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RESEARCH ARTICLE

GRAFTING, AN ALTERNATIVE METHOD FOR CONTROL OF FUSARIUM WILT DISEASE IN WATERMELON

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ABSTRACT

The aim of this research is to control the pathogenic fungus, which causes Fusarium wilt disease in watermelon, *Citrullus lanatus var lanatuscv.* (Crimson Sweet 0015) by grafting it onto pumpkin, *Cucurbita moschatacv.* (Tetsukabuto). Pathogenic fungus was isolated from the infected roots of watermelon seedlings through growing it into PDA culture. In this study, Tongue approach grafting method was applied. Plants have been divided into four groups. Only two groups have been injected with spores of *Fusarium oxysporum* $1x10^6$ conidia / ml, then plants were planted in industrial sterile soil contains peat moss and vermiculite (1:1 vol/vol) in pots at a completely randomized design. Finally, results of observations were collected after the disease symptoms appeared on the plants. The results and statistical analysis for data showed that grafting had a positive effect, where the grafted plants were better than non-grafted in all the measurements in terms of the weight of the shoot and root, the length of stems and roots, as well as the number and weight of fruits. These results also indicated that grafting of watermelon onto specific rootstock (pumpkin) has left a positive impact on plants disease resistance. Therefore, the results of this study conclude that the grafting is an advantageous alternative method to the control of Fusarium wilt disease in watermelon.

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INTRODUCTION

Watermelon, *Citrullus lanatus,* family *Cucurbitaceae*, is an important vegetable; it has been widely cultivated all over the world. Its fruit has been accepted as a delicious fruit. It is a source of liquid containing over 90% water and 10 to 12% total solids including vitamin A, C, B6 and potassium (USDA, 2001). Recently, watermelon fruits have become recognized more for their nutritional qualities. It has been reported that the red pigment of watermelon, lycopene, has inhibited qualities of some forms of cancer (USDA, 2007) as well as cardiovascular disease (Sesso *et al*. 2003). Watermelon constituted 5.7 % of total cultivated area in the Gaza Strip in 2013. During the last 3 years, the total area cultivated with watermelon in the Gaza Strip had been reduced from more than 6000 to less than 4612 dunums. Among the main reasons for such reduction was the infection with soil borne diseases. These diseases cause a decrease in yield and quality (MOA, 2014).Watermelon and pumpkin, *Cucurbita moschata* are belong to the same family Cucurbits (*Cucurbitaceae*); they are deep-rooted plants and have similar soil, light and water requirements, where they need regular irrigation (Marr, 2004). All plants classified under the family of *Cucurbitaceae* are affected by several vascular wilt diseases caused by different pathogenic stains of the fungus *Fusarium oxysporum*, which are morphologically similar, but generally, it is host-specific. Consequently, Fusarium wilt of watermelon has been caused by *Fusarium oxysporum f. sp. Niveum* (FON) and became one of the oldest described Fusarium wilt diseases (Egel and Martyn, 2007). Fusarium fungi live in the soil and attack plants at all stages of growth. If growers continually plant watermelon in the same soil eventually, they will wind up with a disease problem called Fusarium wilt. Fusarium wilt is characterized by wilting of the vines, which at first may recover during the evening, but eventually wilt permanently (Egel and Martyn, 2007)Until now, there are three ways of avoiding the infection of watermelon by *Fusarium oxysporum f. sp. niveum*: rotate the fields, treat with methyl bromide to kill the fungus, or grow resistant cultivars. The first two solutions are becoming less workable; land is becoming less available for rotations, and methyl bromide is being discontinued due to environmental concerns, while watermelon cultivars are available with varying resistance to only two races of Fusarium. Although alternative crop rotation fields and other fumigants are being

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tested and developed. Grafting with resistant rootstocks offers one of the best methods to avoid soil-borne diseases. Thus, using grafted rootstocks seems to be an effective solution (Egel and Martyn, 2007).Grafting is an alternative approach to reduce crop damage resulting from soil-borne pathogens and increases plant a biotic stress tolerance, which in turn increases crop production. Grafting is a method of asexual plant propagation that joins plant parts for them to live together. Therefore, they will grow as one plant (Lee, 2003). Rootstocks-scion interaction showed tolerance against soil borne pathogens such as Fusarium wilt (Cohen *et al*., 2007). Fusarium wilt caused by *Fusarium oxysporum* that seriously damage watermelon roots and may have little or no effect on the roots of gourds, squash, or pumpkins. This selectivity among species has enabled grafting to be used to limit soil-borne diseases among cucurbit crops and used as rootstocks for watermelon (Yetisir, 2001).

Mechanisms of disease tolerance in grafted plant of the rootstocks as it is accepted that the root system synthesizes substances resistant to pathogen attack and these are transported to the shoot through the xylem (Biles *et al*., 1989).The tongue approach method: is the famous grafting technique, which is used for watermelon because of its simplicity, high success rate, and little care since it does not require healing chambers (Lee and Oda, 2003). In Palestine, a limited research has been done on the effects of grafting on increasing resistance to soil borne disease as described by Sawalha (2012).The main objective of our study is trying to prove whether the tongue approach grafting method in local conditions can be achieve great success in controlling of *Fusarium oxysporum* in watermelon *Citrullus lanatus var lanatuscv.* (Crimson Sweet) as an alternative method.

MATERIALS AND METHODS

1. Isolation and Identification of the *Fusarium oxysporum*

Fusarium oxysporum was isolated from infested roots of watermelon plants, which were collected from watermelon plot in plastic greenhouse in Biet Lahia northern of Gaza strip. The plants had a typical symptom of Fusarium wilt. Selected a 4 cm piece of basal stems at first least 20 cm above the soil surface. Each sample was washed thoroughly in running tap water and air dried before it was processed. The materials were then surface sterilized by immersing them sequentially in 70% ethanol for 1min then in 2 % - 4 % NaOCl for 1min and rinsed it with sterile distilled water. Then, outer tissues were removed and the inner tissues of 1–2 mm size were carefully dissected and placed on Petri dishes containing PDA media. The media were supplemented with streptomycin sulphate (100mg/L).The plates were incubated at 25±28 ^{o}C. The isolated fungal was identified as *F. oxysporum f. sp. Niveum.*

2. Cultivation and Spore Production

The developing fungal colonies from the plated seedling segments were purified by hyphal tip technique. Purring cultures of all isolated fungi were cultivated into PDA medium.

