# Effects of Citrus Rootstocks on Fruit Yield and Quality of 'Nadorcott' Mandarin

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## Abstract

The effects of citrus rootstocks on the performance and fruits characteristics of commercial varieties are known and well documented. These effects, as well as the resistance to biotic and abiotic stresses, constitute the main criteria that direct the rootstock choice for a new citrus orchard. The Moroccan variety 'Nadorcott' mandarin also called 'W. Murcott' and 'Afourer' is relatively new. 'Nadorcott' is a popular late mandarin cultivar, owing to its good eating quality and excellent bearing capacity. Thus, there are few undertaken research and available results related to its behavior on the widely used rootstocks in the main citrus growing areas of Morocco Kingdom. This paper presents the results of a field trial carried out in the North West Morocco, a coastal area, to evaluate the effects of five rootstocks on 'Nadorcott' yield and fruit quality: juice content, total soluble solids (TSS), acid content (A), maturity index expressed as TSS/A ratio and Citrus Color Index (CCI). The results show that the highest yields were observed on citrange C-35 and C*itrus macrophylla* (MAC) over the three seasons. Additionally, percentage of juice content over two successive years of fruits produced on C-35, Troyer citrange (CT), Carrizo citrange (CC) and Swingle citrumelo (SW) was about 53 % but did not exceed 50 % for C*itrus macrophylla*. The highest TSS was obtained on CC rootstock. However, the TSS was less than 10 in 2013 and around 11 °Brix in 2014 for *Citrus macrophylla* and above 12 °Brix for the other rootstocks. Regarding the maturity index, apart from the low value (11.3) scored by MAC, in 2013 due to a low TSS, there was no significant difference between the maturity indices of the fruits of the mandarin 'Nadorcott' produced on the different rootstocks tested. Furthermore, the five rootstocks had no effect on the fruit color parameters of 'Nadorcott' mandarin.

**Keywords:** citrus, Nadorcott, rootstock, yield, quality.

# Effets du porte-greffe sur le rendement et la qualité des fruits de la mandarine «Nadorcott»

## Résumé

Les effets des porte-greffes d'agrumes sur les performances et les caractéristiques des fruits des variétés commerciales sont connus et bien documentés. Ces effets, ainsi que la résistance aux stress biotiques et abiotiques, constituent les principaux critères qui orientent le choix d'un porte-greffe pour la mise en place d'un nouveau verger d'agrumes. La variété marocaine de mandarine «Nadorcott» également appelée «W. Murcott » ou « Afourer » un mandarinier tardif populaire, en raison de sa bonne qualité gustative et de son excellente capacité productive. Peu de recherche ont été entreprises et peu de résultats sont disponibles sur son comportement en association avec les porte-greffes largement utilisés dans les principales zones de production d'agrumes au Maroc. Cet article, présente les résultats d'un essai porte-greffe installé dans le nord-ouest du Maroc, une zone côtière, dans le but d'évaluer les effets de cinq porte-greffes sur le rendement de la 'Nadorcott' et sur la qualité des fruits notamment la teneur en jus, les sucres solubles totaux (TSS), l'acidité (A), l'indice de maturité exprimé par le rapport (TSS/A) et sur la coloration de l'écorce exprimée par Citrus Color Index (CCI). Les résultats obtenus montrent que les rendements les plus élevés, au cours des trois saisons, ont été réalisés par le citrange C-35 et le *Citrus macrophylla* (MAC). En outre, le pourcentage de teneur en jus, sur deux années consécutives, des fruits produits avec le C-35, le citrange 'Troyer' (CT), le citrange 'Carrizo' (CC) et le citrumelo 'Swingle' (SW) était d'environ 53% mais il ne dépassait pas 50 % pour le *Citrus macrophylla*. Le TSS le plus élevé a été obtenu avec le porte-greffe CC. Cependant, le TSS était inférieur à 10 en 2013 et autour de 11 °Brix en 2014 pour le Citrus macrophylla et il était supérieur à 12 °Brix pour les autres porte-greffes. Concernant l'indice de maturité, hormis la valeur de (11,3) notée par MAC, en 2013 en raison d'un TSS faible, il n'y avait pas de différence significative entre les indices de maturité des fruits du mandarin 'Nadorcott' produits sur les différents porte-greffes testés. De plus, les cinq porte-greffes n'ont eu aucun effet sur les paramètres de couleur des fruits du mandarinier 'Nadorcott'.

