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Efficiency of Grafting Watermelon Scions on Resistant Rootstocks for Controlling Fusarium Wilt under Greenhouse and Field Conditions

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Efficiency of grafting watermelon scions on resistant rootstocks for controlling Fusarium wilt under greenhouse and field conditions was evaluated. Two grafting methods, *i.e.* tongue approach graft and hole insertion graft, were evaluated for grafting three watermelon scions, *i.e.* Aswan hybrid and cv. Giza 1, on four rootstocks, *i.e.* Wild watermelon, Bottle Gourd, Strong Tosa and Ferro. Results indicated that the most effective method is tongue approach graft with Aswan hybrid and cv. Giza 1 which recorded 92.0 to 96.0 % survived plants except cv. Giza 1 that was grafted on Bottle Gourd. Grafting of Aswan hybrid and cv. Giza 1 on Bottle Gourd, Strong Tosa and Ferro rootstocks significantly reduced the wilt disease incidence. Complete protection of Fusarium wilt was obtained with both cultivars grafted on Bottle Gourd and Strong Tosa. Grafting of both cultivars on Ferro rootstock resulted in reducing disease incidence by 95.2 % for Giza 1 and Aswan hybrid. Also, the highest increase in enzyme activities was obtained with both cultivars grafted on all the tested rootstocks. Grafting increased peroxidase, chitinase and β-1,3–glucanase activities as compared with un-grafted plants. Moreover, under field conditions grafting of two watermelon scion, *i.e.* Aswan hybrid and cv. Giza 1, on three rootstocks, *i.e.* Bottle Gourd, Strong Tosa and Ferro, to study the effect of grafting on Fusarium wilt incidence and fruit yield. Results revealed that all treatments reduced the wilt incidence during the two growing seasons. Complete protection of Fusarium disease was obtained with both scions grafted on all rootstocks. The highest increase in watermelon yield was obtained with Aswan hybrid grafted on each of Bottle Gourd, Strong Tosa and Ferro which increased fruit yield by 175.3, 166.3, 165.2%, respectively as compared with un-grafted cultivars.

Keywords: Aswan hybrid, Bottle Gourd, cv. Giza 1, ferro, Fusarium wilt, grafting, Strong Tosa and watermelon.

Watermelon (*Citrullus lanatus* (Trunb.) Matsum and Nakai) is a widely cultivated vegetable which consumed globally. However, the growth of this plant is often threatened by Fusarium wilt in soils where watermelon is continuously mono-cropped. Fusarium wilt of watermelon caused by *Fusarium oxysporum* Schleicher: Fr. f.sp. *niveum* (E.F. Smith) Snyder and Hans (Booth, 1971). The fungus is found worldwide in subtropical and tropical regions causing substantial losses. Watermelon wilt appears during the growing season at different stages of plant growth from seedling to mature stages and might happen earlier to cause pre-emergence damping-off (Sheng *et al.,* 2009 and Lu *et al.*, 2014). Also, Booth (1971) reported that *F. oxysporum* f.sp. *niveum* causes damping-off, stunting of watermelon seedlings and wilt of older plants.

Grafting of watermelon on other cucurbit rootstocks to control soil borne diseases has been one of the highly successful control methods especially when the produced crop from grafted plants is equal to or better than that of the non-grafted plants (Rivero *et al.,* 2003 and 2004). Grafting watermelon on resistant cucurbit rootstocks has become of greater interest as an alternative to methyl bromide fumigation for controlling soil borne diseases (Yetisir 2003; Cohen *et al.,* 2005; Glala, 2010 and Keinath and Hassell, 2014). Use of susceptible watermelon seedlings grafted on resistant rootstocks have an acquired resistance to soil borne diseases was suggested by several researchers as an environmentally safe alternative to using fungicides (Rivero *et al*., 2003; Miguel *et al.,* 2004; Boughalleb *et al.*, 2008 and Keinath and Hassell, 2014).

The present work was designed for evaluation of watermelon cultivars grafted on resistant rootstocks for controlling Fusarium wilt under greenhouse and field conditions.

Materials and Methods

Rootstocks:

Four rootstocks, *i.e.* Wild watermelon (*Citrullus lanatus* var. *citroides*), Bottle Gourd (*Lagenaria siceraria*), were kindly provided by Dr. Ahmed Abd Alla Galal, Professor of Vegetable, Vegetable Dept., N.R.C., Egypt. Meanwhile, Strong Tosa and Ferro Squash Hybrid (*Cucurbita moschata* x *C. maxima*) were obtained from Syngenta Company, Madrid, Spain.

