

Heterosis for Yield Components and Fruit Traits in Tomato under Condition of Fusarium Infection and Biological Control by Antagonistic Bacteria

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ABSTRACT

This study aimed to induce hybrid genotypes resistant to fusarium wilt disease in tomato, as well as using *Bacillus thuringiensis* as a biological control agent against *Fusarium oxysporum*. Four tomato varieties were used in this study to induce 12 F₁ hybrids and their reciprocal hybrids via diallel crosses. High significant heterosis relative to the mid-parent was obtained with the largest value by P₁×P₂ for plant height, in addition to significant heterosis was obtained by the reciprocal hybrid for the same trait in fungi and control treatments. The parental variety P₃ had the highest mean values of total yield per plant in the four treatments where the bacterial treatment T₄ gave the highest mean value of total yield per plant in relation to other treatments. The reciprocal hybrid P₃×P₁ gave the highest mean values in the four treatments for the total weight of fruits per plant which referred to the maternal effect. The hybrid P₂×P₃ gave highly significant values of heterosis in the four treatments for weight of three early collections and total weight of fruits per plant. The results appeared that *Bt* treatments enhanced all traits measured in this study especially chemical parameters. This indicated that *Bt* played a major role in the control of natural infection due to biotic stress. In addition, tomato showed higher heterosis in crosses and reciprocal crosses which depends on the distance between varieties.

Keywords: Heterosis, tomato, *Bacillus thuringiensis*, *Fusarium oxysporum*.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.; 2n=24) belongs to Family *Solanaceae*. Tomato is one of the most important vegetable crops all over the world including Egypt. Tomato is a rich source of vitamin A, C and minerals like Ca, P, K and Fe (Dhaliwal *et al.*, 2003).

Tomatoes are major contributors of antioxidants such as carotenoids (especially, lycopene and β-carotene), phenolic, ascorbic acid (vitamin C) and small amounts of vitamin E in daily diets (Rai *et al.*, 2012). Heterosis is a biological phenomenon manifesting itself in hybrids that are more vital, adaptive and productive than their parents. Heterosis has been explained by over-dominance and by additive effects (Bai and Lindhout, 2007).

Fusarium causes vascular wilt of vegetables, flowers, ornamentals and other important crops. Different host plants are attacked by special forms or races of *F. oxysporum*. The disease caused by this fungus is characterized as a wilted plants, yellowed leaves and minimal/reduced or even total loss/absent crop yield (Pataki *et al.*, 2000). In order to produce hybrids that are carriers of resistance gene it is necessary to test reaction of existing material to the pathogen and establish the potential of existing genotypes that can be used in agriculture. Biological control offers an important alternative to synthetic chemicals. The use of bacteria as *Bacillus sp.*, have been investigated because of their properties to produce antifungal metabolites and protect plants from fungal infection (Nourozian *et al.*, 2006).

This study aimed to investigate the inheritance of resistance for Fusarium wilt disease in tomato, as well as, using *Bacillus thuringiensis* as a biological control agent against *Fusarium* wilt to enhancing the growth and yield traits of tomato.

MATERIALS AND METHODS

Genetic materials

Four tomato varieties belong to species *Lycopersicon esculentum* Mill were used. These parental varieties were Fatma (P₁), Castel rock (P₂), Tigerella (P₃) and Marglop (P₄). The seeds of these parental varieties were kindly provided from Vegetable Research

Department, Horticulture Research Institute, Agriculture Research Center, Giza, Egypt. Bacterial strain used in this study was *Bacillus thuringiensis* which kindly provided from Bacillus Genetic Stock Center, Biochemistry Dept., Ohio University, Columbus, USA. This strain was maintained on TGY medium as a complete medium according to Mazza *et al.*, (1992). *Fusarium oxypourm f.* used in this study was obtained from Plant Protection Research Institute, Agriculture Research Center, Egypt. PDA medium was used as a complete medium for growing and maintained *Fusarium oxypourm* according to Leslie and Summerell (2006).

Experimental design

The four parental varieties and their F₁, F_{1r} hybrids were arranged in Randomize Complete Blocks Design with three replicates. The seedlings were transplanted to the pots after 45 days from sowing. Soil in pots consists of land soil and sand 1:1 without any source of fertilization. The plants were treated with *Fusarium oxypourm* three times weakly after two weeks from transplanting. Plants were three weeks inoculated weakly with bacterial suspension (10⁹ cells/ml) at the time of flowering for four times with the rate of 5 ml/plant. Treatments inoculated: control plants without any inoculation by fungi or bacteria T₁, plants treated with *Fusarium oxypourm* T₂, plants treated with *Bt* + *Fusarium* T₃, plants treated with *Bt* T₄. Pots preparation, fertilization and other practices were carried out according to the recommendations of the Egyptian Ministry of Agriculture. Data were recorded from randomly chosen plants of three replications using the following traits; plant height, number of fruits per plant for the first three pickings, weight of fruits per plant of the first three pickings, total number of fruits per plant, total weight of fruits per plant, ascorbic acid content according to Sadasivam and Balasubraminan (1987). The estimation of total phenols was measured according to Bary and Thorpe (1954).

Statistical analysis

Data were collected on P₁, P₂, F₁ and F_{1r} hybrids for yield components and other biochemical traits were subjected to statistical analysis of Randomed Complete Blocks Design as outline by Steel and Torrie (1960).

Heterosis is the percentage increase of the F₁ hybrid in relation to the mid - parent according to Singh and Chaudary (1985) as follows;

$$H\% = \frac{F_1 - M.P}{M.P} \times 100$$

$$F_1 = \frac{\sum F_{1j..}}{P(P-1)} \quad \text{for all hybrids and}$$

$$\text{As } \frac{\sum F_{1j.}}{P(P-1)/2} \quad \text{for } F_1 \text{ or } F_{1r} \text{ reciprocals.}$$

RESULTS AND DISCUSSION

The mean performance of parental varieties and their F₁ hybrids for plant height, ascorbic acid and phenol compound in the four treatments are presented in Table 1. The results indicated that genotypes showed highly significant differences to all treatments. Plant height showed that the parental genotype Fatma (P₁) was higher than Castel rock (P₂) in control T₁ and fungi treatment T₂. Parent Fatma (P₁) gave high value in fungi treatment than control which proved the resistance of this variety to *Fusarium* wilt. The parental variety Fatma (P₁) had highest mean values in control T₁ and in fungi and bacterial treatment T₃. The parental variety Castel rock (P₂) had highest mean value in fungi treatment T₂ and in bacterial treatment T₄ and it had the highest mean value, for ascorbic acid trait. For phenol compound the parental variety Fatma