**Mots clés:** agrumes, Nadorcott, porte-greffe, rendement, qualité.

# تأثير حوامل طعم الحمضيات على الإنتاجية وعلى جودة فاكهة ماندرين'نادوركوت'

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**ملخص**

إن تأثيرات حوامل طعم الحمضيات على أداء وخصائص ثمار الأصناف التجارية معروفة وموثقة جيدًا. هذه التأثيرات، بالإضافة إلى مقاومة الضغوط الحيوية وغير الحيوية، تشكل المعايير الرئيسية التي توجه اختيار حامل الطعم لبستان حمضيات جديد. يُطلق على الصنف المغربي الجديد نسبيًا 'نادوركوت' ايضا اسم 'Afourer' أو'M. Murcott'. 'نادوركوت' هو أحد أصناف الماندرين المتأخرة، له جودة وقدرة إنتاجية عالية. هناك عدد قليل من الأبحاث التي تم إجراؤها على سلوك النادوركوت مع حوامل الطعم المستخدمة في مناطق زراعة الحمضيات الرئيسية في المملكة المغربية. في هذا البحث نقدم، نتائج تجربة أجريت في شمال غرب المغرب، وهي منطقة ساحلية، لتقييم آثار خمسة حوامل طعم على محصول 'نادوركوت' وجودة الفاكهة: محتوى العصير، المحتوى الحمضي (A)، السكر (TSS)، مؤشر النضج المعبر عنه بنسبة **(**TSS/A**)** ومؤشر لون الحمضيات (CCI). أظهرت النتائج أن أعلى إنتاجية قد لوحظت على C*itrus macrophylla* و C-35 citrange خلال الفصول الثلاثة. بالإضافة إلى ذلك، كانت النسبة المئوية لمحتوى العصير على مدى سنتين متتاليتين من الفاكهة المنتجة على C-35, CT, CC و Swingle حوالي 53٪ ولكنها لم تتجاوز 50٪ بالنسبة ل C*itrus Macrophylla*. تم الحصول على أعلى نسبة TSS في CC. ومع ذلك، كانت نسبة السكر أقل من 10 في 2013 وحوالي 11 درجة بريكس في 2014 في *Macrophylla Citrus* وأكثر من 12 درجة بريكس عند حوامل الطعم الأخرى. فيما يتعلق بمؤشر النضج، بصرف النظر عن القيمة المنخفضة (11.3) التي سجلتها C*itrus Macrophylla*، في 2013 و بسبب انخفاض نسبة السكر، لم يكن هناك فرق كبير بين مؤشرات نضج ثمار ماندرين 'نادوركوت'على حوامل طعم مختلفة. علاوة على ذلك، لم يكن لحوامل الطعم الخمسة أي تأثير على لون الفاكهة (CCI) لثمار ماندرين 'نادوركوت'.

**الكلمات المفتاحية:** الحمضيات، نادوركوت، حامل الطعم، المحصول، الجودة.

## Introduction

Citrus grower's income depends mainly on the yield and quality of the fruit. Their ability to achieve high profits, is however, largely a matter of the orchard management system and the right choices made at the start of the orchard site and the rootstock. Indeed, rootstocks are very important for adaptability to pedo-climatic conditions as well as for tolerance to major biotic and abiotic stresses. In addition to their effect on the earliness and the quality of the fruits (Castle, 1995).

In Morocco, as is the case in many citrus-growing countries, the use of sour orange as a rootstock rapidly declined due to the threat of tristeza virus. Researchers and citrus growers have mobilized their efforts to find alternative rootstocks.