3. The Grafting Process

The seeds of the rootstocks of pumpkin *Cucurbita moschatacv.* (Tetsukabuto) were sown 20 days later than the seeds of the scions of watermelon *Citrullus lanatus var lanatuscv.* (Crimson Sweet 0015) to ensure similar stem diameters at the grafting time due to the differences in growth vigor. Seeds were sown in 150-cell styrophoam trays under greenhouse conditions. The trays were filled with soil mixture (peatmoss and vermiculite in 1:1v/v).

3.1. Tongue Approach Grafting (TAG) method

Rootstock and scion seedlings should have one or two true leaves. With a- sharp knife or razor blade, cut an angled slit halfway through the stem of the rootstock and an oppositely angled slit halfway through the stem of the scion. Match the slits so that they overlap and then, seal with aluminum foil or specialty materials available for this purpose (clips). Place the grafted seedlings in a seedling tray with larger cell size than what they were grown in. Place root balls of both rootstock and scion together in the same cell and add potting media if needed to fill the larger cell. After healing of graft union, requires removal of top portion of rootstock about nine days after making graft. Also, requires severing of scion roots after an additional two or three days. Transplanted to the field after three to four leaves have developed in about three more days. The grafting process takes about 10–15 days. (Cushman, 2006).

4.Watermelon infection and transplanting

4.1. Fusarium spore suspensions

After the isolation of the fungus from infected watermelon *F. oxysporum f. sp. niveum* conidia were prepared by growing plate cultures into PDA at 28°C for 10 days in the dark to induce sporulation. Plates were drenched with sterile distilled water, and spores were carefully freed from the culture surface with a fine artist's brush. Afterward, the suspension was filtered through three layers of sterile cheesecloth to eliminate mycelial fragments (Ling *et al*., 2012).The density of the spore suspension of each isolate was determined and adjusted to $1x10^6$ conidia/ml (Boughalleb *et al*., 2007).

4.2. Plant inoculation

F. oxysporum f. sp. niveum were injected in watermelon plant by using sterile glass beakers 250 ml contain spore suspensions were prepared from cultures grown on PDA at room temperature for 10 days at a concentration of 1x106 conidia/ml. Seedlings of watermelon were uprooted, soil particles were removed from the roots by washing with distilled water, then cut part of it. 128 seedlings were selected and separated to four groups of 32 seedlings in each group. Two seedling groups of each grafted and non-grafted watermelon were inoculated with the fungus by dipping the roots into the inoculums for 15-20 seconds swirled several times to enable conidia to adhere to the roots. While the others two groups of grafted and non-grafted (control) were prepared by dipping their roots into sterile distilled water. (Boughalleb *et al*., 2007).

4.3. Watermelon transplanting

Pots were arranged into 8 rows, each row had 6 m in length and contained 16 Pots. Pots were filled with 12 liters of sterile peatmoss and vermiculite (1:1 vol/vol). After inoculation, the grafted and non-grafted seedlings were then hand planted (one seedling per pot) according to a completely randomized block design with 4 replications, each one is consisting of 32 plants. Plants were irrigated with small amounts of water so that the fungus would not leave the plants. Drip irrigations system was used so that the plants would be irrigated systematically with 1-4 L / day gradually according to the age and size of plant. The observations of fungi effect on the growth were collected after 30 of inoculating.

5. Types of the plant groups

1- Grafted &Infected Watermelon (GI).
2- Grafted & Non-Infected Watermelon (GNI).
3- Non-Grafted &Infected Watermelon (NGI).
4- Non-Grafted & Non-Infected Watermelon (NGNI) (Control).

6. Statistical analysis

Data were analyzed using IMB SPSS statistics Version 20 using Analysis of Variance (ANOVA). Significance of differences among groups was tested using the least significant difference (LSD) method. LSD values were calculated at P value = 0.05.

RESULTS

1. Isolation of Suspected Pathogen from Diseased Plants Roots

The diseased watermelon plant samples were externally examined for characteristic symptoms and subjected to pathogen isolation procedure. Diseased roots showed emergence of fungi, which were isolated and maintained on PDA, medium. Especially, the lesion areas of roots with characteristic brown rot showed emergence of fungi, which were later, identified to be Fusarium.

2. Characteristics of *Fusarium oxysporum* on PDA culture

Fusarium grow producing white, lavender, pink, salmon, or gray colonies on potato dextrose agar. Colonies have velvety or cottony surfaces and some species change color during incubation. Conidia formed on PDA are usually variable in shape and size and so are less reliable for use in identification. However, colony morphology, pigmentation and growth rates of Fusarium species on PDA are reasonably consistent if the medium is prepared carefully and if the cultures are initiated from standard inocula and incubated under standard conditions.

3. Microscopic identification of *Fusarium oxysporum*

Definitive diagnosis requires the isolation of Fusarium species from diseased watermelon. Microscopically, Fusarium species characteristically produce microconidia, macroconidia and Chlamydoconidia. Microconidia are unicellular and ovoid with zero to three septae forming false heads at the ends of conidiophores. Macroconidia are multicellular sickle-shaped clusters with three to five septae and foot-shaped basal cells. Chlamydoconidia are sometimes present, occurring singly or in groups, with rough or smooth walls.

