Effect of nitrogen level application on yield and fruit quality of Navel orange variety in a sandy soil

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Abstract

The objective of the present paper was to evaluate the effect of nitrogen level on yield and fruit quality of citrus and to determine the optimum N fertilizer rates of Navel orange variety budded on Troyer citrange rootstock in field conditions. The orange Navel orchard spaced 7mx7m (204 trees/ha) grown in 1964 on a sandy soil at the experimental station of El Menzeh, INRA Morocco. The experiment was set up in a complete randomized block design with three blocks and the experimental unit was composed on 4 consecutive trees in the row. Four fertilization treatments of N (Kg/ha) (T_0 (control): 0, T_1: 100, T_2: 200, T_3: 300) were applied to Navel citrus tree in field conditions over two seasons 2012-2013 and 2013-2014.Fruit yield, fruit weight, fruit size, total soluble sugar (TSS) content, acidity of juice and maturity index of Navel orange were significantly affected by increasing N level. Fruit yield/tree was improved significantly with increase in N rate. Significant highest yields (129.21 and 139.82. kg/tree) were recorded under treatments T_2 and T_3 respectively. The lowest fruit yield/tree was obtained from untreated control plot. Maximum fruit weight (268.54 and 276.50 g) and fruit size (78.94 and 80.87 mm) was recorded with the same treatments T_2 and T_3 respectively. Total soluble sugar content was also maximum in trees receiving treatment (T_2) and treatment (T_3) 12.20 and 11.70°Brix respectively. Significant increase in acidity of juice of fruit Navel orange was also recorded by increasing the rate of N. The highest acidity (1.13 and 1.20%) was achieved by the same treatments T_2 and T_3 respectively. Two-year studies showed that application of fertilizers at the rate of 200 Kg N/ha would be optimum for achieving higher yield and better fruit quality of Navel orange variety in sandy soil in Gharb area.

Key words: Morocco, citrus, rootstocks, Nitrogen, yields, fruit quality.

Etude de l'effet de la dose d'azote sur le rendement et la qualité des fruits de la variété Navel sur un sol sableux

Résumé

L'objectif de cet essai est d'évaluer l'effet de la dose d'azote sur le rendement et la qualité des fruits et de déterminer la dose optimale en azote pour les arbres de l'orange Navel greffé sur le porte-greffe citrange Troyer planté en 1964 en plein champ à un espacement de 7mx7m (204 arbres/ha) au niveau de la station expérimentale d'El Menzeh, INRA Maroc. Le dispositif adopté est un bloc aléatoire complet avec trois blocs rangés en 4 arbres consécutifs par bloc sur la même ligne. Quatre doses de N ont été testés : (T0 (Témoin) : 0, T1 : 100, T2 : 200, T3 : 300 Kg N/ha). Les paramètres mesurés sont : le calibre des fruits, le poids moyen par fruit, la qualité des fruits (le rendement en jus, l'acidité du jus, l'extrait sec soluble (ESS ou °Brix) et l'indice de maturité (E/A)) et le rendement en fruits. Le rendement en fruits, le poids moyen des fruits, le calibre des fruits, l'extrait sec soluble (TSS), l'acidité du jus et l'indice de maturité de l'orange Navel ont répondu significativement à l'augmentation de la dose d'azote. Le rendement en kg de fruits/arbre a été considérablement amélioré avec l'augmentation de la dose d'azote. Par ailleurs, les rendements les plus élevés (129.21 et 139.82 kg/arbre) ont été enregistrés sous les traitements T_2 et T_3 respectivement. Par contre, le rendement en fruits/arbre le plus faible a été obtenu chez les arbres non fertilisés (témoin). Le poids des fruits (268.54 et 276.50g) et la taille des fruits (78.94 et 80.87 mm) les plus élevés ont été enregistrés avec les même traitements T_2 et T_3 respectivement. La teneur totale en sucre soluble (TSS) la plus élevée a été enregistrée chez les arbres des traitements T_2 et T_3 (12.20 et 11.70 °Brix respectivement). Par ailleurs, une augmentation significative de l'acidité du jus de fruits de l'orange Navel a été également enregistrée en augmentant la dose d'azote. L'acidité la plus élevée a été obtenue par les mêmes traitements T_2 et T_3 (1,13 et 1.20 % respectivement). L'application de 200 Kg de N /ha a permis d'avoir un rendement maximal et une qualité optimale des fruits des oranges Navel greffés sur le porte-greffe citrange Troyer sur un sol sableux dans la région de Gharb.