The mandarin variety 'Nadorcott' (*Citrus reticulata* Blanco), also known under the names 'Afourer' in Morocco and the European Union, 'W. Murcott' and 'Delite' in the United States of America, is a Moroccan hybrid selection of 'Murcott' and an unknown pollinator parent (Nadori, 1998, 2004). It is reported as self-incompatible and produces seedless fruit in the absence of cross-pollination (Bono and *al*., 2000; Chao, 2005).The flesh of fruit is very juicy and sweet, with high sugar content and good acidity level. Fruit reaches commercial maturity in mid to late February (Agusti, 2014). Being a new variety of a great commercial prospect, few studies have been reported about its behavior on different rootstocks.

The objective of this study is to evaluate the effect of five rootstocks on 'Nadorcott' trees productivity and on fruit quality.

## Materials and Methods

### Field trial and plant material

In this field trial, Nadorcott' mandarin was budded onto the following five rootstocks (treatments): 'Troyer' citrange [(*Citrus sinensis* (L.) Osbeck × *Ponicrus trifoliate* (L.) Raf. ] (CT), 'Carrizo' citrange [(*Citrus sinensis* (L.) Osbeck × *Ponicrus trifoliate* (L.) Raf. ] (CC), 'Swingle' citrumelo [*P. trifoliata* (L.) Raf. × *Citrus paradisi* Macfad.)] (SW), C-35 citrange (C35) and *Citrus macrophylla* (M). This experimental grove was planted in June 2008 at Caidat of Bahhara Oulad Ayad, province of Kenitra, Gharb region. In SEBNAK farm located 2 km from Atlantic coast, in North-West of the Morocco kingdom (Latitude: 34°46'41.5''N, Longitude: 6° 19'59.5''W).

The weather in the farm zone is quite humid compared to the other Moroccan citrus areas: year rainfall varies strongly (400 to 800 mm), high temperatures in summer, moderate sunlight during late autumn and winter with low temperatures that can drop to -5 °C in December, January or February. In this period, fog, mist and dew are frequent and reduce harvest time to few hours per day.

The land is waving and the soil is well drained. Its texture is sandy to loamy in the 0-30 cm horizon layer and loamy with porous rocks and red clay in lower strata. There is no lime and *pH* is neutral (7 to 7.5).

Drip irrigation is realized by pumped underground water, which is of good quality. Adopted spacing for planting is 6 m x 2 m. (HCP, 3013).

### Yield and Fruit quality measurements

Fruits were harvested and weighed per tree during the harvest seasons of the years 2013 to 2015.

Monitored quality parameters are:

- ✓ Juice content: as ratio (%) of the weight of the fruit juice and that of fresh fruit. The juice is extracted by pressing 20 fruits in an electric press juice on a rotating rotor.

- ✓ Titratable acidity (TA): citric acid quantity per 100 g of juice as determined by proportioning a sodium hydroxide solution 0.1N with endpoint *pH* 8.1. Phenolphthalein (1%) was used as a color indicator (AOAC, 2011).

- ✓ Total soluble solids (TSS) as sugars or °Brix determined using a digital hand-held refractometer.

## Fruit color measurements

Fruit skin color was randomly measured on two opposite sites at fruit equator usinga Konica Minolta CR-400 Chroma Meter (Minolta CR-400, Japan). The Hunter Lab parameters (L, a and b) were used to calculate the corresponding Citrus Color Index (CCI) using the following equation: CCI = (1000 * a) / L * b; where 'L' represents the relative lightness of color with 'a' range from 0 (darkness) to 100 (brightness). Both 'a' and 'b' scales are varying from -60 to 60. 'a' value represents greenish and redness as the value increase from negative to positive, while 'b' is negative for blueness and positive for yellowness.

## Statistical analysis

The trial was installed according to a complete randomized block design with five replicates and five trees per plot. Data were collected and analyzed using SAS system and the means compared by T test (LSD) at the ≤ 0.05 % level of probability.

