugar and Crimson Sweet X Baby Sugar, respectively. Meanwhile, over dominance were detected in the crosses Sugar Baby X Charleston Gray and Sugar Baby X Crimson Sweet (**Table**, **4**). The differences in these results may be due to that earliness was inherited quantitatively.

The broad sense heritability estimates were 60.86%, 69.09%, 63.37% and 73.91%. Meanwhile, the narrow sense heritability were 27.87%, 27.52%, 30.39% and

Table (4): Potence ratio, broad (B.S.H.) and narrow sense heritability (N.S.H.) and minimum number of effective gene pairs estimates for some watermelon crosses.

Characters	Earliness				Total yield/plant			
Crosses	P. ratio	B.S.H.	N.S.H.	No. of gene pairs	P. ratio	B.S.H.	N.S.H.	No. of gene pairs
Charleston Gray X Sugar Baby	0.03	60.86	27.87	1	1.92	65.73	29.37	1
Sugar Baby X Charleston Gray	-1.22	69.09	27.52	1	1.40	66.10	20.15	1
Crimson Sweet X Sugar Baby	0.75	63.37	30.39	3	2.40	51.87	11.44	2
Sugar Baby X Crimson Sweet	1.37	73.91	22.72	2	0.87	59.77	13.62	5

22.72% for the crosses Charleston Gray X Baby Sugar, Baby Sugar X Charleston Gray, Crimson Sweet X Baby Sugar and Baby Sugar X Crimson Sweet, respectively (**Table**, **4**). Thus, selection would be non-effective in the four crosses with regard to this character.

With regard to number of the gene pairs differentiating the two parental cultivars for earliness was from 1 to 3 pairs of gene in all crosses under study (**Table**, 4).

Table (4): Potence ratio, broad (B.S.H.) and narrow sense heritability (N.S.H.) and minimum number of effective gene pairs estimates for the different watermelon crosses.

Total yield per plant:

The results presented in **Table (**5) show that the parental cultivar Charleston Gray had the highest total yield/plant (8731.67kg) followed by Crimson Sweet (8258.33 kg) and Baby Sugar (4688.33 kg). These results were agreement with those reported by **Norton *et al* (1995**) and **Wang *et al* (1997**) they found that there were highly differences between *Citrullus lenatus* cultivars for total yield.

The F1 plants of all crosses were higher than both parents for total yield/plant except in the cross Baby Sugar X Crimson Sweet, which was intermediate between both parents. The potence ratio (p) calculated in the crosses Charleston Gray X Baby Sugar, Baby Sugar X Charleston Gray and Crimson Sweet X Baby Sugar indicated over dominance for high yield/plant, Meanwhile partial dominance for high yield/plant in the cross Baby Sugar X Crimson Sweet (**Table**, 4).

Total yield/plant was found to be inherited quantitatively, Based on the frequency distribution of this character in the F_2, Bc_1 and Bc_2 populations of all crosses (**Table**, 5).

The broad sense heritability values for total yield/plant were 65.73%, 66.10%, 51.87% and 59.77%, while the narrow sense heritability values were 29.37%, 20.15%, 11.44% and 13.62% in the crosses Charleston Gray X Baby Sugar, Baby Sugar X Charleston Gray, Crimson Sweet X Baby Sugar and Baby Sugar X Crimson Sweet, respectively, (**Table**, 4). These results indicated that the environmental variation influenced total yield/plant more than the genetic variation. Based on these results, selection for high total yield/plant in the segregating generations should be performed in replicated experiments.

The number of effective gene pairs controlling total yield/plant ranged from 1 to 5 in all crosses under this study.

Table (5): Frequency distribution for total yield/plant in different populations for some watermelon crosses.