Mots clés : Maroc, agrume, porte-greffes, Azote, rendement, qualité des fruits.

دراسة تأثير كمية الأزوت على إنتاج وجودة فاكهة أشجار الحمضيات صنف النافيل في التربة الرملية

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ملخص

أجري هذا البحث الحقلي بغرض دراسة تأثير كمية الازوت على المردود وجودة الثمار وتحديد الكمية المثالية لأشجار البرتقال نافيل (orange Navel) المطعمة على citrange Troyer المزروعة في محطة التجارب المنزه بالمعهد الوطني للبحث الزراعي بالقنيطرة. تم اختبار أربع كميات من الازوت T_0: 0 ، T_1: 100، T_2: 200، T_3: 300 كلغ من الازوت في الهكتار . أثبتت النتائج أن المردود، متوسط وزن الفاكهة، حجم الفاكهة، نسبة السكر في العصير، الحموضة ومؤشر نضج برتقال النافيل استجابت بشكل ملحوظ لزيادة كمية الازوت. علاوة على ذلك، تم تسجيل أعلى مردود (129.21 و 139.82 كجم / شجرة) عند الأشجار التي تلقت T_2 و T_3 على التوالي. في المقابل، تم الحصول على أدنى مردود من الفاكهة في الأشجار غير المسمدة (الشاهد). تم تسجيل أعلى وزن للفاكهة (268.54 و 276.50 جم) وحجم الفاكهة (78.94 و80.87 مم) و نسبة السكر في العصير (12.20 و 11.70 °Brix) باستخدام نفس الكميات T_2 و T_3 على التوالي. أظهرت النتائج أن تطبيق 200 كجم من الازوت في الهكتار مكن من الحصول على مردود عالي وجودة مثالية لفاكهة برتقال النافيل في التربة الرملية في منطقة الغرب.

الكلمات المفتاحية: المغرب، الحوامض، حامل الطعم، المردود، جودة الفاكهة، تأثير الازوت.

Introduction

Citrus are the most widely produced fruit crops in the world. In Morocco, the Citrus sector is one of the main fruit productions and plays an important socio-economic role, with a current area of 125,000 Ha and an average production of around 2 million T/year (Anonymous, 2019). Economically, citrus exports, which hover around an average of 500,000 tons per year, represent an important source of foreign exchange with the equivalent of nearly 3 billion DH per year (Anonymous, 2019). The varietal profile of the national citrus orchard is composed of a diversified range of varieties, but which remains dominated by three groups of varieties, namely, the Clementine group with 35%, Maroc Late with 21% and Navel orange with 18% (Anonymous, 2019). Unfortunately, the citrus productivity in Morocco is low (19 T/ha) as compared to that in other countries such as Spain, Turkey and Egypt (20-34 T/ha) (FAOSTAT, 2019). This situation is occurred because the citrus crop is exposed to several biotic and abiotic stress and poor nutrient status of the soil as well as the use of imbalanced nutrients.

