



Effect of nitrogen rates on fruit quality of four commercially seedless grapefruit (Citrus paradisi Macf.) cultivars in Gezira state, central Sudan

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ABSTRACT

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Experiments were carried out for two seasons (2018/2019 and 2019/2020) at the Horticultural Research Centre Farm of the Agricultural Research Corporation (ARC), Wad Medani, Sudan, to evaluate physicochemical characteristics of four introduced commercially seedless grapefruit cultivars and to determine effects of nitrogen rates on fruit quality under arid conditions of central Sudan. Four grapefruit cultivars were used in this study, Shamber, Rio Red, Ray Ruby and Frost Marsh. Treatments consisted of four nitrogen rates 0, 43, 86 and 129 kg N ha (0, 600, 1200 and 1800 g urea/tree), applied in split dose. The experimental design was a completely randomized block design, with three replications and four trees/plot. The fruit quality measurements consisted of fruit weight (g), rag weight (g), Juice volume (ml), fruit length (cm), fruit diameter (cm), rind thickness (mm), total soluble solids (TSS), Total acidity, PH of Juice and Ascorbic acid content. Results showed highly significant differences among the four cultivars with respect to all quality parameters during the two seasons. Ray Ruby, Rio Red and Shamber cultivars recorded the highest values of fruit weight (g), rag weight (g), juice volume (ml) and peel thickness (mm) compared to Frost Marsh. Ray Ruby also recorded the highest values of total acidity and TSS% compared to the other cultivars. Results indicated that Ray Ruby and Rio Red had a value of TSS/ acid ratio around 7.00 which is the acceptable ratio for grapefruit maturity in most international markets. Different nitrogen rates showed significant differences on fruit quality on the four commercially seedless grapefruit cultivars. Results indicated that application of N rate up to 129 kg N/ha had a positive effect on fruit quality. Application of N at 129 kg N/ha resulted in the highest values of ascorbic acid, pH of juice and total soluble solids (TSS), and least values of total acidity as compared to the control in both seasons. Further studies are needed to test the effect of N rate higher than 129 kg N/ha.

KEYWORDS

nitrogen rates; fruit quality ; grapefruit

Experiments were carried out for two seasons (2018/2019 and 2019/2020) at the Horticultural Research Centre Farm of the Agricultural Research Corporation (ARC), Wad Medani, Sudan, to evaluate physicochemical characteristics of four introduced commercially seedless grapefruit cultivars and to determine effects of nitrogen rates on fruit quality under arid conditions of central Sudan. Four grapefruit cultivars were used in this study, Shamber, Rio Red, Ray Ruby and Frost Marsh. Treatments consisted of four nitrogen rates 0, 43, 86 and 129 kg

N ha (0, 600, 1200 and 1800 g urea/tree), applied in split dose. The experimental design was a completely randomized block design, with three replications and four trees/ plot. The fruit quality measurements consisted of fruit weight (g), rag weight (g), Juice volume (ml), fruit length (cm), fruit diameter (cm), rind thickness (mm), total soluble solids (TSS), Total acidity, PH of Juice and Ascorbic acid content. Results showed highly significant differences among the four cultivars with respect to all quality parameters during the two seasons. Ray Ruby, Rio Red and Shamber cultivars recorded the highest values of fruit weight (g), rag weight (g), juice volume (ml) and peel thickness (mm) compared to Frost Marsh. Ray Ruby also recorded the highest values of total acidity and TSS% compared to the other cultivars. Results indicated that Ray Ruby and Rio Red had a value of TSS/acid ratio around 7.00 which is the acceptable ratio for grapefruit maturity in most international markets. Different nitrogen rates showed significant differences on fruit quality on the four commercially seedless grapefruit cultivars. Results indicated that application of N rate up to 129 kg N/ha had a positive effect on fruit quality. Application of N at 129 kg N/ha resulted in the highest values of ascorbic acid, pH of juice and total soluble solids (TSS), and least values of total acidity as compared to the control in both seasons. Further studies are needed to test the effect of N rate higher than 129 kg N/ha.