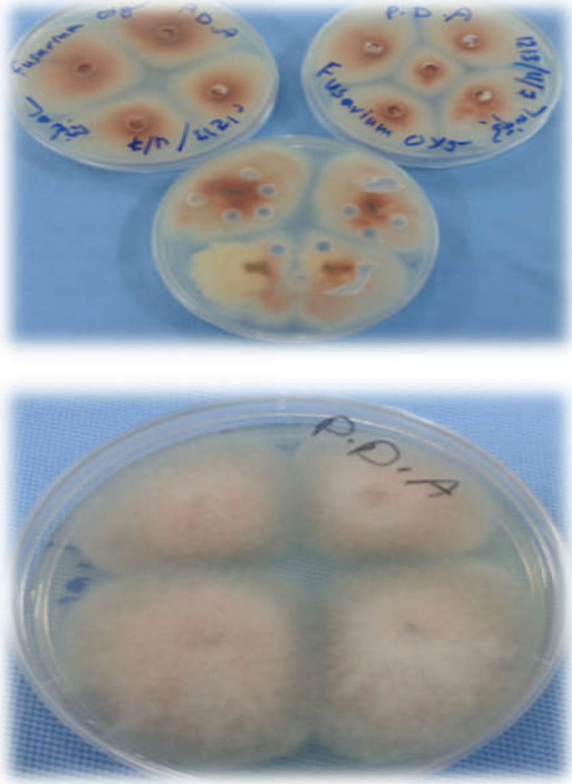

Fig. 1. Characteristics of Fusarium oxysporum isolated from diseased plants roots

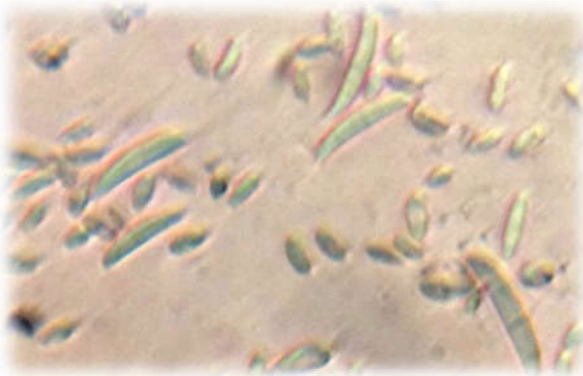

Fig. 2. Spores of Fusarium oxysporum isolated from wiled non-grafted plant

4. Effect of grafting on plant growth

After 11 weeks, the fruit was harvested, counted and weighted, the aerial plant part was cut at the basal stem then the plant length measured and the vegetative fresh weight was recorded. The roots were up taken then washed to remove soil; their lengths were measured and fresh weight were recorded. Thereafter aerial parts and roots were placed in oven with circulating air and dried at 95 ^{0}c for 24 hours until the constant weight was achieved; dry weight was recorded. The material was finely ground and stored in plastic bags (Karagiannidis *et al*., 2002).

Table 1. Effect of grafting on dry and fresh weight of shoot and root of plants

Group	N	Shoot DW (g/plant)	Root DW (g/plant)	Shoot FW (g/plant)	Root FW (g/plant)
GI	32	79.12(a)	2.93 (a)	570.54 (a)	16.45 (a)
NGI	32	42.02 (b)	1.80 (b)	79.47 (b)	10.01 (b)
GNI	32	228.18(c)	1.95 (b)	589.43 (a)	10.08 (b)
NGNI	32	46.83 (b)	1.96 (b)	139.74 (b)	8.25 (b)

* Means of similar letters in each column are not significantly different at P = 0.05

Table 2. Effect of grafting on stem and root length and number andweight of watermelon Fruit

Group	N	Stemlength (cm)	Rootlength (cm)	Fruit number (fruits /plant)	Fruit weight (g / fruit)
GI	32	226.14 (a)	104.83(a)	1.38 (a)	2804.31 (a)
NGI	32	164.17 (b)	37.19 (b)	0.88 (b)	980.94 (b)
GNI	32	239.81 (a)	85.00 (c)	1.06 (b)	2781.69 (a)
NGNI	32	160.50 (b)	39.91 (b)	1.00 (b)	1213.91 (b)

* Means of similar letters in each column are not significantly different at P = 0.05

In the current study, the analysis of data concentrated on the following comparisons

- **The first comparison**: is between GI and NGI in order to understand the effect of grafting as control of Fusarium wilt.
- **The second comparison**: is between GNI and NGNI in order to measure the effect of grafting on growth of watermelon plants in the absence of infection by Fusarium.
- **The third comparison**: is between GI and GNI. This comparison aims to measure the effect of the existence of Fusarium on the grafted watermelon compared with grafted watermelon on the absence of Fusarium.
- **The fourth comparison**: is between NGI and NGNI. We aim by this comparison to show how the growth of non-grafted and infected plants is influenced.

The four comparisons are the main interest of us, as they will elucidate the effect of grafting on plant growth and controlling of Fusarium wilt disease.

4.1. Effect of grafting on dry and fresh weight of shoot and root

Table 1. Illustrates the significance in the mean values of dry and fresh weight for shoot and root; that makes a comparison between of GI, NGI, GNI groups compared to NGNI watermelon as control.

4.3. Effect of grafting on length of stems, roots and on the number and the weight of watermelon fruit

Table 2. Illustrates the significance in the mean values of the effect of grafting on stem, root length and number and weight of fruit, between GI, NGI, GNI groups compared with NGNI watermelon as control.

4.4. Effect of grafting on infected plants in case of GI and NGI

4.4.1. Dry and fresh weight

The results of all measurements in Table (1) and Figure (3) illustrate that the mean of grafted and infected plants is higher

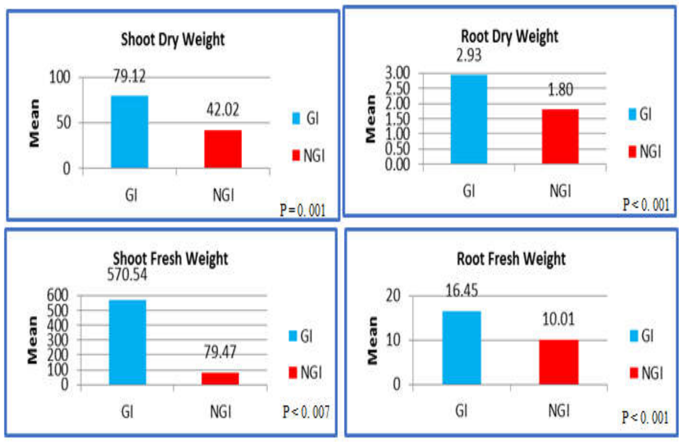

Fig. 3. Comparison of the effect of grafting on the dry and fresh weight of shoot and root of infected plants

than in non-grafted and infected plants, and there is statistically significant difference between them at (P value = 0.05); in case of dry and fresh weight of shoot and root. These results signify that the growth of GI is better than in NGI. This implies that grafting controlled Fusarium.