## Results and discussion

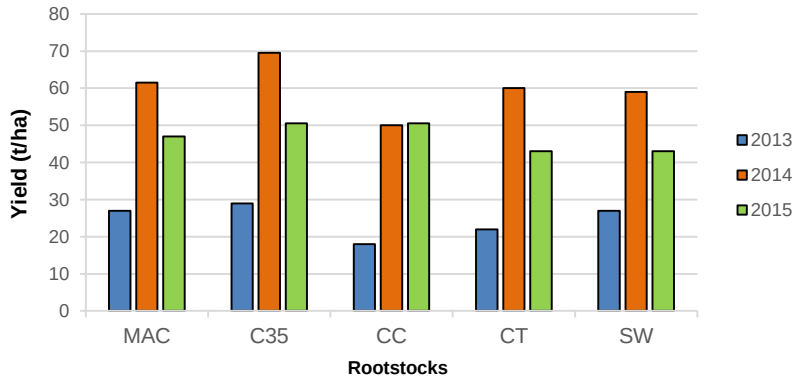
### Fruit yield

The results of the effects of different rootstocks on fruit yield of 'Nadorcott' mandarin are shown in Fig.1. The highest cumulative yields of 'Nadorcott' mandarin, during the three considered seasons, were obtained from the trees on C-35 citrange and on Macrophylla with cumulative yields of around 154 and 142 t/ha respectively. The trees on Carrizo citrange had the lowest cumulative yield (124 t/h). The trees on Troyer citrange and Swingle citrumelo produced similar yield and did not show any significant difference. In general, vigorous rootstocks like Macrophylla would induce high fruit yield (Al-Jaleel and Zekri, 2003). Similarly, in Brazil significant effects of rootstocks on fruit yield of Satsuma mandarin were also detected (Cantuarias-Avilés and *al*., 2010).

We note that for the five rootstocks, there is inter-annual variability in productivity (Fig. 1). This alternate bearing phenomena was reported by other researchers (Stander and *al*., 2017; Stander and Cronjè, 2016). The alternating yields of 'Nadorcott' mandarin can be explained by the fact that 'Nadorcott' is a late maturing mandarin cultivar that developed from a seedling of the strongly alternate-bearing 'Murcott' mandarin (Nadori, 2006) and can be prone to alternate bearing under certain hormonal or/and nutritional conditions (Stander and *al*., 2017; Stander and Cronjè, 2016).

The hormonal theory of alternate bearing suggests that phytohormones are responsible for floral inhibition during an ''on'' year (Martínez-Alcàntara and *al*., 2015; Muñoz-Fambuena and *al*., 2011; Verreynne and Lovatt, 2009). The nutritional theory of alternate bearing, on the other hand, suggests that flowering response is determined by fruit load and availability of carbohydrates (Monerri and *al*., 2011; Dovis and *al*., 2014; Martínez-Alcàntara and *al*., 2015).

**Fig.1: Average yield of "Nadorcott" mandarin grafted onto different rootstocks**




**MAC: Citrus macrophylla C35: C-35 citrange CC: Carrizo citrange CT: Troyer citrange SW: Swingle citrumelo**

Yield difference among rootstocks and their interactions with different citrus cultivars could be attributed to differences in morphology and physiology of rootstocks, which are reflected as tree growth vigour, size and depth of roots, water and nutrients

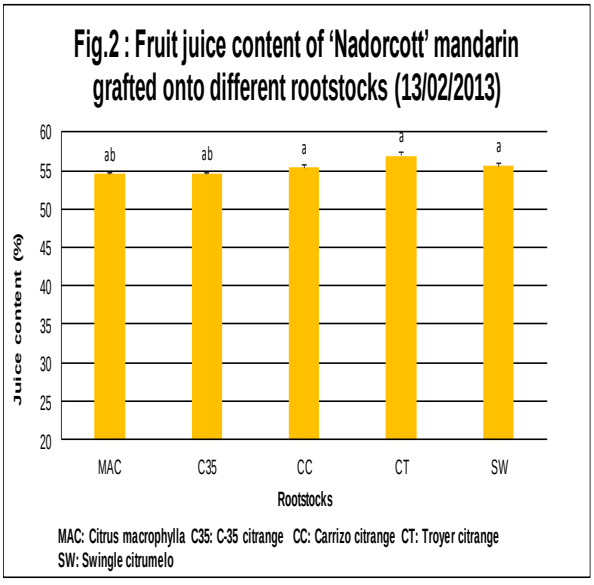
uptake capability, carbohydrate synthesis, and also their adaptation to climatic and soil conditions, good compatibility between rootstock and cultivar and the possibility of fruiting potential of a cultivar on certain rootstocks (Continella and *al*., 1998; Zekri and Parsons, 1989; Castle, 2010a).
In Morocco, at El Menzeh experimental station, a behavioral study of three clementine clones 'Sidi Aissa', 'Ain Taoujdate' and 'Cadoux' on six common rootstocks, showed a graft incompatibility between these clones and trifoliate orange, and Marrakech citrange in other part. Production and development of trees were poor on both rootstocks. On the other four rootstocks, the clementine selections 'Sidi Aissa' and 'Ain Taoujdate' proved to be significantly more productive than 'Cadoux' which was the most multiplied in Morocco after the 1960 (Nadori and *al*., 1983a).