INTRODUCTION

The vast cultivable land and suitable climatic conditions of Sudan offers a good potential for growing citrus species with good opportunities to world markets. The hot arid conditions of central Sudan is best suited for grapefruit culture. The traditionally grown grapefruit cultivars in Sudan are Foster and Duncan. Although fruits of these cultivars are of good quality they are very seedy and don't compete in international markets (Babiker *et al.*, 2006). In the last two decades of the twentieth century, several grapefruit cultivars including Frost Marsh, Red Blush, Shamber and Miami, have been introduced to Sudan. Introduced cultivars showed excellent fruit quality in the hot arid conditions, of central Sudan (Sidahmed and Khalil, 1997). More recently the leading commercially seedless cultivars in international markets (Ray Ruby and Rio Red) were introduced and evaluated under shendi conditions (Abdelrahman, 2019). The physico chemical characteristics of these cultivars and factors affecting their production under arid conditions of central Sudan need to be evaluated.

Nitrogen is one of the most important nutrients determining citrus fruit quality (Obreza and Morgan 2008, Hifiny *et al.*, 2013). The use of nitrogen fertilizers in citrus production in Gezira State, central Sudan, is limited and when applied farmers apply random rates. The effect of low and excessive levels of nitrogen on citrus fruit quality is well documented in literature with variable results. Elhassan *et al.* (2011) reported that application of high rates of urea, manure and foliar fertilizers resulted in dark green Foster grapefruits with thick peel and reduced vitamin content. Babiker *et al.* (2006), observed poor fruit quality of Miami grapefruit with low nitrogen supply. Legaz *et al.* (1992), found that rind thickness and acidity is increased with increasing N application. Therefore, the objective of this research is to evaluate physico chemical characteristics of four introduced commercially seedless grapefruit cultivars and to determine effects of nitrogen rates on fruit quality under arid conditions of central Sudan.

MATERIALS AND METHODS

Experiments were carried out for two seasons (2018/2019 and 2019/2020) at the Horticultural Research Centre Farm of the Agricultural Research Corporation (ARC), Wad Medani, Sudan. The area lies within the arid

climate (latitude 14° 23' N, longitude 33° 29' E, altitude 405 masl). The soil at the experimental site is a heavy cracking soil of the central clay plain. Results of soil physical and chemical properties of the experimental showed 31% sand, 21% silt, 44% clay, average soil pH was 7.5. Four grapefruit cultivars were used in this study, Shamber, Rio Red, Ray Ruby and Frost Marsh. The trees were budded on sour orange root stock, planted in February 2009, spaced at 8×8m, irrigated every 7-10 days and received all cultural practices as recommended. The trees selected for this study were free from pests and diseases and were uniform considering age, size and vegetative growth. Treatments consisted of four nitrogen rates 0, 43, 86 and 129 kg N ha (0, 600, 1200 and 1800 g urea/tree), broadcasted in the form of urea in split doses. The first dose was applied in June, before flowering and the second application was in September after fruit setting. A completely randomized block design with three replications and four trees/ plot was used.

Ripe fruits were harvested every three weeks, weighted, counted and used for fruit quality analysis. Five fruit samples were randomly selected from each treatment. Fruits were assessed for physical and chemical characteristics. Physical characters include fruit weight (g), fruit length (cm), fruit diameter (cm), rind thickness (mm), juice volume (ml) and rag weight (g). The fruit weight (g) and rag weight (g) were measured directly by scales. Juice volume was measured using a measuring cylinder. Fruit diameter, fruit length and rind thickness were measured using a vernier caliper. Chemical characteristics included total soluble solids, total acidity(%) and ascorbic acid content. Total soluble solids were determined using a hand refractometer, Total acidity (%) was determined by titration against 0.1N NaOH to phenolphthalein end point. Ascorbic acid content was determined using the method of Ranagana (1977), and Juice pH was determined using a pH meter.