However the citrus yield, could be significantly increased by adopting a balanced nutrient management (Mattos *et al.*, 2003 ; Cantarella *et al.* 2003; Quaggio *et al.*, 2006). The response of fertilization in improving the growth, yield, and quality of different citrus fruits is well referenced (Ezzoubir *et al.*, 1988b; Ghosh, 1990; Kumar *et al.*, 1993; Ram *et al.*, 1997 and Shukla *et al.*, 2000; Ait Houssa *et al.*; 2006).
Nitrogen is a key element that plays various roles in the plants. It is an important component of chlorophyll and it is the main nutrient involved in the synthesis of amino acids (Muñozhuerta *et al.*, 2013, Weinbaum *et al.* 2002). Alva *et al.*, (2008) demonstrated that the application of N fertilizer increases yield and enhances the quality of citrus. Recently, Liao *et al.* (2019) reported that the fruit yield of 'Huangguogan' variety grafted on trifoliate orange (*Poncirus trifoliata*) increased with the increase in N application until the 1.83 kg/tree/Y and then slightly decreased. Increasing rates of N application has significant effect on citrus fruit yield and juice quality (Jones and Embleton, 1959; Mungomery *et al.*, 1978, Lee and Kader 2000 Alcobendas *et al.*, 2013; Habasy Randa, 2017).

High N fertilization reduces total soluble sugar (TSS, °Brix) (Smith, 1967; Obreza and Rouse, 1993; Nath and Mohan, 1995) and slightly increase total acidity (TA, %) (Jones and Embleton, 1958; Chapman, 1986; Lee and Chapman, 1988; Okada *et al.*, 1992; Habasy Randa, 2017).

In addition, Habasy Randa, (2017) reported that vegetative growth; leaf chemical components (except P, K and Mg); fruit setting %, yield and fruit quality parameters of Navel orange onto sour orange rootstock, were positively increased with increasing N levels. However, increasing levels of N from 100 to 120 kg N/Y/Fed (i.e. 238 to 286 kg N/Y/Ha) had significant effect on promoting fruit weight and sizes (height & diameters), TSS, TSS : TA ratio, and reducing Vitamin C content and nitrate and nitrite in juice. N supply affects the content of total soluble sugar and total acidity (Lee and Kader 2000, Alcobendas *et al.*, 2013), which can influence the taste and flavor of fruits. Fruit yield and quality of citrus are greatly influenced by N and K because these nutrients are subjected to losses in the environment

(Cantarella *et al.* 2003) and are the ones most exported by citrus fruits (Mattos *et al.*, 2003).

Most studies carried out in Morocco especially by SASMA Laboratory and agronomic institutes (ENA in Meknes, IAV-HII in Rabat and Agadir) and INRA-Maroc, were conducted for citrus varieties grafted on a common (sour orange) rootstock. According to such studies several amount were recommended for an adult orchard and varying from 120 to 250 kg of N/ha (INRA, 1968; Nadir M. 1971; Loussert, 1987; El Khamass *et al.*, 1996 ; El-Ayadi *et al.*, 1998; Ait Houssa *et al.*, 2006). Most of the experimentations were investigated in clay soil conditions; however, few studies have explored the effect of nitrogen level on the productivity and fruits quality under sandy soil conditions.

We speculated that the optimal application rate of N fertilizer could increase yield, fruit size, the sugar content (TSS), acidity (TA) and TSS:TA ratio of Navel orange under sandy soil conditions. Hence, this work aims to investigate the effect of N fertilization on Navel orange fruit yield and quality, by assessing the yield, fruit weight, fruit size, total soluble sugar, total acidity, TSS:TA ratio and fruit juice content.

Material and Methods

A field experiment was conducted in El Menzeh's experimental station of INRA Kenitra in Morocco on Navel orange trees budded on Troyer citrange rootstock planted in 1964 at 7.0×7.0m spacing with 204 trees/ha. The soil of the experiment field is typically a deep sandy soil with a depth of 1.5m. The maximum of the root system is located in the top 50 cm depth of soil. Before performing the experiment, soil samples were collected for soil physical and chemical properties using standard laboratory methods (Table 1). The texture of the soil is sandy with 60% sand, 35% clay and 5% fine silt. The organic matter content is 1.9% and a pH-water of 6.4. Soil P (P_2O_5) available was 166.59 ppm, whereas exchangeable K (K_2O) was 174.25 ppm, according to soil analysis results (Table 1.)
The irrigation system is sprinkler covering the irrigated area at 14m radius with the flow rate at 1.5m^3/h at pressure of 2.5 bar.

