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Impact of nitrogen and potassium fertilisation levels and scheduling on "Nules" clementine variety yield and quality at southern Morocco

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ABSTRACT

In this work, the impact of nitrogen (N) and potassium (K_2O) fertilizers rates and application scheduling on "Nules" Clementine variety yield, size and quality was evaluated for two consecutive years (2014 and 2015). The experiment was carried out in a commercial citrus orchard located in Taroudant province in Morocco where a randomized complete block design was adopted. Among 6 treatment programs tested, the treatment N°6 appeared to be the most suitable as fertilization program for citrus clementine "Nules" grown under the semi arid climate of southern Morocco. This program is a combination of 240 kg/ha of N and 160 kg/ha of K_2O scheduled as follow: Nitrogen 15% before bud initiation (BB), 30% between bud growth (BG) and full blooming (FB), 35% from FB to the physiological fruits dropping of June (PD), 20% between PD and fruit color changing (CC) and 0% from CC to the end of harvesting (EH). Potassium: 15% (BB), 20% (BG-FB), 15% (FB-PD), 25% (PD-CC) and 25% (CC-EH). Statistical analysis showed highly significant differences between the treatments. Treatment 6 showed the highest results in terms of fruit yield, size and juice content, whereas treatments 1 and 2 showed the lowest results respectively. However, no significant differences were recorded in term of total soluble solids and TSS/TA ratio even titrable acidity was higher in the case of treatment 6.

Keywords: Citrus; nitrogen; potassium; fertilization levels; scheduling; fruit size.

INTRODUCTION

In Morocco, the citrus production and export sector play a very important social and economic role and it is considered as a main branch of the national economy. Citrus plantings cover approximately 85 000 ha with an annual production of 1.7 million tons of which 90% are used for fresh consumption either in the domestic or the export markets [1]. Numerous scientific studies have demonstrated a relationship between nitrogen or potassium fertilization and yield, fruit size and quality of citrus [2-4]. Citrus fruit yield is largely regulated by nitrogen and potassium supply since they affects photosynthesis, specific leaf weight, and cell turgidity and extensibility. Although optimal nitrogen availability results in green foliage color and increased crop yield, excess of nitrogen can lead to luxury consumption by the tree, negative impacts on fruit size and reduced commercial value for harvested fruits [5]. The impacts of irrigation and mineral nutrition management on fruit quality of citrus are very important and should be taken into consideration to increase farm profitability and enhance sustainability and worldwide competitiveness. The most important mineral nutrients influencing fruit quality are nitrogen, phosphorus and potassium. Some micronutrients like boron and zinc can also affect fruit quality, but only if they are deficient in the tree [6].

This work is a continuation of the investigations initiated on 2011 in order to optimize the mineral fertilization in a citrus orchard under the local conditions of southern Morocco. The objectives of the present experimentation carried out during two consecutive years (2014 and 2015) is to assess the effects of different nitrogen and potassium rates and scheduling, on the fruit yield, size and quality of "Nules" citrus clementine variety. The results of this work can provide useful information for the development of citrus nutrition management guidelines more suited to local conditions of southern Morocco.

MATERIALS AND METHODS

2.1. Experiment site

The experiment was carried out in a commercial citrus orchard located in southern Morocco at the biggest citrus production area of the country at Taroudant province. The experimental site is planted with citrus trees of seven years old (age at the beginning of the experiment) containing "Nules" variety (Citrus reticulata) grafted on Citrus macrophylla rootstock. The plots had the same row orientation at 6x4m spacing (416 trees/ha).

2.2. Experimental design

The experiments were carried out during two consecutive years 2014 and 2015 and a randomized complete block design was adopted. The experimental site was divided into twenty four experimental plots (six treatments with four repetitions). Each plot is formed by twenty trees. The six treatments results from three different levels of applied nitrogen and potassium (N_iK_i) associated with two different fertilization scheduling (R_i) during the annual cycle of citrus trees. Phosphorus level is fixed at 70U (Kg/ha/year) of P_2O_5 for all treatments. The details of the experimental treatments are listed below in Table 1.

Table 1: Experimental treatments details (Ti).

