Effect of grafting on vegetative growth and quantitative production of muskmelon (Cucumis melo L.)

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Abstract
Plants of muskmelon variety “Calypso” were used as scion and non grafted control while two hybrids (Cucurbita maxima x Cucurbita moschata), TZ148 and Ferro as rootstocks. Grafted and non-grafted plants were grown under a monotunnel heated and irrigated by geothermic water in the South of Tunisia. Plants were grown in soilless culture on sand and compost. This trial has revealed that, on sand as well as on compost, grafted plants were more vigorous than self-rooted ones. This vigor was highlighted by values of length and volume of roots, plant height, stem diameter, leaf area and fresh and dry matter of leaves. Indexes of growth represented by LAI, SLA, RGR and NAR were strongly improved by grafting particularly by TZ148. This improvement implied a hasty vegetative growth. Moreover, precocity of production was greater for grafted plants. In addition to their early production, grafted plants produced more fruits on sand and compost. The average weight of fruits was enhanced, too, by this agricultural practice. Thus, the major part of fruits produced by grafted plants had a weight superior to 600g.

Key words: Muskmelon, grafting, vegetative growth, indexes of growth, quantitative production

Introduction
In Tunisia, greenhouses cultivation is widespread specially because this system permits to produce out-of-season vegetables under controlled climatic conditions. In the northern part, these structures are unheated but in the South, they are developed ones, heated and irrigated by geothermic waters. Heating has permitted a gain of precocity and an amelioration of gustative quality that are limited under condition of low temperature (Mougou, 1987). Notwithstanding, it has created a favorable biotope for dissemination of pathogenic agents (Martyn, 1983) and amplification of salinity seeing the inner high evaporation. Indeed, few years after beginning farmers have complained these constraints.

Regarding to the agricultural, economical and social importance of this sector, Tunisia has aimed to overcome such hostile conditions of culture by adopting several practices like solarization, water washing, rotation of cultures and amendment of sand and organic matter. However, efficiency of these techniques was imperfect (Radhouani et al., 2008).

In the world, many promising practices are adopted in order to surmount such constraints. Grafting is one of these techniques which is in root of becoming a popular agricultural practice. Khah et al. (2006) reported that Spain is the most important country for the spreading of vegetable grafting mainly with tomato and watermelon.

The use of grafted plants is considered an innovative technique which ameliorates vegetative growth (Jebari and Aounallah-Chouka, 1999; Zhusheng et al., 2000; Rochdi et al., 2005) and improves flowering (Lardizabal and Thompson, 1990). Consequently, productivity yield is increased (Wheaton et al., 1995; Georgiou, 2000; Al-Jaleel et al., 2005). Moreover, it was highlighted that this practice is able to conciliate plants with hard conditions of culture such as salinity (Edelstein et al., 1999; Santa-Cruz et al., 2002; Fernandez et al., 2004; Rochdi et al., 2005; Ruiz et al., 2006), low (Bulder et al., 1990) and high (Rivero et al., 2003; Están et al., 2005) temperature, and drought (AVRDC, 2000). Besides, the use of grafted plants is seen as an alternative for chemical sterilization (Ginoux, 1993; Ginoux et Buffière, 1998) since it provides plants with resistance against soil-borne pathogens (Scheffer, 1957; Lee, 1994; Cohen et al., 2005). Nevertheless, the reliability of grafting depends on interaction between rootstocks and scions as it was reported by Khah et al. (2006). Moreover, Romano and Paratore (2001) remarked that the choice of rootstock affects the effectiveness of this agricultural practice.

In this framework, the aim of this research was to evaluate the effect of two rootstocks on vegetative growth and production of muskmelon (Cucumis melo L.) cultured on soilless media under a greenhouse heated and irrigated by geothermic water in the South of Tunisia.