Table 1. Soil characteristics at the 0–60 cm layer of the experimentation site in El Menzeh experimentation farm.

Clay (%)	Slit (%)	Sand (%)	pH	Organic matter (%)	P_2O_5 (ppm)	Exchangeable K (K_2O, ppm)	EC (dS/m)	Hcc (%)	Hpf (%)
35	5	60,0	6,4	1.9	166,59	174,25	0,795	4,87	1,39

The experiment was laid out in a complete randomized block design with three replicates. Each treatment was replicated three times (four trees per each). Four fertilization treatments based on the rates of nitrogen were applied to Navel citrus during two seasons (2012-2013 and 2013-2014): T0 (control): 0, T1: 100, T2: 200, T3: 300 (in Kg/ha). Nitrogen, phosphorus and potassium were applied as ammonium

nitrate (33.5%), triple superphosphate (TSP) (0-45-0) and potassium sulphate (0-48-50%), respectively. Fertilizer amounts from each treatment were mixed and applied to the soil surface under tree canopy in bands 50 cm wide and 1m away from the tree trunk. N (as ammonium nitrate) and K (as potassium sulphate) fertilizer were applied at three times, at March (40%), June (40%) and August (20%) during both seasons. P (as triple superphosphate) was applied one time two weeks before flowering (in February of 2013 and 2014). All the trees were subjected to common horticultural practices (except nitrogen fertilizers) that already applied in the orchard.

Yield and fruit weight and size

***Fruit yield* (kg / tree):** Total weight of the harvested fruits in kg was measured at harvest time for all the trees receiving the same treatment.
***Fruit weight** (g)* is determined by measuring average weight of the 30 fruits sampled at harvest time around the canopy tree and at 1.5m height.
Fruit diameter (mm) average diameter of ten fruits was recorded.

Fruit quality characteristics

Juice content (%) is obtained by a rotary extractor from 10 fruits sampled at harvest time. The juice content expressed as a percentage by weight is given by the formula:
Juice content (%) = Weight of juice extracted from 10 fruits × 100/ Total Weight of 10 fruits

Total solid soluble content (TSS) was determined by a digital refractometer which reports the amount of sugar in °Brix.

Total acidity of juice (TA) is obtained according to the following formula: **A = Vs/ 10** (Vs: Volume of solution of the NaOH (ml) used for the titration and 10: Volume (ml) of juice used).

Maturity indices are determined by the ratio: **(TSS/TA)** (SSC: Soluble solid content (°Brix) and A: acidity (%)).

Statistical analysis

The results were expressed as means ± standard errors (SE). Data were analyzed using the proc GLM procedure in a split-plot design (two-way ANOVA) with Year (season) is the main factor (main plot) and a treatment (N application rate) is the second factor (sub-plot), using SAS (Statistical Analysis System version 9.1) software since the measurements were made at different times (over two season or year). Differences between treatments least square means were compared using Duncan's multiple-range test at $P \leq 0.05$. Figures were prepared using the Microsoft Excel (2007) software.

Results and discussion

The effect of N application rate on Navel orange yield, fruit size and fruit weight are shown in Table 2 & 3. The results show that Nitrogen had significant effect on yield and fruit quality of Navel orange. Whereas the effect of interaction Year x N treatment was significant for fruit weight, total acidity and TSS:TA ratio.

Table 2. p-value from ANOVA about the effect of N fertilization on yield, fruit size, fruit weight fruit juice content, total acidity, total soluble sugar and TSS:TA ratio of orange Navel at harvest.

Parameters	Year	N treatment	Year X N treatment
Fruit yield (kg/tree)	0.5448	0.0002	0.0657
Fruit yield (t/ha)	0.5448	0.0002	0.0657
Fruit size (mm)	0.1587	0<0.0001	0.8097
Fruit weight (g)	0.3204	0.0018	0.0480
Juice content (%)	0.0040	0.0046	0.2004
Total acidity (TA %)	0.9055	0.0035	0.0335
TSS (°Brix)	0.3434	0.0021	0.2380
TSS:TA ratio	0.6745	0.0047	0.0001

There was a gradual and significant improvement on fruit weight, fruit size and fruit yield with increasing levels of N from 0 to 200 kg of N/ha/year. However, the fruit yield/tree receiving 200 and 300 kg of N/ha/year are not significantly different (Table 3).