(P₁) had the lowest mean values in the four treatments which indicate that, the parental variety Fatma (P₁) was resistant to *Fusarium* wilt and bacteria also reduce the infection of disease. The F₁ hybrid P₁×P₂ had highest mean value in control T₁ and in fungi treatment T₂ and it was higher than F_{1r} hybrid over the two treatments for plant height. The F₁ hybrid P₁×P₂ had highest mean values in the four treatments for ascorbic acid. Phenolic compounds showed that, F₁ hybrid P₁×P₂ had a lowest mean value in fungi treatment T₂ and in fungi and bacterial treatment T₃, but the F_{1r} reciprocal hybrid P₂×P₁ had lowest mean values in control T₁ and in bacterial treatment T₄. The results showed highly significant heterosis relative to the mid-parent for plant height, with a largest value was 32.8% for P₁ × P₂ in control, while heterosis for the reciprocal hybrid was also significant in control T₁ and fungi treatment T₂. The F₁ hybrid of P₁×P₂ had highly significant values for ascorbic acid in the four treatments. On the other hand, phenol compound was not significant in control T₁ for F₁ and their F_{1r}, but the F₁ hybrid of (P₁×P₂) had negative significant values -30.3% in fungi treatment T₂ and -54.9% in fungi and bacteria treatment T₃. While, the reciprocal hybrid of P₂×P₁ had highly significant of -49.6% in T₄ bacterial treatment. The results presented in Table 2 appeared that the parental variety Fatma (P₁) was the best parent in control T₁ for plant height and ascorbic.

Table 1. The mean performance of parental varieties P₁, P₂ and their hybrids and heterosis for plant height and some of chemical traits under treatments.

Traits & Treat. Geno & Heterosis	Plant height (cm)				Ascorbic acid				Phenol compounds			
	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄
P ₁	46.3	58	-	-	17	14.6	17.3	21.3	0.226	0.613	0.203	0.346
P ₂	41	43	-	-	16.1	14.8	16.3	21.6	0.261	0.753	0.566	0.433
M.P	43.6	50.5	-	-	16.5	14.7	16.8	21.3	0.243	0.683	0.384	0.389
F ₁	58	55.3	-	-	18.6	16.5	19.3	26	0.341	0.476	0.173	0.226
F ₁ -M.P	14.4	4.8	-	-	2.1	1.8	2.5	4.7	0.098	-0.207	-0.211	-0.163
H ₁ %	32.8*	9.50	-	-	12.7**	12.2**	15.3**	21.2**	40.3**	-30.3**	-54.9**	-41.9**
F _{1r}	53.6	56.6	-	-	18.1	15.4	17.8	23.6	0.293	0.791	0.336	0.196
F _{1r} -M.P	10	6.1	-	-	1.6	0.7	1	2.3	0.05	0.108	-0.048	-0.193
H _r %	22.7*	12.1*	-	-	9.69**	4.76	5.95	10.7**	20.5*	15.8**	12.5*	-49.6**
L.S.D	0.05	10.9				1.16				0.043		
	0.01	14.5				1.52				0.057		
F ₁ -F _{1r}	4.4	-1.3	-	-	0.5	1.1	1.5*	2.4**	0.048	-0.315**	-0.163**	0.03
L.S.D	0.05	12.5				1.33				0.051		
	0.01	16.7				1.75				0.066		

T₁: Control; T₂: Fungi treatment; T₃: Fungi and bacteria treatment and T₄: Bacterial treatment.

P₁: Fatma P₂: Castel rock H₁%: Heterosis and H_r%: Reciprocal heterosis.

Table 2. The mean performance of parental varieties P₁, P₃ and their hybrids and heterosis for plant height and some of chemical traits under treatments.

Traits & Treat. Geno. & Heterosis	Plant height (cm)				Ascorbic acid				Phenol compounds			
	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄
P ₁	46.3	58	-	-	17	14.6	17.3	21.3	0.226	0.613	0.203	0.346
P ₃	40.3	60.3	-	-	15	13.3	14.6	16.3	0.223	0.22	0.253	0.22
M.P	43.3	59.1	-	-	16	13.9	15.9	18.8	0.224	0.416	0.228	0.283
F ₁	57.3	65.3	-	-	17.7	15.2	17.6	22.3	0.266	0.343	0.24	0.21
F ₁ -M.P	14	6.2	-	-	1.7	1.25	1.7	3.5	0.042	-0.073	0.012	-0.073
H ₁ %	32.3*	10.3	-	-	10.6**	8.99*	10.6**	18.6**	18.7	-17.5**	5.26	-25.8**
F _{1r}	47.6	40	-	-	20.5	19.6	20	22	0.27	0.196	0.12	0.183
F _{1r} -M.P	4.3	19.1	-	-	4.5	5.7	4.1	3.2	0.046	-0.22	-0.108	-0.1
H _r %	9.93	-32.2**	-	-	28.1**	40.6**	25.7**	17**	19.1*	52.8**	-47.3**	-35.3**
L.S.D	0.05	10.9				1.16				0.043		
	0.01	14.5				1.52				0.057		
F ₁ -F _{1r}	9.7	25.3**	-	-	-2.8**	-4.4**	-2.4**	0.3	-0.004	0.147**	0.12**	0.027
L.S.D	0.05	12.5				1.33				0.051		
	0.01	16.7				1.75				0.066		

T₁: Control; T₂: Fungi treatment; T₃: Fungi and bacteria treatment and T₄: Bacteria treatment.

P₁: Fatma P₃: Tigerella H₁%: Heterosis and H₂%: Reciprocal heterosis.

For phenol compound the parental variety Trigella (P₃) had the lowest mean values in the four treatments which reverse the resistance of the same parent. The F₁ hybrid P₁×P₃ was better than its F_{1r} P₃×P₁ in the two treatments for plant height. The reciprocal hybrid (F_{1r}) P₃×P₁ had the highest mean values in T₁, T₂ and for ascorbic acid. For phenol compound, the lowest mean value showed with F_{1r} reciprocal hybrid P₃×P₁ in fungi treatment T₂. The F₁ hybrid between P₁×P₃ showed a low and significant values in control T₁ and in fungi treatment T₂ for plant height. For ascorbic acid heterosis of the reciprocal hybrid P₃×P₁ showed significant values in control T₁, fungi treatment T₂ and fungi and bacterial treatment T₃. The hybrid P₁×P₃ showed significant value (18.6%) for ascorbic acid in bacterial treatment T₄. Phenol compound was not significant in control T₁ and fungi and bacterial treatment T₃ in both of F₁ & F_{1r} hybrids. The reciprocal hybrid P₃×P₁ showed highly significant values of phenolic compounds in fungi treatment T₂ and in bacterial treatment T₄.