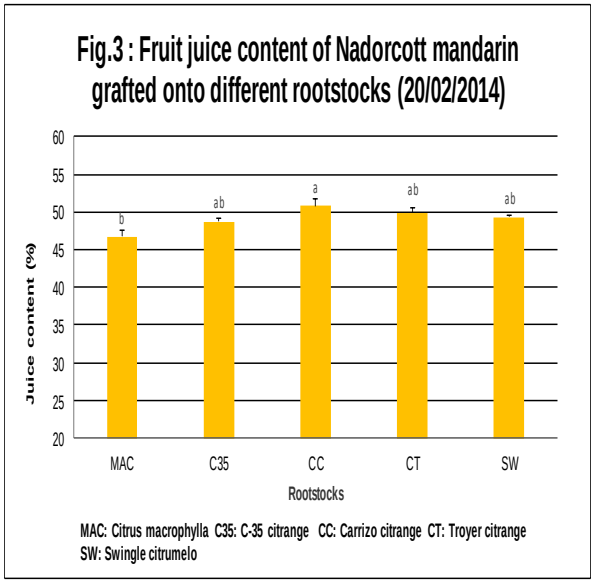
In three rootstocks trials, Nadori and *al*. (1983b) showed significant effects of these rootstocks on the productivity and quality of the fruits of the 'Valencia late' orange, 'Shambar' grapefruit and clementine over a period of ten years. The '*Rangpur*' and *'Rough lemon'* gave the highest yields of fruit but with low quality, followed by the '*Troyer citrange'* which gave the best internal quality. The mandarin 'Cleopatra' and 'Sour orange' have resulted in average yields and good quality fruit. The results were obtained on sandy, non-calcareous soil at neutral *pH.*

**Juice content**

With regard to the juice content, the CC, CT, SW and C-35 rootstocks ensured a high percentage of juice, contrariwise MAC recorded a slightly lower rate (Fig. 2 and 3). However, fast and important decrease of fruit quality, mainly percentage of juice and acidity, were observed during cold storage on fruit harvested from trees on Macrophylla. These fruits can't be marketed forty days after harvest even under cold storage (El Guilli and *al*., 2016).

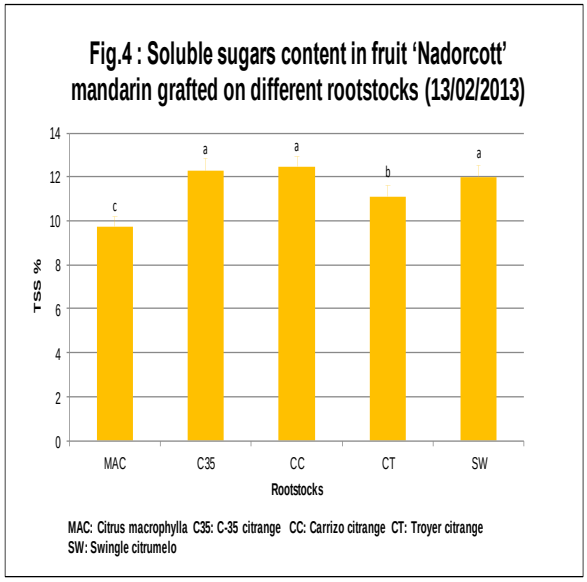
Castle and *al*. (1993) reported that trees on Macrophylla in rootstock trials have consistently produced fruit with the lowest juice quality. For all rootstocks, the fruit juice content meets the standards for export of the fruits of Moroccan mandarin that must be at least 40 %.