4.4.2. Length of stem, root, the number, and the weight of watermelon fruits

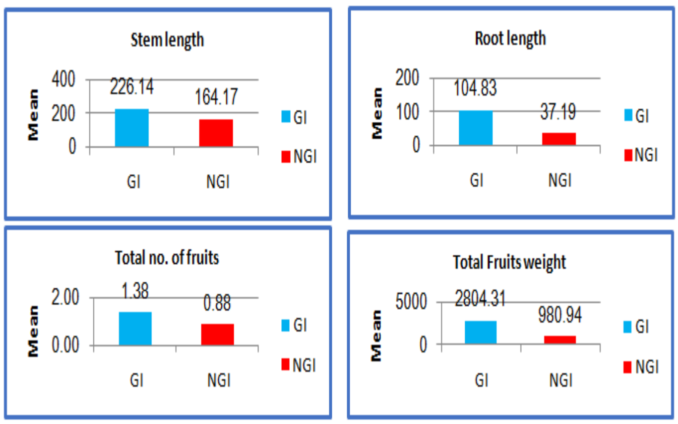

Fig. 4. Comparison of the effect of grafting on the length of stem, root and on the number and the weight of infected watermelon fruit. (P Value measured for all was < 0. 001)

The results in all situations as in Table (2) and Figure (4) show that the growth of infected and grafted plants are statistically better than the growth of infected and non-grafted plants that represented by length of stem and root and number and weight of watermelon fruit and have statistical significant difference at (P value = 0.05).

4.5. Effect of grafting on non-infected plants in case of GNI and NGNI

4.5.1. Dry and fresh weight

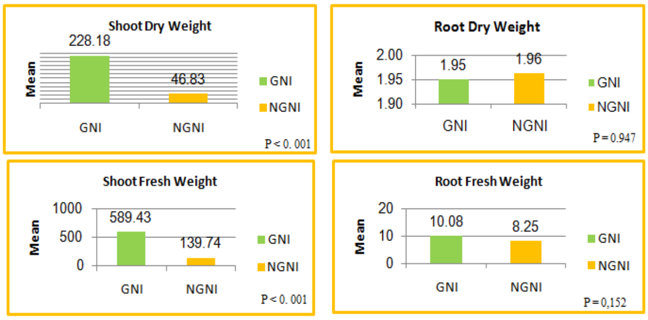

Fig. 5. Comparison of the effect of grafting on dry and fresh weight of shoot and root of non-infected plant

The results in Table (1) and Figure (5) show that the growth of grafted and non-infected plants are greater than in non-grafted and non-infected ones as control, except rootdry weight. There is a statistical significant difference between GNI and NGNI in case of fresh and dry weight of shoot at (P value = 0.05);but have not a significant difference in case of fresh and dry weight of root.

4.5.2. Length of main stem, root and the number and weight of watermelonfruits

The results in all the measurements as in Table (2) and Figure (6) confirm that the growth of grafted and non-infected plants are better than the non-grafted and non-infected ones as the control and have statistical significant difference at (P value = 0.05) except the number of fruit, where GNI have a little greater than NGNI.

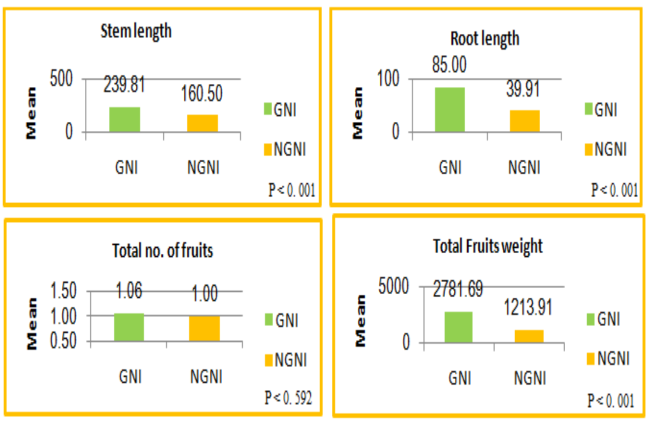

Fig.6. Comparison of effect of grafting on the length of stem, root and on the number and the weight of non-infected watermelon fruit

4.6. Effect of grafting on infected or non-infected plants in case of GI and GNI

4.6.1. Dry and fresh weight

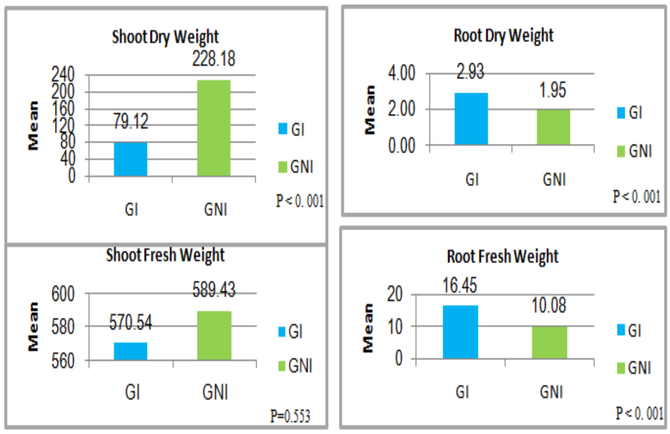

Fig. 7. Comparison of the effect of grafting on dry and fresh weight of shoot and root of infected or non-infected plant

All the results in Table (1) and Figures (7) illustrate that grafting has a positive effect on the growth of plants and has resistance to infection in a clear statistically relationship in the case of making a comparison between grafted and non-infected plants with grafted and infected ones, in terms of the shoot, root dry and fresh weight of plants, it is noticeable that the GI plants have root dry and fresh weight greater than the GNI which we will explain later.

4.6.2. Length of main stem, root, the number, and the weight of watermelon fruit

The results in Table (2) and Figure (8) indicate that the mean of the length of stem and root and number and weight of fruitwhich statistically proved the role of grafting in overcomingthe infection, where GI plants have given better growth thanGNI plants except the length of stem. This once again confirms the positive impact of grafting.