The results presented in Table 3 showed that parental variety Fatma (P₁) recorded the highest mean

values of the two treatments for plant height. The parental variety Fatma (P₁) had the highest mean values in control T₁, fungi treatment T₂ and bacterial treatment T₄ but the parental variety Marlob (P₄) had highest mean value in fungi and bacterial treatment T₃ for ascorbic acid. The parental variety Marglob (P₄) had the lowest mean values in four treatments for phenolic compounds which reverse to the resistance of Fusarium wilt. The F_{1r} reciprocal hybrid P₄×P₁ had highest mean value in the two treatments for plant height. The results indicated the role of bacteria against fusarium wilt, as well as, phenolic compounds which helping the plants to overcome fungal infection. The results showed the presence of high and positive heterosis for F₁ reciprocal versus mid-parent under the two treatments for plant height. The F_{1r} reciprocal hybrid P₄×P₁ had significant values in both of fungi and bacterial T₃ and bacterial treatment T₄, while the hybrid P₁×P₄ had highly significant values in control T₁ and fungi treatment T₂ for ascorbic acid. Heterosis of phenolic compounds was highly significant in bacterial treatment T₄.

Table 3. The mean performance of parental varieties P₁, P₄ and their hybrids and heterosis for plant height and some of chemical traits under treatments.

Traits& Treat. Geno.& Heterosis	Plant height (cm)				Ascorbic acid				Phenol compounds			
	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄
P ₁	46.3	58	-	-	17	14.6	17.3	21.3	0.226	0.613	0.203	0.346
P ₄	34	27.6	-	-	16.1	12.6	17.5	19.8	0.176	0.161	0.113	0.156
M.P	40.1	42.8	-	-	16.5	13.6	17.4	20.5	0.314	0.387	0.158	0.251
F ₁	50.8	40	-	-	18.1	15.6	17.8	21.8	0.284	0.443	0.29	0.17
F _{1r} -M.P	10.7	-2.8	-	-	1.6	2	0.4	1.3	-0.031	0.056	0.132	0.081
H ₁ %	26.6	6.54	-	-	9.69**	14.7**	2.29	6.34*	-9.56	14.4*	83.5**	-32.3**
F _{1r}	51.6	60.3	-	-	17.1	15.5	18	22	0.283	0.72	0.613	0.213
F _{1r} -M.P	11.5	17.5	-	-	0.6	1.9	0.6	1.5	-0.031	0.333	0.455	-0.038
H _r %	28.5*	40.8**	-	-	3.63	13.9**	3.44	7.31*	-9.87	86**	100**	-15.1
L.S.D	0.05	10.9				1.16				0.043		
	0.01	14.5				1.52				0.057		
F ₁ -F _{1r}	-0.8	-20.3**	-	-	1	0.1	-0.2	-0.2	0.001	-0.277**	-0.323**	-0.043
L.S.D	0.05	12.5				1.33				0.051		
	0.01	16.7				1.75				0.066		

T₁: Control; T₂: Fungi treatment; T₃: Fungi and bacteria treatment and T₄: Bacterial treatment.

P₁: Fatma, P₄: Marglob H₁ %: Heterosis and H_r %: Reciprocal heterosis.

The parental variety Castel rock (P₂) recorded highest mean value of plant height in control compared with Tigerella (P₃) in Table 4. The parental variety Castel rock (P₂) had highest mean values of ascorbic acid in all treatments which appeared the best value was 21.6 mg in bacterial treatment T₄. The parental variety Tigerella (P₃) was resistant to fusarium wilt disease which do not leading plant genotype to produce highest mean values of phenolic compounds. The F_{1r} hybrid P₃×P₂ recorded the highest mean value of plant height 61.3cm in control T₁ while, F₁ hybrid P₂×P₃ showed highest mean value of 49.6 cm in fungi treatment T₂. For ascorbic acid the F₁ hybrid P₂×P₃ showed highest mean values in T₁, T₃ and T₄ but the F_{1r} reciprocal hybrid P₃×P₂ had highest mean value in fungi treatment T₂, however, the best value was in bacterial treatment T₄. The F₁ hybrid P₂×P₃ had lowest mean values of phenolic compounds (0.22 mg) in fungi treatment T₂ and in bacterial treatment T₄ but the F_{1r} reciprocal hybrid P₃×P₂ had lowest value in control T₁ in fungi and bacterial treatment T₃. Heterosis for the F_{1r} hybrid P₃×P₂ was significant in control treatment for plant height. The F₁ hybrid P₂×P₃ showed highly and significant values of

ascorbic acid in four treatments and the reciprocal hybrid P₃×P₂ showed highly significant values in four treatments also. The hybrid P₂×P₃ had negative significant heterosis (-54.7%) for phenolic compounds in fungi treatment T₂ but the F_{1r} reciprocal hybrid P₃×P₂ showed negative and highly significant heterosis -48.5% and -47.9% in fungi treatment and fungi and bacterial treatment T₃, respectively.

The results in Table 5 showed that the parental variety Castel rock (P₂) showed the best results in the two treatments if compared with the parental variety Marglob (P₄) for plant height. The parental variety Castel rock (P₂) showed the highest mean values in the four treatments versus the parental variety Marglob (P₄) for ascorbic acid. The parental variety Marglob (P₄) had highest mean values in the four treatments versus the parental variety Castel rock (P₂) and the best value was in bacterial treatment (T₄) for phenolic compounds. The lowest mean value of phenolic compounds was the best which shown in the parental variety (P₄).

The F_{1r} reciprocal hybrid P₄×P₂ recorded the best mean values for plant height over the two treatments which showed the maternal effect in hybridization. The results

showed the F₁ hybrid P₂×P₄ had high mean values of ascorbic acid in fungi treatment T₂ (17.6 mg) and in bacterial treatment T₄ (22mg) while, the F_{1r} reciprocal hybrid P₄×P₂ showed the highest mean values in control T₁ (19.3 mg) and in fungi and bacterial treatment (18.6 mg) T₃. The results showed the F₁ hybrid P₂×P₄ had the lowest mean value for phenolic compounds. The heterosis of plant height in reciprocal hybrid versus the mid-parent for P₄×P₂ was significant in the two treatments. The F_{1r} reciprocal hybrid P₄×P₂ showed significant content of ascorbic acid in

control T₁ and in fungi and bacterial treatment T₃, but the hybrid P₂×P₄ showed highly significant value in fungi treatment T₂ and in bacterial treatment T₄. Heterosis of phenolic compounds was significant in control T₁ among both F₁ and their F_{1r}. In addition, the hybrid of P₂× P₄ showed significant heterosis percent for phenolic compounds in fungi treatment T₂, in fungi and bacterial treatment T₃ and in bacterial treatment T₄.

Table 4. The mean performance of parental varieties P₂, P₃ and their hybrids and heterosis for plant height and some of chemical traits under treatments.