Watermelon cultivars:

Watermelon cultivars (cv. Giza1) was obtained from Dept. of Vegetable Crops, Agric. Res. Centre, Giza, Egypt. Meanwhile, Aswan Hybrid was obtained from Sakata Company, Japan.

Source of the causal fungus:

An aggressive isolate of *Fusarium oxysporum* f.sp. *niveum* (isolated from cv. Giza 1) was obtained from a previous study (Mahdy *et al.*, 2014). Among the different host plants, watermelon cultivars only were susceptible to infection with this isolate of *F. oxysporum* f.sp. *niveum.*

Evaluation of different rootstocks against F. oxysporum f.sp. *niveum infection:*

All the tested rootstocks and watermelon cultivars were evaluated against *F. oxysporum* f.sp. *niveum* the causal agent of watermelon wilt under greenhouse conditions.

Preparation of F. oxysporum niveum inoculum:

Inoculum of *F. oxysporum* f.sp. *niveum* was prepared by culturing in 50 ml potato dextrose broth (PDB) medium in 250 ml Erlenmeyer flasks for 15 days at 25±2°C, Inoculum of *F. oxysporum* f.sp. *niveum* was prepared from the growing upper solid layers (mycelium growth) which were blended in sterilized water.

Colonies forming units (cfu) were adjusted to 10^6 cfu/ml using haemocytometer slide. Soil infestation was carried out at the rate of 50 mL (10^6 cfu / ml)/kg soil (Elad and Baker, 1985).

Soil infestation:

Sandy-loamy soil was autoclaved at 120°C for 1 h. Plastic pots (30 cm diameter, 5.0 kg soil) containing sterilized sandy-loamy soil were artificially infested at the rate of 50 ml (10^6 cfu/ml)/kg soil (Elad and Baker, 1985). Eight pots were used as replicates for each treatment. Disinfected seeds of four rootstocks namely; Wild watermelon, Bottle Gourd, Strong Tosa and Ferro in addition to watermelon cultivars, *i.e.* cv. Giza 1 and Aswan hybrid, were sown at the rate of 8 seeds/pot, meanwhile, 8 pots were used as replicates for each treatment.

Assessment of dead plants:

Fusarium damping off and/or wilt was measured as percentage of dead plants at 15 and 30 days after sowing (Booth 1971) as follow:

$$\text{Percentage of dead plants (\%)} = \frac{\text{Number of dead plants}}{\text{Total number of planted seeds}} \times 100$$

Evaluation of two methods of grafting watermelon scions on different rootstocks:

Two grafting methods, *i.e.* tongue approach graft and the hole insertion graft, were evaluated by grafting two watermelon scions, *i.e.* Aswan hybrid and cv. Giza 1, on three rootstocks, *i.e.* Bottle Gourd, Strong Tosa and Ferro. Evaluation of grafting methods was measured as percentage of successful grafted watermelon cultivars on the rootstocks.

a- Tongue approach graft:

Seeds of watermelon cultivars (scions) were sown each in 84 cells/tray, while, rootstocks were seeded one week later into other trays. Rootstock and scion seedlings have one or two true leaves were used for grafting process. A sharp knife or razor blade was used to cut an angled slit halfway through the stem of the rootstock and an oppositely angled slit halfway through the stem of the scion. Matching the slits was done for they overlapped and then sealed with clips. Placed roots of both rootstock and scion together in pots (12 cm- diam.) and adding potted soil if it is needed to fill the larger cell. Grafted seedlings were left in greenhouse for adaptation (Edelstein, 2004). Grafted watermelon transplants (30 days old) were planted in sterilized soil at the rate of 5 transplants/pot and 10 replicates were used. Percent of successful grafted watermelon cultivars on the rootstocks was recorded.

b- Hole insertion of graft:

Seeds of watermelon cultivars (scions) were sown, each in 84 cells/tray, while, rootstocks were seeded one week later into other trays. Rootstock and scion seedlings have one or two true leaves were used for grafting process. With a pointed probe was removed the true leaf from the rootstock. The probe to open a slit along one side on the upper portion of the rootstock's stem was used, where the stem connects to the cotyledons. The scion was cut and inserted into the rootstock. The place with a grafting site was hold using clip. The grafted seedlings were placed in a chamber with high humidity at about 24 ^{o}C and discard the unused parts

(Edelstein, 2004). Grafted watermelon transplants (30 days old) ware transplanted in sterilized soil at the rate of 5 transplants/pot and 10 replicates were used. Percent of successful grafted watermelon cultivars on the rootstocks was recorded.