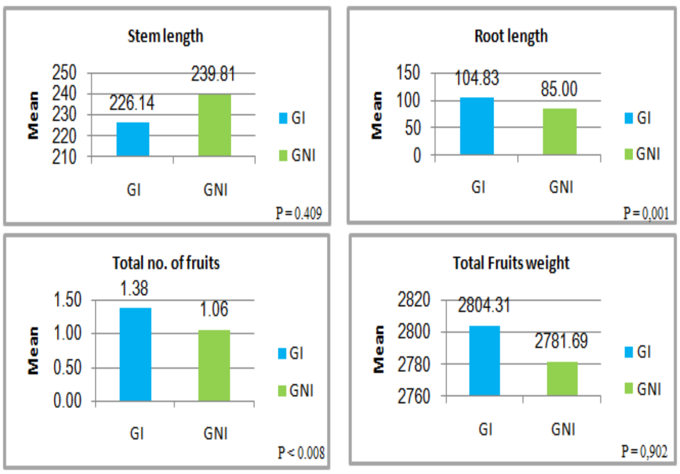

Fig. 8. Comparison of the effect of grafting on the length of stem, root and on the number and the weight of infected or non-infected watermelon fruit

4.7. Effect of infection or non-infection on non-grafting plants in case of NGI and NGNI

4.7. 1. Dry and fresh weight

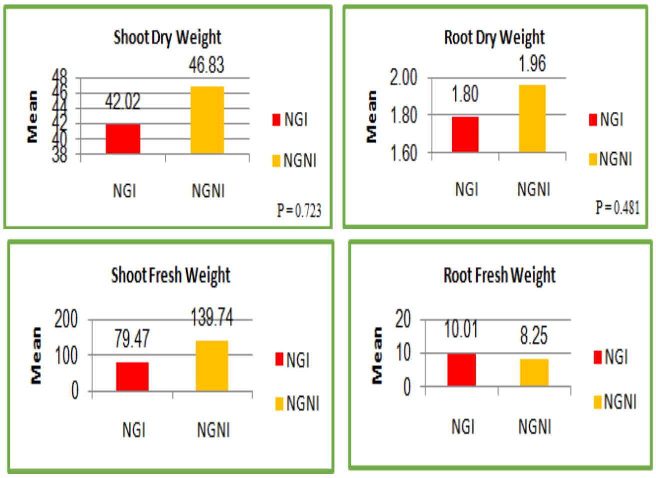

Fig.9. Comparison of the effect of infection or non-infection on dry and fresh weight of shoot and root of non-grafted plants

The results in Table (1) and Figure (9) show that the fungus infection has a negative effect on the vegetative growth. The growth of non-grafted and infected plants is less than non-grafted and non-infected ones, while the growth of root of NGI is better than in the non- NGNI as we will explain later. All the results have not statistical significant differences.

4.7.2. Length of main stem, root, the number, and the weight of watermelon fruit

The results in Table (2) and Figure (10) show the negative impact of the presence of infection on the length of the roots, numbers and weights of the fruit, where all results in case ofnon-grafted and infected plants are less than non-grafted and non-infected ones without statistical significant differences except the stem length, which we will explain later.

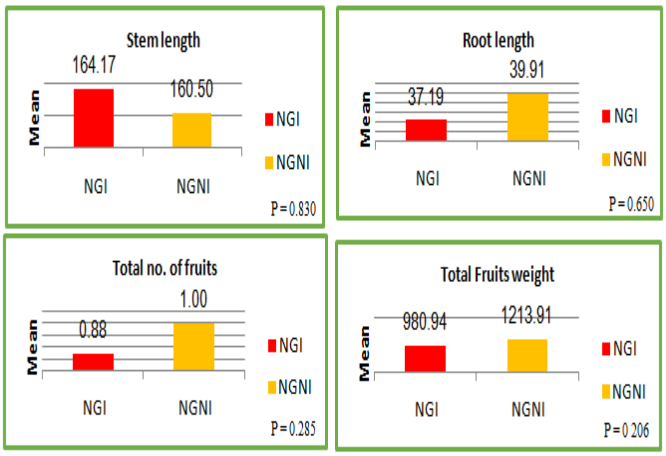

Fig. 10. Comparison of the effect of infection or non-infection on the length of stem, root and on the number and the weight of non-grafting watermelon fruit

DISCUSSION

1. Characteristics of *Fusarium oxysporum* on PDA culture

Fusarium oxysporum usually produces a pale to dark violet or dark magenta pigment on the agar if incubated in dark place. PDA is used by some researchers for the isolation of Fusarium species. We do not recommend this medium for this purpose as many saprophytic fungi and bacteria also can grow on the medium and interfere with the recovery of the Fusarium present. If PDA is used for the recovery of fungi from plant material, then the concentration of potato and dextrose should be reduced by 50 -75 %, and broad–spectrum antibiotics should be included in the medium to inhibit bacterial growth (Rothrock and Gottlies, 1981).

2. Identification of the Pathogen

Pathogen was identified by studying cultural characteristics and microscopic features (Leslie and Summerell, 2006; Watanabe, 2002; Summerell *et al*., 2003; Gagkaeva, 2008). The pathogen sample was also sent to Fungal Identification Service of Ministry of Agriculture, for confirmation of its identity and deposition.

3. Effect of grafting on plant growth

Grafting has been proposed as a major component of an integrated management strategy for protecting plants from soil borne diseases in areas where farmland is limited and farmers are forced to grow the same crop over successive years (Ling *et al*., 2012).Watermelon, *Citrullus lanatus* is one of the most important economic vegetable crops damaged by Fusarium wilt, which is caused by *Fusarium oxysporum f. sp. Niveum*. Thisis economically important wilting pathogen of watermelon because it causes significant yield losses in watermelon (Egel and Martyn, 2007).In this study, our attention is to evaluate the effect of grafting as alternative method for getting rid of Fusarium and in consequence amelioration of watermelon plant growth. Therefore, we focus to analyze four comparisons as in a Table 5.