Traits & Treat.	Plant height (cm)				Ascorbic acid				Phenol compounds			
	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄
P ₂	41	43	-	-	16.1	14.8	16.3	21.6	0.26	0.753	0.566	0.433
P ₃	40.3	60.3	-	-	15	13.3	14.6	16.3	0.223	0.22	0.253	0.22
M.P	40.6	51.6	-	-	15.5	14.1	15.4	18.9	0.241	0.486	0.409	0.326
F ₁	55.3	49.6	-	-	19.3	16	20.1	22.3	0.29	0.22	0.22	0.166
F ₁ -M.P	14.7	-2	-	-	3.8	1.9	4.7	3.4	0.049	-0.266	-0.189	-0.16
H ₁ %	36.1**	-3.96	-	-	24.5**	13.5**	30.5**	18.6**	20.3**	-54.7**	-46.2**	-49**
F _{1r}	61.3	40	-	-	18.6	17.7	20	22	0.27	0.25	0.213	0.316
F _{1r} -M.P	20.7	-11.6	-	-	3.1	3.6	4.6	3.1	0.029	-0.236	-0.196	-0.01
Hr %	50.4**	-22.5*	-	-	20**	25.5**	29.8**	17**	12.5	-48.5**	-47.9**	-3.06
L.S.D	0.05	10.9				1.16				0.043		
	0.01	14.5				1.52				0.057		
F ₁ -F _{1r}	-6	9.6	-	-	0.7	-1.7*	0.1	0.3	0.02	-0.03	0.007	-0.15**
L.S.D	0.05	12.5				1.33				0.051		
	0.01	16.7				1.75				0.066		

T₁: Control, T₂: Fungi treatment, T₃: Fungi and bacteria treatment and T₄: Bacterial treatment.

P₂: Castel rock P₃: Tigerella H₁%: Heterosis H_r%: Reciprocal heterosis.

Table 5. The mean performance of parental varieties P₂, P₄ and their hybrids and heterosis for plant height and some of chemical traits under treatments.

Traits & Treat.	plant height (cm)				Ascorbic acid				Phenol compounds			
	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄
P ₂	41	43	-	-	16.1	14.8	16.3	21.6	0.26	0.753	0.566	0.433
P ₄	34	27.5	-	-	16.1	12.6	17.5	19.8	0.176	0.161	0.113	0.156
M.P	37.5	35.3	-	-	16.1	13.7	16.9	20.7	0.218	0.457	0.339	0.294
F ₁	54	48	-	-	18.8	17.6	18.1	22	0.286	0.266	0.196	0.186
F ₁ -M.P	16.5	12.7	-	-	2.7	3.9	1.2	1.3	0.068	-0.191	-0.143	-0.108
H ₁ %	43.7	35.6*	-	-	16.7**	28.4**	7.10*	6.28*	31.2**	-41.8**	-42.2**	-36.7**
F _{1r}	58.6	48.6	-	-	19.3	15.6	18.6	21.8	0.326	0.616	0.4	0.293
F _{1r} -M.P	21.1	13.3	-	-	3.2	1.9	1.7	1.1	0.108	0.159	0.061	-0.001
Hr %	56.2**	37.6*	-	-	19.8**	13.8**	10.1**	5.31	49.5**	34.8**	17.9**	-0.34
L.S.D	0.05	10.9				1.16				0.043		
	0.01	14.5				1.52				0.057		
F ₁ -F _{1r}	-4.6	-0.6	-	-	-0.5	2**	-0.5	0.2	-0.04	-0.35**	-0.204**	-0.107**
L.S.D	0.05	12.5				1.33				0.051		
	0.01	16.7				1.75				0.066		

T₁: Control, T₂: Fungi treatment, T₃: Fungi and bacteria treatment and T₄: Bacterial treatment.

P₂: Castel rock P₄: Marglob H₁%: Heterosis H_r%: Reciprocal heterosis.

The results summarized in Table 6 showed superiority of the parental variety Tigerella (P₃) over the parental variety Marglob (P₄) for plant height under the two treatments. Parental variety Marglob (P₄) had high mean values of ascorbic acid in control T₁, in fungi and bacterial treatment T₃ and in bacterial treatment T₄, but parental variety Tigerella (P₃) had high mean value in fungi treatment T₂. The parental variety Marglob (P₄) showed the lowest mean values in all the four treatments for phenolic compounds and the lowest value was shown in bacterial treatment T₄ which proved the role of bacteria to protect plant from wilt disease. The F₁ hybrid P₃×P₄ showed high mean value of plant height in control T₁, followed by fungi treatment T₂. On the other hand, the F₁ hybrid P₃×P₄ gave highest mean values of ascorbic acid in the four treatments and the best value was in bacterial treatment T₄. The F₁ hybrid P₃× P₄ showed the lowest mean values of

ascorbic acid in fungi treatment T₂ and in fungi and bacterial treatment T₃, while the reciprocal hybrid P₄×P₃ showed lowest mean values in control T₁ and in bacterial treatment T₄. Heterosis of plant height versus mid-parent for the hybrid P₃×P₄ was highly significant in control T₁, while in F₁ and F_{1r} had non significant in fungi treatment T₂. The reciprocal hybrid P₄×P₃ showed highly significant values in the four treatments for phenol compounds. On the other hand, the hybrid P₃×P₄ gave highest values in the four treatments for ascorbic acid.

Similar results were obtained by Sunil *et al.*, (2013), Singhi and ASati (2011), Biswas *et al.*, (2012), Manojkumar *et al.*, (2016) and Kansouh and Zakher (2011), they found highly significant differences among tomato genotypes for plant height, ascorbic acid, phenolic compounds and fruit yield per plant. The results obtained in Table 7 showed that the parental variety Castel rock (P₂)

had the best mean values in the four treatments for NF3P and TNF versus parental variety Fatma (P₁). While, parental variety Fatma (P₁) had the best mean values in the four treatments for WF3P.

Table 6. The mean performance of parental varieties P₃, P₄ and their hybrids and heterosis for plant height and some of chemical traits under treatments.

Traits & Treat. Geno.& Heterosis	Plant height (cm)				Ascorbic acid				Phenol compounds			
	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄
P ₃	40.3	60.3	-	-	15	13.3	14.6	16.3	0.223	0.22	0.253	0.22
P ₄	34	27.6	-	-	16.1	12.6	17.5	19.8	0.176	0.161	0.113	0.156
M.P	37.1	43.9	-	-	15.5	12.9	16	18.1	0.199	0.19	0.183	0.188
F ₁	53.3	45.6	-	-	19.5	15.2	18.5	23.3	0.5	0.343	0.213	0.206
F ₁ -M.P	16.2	1.7	-	-	4	2.3	2.5	5.2	0.301	0.153	0.03	0.018
H ₁ %	43.4**	3.87*	-	-	25.8**	17.8**	15.6**	29.4**	151**	80.5**	16.3	9.57
F _{1r}	42.6	49.3	-	-	17.3	15	17.6	23	0.293	0.45	0.24	0.133
F _{1r} -M.P	5.5	5.4	-	-	1.8	2.1	1.6	4.9	0.094	0.26	0.057	-0.055
H _r %	14.8	12.3	-	-	11.6**	16.2**	10*	27.1**	47.2**	136**	31.1**	-29.2*
L.S.D	0.05		10.9			1.16				0.043		
	0.01		14.5			1.52				0.057		
F ₁ -F _{1r}	10.7	-3.7	-	-	2.2**	0.2	0.9	0.3	0.207**	-0.107**	-0.027	0.073**
L.S.D	0.05		12.5			1.33				0.051		
	0.01		16.7			1.75				0.066		

T₁: Control; T₂: Fungi treatment; T₃: Fungi and bacteria treatment and T₄: Bacteria treatment
P₃: Tigerella P₄: Marglob H₁%: Heterosis and H_r%: Reciprocal heterosis.