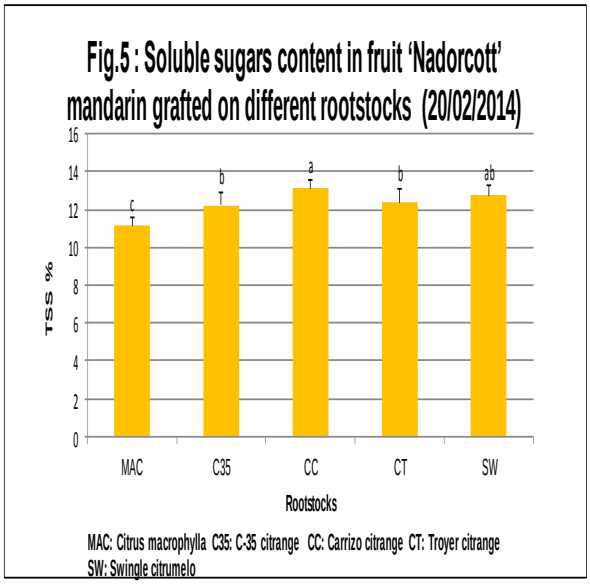


## Total soluble solids

The fruits produced on the *Citrus macrophylla* gave a low TSS with statistically significant difference at p ≤ 0.05 % compared to those obtained on the other rootstocks. Poncirus and its hybrids are known to favor high quality of mandarin and orange production, while *C. macrophylla* is very productive but reduces fruit quality (Abouzar and Nafiseh, 2016).

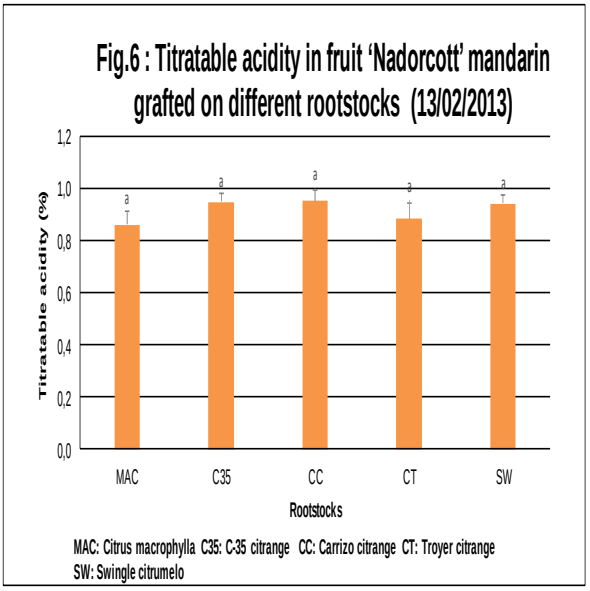


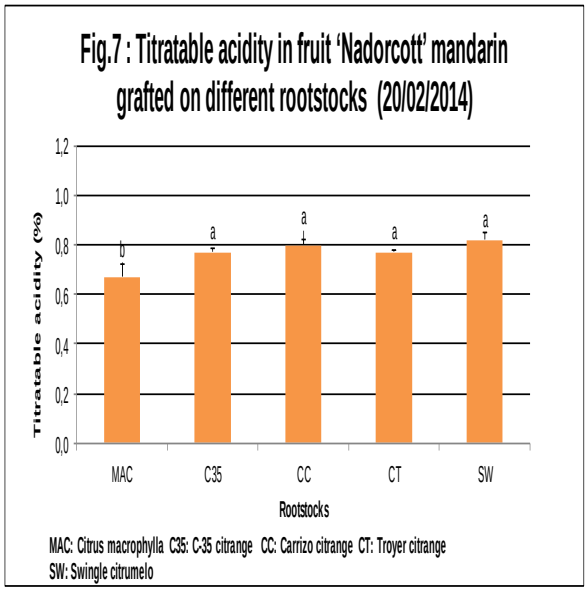




In the trial carried out by Tazima and *al.* (2013) to assess the performance of 'Okitsu' Satsuma mandarin grafted onto nine rootstocks in the northern region of the Paraná State, Brazil, in terms of plant growth, plant yield and fruit characteristics, the highest values for TSS were observed for fruits from trees on the trifoliate orange, 'Volkamer' lemon, and 'Carrizo' citrange rootstocks.