N_iK_i		N(U)	P_2O_5(U)	K_2O (U)
	N_1K_1	160	70	240
	N_2K_2	200	70	200
	N_3K_3	240	70	160

Fertilization scheduling (R_i)			BB	BG-FB	FB-PD	PD-CC	CC-EH
	R_1	N	0%	50%	25%	25%	0%
		P_2O_5	20%	30%	25%	15%	10%
		K_2O	0%	25%	25%	50%	0%
	R_2	N	15%	30%	35%	20%	0%
		P_2O_5	20%	30%	25%	15%	10%
		K_2O	15%	20%	15%	25%	25%

Treatments

T1	T2	T3	T4	T5	T6
N_1K_1/R_1	N_1K_1/R_2	N_2K_2/R_1	N_2K_2/R_2	N_3K_3/R_1	N_3K_3/R_2

**BB: Before bud initiation; BG: Bud growth; FB: Full blooming; PD: Physiological dropping of fruits; CC: Fruit colour changing; EH: End of harvesting.*

2.3. Soil, water and climate conditions

The plots forming the experimental site were located on adjacent blocks and established on a loamy clay soil with high pH and high soil potassium, magnesium calcareous content (see soil chemical analysis in Table 2).

Table 2: Soil chemical analysis

		pH	EC*	Organic matter	Actif calcarious	Total calcarious	Total N	P_2O_5	K_2O	MgO	CaO	Na
				(%)			(g/Kg)	(ppm)				
Sample	1	8.3	0.21	0.92	7.3	13.9	0.87	103	231	508	7720	37
	2	8.2	0.19	0.81	5.6	11.8	0.77	73	192	612	5971	43
	3	8.3	0.24	0.78	5.8	12.2	0.73	87	219	579	8153	29

**EC (1/5 extract: mS/cm)*

Irrigation water is pumped from underground source. It is characterized by medium salinity and high hardness and pH value. This water contains high content of calcium, magnesium and sulfur that can satisfy the citrus tree needs during all the annual cycle considering a total irrigation water volume per year of 8000 m^3/ha (see irrigation water chemical analysis in Table 3).

The climate is Mediterranean semi-arid with very low and irregular rainfall (100 to 150 mm/year) distributed between late autumn and early spring. Temperatures are slight cold in the winter and very high in the summer and associated sometimes with very low air humidity.

Table 3: Irrigation water chemical analysis

pH	7.6	Na^+ (mg/L)	33
EC (mS/cm)	1.05	NO_3^- (mg/L)	39
NH_4^+ (mg/L)	0.1	H_2PO_4 (mg/L)	0.1
K^+ (mg/L)	1.7	SO_4^{--} (mg/L)	172
Ca^{++} (mg/L)	110	HCO_3^- (mg/L)	278
Mg^{++} (mg/L)	54	Cl^- (mg/L)	44

2.4. Irrigation and Fertilization

The irrigation was performed using double drip lines irrigation system with 75 cm spaced emitters that generate a flow of 4 l/h/emitter. Daily reference evapo-transpiration ETo was calculated using the formula of De Villèle [7]. All the twenty four experimental plots received the same quantity of water irrigation. The irrigation system design was modified to allow different quantities of nitrogen, phosphorus and potassium solution to be delivered to the respective treatment plots which were randomized within the experiment block.

The fertilization program (the six treatments) is performed using four chemical fertilizers (ammonium nitrates, mono-ammonium phosphate, potassium nitrates and sulfates salts) applied by hand to each plot every week. The trees micronutrients requirement was satisfied by four foliar applications of a commercial mixture of chelated micronutrients (Fe 5%, Zn 3%, Mn 3%, B 2%, Cu 1% and Mo 0.2%) on February, March, May and July at a rate of 4 kg/ha/application.

2.5. Fruit sampling for yield and quality evaluation

Fruit yield measurement was performed for each plot after the end of harvesting. Ten fruits of mean size were collected randomly from each plot for fruit quality analysis. Five fruit quality parameters were determined at the laboratory according to Rangana [8] and Soule et al., [9]. The tested parameters are fruit yield, fruit size, fruit juice content (%), total soluble solids (TSS), titrable acidity (TA) and TSS/TA ratio. Data were analyzed using MINITAB statistical software version 15.1.1.0. Treatment means were separated by Tukey's test at $P \leq 0.05$.