Data were statistically analyzed using STATISTICS 8 programme. Mean separation was done according to Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Effects of cultivars on fruit physical characteristics

The main effects of cultivars on fruit physical characters of four commercially seedless grapefruit cultivars showed high significant differences in both seasons (Table 1). Tested cultivars showed a highly significant differences for fruit weight, rag weight, juice volume, fruit length, fruit diameter and peel thickness per fruit. In both seasons the highest fruit weight was obtained by Ray Ruby cultivar (429.3 g and 421.9 g), whereas, Frost Marsh resulted in the lowest fruit weight (369.08b g and 362.08 g). A similar trend was observed in rag weight. The increase in fruit weight was accompanied by an increase in rag weight. The highest juice volume per fruit was also recorded by Ray ruby, followed by Rio red and the lowest value was recorded by Frost Marsh and Shamber. The overall means of fruit length and fruit diameter revealed that Frost Marsh cultivar recorded higher values of fruit length and fruit diameter compared with other cultivars. There were no significant differences between other cultivars with respect to fruit shape. Fruits of all cultivars had a similar spheroid shape with a convex base. Ray ruby showed the highest values of peel thickness and frost marsh showed the lowest values. Several authors reported diversity in fruit morphology of grapefruit cultivars (Sidahmed and Geneif 1984, Abdelrahman2019, Muhammad *et al*(2020).The present results agreed with findings of Sidahmed and Geneif (1984), that Frost marsh had a higher value of fruit length and fruit diameter compared to other cultivars and with Muhammad *et al*(2020) who studied fruit quality of 6 pigmented cultivars under agro-climatic conditions of Pakistan and reported a higher value of fruit weight and juice volume of Ray Ruby and Rio Red.

Effect of nitrogen rates on fruit quality of four commercially seedless grapefruit (*Citrus paradisi* Macf.) cultivars in Gezira state, central Sudan

Table.1. Main effects of tested cultivars on fruit physical characteristics (2018/2019) - (2019/20)

Cultivars	Fruit weight(g)	Rag weight per fruit(g)	Juice volume per fruit (ml)	Fruit length (cm)	Fruit diameter (cm)	Peel thickness (mm)
<u>Season 2018/2019</u>						
Frost Marsh	369.08 b	54.60 b	159.58 c	10.63 a	11.24 a	0.54 c
Shamber	408.33 a	64.56 a	161.58 c	8.64 b	9.06 b	0.59 b
Rio Red	421.92 a	67.85 a	165.33 b	8.51 b	9.11 b	0.61 b
Ray Ruby	429.33 a	69.06 a	170.35 a	8.70 b	9.30 b	0.64 a
Sig. level	***	***	***	***	***	***
SE±	34.07	5.73	1.75	0.26	0.26	0.03
CV%	7.28	7.80	0.93	2.52	2.37	4.04
<u>Season 2019/2020</u>						
Frost Marsh	362.08 b	58.50 b	151.58 c	10.13 a	11.33 a	0.57 c
Shamber	401.33 a	67.08 a	153.58 c	7.96 b	9.16 b	0.62 b
Rio Red	414.92 a	71.58 a	157.33 b	8.01 b	9.21 b	0.64 b
Ray Ruby	421.92 a	71.83 a	167.35 a	8.20 a	9.40 b	0.66 a
Sig. level	***	***	***	***	***	***
SE±	34.07	5.11	1.75	0.26	0.26	0.03
CV%	7.41	6.62	0.98	2.67	2.34	4.04

* Means in the same column followed by the same letter(s) are not significantly ($P \leq 0.05$) different accordingly Duncan's Multiple Range Test (DMRT)

Effect of N rates on fruit physical characters

The main effects of N rates on fruit physical characteristics of four commercially seedless grapefruit cultivars showed high significant differences among cultivars in both seasons (Table 2). Tested cultivars showed highly significant differences with respect to Fruit weight, Rag weight, Juice volume, Fruit length, Fruit diameter and peel thickness per fruit.