The results showed that the bacterial treatment was the best in relation to the other treatments of the F_{1r} reciprocal hybrid P₂×P₁ which had high mean values of yield components in the four treatments and the best value was shown in bacterial treatment T₄ for NF3P, while the F₁ hybrid P₁×P₂ had the highest mean values in the four treatments for TNF. On the other hand, the F_{1r} reciprocal hybrid P₂×P₁ showed highest mean values of yield in control T₁, in fungi and bacterial treatment T₃ and bacteria

treatment T₄. The F_{1r} reciprocal hybrid P₂×P₁ showed the highest mean values in the four treatments for TWF. The F_{1r} reciprocal hybrid P₂×P₁ showed significant heterotic values in the four treatments for NF3P. In addition, TNF had highly and significant in the reciprocal hybrid if compared with the hybrid of P₁×P₂ in the four treatments. High significant heterosis of yield was shown in the four treatments for the reciprocal hybrid P₂×P₁ if compared with hybrid P₁×P₂ for TWF.

Table 7. The mean performance of parental varieties P₁, P₂ and their hybrids and heterosis under the four treatments for yield component traits.

Traits& Treat Geno.& Heterosis	NF3P				WF3P				TNF				TWF			
	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄
P ₁	26.6	22	30.3	34	0.323	0.255	0.355	0.426	75.6	60	87.6	103	1.02	0.891	1.12	1.25
P ₂	37.3	30.6	42	48.6	0.312	0.245	0.34	0.353	81.3	68.6	97.6	114	1.06	0.826	1.15	1.51
M.P	31.9	26.3	36.1	41.3	0.317	0.235	0.347	0.389	78.4	64.3	92.6	108	1.04	0.858	1.13	1.38
F ₁	37.7	30.6	45	51.6	0.507	0.465	0.529	0.601	119.3	91	135	165	1.68	1.53	1.76	1.92
F ₁ -M.P	5.8	4.3	8.9	10.3	0.19	0.23	0.182	0.212	40.9	26.7	42.4	57	0.64	0.672	0.63	0.54
H ₁ %	18.2**	16.3**	24.6**	24.9**	59.9	86	52.4	56.8	52.2**	41.5**	45.7**	52.7**	61.5*	78.3*	55.7*	39.1*
F _{1r}	43	33.6	45.6	55.6	0.528	0.395	0.568	0.633	109.6	83.3	121.3	158	1.80	1.62	1.90	2.10
F _{1r} -M.P	11.1	7.3	9.5	14.3	0.211	0.16	0.221	0.244	31.2	19	28.7	50	0.76	0.762	0.77	0.72
H _r %	34.7**	27.7**	26.3**	34.6**	66.5	43.6	63.6	62.7	39.8**	29.5**	30.9**	46.2**	73.1*	88.8*	68.1*	52.2*
L.S.D	0.05		2.12			2.51				4.69				0.098		
	0.01		2.79			3.28				6.16				1.28		
F ₁ -F _{1r}	-5.3**	-3*	-0.6	-4**	-0.021	0.07	-0.039	-0.032	9.7**	7.7**	13.7**	7*	-0.12*	-0.09	-0.14*	-0.18**
L.S.D	0.05		2.45			2.89				5.42				0.113		
	0.01		3.22			3.79				7.11				0.148		

T₁: Control; T₂: Fungi treatment; T₃: Fungi and bacteria treatment and T₄: Bacterial treatment.

P₁: Fatma P₂: Castel rock H₁%: Heterosis and H_r%: Reciprocal heterosis.

NF3P: Number for fruits of the first three pickings, WF3P: Weight of fruits for the first three pickings, TNF: Total number of fruits and TWF: Total weight of fruits.

The reciprocal hybrid (P₂×P₁) showed highly significant heterotic percent in the four treatments for TWF. The results presented in Table 8 showed that the parental variety Tigerella (P₃) had the highest mean value in the four treatments for number of fruits to the first three pickings NF3P and total number of fruits. While, the parental variety Fatma (P₁) had highest mean values in control T₁ (0.322 kg) and in bacterial treatment T₄ (0.411 kg) versus the parental variety Tigerella (P₃) which had the highest mean values in fungi treatment T₂ (0.287 kg) and in fungi and bacteria treatment T₃ (0.360 kg) for weight of fruits in the first three pickings. Furthermore, the parental variety Tigerella (P₃) had the highest mean values of yield in the four treatments, where bacterial treatment T₄ gave the highest mean value of total yield. The F₁ hybrid P₁×P₃

had the highest mean values of yield in control T₁, fungi treatment T₂ and fungi and bacterial treatment T₃. However, the F_{1r} reciprocal hybrid P₃×P₁ had the highest mean value of yield in bacterial treatment T₄ for NF3P. The F_{1r} reciprocal hybrid P₃×P₁ showed the highest value in the four treatments for TNF. On the other hand, the F₁ hybrid P₁×P₃ gave the highest mean values for weight of fruits in fungi treatment T₂ and bacterial treatment T₄. In addition, the F_{1r} reciprocal hybrid P₃×P₁ showed the highest mean values of fruits weight in control T₁ and fungi and bacterial treatment T₃.

The F_{1r} reciprocal hybrid P₃×P₁ gave the highest mean value in all treatments for TWF and the best value was shown in bacterial treatment T₄ which revered to bacteria enhancing the growth of plants. The F₁ hybrid

P₁×P₃ gave the highest heterotic values for early number of yield in control T₁ (36.4%), fungi treatment T₂ (27.9%), in fungi and bacteria treatment T₃ (27.8 %) and bacteria treatment T₄ (39.1%). But, total number of yield the reciprocal hybrid of P₃×P₁ gave the highest and significant values in the four treatments. The reciprocal hybrid of P₃×P₁ gave highly significant values in all treatments for total weight of yield.

The results presented in Table (9) showed that the parental variety (P₁) among all treatments showed early and total number of fruits and total weight of fruits of traits where the best value gave by bacterial treatments T₄. The

F_{1r} reciprocal hybrid P₄×P₁ had high value for early number of fruits in control T₁, fungi and bacterial treatment T₃ and in bacterial treatment T₄, but the F₁ hybrid P₁×P₄ gave highest mean value in fungi treatment T₂. The results showed that the F₁ hybrid P₁×P₄ had the highest mean values in all treatments for early weight of fruits, total number of fruits and total weight of fruits. Highly significant heterosis values were obtained by the reciprocal hybrid P₄×P₁ in treatments for early number of fruits while, the F₁ hybrid P₁×P₄ had high significant value in all total number of fruits and total weight of fruits.