Table 3. Types ofcomparisons between plant groups

First comparison	GI and NGI
Second comparison	GNI and NGNI
Third comparison	GI and GNI
Fourth comparison	NGI and NGNI

3.1. Effect of grafting on infected plants as control of Fusarium wilt in case of GI and NGI

3.1.1. Dry and fresh weight

The results in all analysis showed that the vegetative growth of grafted and infected plants (GI) was better than non-grafted and infected plants (NGI) and had a significant difference at P value = 0.05. In addition, regarding the growth of roots, the results are similar to the result of vegetative growth and had a clear significant difference as shown in Table (1) and Figure (3).These results indicated that the growth of pumpkin roots as rootstocks were better than the self-rooted of watermelon in presence of Fusarium; this lead to more vegetative growth. Meanwhile, the results showed that pumpkin roots had higher resistance to Fusarium wilt compared to watermelon roots. These results are a satisfied answer for the main goal of our study. In accordance with these results, Lee (1994) and Ioannou *et al*., (2001) found that grafted plants were more vigorous than self-rooted ones and had a larger central stem diameter. In addition, the increase in growth of grafted plants relates to stronger root growth of the rootstock (Yetisir and Sari, 2004). The vigorous rootstocks were reported to exhibit excellent tolerance to the most of serious soil borne diseases (Liu *et al*., 2009).

3.1.2. Length of main stem, root and the number and weight of watermelon fruit

On comparing the results of the growth based on the length of stem and root and the number and weight of watermelon fruit, the results supported clearly the previous out comes, where grafting had a significant positive impact on growth in the case of grafted and infected plants as shown in Table (2) and Figure (4). This agrees with Mohamed *et al*., (2012) results that indicated that pumpkin rootstock increased the yield per plant.

3.2. Effect of grafting on non-infected plants in case of GNI and NGNI

3.2.1. Dry and fresh weight

A comparison between grafted and non-grafted watermelon (control) in absence of infection, showed that grafting gave a clear preference for vegetative growth compared with the control and had a clear statistical significance difference. These results supported clearly the above results, whereas the growth of the pumpkin roots gave preference vegetative growth for watermelon scion even if compared with the self-rooted of watermelon. The comparison between GNI and NGNI based on the growth of the roots, the results showed that the growth of roots of GNI which was represented by dry weight was slightly smaller than NGNI control and had no significant difference as shown in Table (1) and Figure(6).This result illustrates the agreement between root and shoot in case of NGNI, which had a little bit better effect on the root growth than the growth of the GNI, where the roots are not from the same origin. Wherever the shoot growth of GNI was better than the shoot growth of NGNI with a clear significant difference, while the root growth of NGNI was slightly better than the root growth of GNI without significant difference.

The nutrition that resulted from the root in grafted plants caused vegetative growth without being affected by the root-shoot variation and cause normal growth of roots. Therefore, the strength of rootstocks supports the stability of the plant; this indicates that the roots here have a clear impact on supporting the plant growth. However, in case of roots growth itself, the congruence between shoot and root had a stronger impact on supporting and increasing the growth of roots. These results indicated that the flow of nutrients (mineral and water) from roots to shoot was not affected regardless of rootstock-scion, but the flow of the carbohydrates from shoot to roots seem to be affected slightly because of variation of the scion-rootstock between the two groups. If that is proved true, this result can be regarded as an important discovery of this important research. This effect is mainly attributed to a scion-rootstock interaction, which influences various plant physiological processes such as nutrient and water uptake and translocation, hormone synthesis, photosynthesis and other metabolic processes (Rouphael *et al*., 2010).According to Rouphael *et al.* (2008), rootstock-scion combination may affect the mineral concentration of aerial plant parts due to differences of physical characteristics of the root system of grafted plants, which allow for better water and mineral nutrients uptake, compared to non-grafted plants.

In case of the comparison between GNI and NGNI overall results were going in the same direction. That means grafting had a positive impact on the growth of the plant especially in both cases of infected or non-infected plants with the fungus. The results are in accordance and support that the dry weight of roots is one of the evidences that measures root vigor (Alan *et al*., 2007). Plants with vigorous root systems release more cytokinins into the ascending xylem sap resulting in increased yield due to growth promotion (Aloni *et al*., 2010).Moreover, physiologically King *et al.* (2010) explained that the use of pumpkin and bottle gourds as watermelon rootstock encourages all vital stress factors of the plant in a way that improves the health status of the plant by increasing absorption of nutrients and plant tolerance to low soil temperature, salinity and excess humidity.

The results have shown that the roots of pumpkin have the ability to absorb more water compared with the roots of watermelon and this is confirmed by the dry and wet weight of roots as shown in Figure (6). In the case of wet and dry weight of shoot, the results showed that the dry and wet weight in grafted plants was larger than the non-grafted plants and clearly supported by the absence of infection. This demonstrates that the absorption of water and minerals was better than in the roots of pumpkin.

3.2.2. Length of stem, root and the number and weight of watermelon fruit

Regarding to the length of stem and root, the results confirmed the above analysis that the grafting had a significant positive effect on the growth. The results clarified that there is variation between the dry weight and length of roots between GNI and NGNI, where the grafted plants had the longest root with a clear significant difference as in Table (2) and Figure (6), but had a little lower dry weight than non-grafted plants without a significant difference as in Figure (5).This variation is a result of cutting in roots of the grafted plants or because pumpkin roots have node, which filled with water, so when it is dried the weight will decrease a lot. This result agree with Alan *et al*., (2007), where control plants had short main stem, less number of lateral vine and low root dry weight. Furthermore, the difference in root depth between pumpkin (180cm) compared with watermelon (45cm) is perhaps the main reason for protecting those crops from the soil pathogens. In this respect, Sawalha study showed that soil fungi are present mainly in the 20-40 cm depth, while their count decreased progressively below 40 cm depth of the soil horizon (Sawalha, 2012).In addition, the number of fruit in grafted plants was a little better than in the non-grafted plants and had no significant difference at 5% level. This results supported by Mohammed *et al*., (2012) results, which elucidated that the fruit yield and average fruit weight did not significantly differ when watermelon cv. was grafted onto (Tetsukabuto).This result is relatively different from Khankahdani's *et al*., (2012) and Alan *et al*., (2007) results, which explained that fruit yield was positively influenced by grafting when compared with the control. Our result can elucidated by the damage and death of some flower. Regarding to flowering characters, the grafted and non-grafted plants did not show any significant differences (Mohammed *et al.,* 2012).