Table.2. Main effects of N rates on physical characteristics of four commercially seedless grapefruit cultivars

N rates (kg/ha)	Fruit weight(g)	Rag weight per fruit(g)	Juice volume per fruit (ml)	Fruit length (cm)	Fruit diameter (cm)	Peel thickness (mm)
<u>Season 2018/2019</u>						
0	302.25 d	76.13 a	151.67 d	7.52 d	8.12 d	0.74 a
43	385.42 c	69.10 b	161.07 c	8.78 c	9.39 c	0.62 b
86	444.33 b	61.48 c	168.55 b	9.54 b	10.14 b	0.54 c
129	495.67 a	49.15 d	175.60 a	10.53 a	11.06 a	0.46 d
Sig. level	***	***	***	***	***	***
SE±	34.07	5.73	1.75	0.26	0.26	0.03
CV%	7.28	7.80	0.93	2.52	2.37	4.04
<u>Season 2019/2020</u>						
0	295.25 d	79.42 a	143.67 d	7.02 d	8.22 d	0.77 a
43	378.42 c	72.16 b	153.07c	8.28 c	9.48 c	0.66 b
86	437.33 b	65.33 c	160.52 b	0.04 b	10.24 b	0.57 c
129	488.67 a	52.08 d	167.60 a	9.95 a	11.15 a	0.49 d
Sig. level	***	***	***	***	***	***
SE±	34.07	5.11	1.75	0.26	0.26	0.03
CV%	7.41	6.62	0.98	2.67	2.34	4.04

* Means in the same column followed by the same letter(s) are not significantly ($P \leq 0.05$) different accordingly Duncan's Multiple Range Test (DMRT)

Increasing N rate up to 129 kg N/ha resulted in a significant increase in fruit weight and juice volume and a significant decrease in rag weight and peel thickness compared to the control in both seasons. These results are in agreement with those of Hifny *et al.* (2013), who found that application of N to Valencia orange trees increased fruit juice volume and decreased rag percent of Valencia orange in comparison to the control. Similar results were also reported by Montgomery *et al.*, (1978), who showed that increased rate of N produced fruits with greater juice content.

Tables 3 shows the interaction effects of cultivars and N rate on fruit physical characteristics. The .highest juice volume (177.20 ml) was obtained in Ray Ruby cultivar with application of 129 kg N/ha whereas, the lowest juice volume was obtained in Frost Marsh cultivar with no nitrogen applied. No significant differences were obtained on fruit weight , rag weight, fruit length and fruit diameter per fruit in both seasons.

Table.3. Interaction effects of cultivar and nitrogen on physical characteristics of four commercially seedless grapefruit cultivars (2019/20)

Cultivars	N rates (kg/ha)	Fruit weight(g)	Rag weight per fruit(g)	Juice volume per fruit (ml)	Fruit length (cm)	Fruit diameter (cm)	Peel thickness (mm)
Frost Marsh	0	268.67 f	72.66 abcd	140.13 j	8.44 de	9.64 de	0.71 bcd
	43	344.67 cdef	64.33 cdef	147.53 h	9.87 bc	11.07 bc	0.57 fg
	86	390.67 bcde	56.33 ef	156.67 fg	10.48 b	11.68 b	0.54 fghi
	129	444.33 ab	40.66 g	162.00 cde	11.73 a	12.93 a	0.47 hi
Shamber	0	313.00 def	79.00 ab	141.67 ij	6.43 h	7.54 h	0.79 bcd
	43	387.33 bcde	72.66 abcd	150.33 h	7.54 de	8.74 fg	0.67 de
	86	427.00 ab	66.33 bcde	158.47 efg	8.46 de	9.66 de	0.55 fgh
	129	478.67 ab	50.33 fg	163.87 bcd	9.48 c	10.68 c	0.46 i
Rio Red	0	295.33 ef	83.00 a	145.93 hi	6.47 h	7.67 h	0.76 abc
	43	390.00 bcde	76.33 abc	155.40 g	7.85 ef	9.05 ef	0.68 cde
	86	453.00 ab	70.00 abcde	160.67def	8.54 de	9.74 de	0.57 fg
	129	521.33 a	57.00 ef	167.33 b	9.16 cd	10.36 cd	0.52 ghi
Ray Ruby	0	304.00 def	83.00 a	146.93 h	6.82 gh	8.02 gh	0.84 a
	43	391.67 bcd	75.33 abc	159.00 defg	7.86 ef	9.06 ef	0.70 cde
	86	478.00 ab	68.66 abcde	166.27 bc	8.67 d	9.87 d	0.63 ef
	129	511.00 a	60.33 def	177.20 a	9.44 c	10.64 c	0.50 ghi
Sig. level		Ns	Ns	***	NS	NS	**
SE±		95.80	14.38	4.92	0.74	0.74	0.08
CV%		7.41	6.62	0.98	2.67	2.34	4.04