Materials and methods
Crop growth conditions: The experiment was conducted in the experimental field of the Institute of Arid Regions in Kebili (South of Tunisia). It was carried out in a mono tunnel (8.5 m of width x 30 m of length) covered by a white and 200 μm thick polyethylene film. Local sand and compost, formed by fermentation of dry palms with addition of manure, were used as substrates in this trial. Table 1 and 2 illustrated their main characteristics. The study was conducted in soilless media. Substrates were contained in plastic containers with a volume of 33 L. These containers were placed on ground settled down beforehand and covered by a plastic film. They were disposed on a fine layer of gravels. They were perforated to drain excess of water. Heating was realized by the circulation of geothermic
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Plants material: Two commercial hybrids (Cucurbita maxima x Cucurbita mushata) TZ148 and Ferro were used as rootstocks with muskmelon, variety “Calypso” as scion.

A randomized complete block design was adopted with three replications: Two grafting combinations, Calypso grafted on TZ148, Calypso grafted on Ferro, and Calypso non-grafted was considered as control. Each replication was represented by eight plants on each substrate.

Measurements

Determination of vegetative growth: This growth was evaluated by measuring plant height, stem diameter, fresh and dry weight of leaves and leaf area.

Observations were recorded at 49, 64 and 79 days after transplantation. Measurements on leaves were recorded on the fifth leaf from the top. This choice was justified by the fact that it corresponds to a transformation from the state of well to source meristematic activity.

With dry weight data and leaf area, the following growth indices were calculated, according to Radford (1967) and Hunt (1978):

\[
\begin{align*}
\text{Relative Rate of Growth (RGR)} &= \frac{dW}{W} \times \frac{1}{dt} \quad \text{in mg g}^{-1} \text{day}^{-1} \\
\end{align*}
\]

\[
\begin{align*}
\text{Net assimilation rate (NAR), a measure of the biomass production by unit of leaf area during a specific period of time, was calculated as following:} \\
NAR &= \frac{(W_2-W_1)(\text{LA}_2-\text{LA}_1)}{\text{dt} \times \text{m}^{2} \text{day}^{-1}} \\
\end{align*}
\]

Calculation of growth indices: With dry weight data and leaf area, the following growth indices were calculated, according to Radford (1967) and Hunt (1978):

\[
\begin{align*}
\text{Leaf Area Index (LAI)}, \text{which is the leaf area per surface area unit was calculated using the following formula:} \\
\text{LAI} &= \text{Leaf area per plant \times Number of plants/m}^{2}; \text{expressed in cm}^{2}/m^{2} \\
\text{Specific Leaf Area (SLA)}, \text{an indication of the thickness of leaf per unit of leaf area, was determined by the equation:} \\
\text{SLA} &= \text{Leaf area per plant/Leaf weight per plant; in cm}^{2}g^{-1} (\text{dry weight}) \\
\end{align*}
\]

Furthermore, stem diameter increased as a result of this grafting plant to produce a new dry matter in a specific period of time was calculated as following:

\[
\begin{align*}
\text{RGR} &= \frac{dW}{W} \times \frac{1}{dt} \; \text{in mg g}^{-1} \text{day}^{-1} \\
W &= \text{dry weight of sample} \; \text{dt} = \text{d}2 - \text{d}1 \; \text{is the interval of time between samples of measure} \\
\text{Net assimilation rate (NAR), a measure of the biomass production by unit of leaf area during a specific period of time, was calculated as following:} \\
\text{NAR} &= \frac{(W_2-W_1)(\text{LA}_2-\text{LA}_1)}{\text{dt} \times \text{m}^{2} \text{day}^{-1}} \\
\end{align*}
\]

Evaluation of production: Days preceding harvest were counted in order to appraise precocity. The average number and weight of fruits were determined. Fruits were classed into three grades based on their weight (CTIFL, 1991): C1: weight inferior to 600 g; C2: weight ranging between 600 and 900 g; C3: weight superior to 900 g. Total yield per substrate was determined.

Data analysis: An analysis of variance (ANOVA simple) was used to assess the significance of treatment means. Differences between the means of the three categories of plants were compared using the least significant difference (LSD) and Tukey test at the 0.05 probability level.