Effect of grafting watermelon scions on different rootstocks on infection by Fusarium wilt:

To study the effect of grafting on the incidence of Fusarium disease two watermelon scions, *i.e.* Aswan hybrid and cv. Giza 1, were grafted on three rootstocks, *i.e.* Bottle Gourd, Strong Tosa and Ferro. Tongue approach graft method was used as mentioned before. Inoculum of *F. oxysporum* f.sp. *niveum* preparation and soil infestation was carried out as mentioned before. Grafted watermelon transplants (30-day-old) ware planted in sterilized soil and infested with *F. oxysporum niveum* at the rate of 5 transplants/pot, and 10 pots were used as replicates.

.Disease assessment:

Number of wilted plants at 30 days after transplanting was recorded and the percentage of disease incidence was calculated by using the disease index scale: 1 apparently healthy plants ; 2 slight chlorosis of lower ; slight wilt of plants ; 3 necrosis, following of lower leaves, yellow areas on upper leaves ; 4 dead plant (Tziros, *et al.*, 2007).

Also, reduction of diseased plants was calculated as follows:

$$\text{Reduction (\%)} = [(C-T) / C] \times 100$$

Where: C= Disease incidence in control and T= Disease incidence in treatment.

Determination of enzymes activities in grafted watermelon scions on different rootstocks:

Extraction of enzymes:

Plant roots (g) was homogenized with 0.1 M sodium phosphate buffer (pH 7.1) (Goldschmidt *et al.*, 1968) at the rate of 1/3 w/v. The homogenate was centrifuged at 3000 rpm for 15 minutes. The supernatant was used to determine the activity of some enzymes.

Peroxidase assay:

Peroxidase activity was measured by the incubation 0.1 ml of the enzyme extract with 4 ml of guaicol for one minute at 25°C and absorbance at 470 nm was determined. The guaicol solution consisted of 3 ml of 0.05 M K. phosphate, pH 7, 0.5 ml of 2% guaicol and 0.5 ml of 0.3% H_2O_2 (Abeles *et al.*, 1971). Peroxidase activity was expressed as the increase in absorbance at 470 nm/gram fresh weight/one min.

Chitinase assay:

The substrate colloidal chitin was prepared from chitin powder according to the method described by Ried and Ogryd-Ziak (1981).The determination of chitinase activity was carried out according to the method of Monreal and Reese (1969). Chitinase activity was expressed as mM N-acetylglucose amine equivalent released /gram fresh weight tissue/60 minutes.

β-1,3 – glucanase assay:

The method of Abeles and Forrence (1970) was used to determine β-1,3– glucanase activity. Laminarin was used as substrate and dinitrosalicylic acid as reagent to measure reducing sugars. β-1,3-glucanase activity was expressed as mM glucose equivalent released gram fresh weight tissues/60 minutes.

Field experiments:

The experiments were conducted at the Research and Production Station of National Research Centre at Noubariya, Behera governorate during 2013 and 2014 growing seasons and at El- Kanater, Qalubiya governorate during 2014 only. All experiments were applied to study the efficacy of grafting watermelon scions on different rootstocks against watermelon wilt .

Efficacy of grafting watermelon scions on resistant rootstocks for controlling Fusarium wilt under field conditions:

Rootstocks and cultivars:

Three rootstocks, *i.e.* Bottle Gourd, Strong Tosa and Ferro squash hybrid, in addition to two watermelon scions, *i.e.* Aswan hybrid and cv. Giza 1, were used in this experiment.

Grafting method:

Grafting of watermelon cultivars *i.e.* Aswan hybride and cv. Giza 1, on three rootstocks, *i.e.* Bottle Gourd, Strong Tosa and Ferro, were applied using the Tongue approach graft method as mentioned before.

Three field experimentals were carried out during 2013 and 2014 growing seasons. Experiment 1 and experiment 2 were carried out during 2013 and 2014 growing seasons at Nobariya (Behera governorate) while, experiment 3 was carried out at El- Kanater (Qalubiya governorate) during 2014 growing season.