Population	Upper class limite (g)												Total No. of plants	Mean ± SE	Variance
	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000			
Charleston Gray (P_1)	-	-	-	-	-	4	6	3	6	3	3	5	30	8731.67 ± 69	693018.9
Sugar Baby (P_2)	-	-	-	6	19	5	-	-	-	-	-	-	30	4688.33 ± 69	1190804.7
F_1	-	-	3	2	3	1	4	3	-	1	2	11	30	10583.33 ± 69	36863472.0
F_2	-	2	11	16	11	16	15	12	17	11	8	1	120	6985.00 ± 35	43752527.0
BC_1 (F_1 x P_1)	-	-	1	6	9	5	8	9	4	3	6	9	60	7651.67 ± 49	42087373.0
BC_2 (F_1 x P_2)	-	1	3	6	1	3	7	8	9	5	5	12	60	7722.50 ± 49	32569436.0
L.S.D. 0.05 0.01														5372.73 8139.23	
Sugar Baby (P_1)	-	-	-	6	19	5	-	-	-	-	-	-	30	4688.33 ± 62	854903.7
Charleston Gray (P_2)	-	-	-	-	-	4	6	3	6	3	3	5	30	8731.67 ± 62	6930108.9
F_1	-	-	4	-	1	4	1	4	2	2	4	8	30	9550.0 ± 62	26126717.0
F_2	-	-	3	20	24	12	11	7	16	4	6	17	120	6954.58 ± 312	23508933.0
BC_1 (F_1 x P_1)	-	1	3	3	15	1	6	3	1	16	4	7	60	7747.50 ± 44	23819806.0
BC_2 (F_1 x P_2)	-	-	4	6	13	12	6	4	5	4	1	5	60	6368.33 ± 44	18461509.8
L.S.D. 0.05 0.01														4830.40 7317.64	
Crimson Sweet (P_1)	-	-	-	-	-	-	9	5	6	10	-	-	30	8258.33 ± 63	6568302.6
Sugar Baby (P_2)	-	-	-	6	19	5	-	-	-	-	-	-	30	4688.33 ± 63	1190804.7
F_1	-	-	-	-	-	1	1	3	5	5	15	-	30	10751.67 ± 63	12438389.0
F_2	-	1	8	2	16	17	12	7	8	30	11	8	120	8390.42 ± 31	13988348.0
BC_1 (F_1 x P_1)	-	2	2	8	4	5	9	7	5	6	6	6	60	7215.0 ± 44	8254014.1
BC_2 (F_1 x P_2)	-	-	3	3	8	-	11	1	-	13	2	19	60	9242.5 ± 44	18122730.0
L.S.D. 0.05 0.01														4842.47 7335.94	
Sugar Baby (P_1)	-	-	-	6	19	5	-	-	-	-	-	-	30	4688.33 ± 95	1190804.7
Crimson Sweet (P_2)	-	-	-	-	-	-	9	5	6	10	-	-	30	8258.33 ± 95	6568302.6
F_1	-	-	-	1	9	3	-	2	3	4	1	7	30	2028.33 ± 95	35211117.0
F_2	-	6	9	20	7	8	15	14	6	25	6	5	120	8101.83 ± 47	35606760.0
BC_1 (F_1 x P_1)	-	6	7	8	5	1	3	4	2	2	6	16	60	8088.33 ± 67	29002318.0
BC_2 (F_1 x P_2)	-	-	1	3	2	2	4	1	2	3	3	39	60	13393.3 ± 67	37361923.0
L.S.D. 0.05 0.01														7346.38 11129.16	

Leaf chemical composition

It is clearly evident from **Table** (6) that there were highly significant differences between different populations, i.e., P_1, P_2, F_1, F_2, Bc_1 and Bc_2 in the cross Crimson X Sugar Baby for sugars (reducing, non-reducing and total) and phenols (free, conjugate and total) contents of the plant leaves. Leaves of the resistant cultivar Crimson Sweet contained higher phenolic (97.25, 1163.00 and 260.25 mg/100 g f.w.) for free, conjugate and total phenolic, respectively and lower sugars (91.99, 30.84 and 122.83 mg/100 g f.w.) for reducing, non-reducing and total sugars contents, respectively, than the susceptible cultivar Sugar Baby (**Table**, 6). Whereas, the amounts of both phenolic and sugars contents in leaves of the F1 plants were intermediate between the two parents.

Sugars leaves content of Bc_2 plants (166.04, 25.29 and 194.21 mg/100 g F.W. for reducing, non-reducing and total sugars, respectively) were higher than that of the Bc_1 plants (107.96, 7.46 and 115.41 mg/100 g f.w. for reducing, non-reducing and total sugars, respectively). On the other hand, phenols leaves content of Bc_2 plants (63.25, 107.75 and 171.00 mg/100 g f.w. for free, conjugate and total phenolic, respectively) were lower than that of the Bc_1 plants (91.03, 145.98 and 237.01 mg/100 g f.w. for free, conjugate and total phenolic, respectively). The differences observed between Bc_1 and Bc_2 populations in the present study could be due to maternal effect. Such information is very useful in breeding programs to improve resistance to fusarium wilt in watermelon.

Biochemical defense in plant might occur through inhibitors present in plant cells or deficiency in nutrients essential for the pathogen. The relatively high sugars content of susceptible plants may serve as a rich source of food for fusarium wilt fungus resulting in higher level of susceptibility. The present results suggested that defense mechanisms of a chemical nature are responsible for the resistance to infection with fusarium wilt disease. These results agree with those obtained by **Merghany** (**1989**) on powdery mildew on melon; **Abd El-Hafez** ***et al***. (**1990**) and **Fang** ***et al***. (**1994**) on downy mildew in cucumber. Also, **Badr** and **Mohamed** (**1998**) found that, leaves of resistant male parent of cucumber contained higher phenols (free, conjugated and total phenols) and lower sugars (reducing, non-reducing and total sugars) contents than any of the susceptible female parents.