Table 8. The mean performance of parental varieties P₁, P₃ and their hybrids and heterosis under the four treatments for yield component traits.

Traits& Treat.	NF3P				WF3P				TNF				TWF				
	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	
P ₁	26.6	22	30.3	34	0.323	0.255	0.355	0.426	75.6	60	87.6	103	1.02	0.891	1.12	1.25	
P ₃	30.6	26	36	41.6	0.322	0.287	0.360	0.411	79.3	63	91.6	104	1.15	1.02	1.29	1.43	
M.P	28.6	24	33.1	37.5	0.322	0.271	0.357	0.418	77.4	61.5	89.6	103.5	1.08	0.955	1.20	1.34	
F ₁	39	30.7	42.4	52.6	0.512	0.440	0.543	0.633	87	70	100	121	1.66	1.41	1.71	1.87	
F ₁ -M.P	10.4	6.7	9.3	15.1	0.19	0.169	0.186	0.215	9.6	8.5	10.4	17.5	0.58	0.455	0.51	0.53	
H ₁ %	36.4**	27.9**	28.1**	39.1**	59	62.4	52.1	51.4	12.4**	13.8**	11.6**	8.73**	53.7**	47.6**	42.5**	39.5**	
F _{1r}	37.6	30.6	42.3	53.3	0.517	0.429	0.57	0.611	92	76	112	137	1.91	1.73	2.02	2.15	
F _{1r} -M.P	9	6.6	9.2	15.8	0.195	0.729	0.213	0.193	14.6	14.5	22.4	33.5	0.83	0.775	0.82	0.81	
H _r %	31.5**	27.5**	27.8**	41**	19.5	58.3	59.6	46.1	18.9**	23.5**	25**	33**	76.8**	81.1**	68.3**	60.4**	
L.S.D	0.05	2.12				2.51				4.69				0.098			
	0.01	2.79				3.28				6.16				0.128			
F ₁ -F _{1r}	1.4	0.1	0.1	-0.7	-0.005	0.011	-0.027	0.022	-5	-6	-12**	-16**	-0.25**	-0.32**	-0.31*	-0.28**	
L.S.D	0.05	2.45				2.89				5.42				0.113			
	0.01	3.22				3.79				7.11				0.148			

T₁: Control; T₂: Fungi treatment; T₃: Fungi and bacteria treatment and T₄: Bacterial treatment .

P₁: Fatma P₃: Tigerella H₁%: Heterosis and H_r%: Reciprocal heterosis.

NF3P: Number of fruits for the first three pickings, WF3P: Weight of fruits for the first three pickings, TNF: Total number of fruits and

TWF: Total weight of fruits.

Table 9. The mean performance of parental varieties P₁, P₄ and their hybrids and heterosis under the four treatments for yield component traits.

Traits& Treat.	NF3P				WF3P				TNF				TWF				
	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	
P ₁	26.6	22	30.3	34	0.323	0.255	0.355	0.426	75.6	60	87.6	103	1.02	0.891	1.12	1.25	
P ₄	24	16.6	28	32.6	0.282	0.22	0.314	0.350	70	52.6	84	96	0.836	0.662	0.895	0.998	
M.P	25.3	19.3	29.2	33.3	0.302	0.237	0.334	0.388	72.8	56.3	85.8	99.5	1.34	0.776	1.007	1.12	
F ₁	38	30.4	42.3	51.3	0.597	0.542	0.624	0.697	102	81	126	151	1.72	1.56	1.86	1.98	
F ₁ -M.P	12.7	11.1	13.1	18	0.295	0.305	0.29	0.309	29.2	24.7	40.2	51.5	0.38	0.784	0.853	0.86	
H ₁ %	50.2**	57.5**	45.3**	54**	97.6	128	86.8	79.6	40.1**	43.8**	46.8**	51.7**	85.3	101	88	76.7	
F _{1r}	39	30.3	46.3	51.4	0.531	0.358	0.551	0.612	100	78.6	122	145	1.52	1.17	1.59	1.72	
F _{1r} -M.P	13.7	11	17.1	18.1	0.229	0.121	0.217	0.224	27.2	22.3	36.2	45.5	0.18	0.394	0.583	0.6	
H _r %	54.1**	56.9**	59.1**	54.3**	75.8	51.1	64.9	57.7	37.3**	39.6**	42.2**	45.7**	63.7**	50.8**	60.7**	53.5**	
L.S.D	0.05	2.12				2.51				4.69				0.098			
	0.01	2.79				3.28				6.16				0.128			
F ₁ -F _{1r}	-1	0.1	-4**	-0.1	0.066	0.184	0.073	0.085	2	2.4	4	6	0.2**	0.39	0.27**	0.26**	
L.S.D	0.05	2.45				2.89				5.42				0.113			
	0.01	3.22				3.79				7.11				0.148			

T₁: Control; T₂: Fungi treatment; T₃: Fungi and bacteria treatment and T₄: Bacterial treatment

P₁: Fatma P₄: Marglob H₁%: Heterosis and H_r%: Reciprocal heterosis.

NF3P: Number of fruits for the first three pickings, WF3P: Weight of fruits for the first three pickings, TNF: Total number of fruits and

TWF: Total weight of fruits.

The results presented in Table 10 showed that the parental variety Castel rock (P₂) had the highest value among all treatments for number of fruits for the first three pickings and total number of fruits. The parental variety Tigerella (P₃) had the highest mean value in all treatments for early yield and total yield. The F_{1r} reciprocal hybrid P₃×P₂ gave the highest mean values for number of fruits of the three first pickings in control T₁, in fungi and bacterial treatment T₃ and bacterial treatment, but the F₁ hybrid P₂×P₃ had the highest mean values of 34 in fungi treatment T₂. The F_{1r} reciprocal hybrid P₃×P₂ showed the highest mean values in all treatments for total number of fruits. On the other hand, the F₁ hybrid P₂×P₃ gave the highest mean

values in all treatments for early weight of yield and total weight of fruits. It was noticed that the highest mean value was obtained by bacterial treatment T₄ which reversed the important role of bacteria in increasing the total yield of tomato. The number of fruits of three fruits pickings showed significant heterotic values of the reciprocal hybrid P₃×P₂ in control T₁ (12.1%), fungi and bacteria T₃ (11.8%) and bacteria treatment T₄ (11.2%), except 51.9% heterosis in fungi treatment T₂ was found in the F₁ hybrid P₂×P₃. The reciprocal hybrid P₃×P₂ showed highly significant values in all treatments for total number of fruits. However, heterosis of the hybrid P₂×P₃ was significant in all treatments for total weight of fruits.

Table 10. The mean performance of parental varieties P₂, P₃ and their hybrids and heterosis under the four treatments for yield component traits.