Experimental field at the Research and Production Station of the National Research Centre at Noubariya, Behera governorate was designed in randomized complete block with four blocks, each block contained ten plots and each plot was one row (25m length and 3m width, thus making an area of $75m^2$). Grafted watermelon transplants of Giza 1cv. and Aswan hybrid were transplanted in hills at 1.0 meter in between, on rows (3x25 m). Four rows were used as replicates for each treatment. Moreover, Experimental field at El- Kanater, Qalubiya governorate was designed in randomized complete block with four blocks, each block contained ten plots and each plot was one row (15 m length and 3m width, thus making an area of $45m^2$). Grafted watermelon transplants cv. Giza 1 and Aswan hybrid were transplanted in hills at 1.0 meter in between, on rows (3x15m). Three rows were used as replicates for each treatment.

Fusarium wilt incidence was recorded as percentage of wilted plants weekly up to the end of the experiment. Moreover, total yield per feddan (Metric Ton = 1000 kg) was also determined.

Statistical analysis:

Tukey test for multiple comparison among means was utilized (Neler *et al.*,1985).

Results

Evaluation of different scions and rootstocks against infection by F. oxysporum f.sp. *niveum:*

Four rootstocks namely Wild Watermelon, Bottle Gourd, Strong Tosa and Ferro were evaluated against *F. oxysporum* f.sp. *niveum* infection. Results in Table (1) indicate that all tested rootstocks are highly resistant against wilt infection caused by *F. oxysporum* f.sp. *niveum*. Complete protection of disease infection was obtained with rootstocks, *i.e.* Wild Watermelon, Bottle Gourd and Strong Tosa. Meanwhile, Ferro showed 3.1% infection after 30 days of sowing. As for watermelon scions, cv. Giza 1 and Aswan hybrid showed 62.5 and 60.9% infection 30 days after sowing without significant differences.

Table 1. Fusarium disease incidence (%) on different watermelon rootstocks and scions in response to infection by *F. oxysporum* f.sp. *niveum*

Rootstock / scions	Dead plants (%) after sowing (days)	
	15	30
Bottle Gourd	0.0 c *	0.0 c
Strong Tosa	0.0 c	0.0 c
Ferro	3.1 b	3.1 b
Wild Watermelon	0.0 c	0.0 c
Giza 1cv.	15.6 a	62.5 a
Aswan hybrid	15.6 a	60.9 a

* Values with the same letter are not significantly different (P= 0.05).

Evaluation of two grafting methods of watermelon scions on different rootstocks:

Two grafting methods, *i.e.* tongue approach graft and hole insertion graft, were evaluated for grafting two watermelon scions, *i.e.* Aswan hybrid and cv. Giza 1 (scions), on four rootstocks, *i.e.* Wild Watermelon, Bottle Gourd, Strong Tosa and Ferro. Results in Table (2) show that the most effective method is tongue approach graft with Aswan hybrid and cv. Giza 1 which recorded 92.0 to 96.0 % survived plants when grafted on each of Bottle Gourd , Strong Tosa and Ferro except Giza 1 cv grafted on Bottle Gourd which recorded 82.0 % as survived plants. Meanwhile, hole insertion graft method showed moderate success for grafting watermelon cultivars on all the tested rootstocks. Data showed that grafting the two scions on Wild Watermelon (rootstock) resulted little success for grafting which recorded the lowest percentage of survived plants. Bottle Gourd, Strong Tosa and Ferro are compatible for grafting watermelon cultivars. Watermelon scions, *i.e.* cv. Giza 1 and Aswan hybrid, proved to be suitable cultivars for grafting.

Evaluation of grafting watermelon scions *on different watermelon rootstocks:*

Grafting two watermelon scions, *i.e.* cv. Giza 1 and Aswan hybrid, on three rootstocks, *i.e.* Bottle Gourd, Strong Tosa and Ferro, were transplanted in artificially infested soil with *F. oxysporum* f.sp. *niveum* to study the effect grafting on watermelon disease incidence and determination of enzyme activities in grafted watermelon scions on different rootstocks.

Table 2. Percentage of survived plants in response to using two methods of grafting watermelon scions on rootstocks

Grafting method	Rootstock	Watermelon scion	Survived plants (%)
Hole insertion graft	Bottle Gourd	Giza 1	72.0 c *
		Aswan hybrid	82.0 b
	Wild Watermelon	Giza 1	42.0 f
		Aswan hybrid	32.0 g
	Strong Tosa	Giza 1	72.0 c
		Aswan hybrid	86.0 b
	Ferro	Giza 1	66.0 d
		Aswan hybrid	82.0 bc
Tongue approach graft	Bottle gourd	Giza 1	82.0 b
		Aswan hybrid	96.0 a
	Wild Watermelon	Giza 1	42.0 f
		Aswan hybrid	42.0 f
	Strong Tosa	Giza 1	94.0 a
		Aswan hybrid	96.0 a
	Ferro	Giza 1	94.0 a
		Aswan hybrid	92.0 a

* Values with the same letter are not significantly different (P= 0.05).