## Acid content

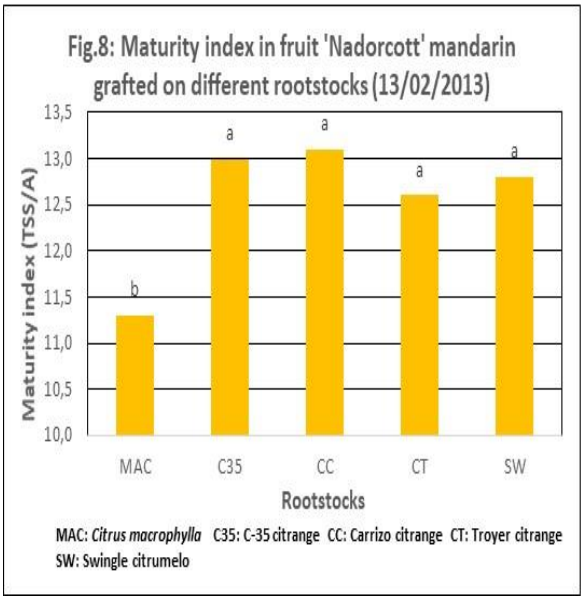
Fruit produced on the *Citrus macrophylla* have low acidity compared to other rootstocks; this decrease in acidity was well marked in 2014. The lack of clear effect of rootstock on acid content of citrus is a common phenomenon recorded in similar studies (Al-Jaleel and Zekri, 2003).

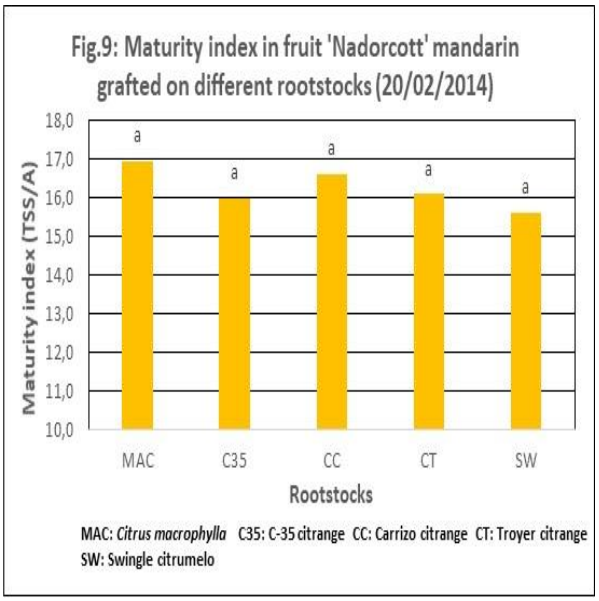



## Maturity index

The fruits produced on the five rootstocks meet the standards of CEE-ONU FFV-14 adopted by the Autonomous Control, Marketing and Export Establishment (EACCE) of Morocco who requiring a maturity index (TSS / A ratio) equal to or greater than 7.5 (Fig. 8 and Fig. 9).




Within the 2013 season, *Citrus macrophylla* induced the lowest maturity index (11.3), while CC and C35 gave the highest indices which correspond successively to 13.1 and 13. In the other hand CT and SW induced to 'Nadorcott' mandarin intermediate indices, successively of 12.6 and 12.8. The low maturity index noted on MAC is due to the low TSS, following a low TSS / A ratio.