Traits& Treat.	NF3P				WF3P				TNF				TWF			
	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄
P ₂	37.3	30.6	42	48.6	0.312	0.245	0.34	0.353	81.3	68.6	97.6	114	1.05	0.826	1.15	1.51
P ₃	30.6	26	36	41.6	0.322	0.287	0.360	0.411	79.3	63	91.6	104	1.15	1.02	1.29	1.43
M.P	33.9	28.3	39	45.1	0.317	0.266	0.35	0.382	80.3	65.8	94.6	109	1.1	0.923	1.22	1.47
F ₁	37.6	34	43	50.6	0.474	0.476	0.590	0.639	90.6	70.6	112	133	1.81	1.62	1.88	2.06
F ₁ -M.P	3.7	5.7	4	5.5	0.157	0.21	0.24	0.257	10.3	4.8	17.4	24	0.71	0.697	0.66	0.59
H ₁ %	10.9 ^{***}	51.9 ^{***}	10.3 ^{***}	10.9 ^{***}	49.5	31.8	68.5	67.3	12.8 ^{***}	8.25 ^{***}	18.3 ^{***}	22 ^{***}	72.4 ^{***}	75.5 ^{***}	54 ^{***}	40.1 ^{***}
F _{1r}	38	30.6	43.6	50.7	0.382	0.312	0.415	0.462	112	90	131	157	1.47	1.21	1.51	1.67
F _{1r} -M.P	4.1	2.3	4.6	5.6	0.065	0.046	0.065	0.08	31.7	24.2	36.4	48	0.37	0.287	0.29	0.2
H _r %	12.1 ^{***}	8.12 ^{***}	11.8 ^{***}	11.2 ^{***}	20.5	17.2	18.5	20.9	39.4 ^{***}	36.7 ^{***}	38.5 ^{***}	44 ^{***}	40 ^{***}	31 ^{***}	23.7 ^{***}	13.6 ^{***}
L.S.D	0.05		2.12			2.51				4.69				0.098		
	0.01		2.79			3.28				6.16				0.128		
F ₁ -F _{1r}	-0.4	3.4 ^{**}	-0.6	-0.1	0.92	0.164	-0.24	0.177	-21.4 ^{**}	-19.4 ^{**}	-19 ^{**}	-24 ^{**}	0.32 ^{**}	0.41 ^{**}	0.37 ^{**}	0.39 ^{**}
L.S.D	0.05		2.45			2.89				5.42				0.113		
	0.01		3.22			3.79				7.11				0.148		

T₁: Control, T₂: Fungi treatment, T₃: Fungi and bacteria treatment and T₄: Bacterial treatment

P₂: Castel rock P₃: Tigerella H₁%: Heterosis and H_r%: Reciprocal heterosis.

NF3P: Number of fruits for the first three pickings, WF3P: Weight of fruits for the first three pickings, TNF: Total number of fruits and

TWF: Total weight of fruits.

The results which obtained in Table 11 showed that the parental variety Castel rock (P₂) had the highest mean value in all treatments for early and total yield components versus the parental variety Marglob (P₄). The F₁ hybrid P₂×P₄ gave the highest mean values in all treatments for early and total yield components.

High significant heterosis were obtained in all treatments for the early yield NF3P, TNF and TWF. The results presented in Table 12 showed that the parental variety Tigerella (P₃) had the highest and best mean values in all treatments for early yield {NF3P and WF3P} and total yield {TNF and TWF} versus the parental variety Marglob P₄. The best values for yield components was shown in bacterial treatment T₄ which referred to the promoting of plant growth which leading to increasing total yield per plant. The F₁ hybrid P₃×P₄ had the highest mean value for number of fruits for the first three pickings among all the treatments.

Also, the F₁ hybrid P₃×P₄ gave highest mean values for weight of fruits for the first three pickings in control T₁ (0.457 kg) and in fungi treatment T₂ (0.360 kg). Meanwhile, the F_{1r} reciprocal hybrid P₄×P₃ had highest mean values for the same trait in fungi and bacteria treatment T₃ (0.506 kg) and in bacteria treatment T₄ (0.58

kg). The F_{1r} reciprocal hybrid P₄×P₃ had highest mean values in all treatments for total number of fruits and total weight of fruits but the highest values was shown in bacterial treatment which reflected the maternal effect on these traits. The F₁ hybrid P₃×P₄ showed significant heterosis in all treatments for number of fruits for the first three pickings. Furthermore, the F_{1r} reciprocal hybrid P₄×P₃ gave high mean values for weight of fruits for the first three pickings in fungi and bacteria T₃ (50.1%) and in bacteria treatment T₄ (52.6%). Significant heterosis were showed for total number of fruits and total weight of fruits in the reciprocal hybrid P₄×P₃ among all treatments. The effect of maternal heterosis were clear in this hybrid (P₄×P₃) for total number of fruits and total weight of fruits. The results of heterosis for yield components were similar to those obtained by Chinedozi *et al.*, (2014), Hussein and Basheer (2016), Hannan *et al.*, (2007), Elsayed (2017) and Alice *et al.*, (2001), they found that tomato hybrids expressed significantly high percentage of positive heterosis over mid-parent for number of flower per plant, number of fruits per plant and fruit weight per plant. Results also showed a direct inhibition of the pathogenic strains manifested by *Bacillus sp.*

Table 11. The mean performance of parental varieties P₂, P₄ and their hybrids and heterosis under the four treatments for yield component traits.

Traits& Treat.	NF3P				WF3P				TNF				TWF			
	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄
P ₂	37.3	30.6	42	48.6	0.312	0.245	0.34	0.353	81.3	68.6	97.6	114	1.05	0.826	1.15	1.51
P ₄	24	16.6	28	32.6	0.282	0.22	0.314	0.350	70	52.6	84	96	0.836	1.98	0.895	0.998
M.P	30.6	23.6	35	40.6	0.297	0.232	0.327	0.351	44.2	60.6	90.8	105	0.943	1.40	1.02	1.25
F ₁	43.6	37	47.6	57	0.671	0.545	0.698	0.778	102	81.3	114	144	2.14	2.41	2.24	2.46
F ₁ -M.P	13	13.4	12.6	16.4	0.374	0.313	0.371	0.427	57.8	20.7	23.2	39	1.19	1.01	1.22	1.21
H ₁ %	42.5 ^{***}	56.7 ^{***}	36 ^{***}	40.4 ^{***}	125	134	113	121	34.9 ^{**}	34.1 ^{**}	25.5 ^{**}	37.1 ^{**}	126 ^{**}	72.1 ^{**}	119 ^{**}	96.8 ^{**}
F _{1r}	37.6	34	43.6	54.3	0.531	0.465	0.579	0.674	99.6	69.6	120	140	1.97	2.32	2.07	2.27
F _{1r} -M.P	7	10.4	8.6	13.7	0.234	0.233	0.252	0.323	55.4	9	29.2	35	1.02	0.92	1.05	1.02
H _r %	22.8 ^{**}	44.1 ^{**}	24.5 ^{**}	33.7 ^{**}	78.7	100	77.1	92	31.7 ^{**}	14.8 ^{**}	32.2 ^{**}	33.3 ^{**}	108 ^{**}	65.7 ^{**}	102 ^{**}	81.6 ^{**}
L.S.D	0.05		2.12			2.51				4.69				0.098		
	0.01		2.79			3.28				6.16				0.128		
F ₁ -F _{1r}	6 ^{**}	3 [*]	4 ^{**}	2.7 [*]	0.14	0.08	0.119	0.104	2.4	11.4 ^{**}	-6 [*]	4	0.17 ^{**}	0.09	0.17 ^{**}	0.19 ^{**}
L.S.D	0.05		2.45			2.89				5.42				0.113		
	0.01		3.22			3.79				7.11				0.148		

T₁: Control; T₂: Fungi treatment; T₃: Fungi and bacteria treatment and T₄: Bacterial treatment.