Evaluation of grafting watermelon scions on different rootstocks against Fusarium wilt incidence:

Results in Table (3) indicate that all watermelon scions grafted on all the tested rootstocks significantly reduced the watermelon disease incidence. Complete protection of Fusarium disease was obtained with both scions grafted on Bottle Gourd and Strong Tosa. Grafting of both scions on Ferro rootstock resulted in reducing disease incidence by 95.2% for cv. Giza 1 and Aswan hybrid after 30 days after transplanting.

Determination of enzyme activities in grafted watermelon scions *on different rootstocks:*

Results in Table (4) illustrate that grafting both watermelon scions on all the tested rootstocks increased the activity of all the tested enzymes as compared to un-grafted plants. The highest increase in peroxidase activity was obtained when both scions, *i.e.* Aswan hybrid and cv. Giza 1, were grafted on Bottle Gourd rootstock, being 225 and 200%, respectively. Meanwhile, grafting on the rootstock Strong Tosa caused the highest increase in chitinase activity, being 261 and 250%, respectively.

β-1,3-glucanase activity show the same trend when Strong Tosa was used as rootstock.

Table 3. Percentage of infection by Fusarium disease in watermelon scions grafted on different rootstocks

Scion/ rootstock	Fusarium disease incidence (%)	Reduction (%)
Giza 1/Bottle Gourd	0.0 c *	100
Aswan/Bottle Gourd	0.0 c	100
Giza 1/Strong Tosa	0.0 c	100
Aswan/Strong Tosa	0.0 c	100
Giza 1/Ferro	2.0 bc	95.2
Aswan/Ferro	2.0 bc	95.2
Un-grafted control		
Bottle Gourd	0.0 c	100
Strong Tosa	0.0 c	100
Ferro	0.0 c	100
Giza 1	42.0 a	—
Aswan hybrid	42.0 a	—

* Values with the same letter are not significantly different (P= 0.05).

Table 4. Effect of grafted watermelon cultivars on enzyme activities as compared with un-grafted cultivars

Scion / rootstock	Enzyme activities					
	Peroxidase(1)		Chitinase(2)		β,1-3- glucanase(3)	
	Activity	Increase (%)	Activity	Increase (%)	Activity	Increase (%)
Giza 1/ Bottle Gourd	17.4 c*	200.0	3.15 a	215.0	8.10 c	224.0
Aswan / Bottle Gourd	19.5 a	225.0	3.24 a	224.0	9.30 a	232.1
Giza 1 / Strong Tosa	17.7 c	205.2	3.50 a	250.0	8.80 b	252.0
Aswan /Strong Tosa	18.5 b	208.3	3.61 a	261.0	10.0 a	257.1
Giza 1 / Ferro	17.4 c	200.0	3.47 a	247.0	8.80 b	252.0
Aswan / Ferro	18.3 b	205.0	3.54 a	254.0	9.66 a	245.0
Giza 1 (un-grafted)	5.8 d	—	1.0 b	—	2.50 d	—
Aswan (un-grafted)	6.0 d	—	1.0 b	—	2.80 d	—

(1) Peroxidase activity expressed as change in absorbance at 470 nm/gram fresh weight/1 min.
(2) Chitinase activity expressed as mM N-acetyle glucose amine equivalent released/gram fresh weight/60 min.
(3) β-1,3-glucanase activity expressed as mM glucose equivalent released/gram fresh weight/60 min.
* Values with the same letter are not significantly different (P= 0.05).

Field experiments:

Efficacy of grafting watermelon cultivars on rootstock for controlling Fusarium wilt of watermelon:

Two watermelon scions, *i.e.* Aswan hybrid and cv. Giza 1, were grafted on three rootstocks, *i.e.* Bottle Gourd, Strong Tosa and Ferro, to study their effect on wilt incidence and fruit yield. Results in Table (5) show that all treatments reduced wilt incidence during the two tested seasons (2013 and 2014). Complete protection of Fusarium wilt was recorded with both scions grafted on all the tested rootstocks. Treating the seed bed of both scions with Topsin-M 70% at 3g/kg soil resulted in reducing the wilt incidence by 63.4 and 63.6% for cv. Giza 1 and Aswan hybrid, respectively. It is worth to note that no patricianly compatibility between cv. Giza 1 and Bottle Gourd.