In the present study, fertilizer application increased average fruit yield from 98.01 to 122.96 kg/tree in 2012-2013 and from 75 to 156.67 kg/tree in 2013-2014. Annual variation in fruit yield of Navel orange/tree was probably due to climatic factors (especially temperature and precipitation) in different seasons. The highest fruit yield was obtained from the treatments T2 and T3 and it was significantly higher than other treatments T0 and T1 (Table 3).

Table 3. Effects of N rates on fruit yield, fruit weight and fruit size of Navel orange over two seasons 2012-2013 and 2013-2014 (Data were presented as mean±SE).

N rate (kg/year)	0	100	200	300
Fruit weight (g)				
2012 - 2013	243.33±19.61a	251.67±17.40a	271.67±11.67a	269.00±20.91a
2013 -2014	163.30±8.39b	201.27±8.89b	265.40±35.87a	284.00±12.29a
Average	203.32±20.25b	226.47±14.26b	268.54±16.93a	276.50±11.36a
Fruit size (mm)				
2012 - 2013	75.00±0.65c	77.03±1.50bc	79.67±1.25ab	81.59±0.99a
2013 -2014	73.76±1.59b	77.36±0.89a	78.20±0.91a	80.15±0.75a
Average	74.38±0.84c	77.20±0.84b	78.94±0.77ab	80.87±0.63a
Fruit yield (Kg/tree)				
2012 - 2013	98.01±17.26a	95.74±10.39a	108.41±10.21a	122.96±16.34a
2013 -2014	75.00±6.69b	102.50±13.03b	150.00±13.60a	156.67±17.07a
Average	86.51±9.35b	99.12±8.18b	129.21±9.38a	139.82±12.08a
Fruit yield (t/ha)				
2012 - 2013	19.98±3.51a	19.53±2.12a	22.13±2.08a	25.08±3.33a
2013 -2014	15.30±1.36b	20.91±2.66b	30.60±2.77a	31.96±3.48a
Average	17.64±1.90b	20.22±1.66b	26.36±1.91a	28.52±2.46a

**: values on each line followed by the same characters are not significant different (Duncan test, p>0.05).*

There was a large increase in yield owing to different N level applications indicating that soil was originally deficient in N as indicated in soil analysis results (Table 1.). Application of fertilizers perhaps helped in maintaining soil fertility and offered favorable response, which was reflected by higher yield. Moreover, supply of sufficient amount of nutrients necessary for better growth and plant development which resulted in higher yield due to higher fruit set and weight. The high and significantly effects of N indicate that the trees require such amount of N for optimum growth and fruit production (Syvertsen and Smith, 1996; Wang *et al.*, 2006).

N fertilization plays an important role in fruit yield and quality; especially in the sandy soil that contain small amounts of available N (Calvert, 1970; Smith *et al.*, 1968; He *et al.*, 2003). Habasy Randa (2017) and Liao *et al.*, (2019) also reported that application of N fertilizer increased the number of fruits/tree of Navel orange and Huangguogan yield. In addition, these results are in agreement with those reported by Du Plessis and Koen (1984), in whose study that maximum fruit yield of orange trees was attained at 225 kg of N/ha.

The fruit weight varied considerably and increased significantly with increasing N levels. Maximum fruit weight (268.54 and 276.50 g) was recorded with application more than 200 kg/ha of nitrogen (T2 and T3) respectively, and it was significantly

superior to other treatment combinations (T0 and T1). The control treatment receiving no fertilizer produced the lowest fruit weight (203.32g) (Table 3.).

Fruit size was influenced significantly by N rates in both years of experiment. Significant increase in fruit diameter of Navel orange was also recorded with treatment T2 and T3 (78.94 and 80.87 mm respectively). The smallest average fruit size was obtained from the control treatment (T0) (74.38 mm) (Table 3).