RESULTS AND DISCUSSION

As it was previously stated, the main objective of this experiment was to compare the effects of different nitrogen and potassium rates and scheduling on the fruit yield and quality of "Nules" citrus clementine variety under semi arid climate of southern Morocco. Tables 4 and 5 show the effects of different treatments on fruit yield and quality parameters.

3.1. Fruit yield and size

Fruit yield and size are ones of the most important parameters in evaluated treatments. Data concerning these parameters are presented in Table 4 and figure 1.

Table 4: Effect of different treatments on fruit yields and size

Treatments	Fruit yield (T/ha)			Fruit size (mm)		
	2014	**2015**	**Pooled mean**	**2014**	**2015**	**Pooled mean**
T1	$29{,}53^{de}$	$36{,}29^{de}$	$32{,}91^{de}$	$60{,}38^{bcd}$	$59{,}38^{bcd}$	$59{,}88^{bcd}$
T2	$30{,}00^{de}$	$35{,}21^{d}$	$32{,}61^{de}$	$60{,}78^{bc}$	$59{,}38^{bcd}$	$60{,}08^{bcd}$
T3	$35{,}00^{bc}$	$38{,}58^{c}$	$36{,}79^{c}$	$60{,}71^{bc}$	$59{,}15^{bcd}$	$59{,}93^{bcd}$
T4	$35{,}86^{bc}$	$41{,}22^{b}$	$38{,}54^{b}$	$60{,}15^{bcd}$	$59{,}00^{bcd}$	$59{,}58^{bcd}$
T5	$38{,}14^{ab}$	$41{,}40^{b}$	$39{,}77^{ab}$	$61{,}05^{bc}$	$60{,}55^{abc}$	$60{,}80^{bc}$
T6	$37{,}78^{b}$	$43{,}11^{ab}$	$40{,}44^{ab}$	$62{,}48^{ab}$	$61{,}63^{ab}$	$62{,}05^{ab}$
Significance	**	**	**	*	**	**

*In a column, means followed by different letters are significantly different at *: 5% level or **: 1% level.*

Fruit yield was observed to be higher in 2015 than in 2014 growing cycle for all treatments which could be due to the phenomenon of bearing alternate resulting from the over production of the experiment orchard during 2013 growing cycle. Statistical analysis showed highly significant differences between the treatments. Treatments 6 and 5 were the ones with the highest fruit yield reaching respectively 43.11 T/ha and 41.40 T/ha during the growing cycle

2015. Treatment 1 and 2 showed the lowest yield giving respectively 36.29 T/ha and 35.21 T/ha. Similar trend of treatments was observed in the growing cycle 2014 but on an average basis it produced less compared to 2015 (Table 4).

Regarding fruit size, the growing cycle 2014 produced fruits with more size compared to 2015. This can be due to lower fruit number per tree during the year 2014 resulting from the phenomenon of bearing alternate cited previously. Data in table 4 demonstrate a significant difference between tested treatments. Treatments 6 and 5 gave the highest fruit size reaching respectively 62.48 mm and 61.05 mm during the growing cycle 2014. However, treatments 4 and 1 showed the lowest fruit size giving respectively 60.15 mm and 60.38 mm. Similar trend of treatments was observed in the growing cycle 2015 but on an average basis it produced smaller fruits compared to 2014 (Table 4).

