Journal of Applied Horticulture, 12(2): 129-134, July-December, 2010

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 mushata*), 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-off-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; Estàn *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

Table 1. Characteristics of local sand

Parameters	Value
Gravel (%)	2.7
Rough Sand (%)	46.3
Fine Sand (%)	48.3
Silt and Clay (%)	2.7
pH	8.2
EC (mS/cm)	2.5
Rate of retention of water (%)	26.0

Table 2. Characteristics of local compost

C/N (%)	Organic matter (%)	Total porosity (%)	pH	EC (mS /cm)	Rate of retention of water (%)
27.1	60	62.2	7.64	4.1	31

water (60°C) in corrugated polypropylene pipes (Ø 25) placed on the plastic between plant rows. The control of daily temperature was done by lateral aeration.

Plants were irrigated 4-5 times daily, depending on the size of the plant and the climatic conditions, by a drip irrigation system with one dripper per plant. To avoid salt accumulation in the substrate, plants were over watered once a week with geothermic waters without nutrients.

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. Measurents 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 (Ouled Djeh *et al.*, 2006). Dry matter was obtained after drying the samples in an oven at a uniform temperature of 70ºC until a constant weight was obtained.

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):

Leaf Area Index (LAI), which is the leaf area per surface area unit was calculated using the following formula:

LAI = Leaf area per plant x Number of plants/ m^2; expressed in cm^2/m^2

Specific Leaf Area (SLA), an indication of the thickness of leaf per unit of leaf area, was determined by the equation:

SLA = Leaf area per plant/ Leaf weight per plant; in $cm^2\,g^{-1}$ (dry weight)

Relative Rate of Growth (RGR), which reflects the ability of plant to produce a new dry matter in a specific period of time was calculated as following:

RGR = d_W/W x 1/dt ; in mg g^{-1} day^{-1}

W = dry weight of sample dt= d2 - d1 is the interval of time between samples of measure

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 = (W2-W1) (LA2- LA1) x ln(LA2)-ln(LA1))/(d2-d1), ($g^{-1}m^{-2}day^{-1}$)

W2 and W1 = dry weight of sample; ln is the natural logaritm.

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): C_1: weight inferior to 600 g; C_2: weight ranging between 600 and 900 g; C_3: 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.

Furthermore, stem diameter increased as a result of this grafting

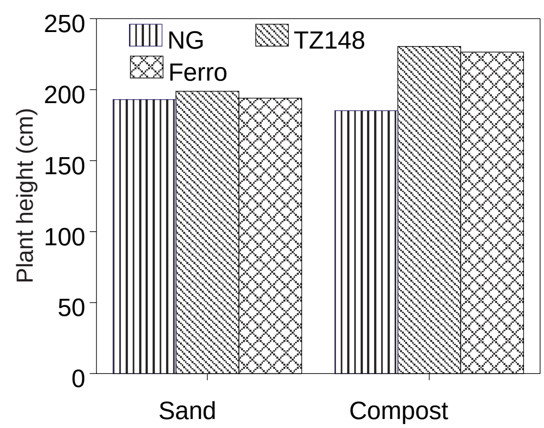

Fig. 1. Effect of grafting on plant height (cm)

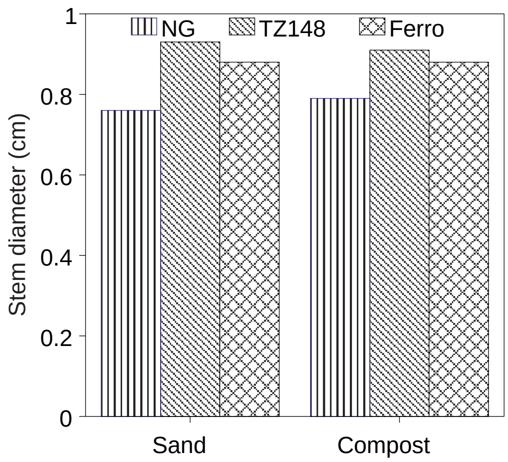

Fig. 2. Effect of grafting on diameter of the stem (cm).

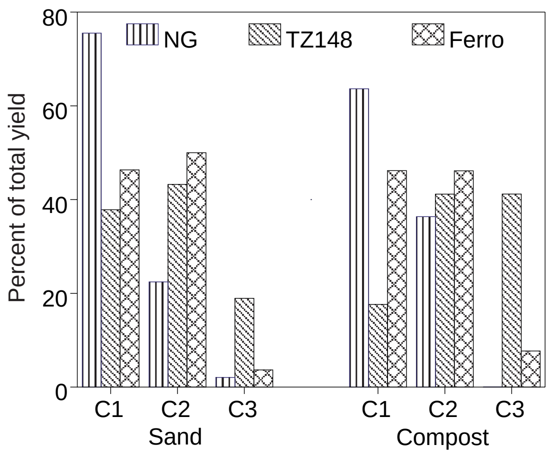

Fig. 3. Effect of grafting on grades of fruits.

technique (Fig. 2). For TZ148, this increment was around 18.27 and 13%, respectively on sand and compost. Ferro has enhanced this parameter by 13.63 and 10.22%, respectively on sand and compost. This observation confirms the findings of Lee (1994) and Ioannou *et al.* (2002) who have emphasized a tendency of grafted plants to attain a larger stem diameter.