Our findings indicated that the fruit quality differed significantly among the N application rate. Concerning the effect of N rate on fruit quality, the obtained data clearly show that increasing the levels of N from 0 to 300 kg/ha/year significantly increased TSS, TA and juice content of Navel orange fruits (Figure 1.&2.), whereas the significant reduction of TSS:TA ratio in juice was observed under 300 kg of N/ha/year (as compared to others) (Figure 3.).

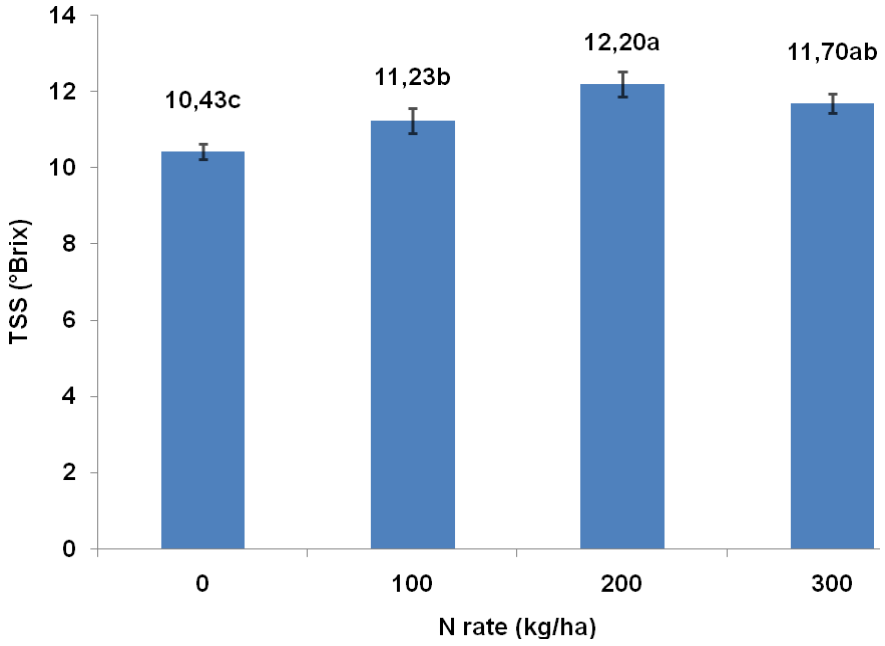

Fig 1. Effects of Nitrogen fertilizer rate on total soluble sugar (TSS, °Brix) content in juice fruit of Navel orange variety

**: values followed by the same characters are not significant different (Duncan test, p>0.05). Error bars indicate the standard error of mean.*