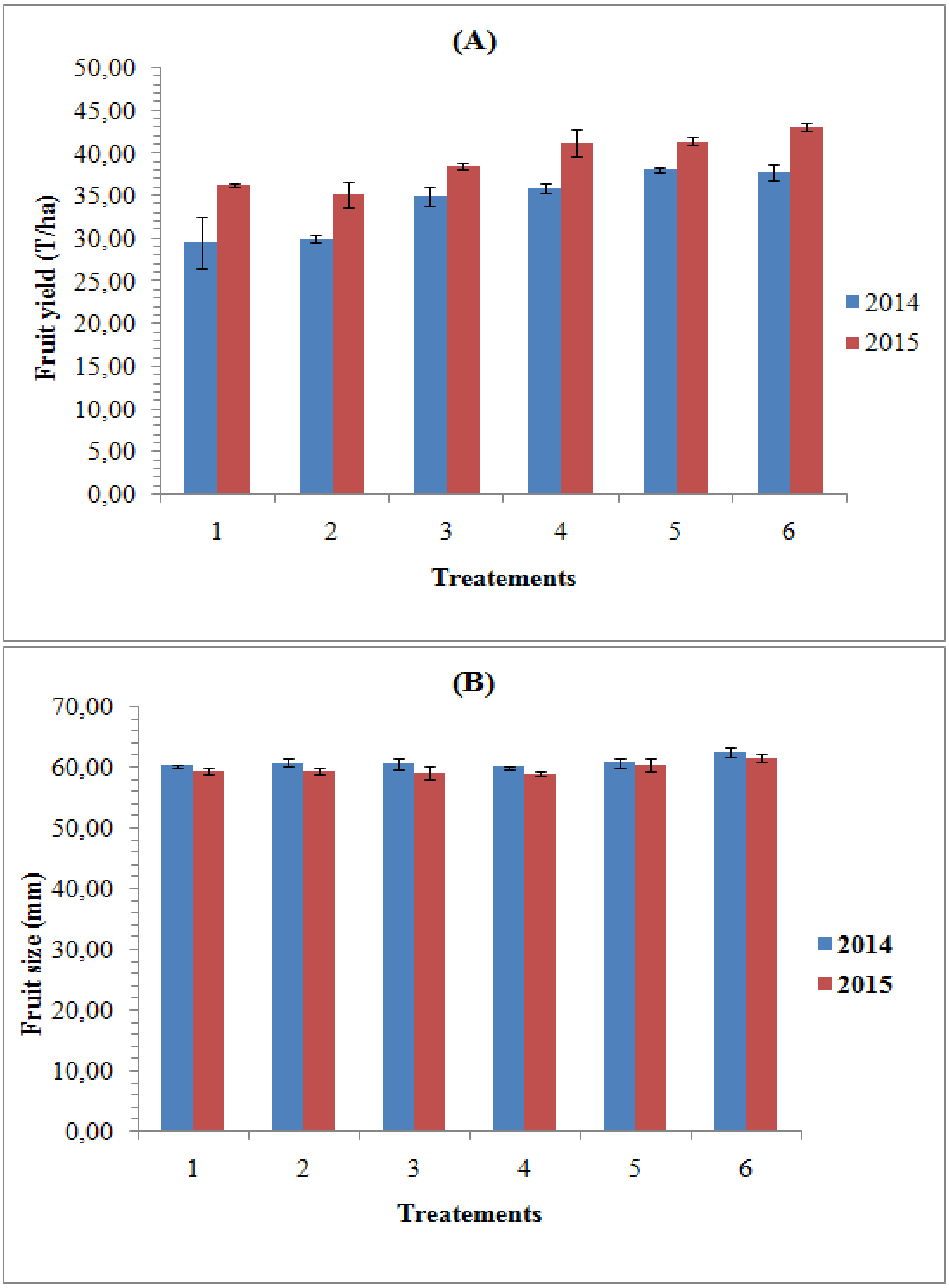

Figure 1: Effect of treatments on fruit yield (A) and size (B)

The above results are according to the findings of Aboutalebi [10] in Iran and Dinar [11] in Sudan. They reported an increase in citrus grape fruit yield while increasing nitrogen supply. Similar results were reported by Shawky et al., [12] and Elhassan et al., [13] in Egypt where climatic conditions are similar to those of the experimental site at southern Morocco. However, these results did not conform to the findings of Hong and Chung [14] in China and Lay and Wang [15] in Taiwan who reported a decline or an insignificant rise in yield as a result of nitrogen fertilization.

These discrepancies in results may be due to the environmental conditions and varietal differences. Indeed, citrus tree requirements of nitrogen are very high under arid climate to perform more vegetative growth. The increase in leaves surface will help trees to resist to negative effects of excessive air temperature and low air humidity during the fruit enlargement stage coinciding with the summer period [16].