It was observed that in both substrates grafting increased fresh weight of leaves. On sand, this effect was similar for the two rootstocks and was around 6.92%. On compost, this effect was more pronounced with TZ148 than Ferro. From the data presented in Table 4, it is seen that leaves of grafted plants, especially those grafted on TZ148, had a higher accumulation of dry matter than those of non-grafted ones. These finding corroborated with the reports on the effect of grafting on tomatoes by Khah *et al.* (2006).

Leaf area values, presented in Table 4, revealed that grafting induced production of larger leaves. However, this effect was not significant on sand. On compost, the increase was recorded for plants grafted on TZ148. Pulgar *et al.* (1998) attributed this

Table 3. Effect of grafting on growth of roots

	NG	TZ148	Ferro	Significance
	Average length of the principal root (cm)			
Sand	24.33a	36a	38a	NS
Compost	29.66a	41a	43.16a	NS
	Average volume of roots (mL)			
Sand	41b	93.33a	100a	***
Compost	59b	94a	96.66a	***

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.

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

Table 4. Effect of grafting on growth of leaves

Parameter	Sand				Compost			
	NG	TZ148	Ferro	Significance	NG	TZ148	Ferro	Significance
Fresh weight (g)	1.68b	1.80a	1.81a	*	1.75b	2.16a	1.76b	**
Dry weight (g)	0.27b	0.29a	0.28b	*	0.28b	0.34a	0.26b	**
Leaf area (cm^2)	53.07a	55.1a	53.58a	NS	55.51b	65.98a	54.37b	**

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.
Levels of significance are represented by *P < 0.05, **P < 0.01, ***P < 0.001, and NS, not significant.

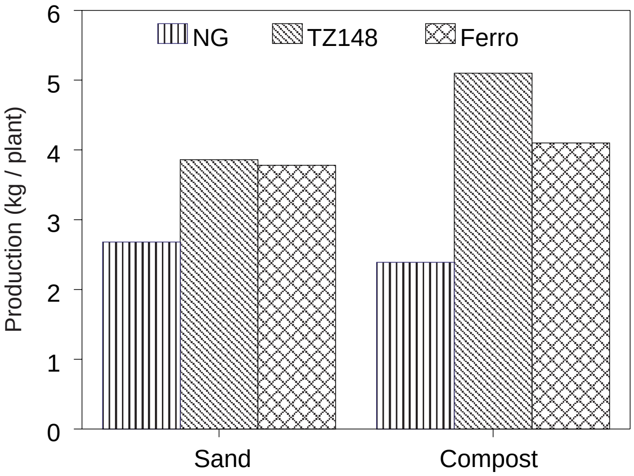

Fig. 4. Effect of grafting on total production (kg plant^{-1})

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. Fahrurrozi (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 have assigned it to their more height.

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

Substrate/ parameter		Date 49	64	79
LAI (cm^2/m^2)				
Sand	NG	6.18a	4.12a	2.63a
	TZ148	6.20a	4.44a	3.38a
	Ferro	6.05a	4.19a	3.23a
Compost	NG	4.97c	4.93b	3.97a
	TZ148	7.17a	6.14a	3.17a
	Ferro	5.85b	4.75 b	3.00a
SLA (cm^2/g)				
	NG	195.39a	254.19a	143.54c
Sand	TZ148	177.23b	193.46c	202.85a
	Ferro	181.52b	215b	185.0b
	NG	219.62a	246.75a	158.9c
Compost	TZ148	180.10c	210.74b	190.65a
	Ferro	198.83b	218.73b	180.2b
RGR (mg/g/day)				
	NG	45.50a	32.47a	26.10a
Sand	TZ148	44.52a	32.31a	26.70a
	Ferro	45.11a	31.17a	26.14a
	NG	42.42a	32.11a	23.56a
Compost	TZ148	40.00a	30.00a	25.00a
	Ferro	-	-	-
NAR (mg/cm^2/day)				
	NG	-6.90c	-3.60c	-3.10b
Sand	TZ148	1.77b	1.34b	1.01a
	Ferro	5.80a	4.30a	3.40a
	NG	-4.13b	-3.14b	-2.53b
Compost	TZ148	7.60a	5.70a	4.60a
	Ferro	-2.60b	-1.60a	-1.20a

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

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

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.

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 (Estàn *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.

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Received: December, 2009; Revised: June, 2010; Accepted: October, 2010