Results

Length of the principal root was not significantly affected by grafting yet the volume of roots was largely intensified by this technique (Table 3). This increment was around 55.58 and 38.1%, respectively on sand and compost. This effect was statistically similar for the two rootstocks. This behaviour of roots endowed by grafting was also highlighted by Rochdi et al. (2005). Rivero et al. (2003) have explained this effect by improvement of the meristematic activity.

Grafted plants were taller than self-rooted ones. Fig. 1 shows that the average height of plants was improved similarly by the two rootstocks on the two substrates. On sand, this improvement was not significant. Non-grafted plants had a height of 193 cm whereas grafted ones revealed values of 198.88 and 194 cm, respectively for TZ148 and Ferro. Conversely, on compost, grafting recorded an increment of 19% when compared to non-grafted plants which had reached a height of 185.22 cm. These results are similar with the findings of Georgiou (2000) and Khah et al. (2006), respectively for mandarin and tomato.

At the end of culture, plants were pulled out and length of the principal root was measured. Volume of roots was estimated as volume of water displaced by roots.

Calculation of growth indices: With dry weight data and leaf area, the following growth indices were calculated, according to Radford (1967) and Hunt (1978):

\[
\begin{align*}
\text{Relative Rate of Growth (RGR)}, \text{which reflects the ability of} \\
\end{align*}
\]

\[
\begin{align*}
\text{Net assimilation rate (NAR), a measure of the biomass production by unit of leaf area during a specific period of time, was calculated as following:} \\
\text{NAR} &= \frac{(W_2-W_1)(\text{LA}_2-\text{LA}_1)}{\text{dt} \times \text{m}^{2} \text{day}^{-1}} \\
\end{align*}
\]

Furthermore, stem diameter increased as a result of this grafting
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Leaf area (cm²) 53.07a 55.1a 53.58a NS 55.51b 65.98a 54.37b **
Dry weight (g) 0.27b 0.29a 0.28b * 0.28b 0.34a 0.26b **
Fresh weight (g) 1.68b 1.80a 1.81a * 1.75b 2.16a 1.76b **

Table 3. Effect of grafting on growth of roots

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sand</th>
<th>TZ148</th>
<th>Ferro</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average length of the principal root (cm)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Sand</td>
<td>24.33a</td>
<td>36a</td>
<td>38a</td>
<td>NS</td>
</tr>
<tr>
<td>Compost</td>
<td>29.66a</td>
<td>41a</td>
<td>43.16a</td>
<td>NS</td>
</tr>
<tr>
<td>Average volume of roots (mL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>41b</td>
<td>93.33a</td>
<td>100a</td>
<td>***</td>
</tr>
<tr>
<td>Compost</td>
<td>59b</td>
<td>94a</td>
<td>96.66a</td>
<td>***</td>
</tr>
</tbody>
</table>

Values followed by the same letters within each line are not significantly different according to test of Tukey at P < 0.05. Levels of significance are represented by *P < 0.05, **P < 0.01, ***P < 0.001, and NS, not significant.

Fig. 2. Effect of grafting on diameter of the stem (cm).

Fig. 3. Effect of grafting on grades of fruits.

amelioration to increased absorption, uptake and transmission of brute sap ingredients that were proved by Lee (1994), Oda (1995) and Al-Jaleel et al. (2005) in conditions of adoption of this practice.

Growth of leaves, represented by their fresh and dry weights and their mean area, was enhanced by grafting. This result was consistent with those indicated by Rochdi et al. (2005) for citrus fruits and Ruiz et al. (2006) for tobacco.

LAI, that constitutes a measure of leafiness per unit ground area of photosynthetic machinery (Amanullah et al., 2007), was affected amply by grafting mainly on compost. Values illustrated in Table 5 showed that on sand the treatments had similar values of this parameter. While, on compost, until 64 days after transplantation, grafted plants, especially those grafted on TZ148, were leafier than non grafted one. Gaytán-Mascorro et al. (2008) have reported this remark for tomatoes and they noted that this situation demands pruning. Moreover, Pulgar et al. (1998) have remarked that grafting increased leaves production.

Seventy nine days after transplantation, non grafted plants showed a slight superiority against grafted one. This superiority may reflect a continued vegetative growth for this category of plants.