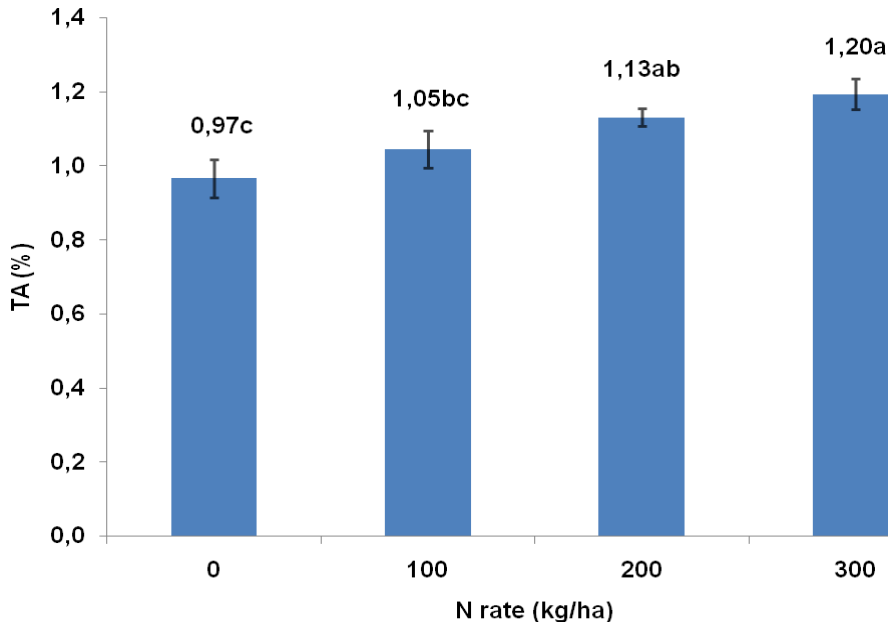

Fig 2. Effects of Nitrogen fertilizer rate on total acidity (TA, %) in juice fruit of Navel orange variety

** Values followed by the same characters are not significant different (Duncan test, p>0.05). Error bars indicate the standard error of mean.*

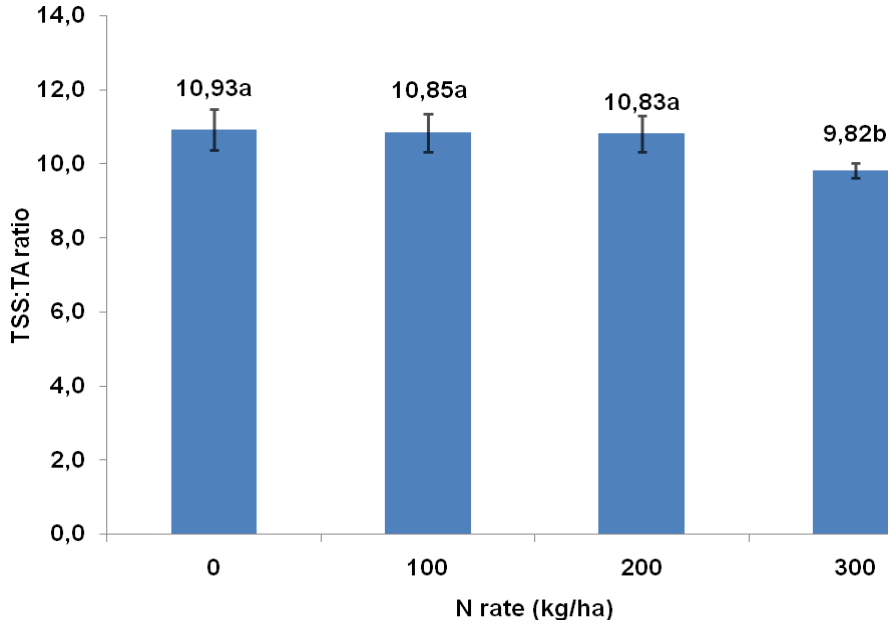

Fig 3. Effects of Nitrogen fertilizer rate on TSS:TA ratio (maturity index) in juice fruit of Navel orange variety

** Values followed by the same characters are not significant different (Duncan test, p>0.05). Error bars indicate the standard error of mean.*

Treatments T2 and T3 (200 and 300 of N kg/ha, respectively) showed a much higher TSS (12.2 and 11.70 °Brix respectively) and TA (1.13 and 1.20%, respectively) than the other treatments, and a lower TSS:TA ratio (9.82, under 300 kg of N/ha) than the other treatments. In contrast, T0 showed a remarkably lower TSS concentration (10.43˚Bx) and TA concentration (0.97%) but higher TSS/TA ratio (10.93) than T3 treatments (Figure 1, 2 & 3). It is also evident that the juice content (%) was significantly improved by increasing N application rate (Figure 4.). These results are in agreement with the results of Stewart *et al.*,(1961), Stewart and Wheaton (1965) and Koo (1979) who observed that total soluble solids (TSS) content of Valencia and Pineapple sweet oranges increased as the nitrogen (N) rate increased. Moreover, this might be due to good nitrogen status, improved plant conditions, efficient functioning of leaf area and increased photosynthetic activity.