3.2. Fruit quality parameters

3.2.1. Fruit juice content

Fruit juice content was observed to be slightly higher in 2014 than in 2015 growing cycle for all treatments except T3. This could be due to lower fruit number per tree during the year 2014 resulting from the phenomenon of bearing alternate cited previously. Data in table 5 show again considerable variability concerning the fruit juice content among the various tested treatments. T5 and T6 gave the highest juice content in fruits reaching respectively 42.96 % and 42.79 %, while T3 and T1 gave the lowest one giving respectively 39.28 % and 40.07 %. Similar trend of treatments was observed in the growing cycle 2015 but on an average basis it produced less juicy fruits compared to 2014 (Table 5). The previous results are in according to other workers that recorded an increment in fruit juice content at high nitrogen supply by fertilization [17].

Table 5: Effect of different treatments on fruit quality parameters

Treatments	Fruit juice content (%)			Titrable acidity (%) (TA)			Total soluble solids (%) (TSS)			Ration (TSS/TA)	
	2014	2015	Pooled mean	2014	2015	Pooled mean	2014	2015	Pooled mean	2014	2015
T1	40,07^{cd}	38,96^{de}	39,51^{de}	1,01^{bcd}	0,95^{bcd}	0,98^{bc}	12,36	12,99	12,68	12,27	13,71
T2	40,38^{cd}	39,57^{cd}	39,97^{cd}	1,00^{bcd}	0,97^{bcd}	0,99^{bc}	12,77	12,92	12,84	12,74	13,29
T3	39,28^{de}	41,81^{bc}	40,54^{cd}	0,99^{cd}	0,96^{bcd}	0,97^{bcd}	12,54	12,89	12,71	12,73	13,46
T4	41,98^{bc}	41,22^{bc}	41,60^{bc}	1,02^{bcd}	1,00^{bc}	1,01^{bc}	12,27	12,42	12,34	12,00	12,45
T5	42,96^{abc}	42,50^{ab}	42,73^{abc}	1,03^{bc}	0,98^{bcd}	1,00^{bc}	12,87	13,34	13,11	12,56	13,65
T6	42,79^{abc}	42,41^{abc}	42,60^{bc}	1,06^{abc}	1,05^{ab}	1,06^{ab}	11,95	12,50	12,23	11,27	11,90
Significance	**	**	**	*	*	*	N.S	N.S	N.S		

*In a column, means followed by different letters are significantly different at *: 5% level or **: 1% level. N.S: non-significant.*

3.2.2. Total soluble solids (Brix) and Titrable acidity

Statistical analysis showed that there is no significant difference in fruit total soluble solids (TSS) between the tested treatments during both the growing seasons 2014 and 2015 (Figure 2). However, it revealed a considerable variability concerning the fruit titrable acidity content where T6 presented the highest titrable acidity in fruits, while T1, T2 and T3 gives the lowest acidity during 2014. Similar trend of treatments was observed in the growing cycle 2015 but on an average basis it produced less acid fruits compared to 2014 (Table 5).