Referring to values of SLA (Table 5), it seems that on sand as well as on compost, until 64 days after transplantation leaves of grafted plants were thicker than those of self-rooted ones. This difference was greater with TZ148 than Ferro. On the contrary, 79 days after transplantation, leaves of grafted plants became thinner. This behavior may be due to the allocation of carbohydrates to prior organs, flowers and fruits.

The ability of plants to produce a supplement photosynthetic product, dry matter, in a specific period deducted from values of RGR was similar for three groups of plants cultivated on the two substrates (Table 5). However, values of NAR, which represents the efficiency of foliar area to produce new matter in a specific period, were fairly different between categories of plants. Thus, on two substrates non grafted plants showed a negative net assimilation whereas plants grafted on TZ148 exhibited positive
values of this parameter. The assimilation of plants grafted on Ferro was different on two substrates: on sand, it was positive while on compost, it was negative and more superior than those of non grafted plants. Negative values of this parameter may imply a minor assimilation that was not enough even for energetic expenses aroused by respiration. Indeed, Snelgar et al. (1980), Marcelis et al. (1998), Saadallah et al. (2001) and Loveys et al. (2002) have affirmed that net assimilation rate constitutes the final result of carbon’s benefit by photosynthates and its release by respiration. This metabolic phenomenon is a major component of NAR. Consequently, it seems that the fifth leaf of non-grafted plants was a well (consumer of photoassimilates) not a source (producer of photoassimilates). This situation may reflect an extended vegetative growth hence a slight rate of this growth. Fahruroz (2000) has adopted this opinion, too, to explain negative values of this parameter for plants of muskmelon. On sand, harvest was begun with plants grafted on TZ148 83 days after transplantation. Four days after, fruits of plants grafted on Ferro had been harvested and after a week, ripening of fruits of non-grafted plants was started. On compost, plants grafted on TZ148 were the first category of plants that produced fruits 86 days after transplantation. One and two days after this date became the ripening of fruits respectively for plants grafted on Ferro and non-grafted one. Grafting increased the average number of fruits per plant (Table 6). This improvement was similar for two rootstocks but it was more prominent on compost than on sand. The maximum number of fruits per plant was 6.42 on compost against 5.66 on sand. Wheaton et al. (1995) indicated this effect for lemon trees and almonds. The higher effect of grafting regarding to non grafted plants was observed, too, with the average weight of fruits that reached a maximum of 0.71 and 0.90kg with TZ148 on sand and compost, respectively (Table 6). Zhusheng et al. (2000) have also noticed this increase for orange. This effect was inferred by more proportion of fruits with high weight (Fig. 3). Indeed, 62.17 and 82.36% of fruits produced by plants grafted on TZ148 respectively on sand and compost had a weight more than 600g (Class C2, C3). For plants grafted on Ferro, this rate was about 53.66 and 53.85%, respectively on sand and compost.