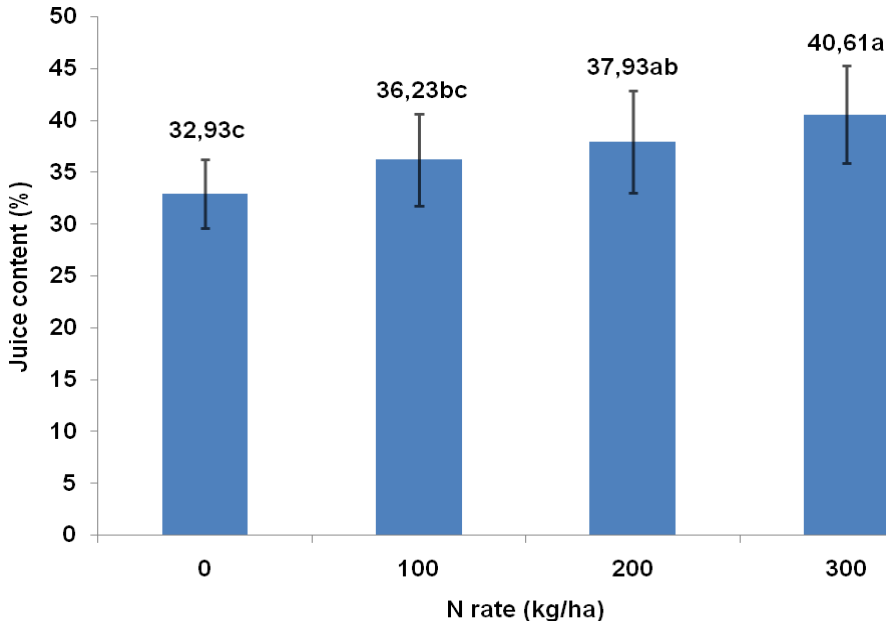

Fig 4. Effects of Nitrogen fertilizer rate on juice content (%) in fruit of Navel orange variety

** : Values followed by the same characters are not significant different (Duncan test, p>0.05). Error bars indicate the standard error of mean.*

These results are in conformity with the results obtained by Singh and Banik (2011) in sweet orange. It was further observed that significant increase in TSS was recorded by the application of organic manure and NPK (Singh and Banik, 2011). This was because adequate dose of N stimulated the functioning of number of enzymes in the physiological process which might have increased the total soluble solid content of the fruits. Also, these results are in harmony with those obtained by Habasy Randa (2017) and Liao *et al.*, (2019) who reported that the yield of citrus variety (Navel orange /Sour orange and Huangguogan/ trifoliate orange) increased with the increase in N application rate but this declined at the higher application rate from 1.83 to 0.6 kg/tree/Year respectively. Similar results have also been reported by Quaggio *et al.* (2002) and Jones *et al.* (1970), who found that N rates higher than 200 kg N ha^{-1} decreased yield and quality. This phenomena could be explained by the over growth of the vegetative organs stimulated by high leaf N concentration as reported by Ait Houssa *et al.* (2006) , and so resulting the reduction of carbohydrate

accumulation in the fruits and led to decreased yield and quality. But, the results in the present work revealed that 200 and 300 Kg N/ha gave a similar yield and quality. This different result can probably be attributed to climate and soil characteristics. However, in this study, the soil had very low organic matter (1.9%) and very low water capacity storage (Beniken *et al.*, 2008). Under such soil conditions with a heavy rain or high irrigation level applied by sprinkler system could leach a nitrogen fertilizer and remained the N in the soil solution at similar amount for T2 and T3. In addition, the rootstock used here has an active root system in the top soil surface (Ezzoubir *et al.*, 1988a).

Conclusion

This study aimed to select the best N level applied for improving yield and fruit quality of Navel orange. Two-year study revealed significant differences in yield and fruit quality in response to the four N treatments tested. In conclusion, we suggest that the application of fertilizers at the rate of 200 Kg of N/ha would be optimum for achieving higher yield and better fruit quality of Navel orange variety budded on Troyer citrange rootstock in a sandy soil and at Gharb region (Morocco) conditions.

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