Table 5. Percentage of watermelon disease incidence in response to grafting watermelon scions on resistant rootstocks under field conditions

Treatment	Wilt incidence (%)			Mean	Reduction (%)
	Exp. 1*	Exp. 2	Exp. 3		
Giza 1/Bottle Gourd	0.0 d **	0.0 d	0.0 d	0.0 d	100.0
Giza 1/Ferro	0.0 d	0.0 d	0.0 d	0.0 d	100.0
Giza 1/Strong Tosa	0.0 d	0.0 d	0.0 d	0.0 d	100.0
Un-grafted (Topsin- Giza 1)	18.0 c	20.0 c	17.0 c	18.3 c	63.4
Un-grafted (Giza 1 Control)	45.0 a	48.0 a	57.0 a	50.0 a	—
Aswan/Bottle Gourd	0.0 d	0.0 d	0.0 d	0.0 d	100.0
Aswan/Ferro	0.0 d	0.0 d	0.0 d	0.0 d	100.0
Aswan/Strong Tosa	0.0 d	0.0 d	0.0 d	0.0 d	100.0
Un-grafted Topsin-Aswan hybrid)	15.0 c	18.0 c	15.0 c	16.0 c	63.6
Un-grafted (Aswan control)	40.0 b	42.0 b	50.0 b	44.0 b	—

* Exp. 1 and Exp. 2 were carried out during 2013 and 2014 growing seasons at Nobariya (Behera Governorate), while Exp. 3 was carried out at El-Kanater (Qalubiya Governorate) during 2014 growing season.

** Values with the same letter are not significantly different (P = 0.05).

Efficacy of grafting watermelon scions on watermelon yield:

Results in Table (6) indicate that all treatments significantly increased the fruit yield of watermelon plants. The highest increase was obtained with Aswan hybrid grafted on Bottle Gourd , Strong Tosa and Ferro where fruit yield increased by 175.3, 166.3, 165.2%, respectively. Grafting of cv. Giza 1 on Strong tosa and Ferro resulted in increasing fruit yield by 108.4 and 113.2%, respectively. Treated seed bed of both cultivars (un- grafted) with Topsin-M 70% at 3g / kg soil resulted in increasing fruit yield by 48.2 and 50.6% for Giza 1cv. and Aswan hybrid, respectively.

Table 6. Influence of grafting watermelon scions on different rootstocks on fruit yield under field conditions

Treatment	Average of watermelon yield (Ton/Fadden)			Mean	Increase (%)
	Exp. 1*	Exp. 2	Exp. 3		
Giza 1/Bottle Gourd	12.0 c**	13.0 c	14.2 c	13.1c	57.8
Giza 1/Ferro	18.0 b	17.2 b	18.0 b	17.7 b	113.2
Giza 1/Strong Tosa	17.0 b	17.5 b	17.8b	17.3 b	108.4
Un-grafted (Topsin - Giza 1)	10.5 c	12.0 c	14.4 c	12.3 c	48.2
Un-grafted Giza 1- control	8.0 d	9.5 d	7.5 c	8.3 d	—
Aswan/Bottle Gourd	24.0 a	24.5 a	25.0 a	24.5 a	175.3
Aswan/Ferro	22.8 a	23.0 a	25.3 a	23.7 a	166.3
Aswan/Strong Tosa	22.5 a	23.0 a	25.3 a	23.6 a	165.2
Un-grafted (Topsin–Aswan hybrid)	12.0 c	13.0 c	15.2 b	13.4 b	50.6
Un-grafted (Aswan hybrid-control)	9.0 d	9.7 d	8.0 c	8.9 d	—

* & ** As described in footnote of Table (5).

Discussion

Watermelon is a widely cultivated vegetable crop which consumed globally. However, the growth of these plant is often threatened by Fusarium wilt in soils where watermelon is continuously mono-cropped. Fusarium wilt in watermelon is caused by *Fusarium oxysporum* f. sp. *niveum* (Booth, 1971). The fungus is found worldwide in soils in temperate, subtropical and tropical regions (Booth, 1971; Sheng *et al.*, 2009 and Lu *et al.*, 2014).