Table 6: Leaf chemical composition of parent, F_1, F_2 BC_1 and BC_2 populations derived from crosses Crimson sweet x Sugar Baby as affected by fusarium wilt disease.

Table (7): Coefficient of correlation values (r) of different characters for some watermelon crosses.

Crosses	Characters	1	2	3	4	5	6	7	8	9	10	11	12	13
	2	-0.003												
Charleston	3	-0.311**	-0.244**											
Gray	4	0.009	-0.346**	0.384**										
X	5	-0.326**	-0.082	0.320**	0.144									
Sugar	6	-0.425**	0.063	0.385**	0.160	0.509**								
Baby	7	-0.474**	0.210*	0.308**	0.078	0.531**	0.900**							
	8	-0.755**	-0.016	0.299**	0.052	0.218**	0.565**	0.587**						
	2	0.122												
Sugar	3	-0.262**	-0.347**											
Baby	4	0.052	-0.284**	0.162										
X	5	0.293**	0.230**	-0.179*	0.062									
Charleston	6	-0.274**	-0.094	0.298**	0.050	0.061								
Gray	7	-0.283**	0.195*	-0.272**	0.081	0.629**	0.480**							
	8	-0.381**	0.159	0.293**	0.199*	0.269**	0.216**	0.388**						
	2	0.130												
	3	-0.295**	-0.350**											
	4	0.051	-0.355**	0.291**										
	5	-0.243**	-0.375**	0.549**	0.026									
Crimson	6	-0.224**	-0.426**	0.541**	0.044	0.970**								
Sweet	7	-0.373**	0.227*	0.678**	0.033	0.927**	0.917**							
X	8	-0.450**	0.043	0.531**	0.158	0.391**	0.325**	0.480**						
Sugar	9	-0.940**	-0.128	0.301**	-0.066	0.174*	0.145	0.307**	0.381**					
Baby	10	-0.691**	-0.081	0.179*	-0.026	0.195*	0.188*	0.245**	0.266**	0.594**				
	11	-0.913**	-0.130	0.303**	-0.065	0.160	0.131	0.300**	0.385**	0.982**	0.454**			
	12	0.951**	0.113	-0.314**	0.077	-0.257**	-0.235**	-0.372**	-0.462**	-0.913**	-0.734**	-0.877**		
	13	0.453**	0.043	-0.223**	0.081	-0.320**	-0.321**	-0.379**	-0.452**	-0.288**	-0.291**	-0.295**	0.490**	
	14	0.906**	0.103	-0.283**	0.056	-0.250**	-0.231**	-0.351**	-0.463**	-0.855**	-0.710**	-0.820**	0.959**	0.495**
	2	-0.244**												
Sugar	3	-0.260**	0.126											
Baby	4	-0.036	-0.215**	0.162										
X	5	-0.378**	0.245**	0.357**	0.077									
Crimson	6	-0.394**	0.097	0.422**	0.077	0.641**								
Sweet	7	-0.440**	0.232**	0.435**	0.007	0.791**	0.701**							
	8	-0.497**	0.430**	0.307**	0.220**	0.663**	0.548**	0.808**						

Characters with the coefficient as follow:
1: wilt disease, 2: number of branches, 3: earliness, 4: fruit set percentage, 5: fruit length, 6: fruit diameter, 7: fruit weight, 8: yield/plant, 9: total phenol, 10: free phenol, 11: conjugated phenol, 12: reducing sugars, 13: non- reducing sugars and 14: total sugars.

Simple correlation:

Plant reaction to fusarium wilt disease was highly significant negative correlated with each of earliness, fruit length, diameter and weight and total yield/plant in all crosses under study (**Table**, 7). Moreover, there were highly significant positive correlation's between plant reaction to fusarium wilt disease and each of reducing, non-reducing and total sugars, whereas, negative correlation with each of total, free and congested phenols in the cross Crimson Sweet X Baby Sugar. In this respect, **Wang *et al* (2002**) found that the resistant cultivars maintained relatively lower content of soluble sugar than the susceptible cultivars.

Significant positive correlation was observed between fruit weight and each of number of branches/plant. Moreover, highly significant positive correlations were found between fruit weight and each of earliness, fruit length and diameter and total yield/plant. In addition, there were highly significant positive correlations between fruit weight and each of total, free and congested phenols, whereas negative correlations with each of reducing, non-reducing and total sugars in the cross Crimson Sweet X Baby Sugar was recorded.