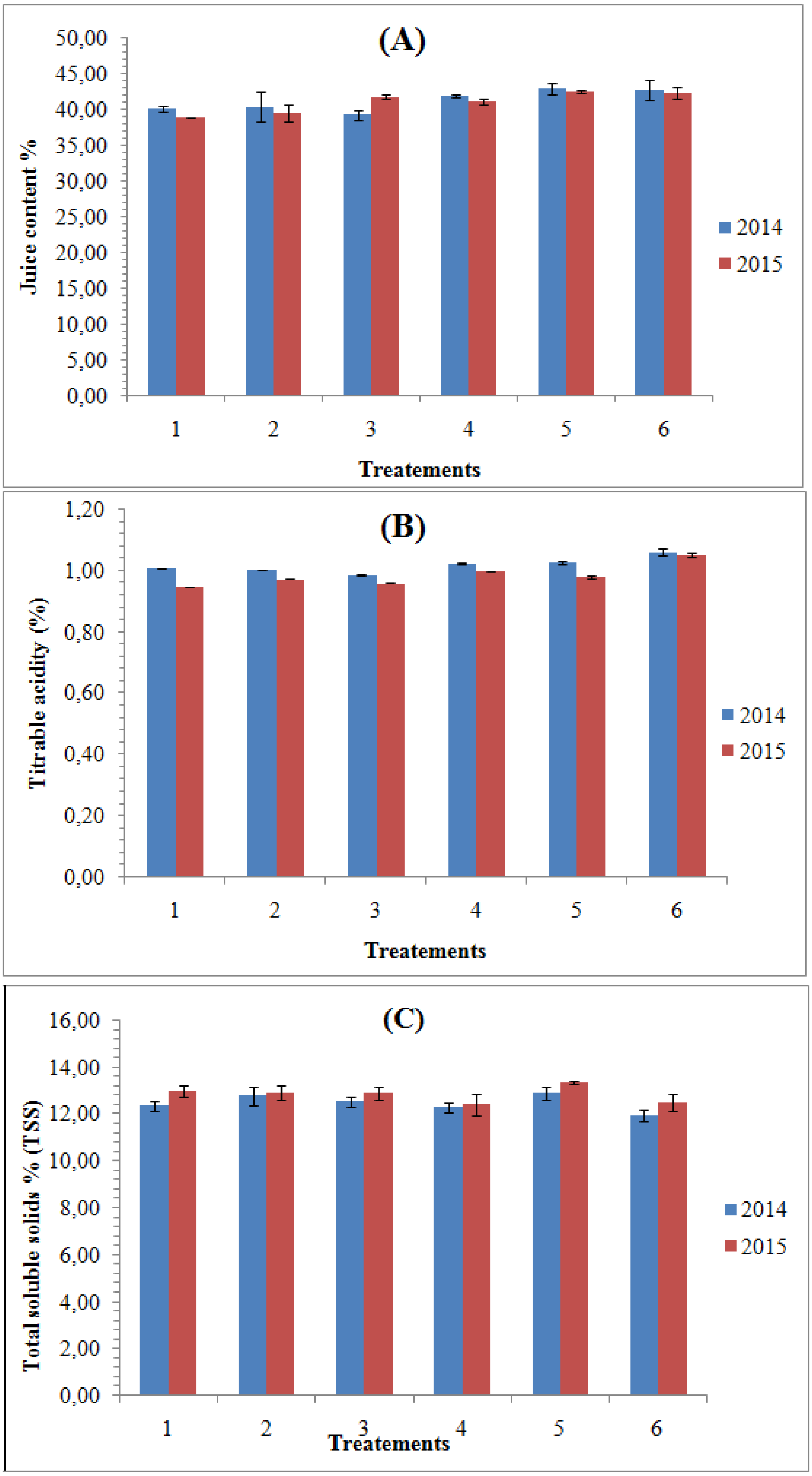

Figure 2: Effect of treatments on fruit juice content (A); titrable acidity (B); and total soluble solids (C)

In this experiment, the negative effect of nitrogen supply on fruit quality is reflected by the high titrable acidity in the case of treatment 6. This result is in agreement with the findings of Obreza [18] and Elhassan et al., [13] who recorded a decrease in the fruit quality while rising nitrogen supply for trees. However, for all treatments, the values of TSS/TA ratio (commonly used as an index of fruit maturity) are within a desirable range (between 8 and 17) of values required to start the fruit harvest. Indeed, comparing the values of the TSS/TA ratio of the different treatments, we can see that treatments 5 and 6 showed low values than the others. Thus, treatments 6 will result in fruit with greater shelf life duration than that of fruits resulting from the other treatments. This, can be explained by their high content of titrable acidity which is very essential to maintain good fruit structure (firmness) and good balance of sugar to acid in the juice (the fruit acidity is consumed with time and accentuated by stress conditions such as high temperatures).

CONCLUSION

According to the previous results based on fruit yield and quality parameters, treatment 6 and 5 appeared to be the most suitable as fertilization program for citrus clementine "Nules" grown under semi arid climate of southern Morocco. Statistical analysis showed highly significant differences between the treatments. Treatment 6 showed the highest results in terms of fruit yield and size, treatment 5 gave more juicy fruits, whereas treatments 1 and 2 showed the lowest results respectively. However, no significant differences were recorded in term of total soluble solids and TSS/TA ratio even titrable acidity was higher in the case of treatment 6. Thus, the results of the present work provide interesting information for the development of citrus mineral nutrition management guidelines more suited to the semi arid climate of southern Morocco.

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