Table 5. Effect of grafting on growth indices

<table>
<thead>
<tr>
<th>Substrate/parameter</th>
<th>Date</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>49</td>
<td>64</td>
</tr>
<tr>
<td>LAI (cm²/m²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>NG 6.18a</td>
<td>4.12a</td>
</tr>
<tr>
<td>TZ148</td>
<td>6.20a</td>
<td>4.44a</td>
</tr>
<tr>
<td>Ferro</td>
<td>6.05a</td>
<td>4.19a</td>
</tr>
<tr>
<td>Compost</td>
<td>NG 4.97c</td>
<td>4.93b</td>
</tr>
<tr>
<td>TZ148</td>
<td>7.17a</td>
<td>6.14a</td>
</tr>
<tr>
<td>Ferro</td>
<td>5.85b</td>
<td>4.75b</td>
</tr>
<tr>
<td>SLA (cm²/g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>NG 195.39a</td>
<td>254.19a</td>
</tr>
<tr>
<td>TZ148</td>
<td>177.23b</td>
<td>193.46c</td>
</tr>
<tr>
<td>Ferro</td>
<td>181.52b</td>
<td>215b</td>
</tr>
<tr>
<td>Compost</td>
<td>NG 219.62a</td>
<td>246.75a</td>
</tr>
<tr>
<td>TZ148</td>
<td>180.10c</td>
<td>210.74b</td>
</tr>
<tr>
<td>Ferro</td>
<td>198.83b</td>
<td>218.73b</td>
</tr>
<tr>
<td>RGR (mg/g/day)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>NG 45.50a</td>
<td>32.47a</td>
</tr>
<tr>
<td>TZ148</td>
<td>44.52a</td>
<td>32.31a</td>
</tr>
<tr>
<td>Ferro</td>
<td>45.11a</td>
<td>31.17a</td>
</tr>
<tr>
<td>Compost</td>
<td>NG 42.42a</td>
<td>32.11a</td>
</tr>
<tr>
<td>TZ148</td>
<td>40.00a</td>
<td>30.00a</td>
</tr>
<tr>
<td>Ferro</td>
<td>- - -</td>
<td></td>
</tr>
<tr>
<td>NAR (mg/cm²/day)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>NG -6.90c</td>
<td>-3.60c</td>
</tr>
<tr>
<td>TZ148</td>
<td>1.77b</td>
<td>1.34b</td>
</tr>
<tr>
<td>Ferro</td>
<td>5.80a</td>
<td>4.30a</td>
</tr>
<tr>
<td>Compost</td>
<td>NG -4.13b</td>
<td>-3.14b</td>
</tr>
<tr>
<td>TZ148</td>
<td>7.60a</td>
<td>5.70a</td>
</tr>
<tr>
<td>Ferro</td>
<td>-2.60b</td>
<td>-1.60a</td>
</tr>
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</table>

Values followed by the same letters within each line for each substrate are not significantly different according to test of Tukey at P < 0.05.

Table 6. Effect of grafting on production

<table>
<thead>
<tr>
<th>Media</th>
<th>NG 5.32a</th>
<th>TZ148 5.44a</th>
<th>Ferro 5.66a</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average number of fruits (fruits/plant)</td>
<td></td>
<td></td>
<td></td>
<td>NS</td>
</tr>
<tr>
<td>Sand</td>
<td>5.28b</td>
<td>5.71ab</td>
<td>6.42a</td>
<td>*</td>
</tr>
<tr>
<td>Compost</td>
<td>0.5b</td>
<td>0.71a</td>
<td>0.66a</td>
<td>*</td>
</tr>
<tr>
<td>Average weight of fruits (kg/plant)</td>
<td></td>
<td></td>
<td></td>
<td>**</td>
</tr>
<tr>
<td>Sand</td>
<td>0.45b</td>
<td>0.90a</td>
<td>0.64ab</td>
<td>**</td>
</tr>
</tbody>
</table>

Values followed by the same letters within each line are not significantly different according to test of Tukey at P < 0.05.

Consequent to these improvements, total production was clearly benefited by grafting (Fig. 4). On two substrates, this increment was more prominent for TZ148. Thus, on sand, plants grafted on this rootstock exhibited a superiority of 30.56 and 2.07%, respectively in relation to non grafted ones and those grafted on Ferro. On compost, this superiority was around 53.13 and 14%, respectively. This enhancement confirms the previous findings for muskmelon (Edelstein et al., 1999; Jebari and Aounallah-Chouka, 1999; Cohen, 2006), tomatoes (Están et al., 2005), lemon (Wheaton et al., 1995; Al-Jaleel et al., 2005) and mandarin (Currie et al., 2000; Georgiou, 2000).

This study showed that grafting of muskmelon has positive effects on the performance by improving vegetative growth due to vigorous roots that favoured considerable uptake of water.
and nutrients and rate of growth deduced, especially, from high values of RGR and NAR. Consequently, production was earlier and higher. These effects are dependent on choice of suitable rootstocks and condition of crop growth.

In Tunisia, where mostly cultivation under heated greenhouses is still conducted in soils, grafting seems to be a useful practice especially when media are saline and infested by many pathogens. Therefore, soilless culture shows a promise for production in greenhouses.

References


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