Total yield/plant was positively correlated with earliness, fruit length, diameter and weight in the crosses Charleston Gray X Baby Sugar, Baby Sugar X Charleston Gray, Crimson Sweet X Baby Sugar and Baby Sugar X Crimson Sweet. Meanwhile, there were highly significant positive correlations between total yield/plant and each of total, free and conjugated phenols, Moreover negative correlations with each of reducing, non-reducing and total sugars in the cross Crimson Sweet X Baby Sugar.

Multiple correlation:

The mutual effect of the different studied components of total yield/plant which measured by plant disease reaction, number of branches/plant, fruit set percentage and fruit length, diameter and weight was presented in **Table** (**8**). The results of the multiple regression analysis indicated significant linear relationship between the combined effect of plant disease reaction, number of branches/plant, fruit set percentage and fruit length, diameter and weight, and the total yield/plant in all studied crosses (**Table**, **8**). The values of R squared (R^2) were 0.647, 0.509, 0.507 and 0.767 which indicates that 64.7%, 50.9%, 50.7% and 76.7% of the variation in total yield/plant observed in the F_2 plants of the crosses under study were related to a real linear relationship between total yield/plant and all characters mentioned above. This result indicated the importance of considering the previously mentioned characters when selecting for high total yield/plant.

Table (8): Multiple regression coefficients between total yield/plant and other characters in some watermelon crosses.

Crosses	Involved indepent variables	R-Square	Multiple R	Significance
Charleston Gray X Sugar Baby	Wilt disease	0.647	0.805	**
	No. of branches			
	Fruit set percentage			
	Fruit length			
	Fruit diameter			
	Fruit weight			
Sugar Baby	Wilt disease			

X Charleston Gray	No. of branches Fruit set percentage Fruit length Fruit diameter Fruit weight	0.509	0.714	**
Crimson Sweet X Sugar Baby	Wilt disease No. of branches Fruit set percentage Fruit length Fruit diameter Fruit weight	0.507	0.712	**
Sugar Baby X Crimson Sweet	Wilt disease No. of branches Fruit set percentage Fruit length Fruit diameter Fruit weight	0.767	0.876	**

**: Significant at 1% level of significance

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توريث وطبيعة المقاومة لمرض الذبول الفيوزاريومى في البطيخ

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***قسم البساتين - كلية الزراعة بمشتهر- جامعة الزقازيق- فرع بنها**

****قسم النبات الزراعي (فرع أمراض النبات) - كلية الزراعة بمشتهر- جامعة الزقازيق- فرع بنها**

***** أقسام بحوث الخضر – معهد بحوث البساتين**

تم إجراء التهجين بين أصناف مختلفة من البطيخ مثل شارلستون جراى X البيبى شوجر والكريمسون اسويت X البيبى شوجر وكذلك ايضا الهجن العكسية وذلك لدراسة توريث وطبيعة المقاومة لمرض الذبول الفيوزاريومى فى البطيخ0 أظهرت نباتات الجيل الأول مقاومة عالية لهذا المرض0 وقد كانت نسبة انعزال النباتات المقاومة الى النباتات الحساسة فى نباتات الجيل الثاني وفى التهجين الرجعى لنباتات الجيل الأول مع الأب الحساس 3: 1 و 1 : 1 على التوالى0 وكانت صفات التبكير فى الإزهار والمحصول الكلى للنبات تورث كميا0 تراوحت طبيعة توريث صفات التبكير فى الإزهار والمحصول الكلى للنبات بين سيادة جزئيه الى فوق السيادة وذلك فى الهجن التى تحت الدراسة0 تقدير درجة التوريث بمعناها الواسع لصفات التبكير في الإزهار والمحصول الكلى للنبات تراوحت ما بين متوسطة الى فوق متوسطة – بينما درجة التوريث بمعناها الضيق تراوحت ما بين منخفضة إلى متوسطة0 عدد أزواج الجينات التى تتحكم فى صفة التبكير فى الإزهار تراوحت بين زوج الى ثلاث أزواج – أما بالنسبة لمحصول النبات الكلى تراوحت بين زوج الى خمسة أزواج من الجينات.

رد فعل النبات تجاه مرض الذبول الفيوزاريومى كان مرتبط ارتباط سالب عالى المعنوية مع كل من التبكير فى الإزهار – طول وقطر ووزن الثمرة ومحصول النبات الكلى0 بينما كانت هناك علاقة موجبة عالية المعنوية بين رد فعل النبات للمرض مع كل من محتوى النبات من السكريات المختزلة والغير مختزله والكلية – بينما العلاقة كانت سالبه مع كل من الفينولات الكلية والحرة والمرتبطة وذلك فى الهجين كريمسون اسويت X البيبى شوجر0 هناك علاقة خطيه عالية المعنوية بين تأثير الصفات الآتية مجتمعه على محصول النبات الكلى وهى رد فعل النبات للمرض – عدد أفرع النبات – نسبة العقد – طول وقطر ووزن الثمرة0