3.3. Effect of grafting on infected and non-infected plants in case of GI and GNI

3.3.1. Dry and fresh weight

The effect of grafting on watermelon growth indicated that grafting affected positively on vegetative and root development of watermelon plants. These results illustrate that plant with vigorous root systems enhanced uptake of water and minerals and increased photosynthesis, which lead to increase of vegetative growth, then yield as shown in Table (1) and Figure (7). Although the plants were grafted and infected, the growth of their roots had better growth than the grafted and non-infected plants with a clear statistical relationship. Root dry weight is one of the indexes that measures root vigor. This shows the importance of grafting for plants especially in the case of infection with the fungus. Therefore, there is a positive correlation between the vigorous of roots and the growth or resistance of *F. oxysporum*. This result can be explained as the irrigation input is removed or reduced for specific periods during the growth cycle of crops as described in eggplant (*Solanum melongena L.*; Kirnak *et al*., 2002) or watermelon (Simsek *et al*., 2004) or it perhaps due to a defect in weights because the process of irrigation and different date of measurement. According to Alan *et al*. (2007), the effect of the grafting on watermelon growth characteristics indicated that grafting affected root and vegetative development of watermelon plants but there is difference between rootstocks in root dry weight.

3.3.2. Length of stems, root and the number and weight of watermelon fruit

The results showed that the root length, number, and weight of fruit were significantly influenced by grafting in case of infection as compared with non-infected plants except main stem length. These results were in the same line with previous states, confirmed the positive effect of grafting on the growth of plants and their overcoming to infection. This result is shown in Table (2) and Figure (8).In accordance with our results Alan *et al*. (2007) study, whereas the root length, main stem length, number of lateral vine and fruit yield were significantly influenced by grafting. It is clear that grafting increases yield since plants are resistant to soil borne disease, have strong root system and increase photosynthesis and this agrees with Mohamed *et al*., findings (2012).

3.4. Effect of infection or non-infection on non-grafting plants in case of NGI and NGNI

3.4.1. Dry and fresh weight

The results in Table (1) and Figure (9).have shown that presence of fungus has a negative effect on the plant growth. This is the problem that our experimental study has solved by grafting which is considered as the main purpose of our study. In the same direction, the growthof non-grafted and infected plants was the least compared with the control. This result indicated that there was a negative effect on root growth followed by the same effect on the vegetative growth. This result illustrated the importance of the grafting process as Mohammed *et al*., (2012) and Alan *et al*., (2007) reported that grafting significantly affected plant growth.Despite of the plant is non-grafted and infected with the fungus; they gave the best growth of root compared with the control group. That maybe because of the physiological reaction to infection by the fungus, which stimulates the plant to produce the largest total root to give greater absorption space to increase water pressure to pump it for all vegetative plants through vascular wood. The results of Atkinson *et al*., (1999); Chaves *et al*., (2003) support our result where they indicated that when water supply is limited, plant structure is modified by increasing the root: shoot ratio.

3.4.2. Length of stem, root, the number, and the weight of watermelon fruit

All results in case of non-grafted and infected plants were less than in the controlled ones. These results indicated clearly the negative impact of infection on the growth which represented by the length of the roots, numbers and weights of the fruit, except stem length.On the other hand, infected plants had a positive effect on the length of the stem in the sense stimulate the growth of the stem more than non-infected plants. That possibly because of the watermelon is a creeping plant in research for water. This result confirms the previous findings that are related to wet weight of the roots. Hence, this thesis gives attention to the importance of grafting and its impact on the growth of plants and overcomes the fungal diseases as in Table (2) and Figure (10). According to Lee (2003), grafting is an important technique for vegetable production and has become a common practice in many parts of the world where sustainable production is performed.

Conclusion

Our study demonstrates that all measured variables were consistently affected by grafting watermelon scion onto Pumpkin rootstock. It can be concluded that in watermelon plants, growth is positively affected by grafting due to the increase in root length, main stem length, number of lateral branches, number of leaves, number of fruit, fruit weights and vegetative fresh weights and dry weights of shoot and root were significantly affected by grafting. These results indicate that grafting watermelon onto specific rootstock influences growth, as well as disease resistance. Finally, the results of our study suggest that grafting in local conditions can be an alternative method to control Fusarium wilt disease in watermelon production.

REFERENCES

Alan, Ö. Özdemir, N. and Günen, Y. 2007. Effect of grafting on watermelon plant growth, yield and quality. *Journal of Agron*. 6(2), p: 362-365.

Aloni B., Cohen R., Karni L., Aktas H. and Edelstein H. 2010. Hormonal signal-ing in rootstock-scion interactions. *Sci Hortic*, 127, p: 119-126.

Atkinson, C.J., M. Policarpo, A.D. Webster, and A.M. Kuden. 1999. Drought tolerance of apple rootstocks: Production and partitioning of dry matter. Plant Soil 206, p: 223-235.

Biles, C.L., Martyn, R.D., Wilson, H.D. 1989. Isozymes and general proteins from various watermelon cultivars and tissue types. *Hort. Science* 24 (5), p: 810-812.

Boughalleb, N., Tarchoun, N., El Mbarki, A. and El Mahjoub, M. 2007. Resistance Evaluation of Nine Cucurbit Rootstocks and Grafted Watermelon (Citrullus lanatus L.) Varieties Against Fusarium Wilt and Fusarium Crown and Root Rot. *Asian J. Plant Pathol.* 2(1), p: 24-29.

Chaves, M.M., Maroco, J.P. and Pereira, J.S. 2003. Understanding plant responses to drought from genes to whole plant. Fun. *Plant Biol*. 30, p: 239-264.

Cohen, R., Burger, Y. and Horev, C. 2007. Introducing grafted Cucurbits to modern agriculture: The Israeli experience. *Plant Dis.* 91, p: 916-923.