Grafting of watermelon cultivars on other cucurbit rootstocks to provide soil borne disease resistance has been highly successful in addition to production a high quality fruits from grafted plants (that is equal to or better than that of the non-grafted plants) (Rivero *et al.*, 2004 and Keinath and Hassell, 2014).

Watermelon grafting has become of greater interest as an alternative to methyl bromide fumigation for controlling soil borne diseases (Koren and Edelstein, 2004 and Cohen *et al.*, 2005). In the present study, four rootstocks namely Wild Watermelon, Bottle Gourd, Strong Tosa and Ferro against *F. oxysporum* f.sp. *niveum* infection were evaluated. Results indicated that all tested rootstocks are highly resistant against Fusarium wilt infection caused by *F. oxysporum* f.sp. *niveum*. Complete protection of wilt infection was obtained when rootstocks, *i.e.* Wild Watermelon, Bottle Gourd and Strong Tosa, were used. In this respect, use of watermelon seedlings grafted on resistant rootstocks which have an acquired resistance to soil borne diseases, was suggested by several researchers as an environmentally safe alternative to methyl bromide (Miguel *et al.*, 2004 and Boughalleb *et al.*, 2008). Moreover, Morra *et al.* (2007) reported that the damage caused by *F. oxysporum* can be reduced with the use of grafting technique of watermelon onto rootstocks of the genera *Cucurbita* or *Lagenaria*. This technique has been also applied in the production of many vegetables to increase the yield of tomato, pepper, eggplant, melon and cucumber plants. Furthermore, Yilmaz *et al.* (2008) stated that vegetable production by grafting on resistant rootstocks has become a common practice to control soil borne pathogens, especially for the cultivation of cucumber, melon, watermelon, tomato, pepper and eggplant in greenhouses in many countries. Grafting is widely used in horticulture for a variety of reasons with field grown vegetables. It is used to increase resistance to soil borne diseases, improve yield, fruit quality, biotic and abiotic stress tolerance (Glala, 2007 and 2010). Increasingly greenhouse vegetable growers are using grafting to decrease susceptibility to root diseases, low soil temperature, salinity and to improve yield and fruit quality through increasing plant vigor (Glala, 2007 and 2010). In the present research, two grafting methods, *i.e.* tongue approach graft and hole insertion graft, were evaluated for grafting three watermelon cultivars, *i.e.* Aswan hybrid, Giza 1 and Gorma (scions), on four rootstocks, *i.e.* Wild Watermelon, Bottle Gourd, Strong Tosa and Ferro. Results revealed that the most effective method is tongue approach graft with Aswan hybrid and cv. Giza 1 which recorded highly survived plants, except for cv. Giza 1 grafted on Bottle Gourd. Meanwhile, hole insertion graft showed moderate success for grafting watermelon cultivars on all the tested rootstocks. It is clearly shown that cv. Gorma and Wild Watermelon (rootstock) showed less success for grafting. In this concern, the total number of survival rate was high in Bottle Gourd, Strong Tosa and Ferro rootstocks. As hypocotyls increased in both length as well as diameter and area, grafting success also increased. Oda (1999) reported increments in the survival rate of *C. maxima* in which the larger number of vascular bundles was assumed to increase the chance of contact between the vascular bundles at the cut surface of hypocotyls. It was observed that the survival rate of the small scions was lower than that of the large scions in all the cultivars on the rootstocks. Yetisir and Sari (2003) reported that the survival rate of grafted plants was inversely correlated with the difference in diameters of scion and rootstock as well as the number of vascular bundles positively affected the growth rate of the grafted watermelon plants. In the present study, grafting of two watermelon scions, *i.e.* Aswan hybrid and cv. Giza1, on three rootstocks, *i.e.* Bottle Gourd, Strong Tosa and Ferro, was tested to determine its effect on Fusarium wilt incidence. Results indicated that grafting all watermelon scions on all the tested rootstocks significantly reduced the wilt incidence. Complete protection of Fusarium wilt was obtained with both scions grafted on Bottle Gourd and Strong Tosa. Grafting of both scions on Ferro (rootstock) resulted in high decrements in disease incidence for cv. Giza 1 and Aswan hybrid. In this concern, watermelon grafting has become of greater interest as an alternative to methyl bromide fumigation for disease avoidance (Koren and Edelstein, 2004; Cohen *et al.*, 2005 and King *et al.*, 2008). Watermelon plants are often grafted on some cucurbit rootstocks which are resistant to soil borne Fusarium disease and tolerant to low temperature. Grafting of watermelon scions on squash, pumpkin or Bottle Gourd (*Lagernaria* spp.) rootstocks is practicable in all the major watermelon production regions of the world (Lee and Oda, 2003). In another study, watermelons were grafted on *Cucurbita maxima*, *C. moschata* and *Lagenaria siceraria* rootstocks.