P₂: Castel rock P₄: Marglob H₁%: Heterosis and H_r%: Reciprocal heterosis.

NF3P: Number of fruits for the first three pickings, WF3P: Weight of fruits for the first three pickings, TNF: Total number of fruits and

TWF: Total weight of fruits.

Table 12. The mean performance of parental varieties P₃, P₄ and their hybrids and heterosis under the four treatments for yield component traits.

Traits& Treat. Geno.& Heterosis	NF3P				WF3P				TNF				TWF			
	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄	T ₁	T ₂	T ₃	T ₄
P ₃	30.6	26	36	41.6	0.322	0.287	0.360	0.411	79.3	63	91.6	104	1.15	1.02	1.29	1.43
P ₄	24	16.6	28	32.6	0.282	0.22	0.314	0.350	70	52.6	84	96	0.836	0.662	0.895	0.998
M.P	27.3	21.3	32	37.1	0.302	0.253	0.337	0.381	74.6	57.8	87.8	100	0.993	0.841	1.09	1.21
F ₁	39.6	34.3	44	52.3	0.457	0.360	0.489	0.56	82	68.3	97.3	115	1.22	1.04	1.31	1.61
F ₁ -M.P	12.3	13	12	15.2	0.155	0.107	0.152	0.179	7.4	10.5	9.5	15	0.227	0.199	0.22	0.4
H ₁ %	45**	62.4**	37.5**	40.9**	51.3	42.2	45.1	47.3	9.92**	18.2**	10.8**	15**	22.8**	23.6**	22.4**	33**
F _{1r}	38.3	32.6	42.6	52	0.455	0.353	0.506	0.58	82	69	97.6	115	1.31	1.27	1.43	1.62
F _{1r} -M.P	11	11.3	10.6	14.9	0.153	0.1	0.169	0.199	7.4	11.2	9.8	15	0.317	0.429	0.34	0.41
H _r %	40.2**	53**	33.1**	40.2**	50.6	39.5	50.1	52.6	9.92**	19.4**	11.2**	15**	31.9**	51**	33.6**	33.8**
L.S.D	0.05		2.12			2.51				4.69					0.098	
	0.01		2.79			3.28				6.16					0.128	
F ₁ -F _{1r}	1.3	1.7	1.4	0.3	0.002	0.007	-0.017	-0.02		-0.7	-0.3	-0.3	-0.09	-0.23**	-0.12	-0.01
L.S.D	0.05		2.45			2.89				5.42					0.113	
	0.01		3.22			3.79				7.11					0.148	

T₁: Control, T₂: Fungi treatment, T₃: Fungi and bacteria treatment and T₄: Bacterial treatment.

P₃: Tigerella P₄: Marglob H₁%: Heterosis and H_r%: Reciprocal heterosis.

NF3P: Number of fruits for the first three pickings, WF3P: Weight of fruits for the first three pickings, TNF: Total number of fruits and TWF: Total weight of fruits.

In conclusion, most of tomato hybrids induced in this study were resistant to *Fusarium* wilt disease and the higher values of vegetative and biochemical traits, as well as, yield components traits were obtained under the effect of *Bt* treatment T₄. These results indicated that *Bt* played a significant role in the course of controlling natural biotic stress which leading to healthy plants increased yield components as well.

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قوة الهجين لصفات الثمار ومكونات المحصول في الطماطم تحت ظروف العدوى بالفيزارييم والمقاومة الحيوية باستخدام التضاد البكتيري

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تهدف هذه الدراسة الي إنتاج تراكيب وراثية هجينة في الطماطم مقاومة لمرض الذبول الفيزاريومي في نباتات الطماطم ، هذا بالإضافة إلي إستخدام بكتيريا الباسيلس ثيرونجنسز كوسيلة للمقاومة الحيوية ضد فطر الفيزارييم . إستخدمت في هذه الدراسة أربع أصناف من الطماطم لإنتاج 6 هجن و 6 هجن عكسية عن طريق نظام التزاوج الدوري الكامل. أوضحت النتائج الحصول علي قوة هجين عالية المعنوية من خلال التهجين بين $P_1 \times P_2$ بالنسبة لصفة طول النبات ، هذا بالإضافة إلي الحصول علي قوة هجين معنوية بواسطة التهجين العكسي بالنسبة لنفس الصفة في المعاملة بالفطر وتجربة المقارنة. أعطى الأب (P_3) قيمة مرتفعة بالنسبة لمحصول النبات في المعاملات الأربعة ، بينما أعطت المعاملة بالبكتريا إذا ما قورنت بالمعاملات الثلاثة الأخرى قيم مرتفعة لنفس الصفة للنبات. بينما أعطى الهجين العكسي ($P_3 \times P_1$) قيمة مرتفعة في المعاملات الأربعة بالنسبة لصفة وزن الثمار الكلي للنبات ويعود ذلك الي تأثير الوراثة اللانوية . أعطى الهجين $P_2 \times P_3$ قوة هجين عالية المعنوية في المعاملات الأربعة بالنسبة لوزن الثمار في الجمعات الثلاثة الأولى و وزن الثمار الكلي للنبات . أوضحت النتائج أن معاملات بكتيريا الباسيلس ثيرونجنسز المستخدمة كعامل للمقاومة الحيوية في هذه الدراسة قد أدت الي تحسين كل الصفات التي تم قياسها في هذه الدراسة و خصوصا الصفات الكيماوية. تضمنت النتائج أيضا أن بكتيريا الباسيلس ثيرونجنسز تلعب دورا هاما في المقاومة الحيوية للعدوى الطبيعية الراجعة لعوامل الإجهاد الحيوي في البيئة. هذا بالإضافة الي أن الطماطم تعتبر مشابهة للنباتات الأخرى في إظهار صفة قوة الهجين والتي كانت مرتفعة في الهجن و الهجن العكسية والتي تعتمد علي البعد الوراثي بين الأصناف المستخدمة كآباء.