Cushman, K. (2006). Grafting techniques for watermelon. University of Florida, Inst. Food Agr. Sci. HS1075, p: 1-5.

Egel, D. S. and Martyn, R.D. 2007. Fusarium wilt of watermelon and other cucurbits. The Plant Health Instructor. DOI: 10.1094/PHI-I-2007-0122-01.

Gagkaeva, T. 2008. Introduction to Fusarium taxonomy, All-Russian Institute of Plant Protection, St. Petersburg, Russia http://fou02.planteforsk/Fusarium/Presentasjoner.

Ioannou N. 2001. Integrating soil solarization with grafting on re-sistant rootstocks for management of soil-borne pathogens of eggplant. *J. Hortic. Sci. Biotechnol*. 7, p: 396-401.

Karagiannidis, N., Bletsos, F., Stavropoulos, 2002. Effect of Verticillium wilt (Verticillium dahlia Kleb.) and mycorrhiza (Glomus mosseae) on root colonization, growth and nutrient uptake in tomato and eggplant seedlings. *Scientia Horticulturae* 94, p: 145-156

Khankahdani, H.H., Zakeri, E., Saeedi, G. and Shakerdargah, G. 2012. Evaluation of Different Rootstocks and Grafting Techniques on Graft Union Percent, Yield and Yield Components of Watermelon CV. 'Crimson Sweet'. *World Applied Sciences Journal* 18 (5), p: 645-651, 2012. ISSN 1818-4952.

King, S.R., Davis, A.R., Zhang, X. and Crosby, K. 2010. Genetics, breeding and selection of rootstocks for *Solanaceae* and *Cucurbitaceae. Sci. Hort*. 127, p: 106-111.

Lee, J.M. 1994. Cultivation of grafted vegetables. 1. Current status, grafting methods, and benefits. *HortScience* 29, p: 235-239.

Lee, J.M. 2003. Report prepared by; Astrit Balliu & Engjell Skreli, 2009.

Lee, J.M. and Oda, M. 2003. Grafting of herbaceous vegetable and ornamental crops. Horticultural Reviews 28, p: 61-125.

Leslie, J.F. and Summerell, B.A. 2006. The Fusarium Laboratory Manual. Blackwell Publishing Ltd., Oxford, U.K., p: 212-218.

Ling, N., Zhang, W., Wang, D., Mao, J., Huang, Q., Guo, S. and Shen, Q. 2012. Root Exudates from Grafted-Root Watermelon Showed a Certain Contribution in Inhibiting Fusarium oxysporum f.sp. *niveum Appl Soil Ecol* 59, p: 13-19.

Liu N., Zhou B., Zhao X., Lu B., Li Y. and Hao J. 2009. Grafting eggplant onto tomato rootstock to suppress Verti-cillium dahliae infection: the effect of root exudates. *HortScience* 44: 2058-2062.

Marr, Charles 2004. Commercial Vegetable Production: Pumpkins, Kansas State University.

Ministry of Agriculture (MOA). 2014. Annual Report.

Mohamed, Fouad, H., Abd EL-Hamed, Khalid E., EL Wan, M., Mohammed W., Hussien, Mennat-Allah N.E. 2012. Impact of Grafting on Watermelon Growth, Fruit Yield and Quality. Department of Horticulture, Faculty of Agriculture Suez Canal University, Ismailia, Egypt 41522. vol. 76, p: 99-118.

Rothrock C. and Gottlies D. 1981. Importance of antibiotic production in antagonism of selected streptomyces species to two soil-borne plant pathogen. *J. Antibiot.* 34, p: 830-83.

Rouphael Y., Schwarz D., Krumbein A., Colla G. 2010. Impact of grafting on product quality of fruit vegetables. *Sci. Hortic.* 127, p: 172-179.

Rouphael, Y., Cardarelli, M., Colla, G. and Rea, E. 2008. Yield, Mineral Composition, Water Relations, and Water Use Efficiency of Grafted Mini-watermelon Plants under Deficit Irrigation. *HortSci.,* 43(3): 730-736.

Sawalha, H. 2012. The use of watermelon (Baladi cultivar) grafting on bottle gourd and pumpkin rootstocks to control the soil-borne fungi causing vascular wilt disease of watermelon in the Plain of Sanoor in Palestine. *Al-AqsaUniversity Journal (Natural Sciences Series),* Vol.16, No.1, P: 39-54, Jan. 2012 ISSN 2070-3155.

Sesso H.D., Liu S., Gaziano J.M. and Buring J.E. 2003. Dietary lycopene, tomato-based food products and cardiovascular disease in women. *J. Nutr.* 133, P: 2336-2341.

Simsek, M., M. Kacura, and T. Tonkaz, 2004.The effects of different irrigation regimes on watermelon [Citrillus lanatus (Thunb.)] yield and yield components under semi-arid climatic conditions. Aust. *J. Agr. Res.* 55, P: 1149–1157.

Summerell, B.A., Salleh, B. and Leslie, J.F. 2003. A utilitarian approach to Fusarium identification. *Plant Disease,* 87(2), p: 117-128.

USDA. Federal Costs of School Food Programs, 2007. Accessed at <http://www.fns.usda.gov/pd/cncosts.htm> on January 17, 2007.

USDA. Foods Sold in Competition with USDA School Meal Programs: A Report to Congress, 2001. Washington, DC: USDA, 2001. USDA. Federal Costs of School Food Programs. Accessed at <http://www.fns.usda.gov/pd/ cncosts.htm> on January 17, 2007.

Watanabe, T. 2002. Pictorial Atlas of Soil and Seed Fungi. Second edition. CRC Press, USA.

Yetisir, H. 2001. Effect of grafted seedling on plant growth, fruit yield and quality in watermelon and investigation of grafting point histologically. Ph.D.thesis. Ukurova University, Department of Horticulture, Adana-Turkey, p: 178.

Yetisir, H. and Sari. N. 2004. Effect of hypocotyl morphology on survival rate and growth of watermelon seedlings grafted on rootstocks with different emergence performance at various temperatures. *Turkish J. Agric. and For.* 28, p: 231-237.

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