These rootstocks influenced resistance to soil borne diseases, plant growth, yield, and fruit quality (Lee and Oda, 2003). In the present study, grafting of two watermelon scions, *i.e.* Aswan hybrid and cv. Giza 1 on three rootstocks, *i.e.* Bottle Gourd, Strong Tosa and Ferro, was studied to detrmine their effect on enzyme activities. Results showed that grafting both watermelon scions on all the tested rootstocks increased all tested enzyme activities. The highest increases in peroxidase, chitinase and β-1,3-glucanase activities were recorded in case of both scions grafted on Bottle Gourd and Strong Tosa rootstocks.

Under field conditions, two watermelon scions, *i.e.* Aswan hybrid and cv. Giza 1, were grafted on three rootstocks, *i.e.* Bottle Gourd, Strong Tosa and Ferro, to study the effect of grafting on Fusarium wilt incidence and fruit yield. Results revealed that all treatments reduced the wilt incidence during the two growing seasons. Complete protection against Fusarium wilt was recorded with both scions grafted on all the tested rootstocks. The highest increase in watermelon yield was observed with Aswan hybrid grafted on each of Bottle Gourd, Strong Tosa and Ferro, as compared with un-grafted cultivars. In general, the main objectives of watermelon grafting could be summarized as follow: a) Controlling the soil borne diseases (Edelstein, 2004 and Glala, 2007). b) Overcoming soil stress, *i.e.* saline stress (Edelstein, 2004 and Yuan *et al.*, 2010), drought stress (Jifon *et al.*, 2006), water flooding stress (Yetisir *et al.*, 2006) as well as overcoming low soil temperature during winter season (Edelstein, 2004). c) Inducing resistance for foliar diseases and pests (Sakata *et al.*, 2006 and Edelstein, 2004). d) Improving plant growth, productivity and fruit quality (Yetisir, 2003 and Khah *et al.*, 2006).

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تقييم كفاءة تطعيم أصناف البطيخ علي أصول مقاومة لمكافحة مرض الذبول الفيوزاريومي تحت ظروف الصوبة و الحقل

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تم استخدام طريقتين للتطعيم هما التطعيم اللساني والتطعيم بالشق القمي لتقييم كفاءتهما في تطعيم اصناف البطيخ علي الاصول المقاومة لمرض الذبول الفيوزاريومي وأوضحت النتائج أن أعلي نسبة نجاح للتطعيم تم الحصول عليها بواسطة طريقة التطعيم باللسان مع الصنف جيزة 1 وهجين أسوان حيث سجل نسبة نجاح بمقدار 92.0 و 97.0 % مع كل الاصول عدا الصنف جيزة 1 مع اليقطين.

أدي تطعيم صنف البطيخ جيزة 1 وهجين أسوان علي أصول اليقطين و استرونج توسا الي الحماية الكاملة ضد مرض الذبول الفيوزاريومي في نباتات البطيخ. بينما أدي تطعيم صنفي االبطيخ علي الأصل فيرو الي حماية مقدارها 95.2 % بالنسبة للصنف جيزة 1 وهجين أسوان ضد مرض الذبول الفيوزاريومي.

أدي تطعيم صنف البطيخ جيزة 1 وهجين أسوان علي أصول اليقطين واسترونج توسا وفيرو الي زيادة معنوية في نشاط انزيمات البيروكسيديز والكيتنيز والبيتا جلوكانيز.

وتحت ظروف الحقل ولمدة موسمين متتاليين أوضحت النتائج أن:- أدي تطعيم صنف البطيخ جيزة 1 وهجين أسوان علي أصول اليقطين و استرونج توسا و فيرو الي الحماية الكاملة من مرض الذبول الفيوزاريومي خلال موسمي النمو وزيادة معنوية في محصول الثمار حيث أدي تطعيم هجين البطيخ أسوان علي أصول اليقطين و استرونج توسا و فيرو الي زيادة معنوية في محصول الثمار خلال موسمي النمو. وتشير النتائج الي امكانية استخدام طريقة تطعيم اصناف البطيخ القابلة للاصابة علي أصول مقاومة لمكافحة مرض الذبول الفيوزاريومي في نباتات البطيخ تحت ظروف الحقل.