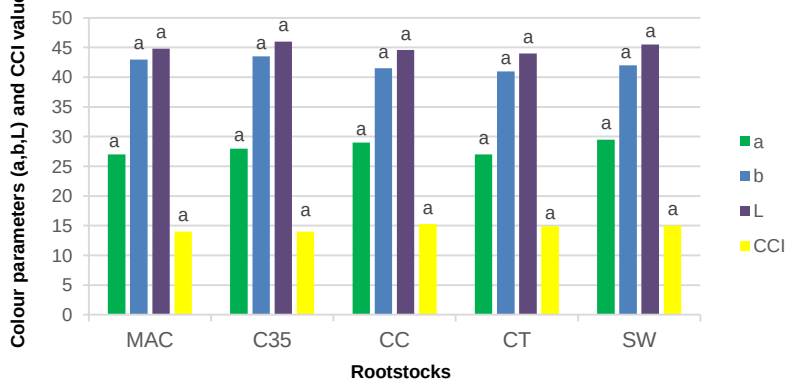
In contrast, in 2014 the fruits harvested on MAC scored the highest maturity index (16.95) although remains statistically not significant compared to the other values recorded by the other rootstocks (Fig. 9).
It is reported that the rootstock affects many characters related to fruit quality. Among these characters: juice content, skin color, soluble solids, acid concentrations and their ratio (Castle, 2010b)

Larger fruit with thicker, rougher peel and lower concentrations of TSS and acid in the juice are generally associated with cultivars budded on fast-growing, vigorous rootstocks such as rough lemon, Volkamer lemon, Citrus macrophylla and Rangpur. However, these rootstocks impart high vigor to the scion and induce high yield. Cultivars on slower growing rootstocks like citranges and citrumelos produce fruit with smooth peel texture and good quality fruit with high TSS and acid content in the juice (Zekri, 2011).

## Fruit color

No significant differences were observed between rootstocks on fruit color parameters (Fig. 10). In addition of rootstock, fruit coloration is governed by several factors such as fruit maturity, tree nutrition, cultivation practices, water availability, and temperature. Fruit color also depends on climatic conditions and groundcover in the orchard (Ladanyia, 2010). In addition, Demirkeser and *al.* (2009) reported that the rootstocks did not affect the skin structure, rind color or ease of peeling for 'Nova' mandarin.

**Fig.10: Effect of rootstocks on fruit color of "Nadorcott" mandarin (2015)**




**MAC: Citrus macrophylla C35: C-35 citrange CC: Carrizo citrange CT: Troyer citrange SW: Swingle citrumelo**

Coloration of typical mature fruit should be present in at least one third of the fruit surface for all mandarins commercialized (European norms and directions about citrus fruit quality standards adopted by EACCE of Morocco).

The Citrus Color Index (CCI) is calculated by the formula proposed by Jimenez-Cuesta et *al*. (1982) below:

**CCI = 1000 X a / L x b**

Citrus Color Index interpretation scale (Jimenez-Cuesta et *al*. 1982)
For a CCI <-15: dark green color
For a -15 < CCI <-7: dark green to yellowish color
For a -7 < CCI <0: yellowish to yellowish green color
For a 0 < CCI <7: yellowish to orange color
For a 7 < CCI <15: dark orange color
For a 15 < CCI: dark orange to pinkish red color.
The obtained results (Fig. 10) show that the CCI of the fruits of Nadorcott exceeds 14 and therefore according to the key of Jimenez-Cuesta and *al*. (1982), they have a dark orange to pinkish red coloration.

## Conclusion

The results of this study show that the rootstocks exert an effect on the yield and quality of the mandarin fruits 'Nadorcott'. Trees on citrange C-35 and C*itrus macrophylla* produced the highest yields with respective cumulative yields of the last three seasons around 154 and 142 t/ha but the fruits produced on Macrophylla have a poor organoleptic quality (According to juice content, brix and acidity) compared to those produced on other rootstocks. In fact, the average percentage of juice over two successive years of fruits produced on C-35, CT, CC and Swingle is about 53 % whereas that of Macrophylla does not exceed 50 %. Similarly, the TSS of fruit produced on this rootstock was lower (< 10 in 2013 and around 11 °Brix in 2014) compared with those of other rootstocks (above 12 °Brix). CC induced on fruit of ‘Nadorcott’ the highest TSS with values of 12.5 and 13.3 successively in 2013 and 2014.

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