* Means in the same column followed by the same letter(s) are not significantly ($P \leq 0.05$) different accordingly Duncan's Multiple Range Test (DMRT).

Effects of cultivars on fruit chemical characters

The main effect of cultivars on fruit chemical characters of four commercially seedless grapefruit cultivars showed highly significant differences in both seasons (Table 4). Tested cultivars showed highly significant differences with respect to total acidity (%), ascorbic acid, pH of juice, and TSS (%) per fruit. Ray Ruby and Shamber cultivars recorded the highest values of total acidity followed by Rio Red and Frost Marsh cultivars in

both seasons. The lowest value of total acidity was obtained by Frost Marsh in both seasons. The highest TSS % was obtained by Ray Ruby cultivar whereas, Frost Marsh resulted in the lowest TSS % in both seasons. These results indicated that Ray Ruby has a higher value of total acidity and TSS and thus a higher value of TSS/ acid ratio compared with other cultivars. The TSS/acid ratio for Ray Ruby was 7.2 in the first season and 7.00 in the second season whereas TSS/acid ratio for Frost Marsh was 6.7 in the first season and 6.3 in the second season.

Results on ascorbic acid content of grapefruit cultivars were variable. Generally the highest values of ascorbic acid were obtained by Frost Marsh and Shamber. Several authors reported differences in chemical characteristics of grapefruit cultivars (Ali- Dinar and Osman, (1984). Muhammad et al (2011), Abo-El-EZet *al* (2011). Sidahmed and Khalil (1997) reported that the introduced cultivar Red Blush among the high yielding cultivars with an excellent fruit quality under Sudan conditions. Our results indicated that Ray Ruby and Rio Red had a value of TSS/ acid ratio around 7.00 which is the acceptable ratio for grapefruit maturity in most international markets.

Table 4. Main effects of cultivars on fruit chemical characteristics of tested cultivars (2018/19-2019/2020).

Cultivars	Total acidity (%)	Ascorbic acid(vit.c) (mg/100 ml)	pH of juice	TSS (%)	TSS/ acid ratio
<u>2018/2019</u>					
Frost Marsh	0.99c	48.46 a	3.88 ab	6.71c	6.7 c
Shamber	1.15 a	47.00 ab	3.70 c	7.25 b	6.3
Rio Red	1.04 bc	41.50 c	3.99 a	7.15 b	6.8
Ray Ruby	1.09 ab	43.91 bc	3.74 bc	7.88 a	7.2
Sig. level	***	***	***	***	***
SE ±	0.05	3.55	0.16	0.22	0.22
CV%	4.81	6.84	3.68	2.73	3.77
<u>2019/2020</u>					
Frost Marsh	1.01 c	51.46 a	3.58 ab	6.41 c	6.3
Shamber	1.15 a	50.00 ab	3.40 c	6.95 b	6.0
Rio Red	1.04 bc	44.50 bc	3.69 a	6.85 b	6.5
Ray Ruby	1.09 b	46.91 c	3.44 bc	7.58 a	6.9
Sig. level	***	***	***	***	***
SE±	0.05	3.55	0.16	0.22	0.22
CV%	4.54	6.42	4.00	2.85	3.69

* Means in the same column followed by the same letter(s) are not significantly ($P \leq 0.05$) different accordingly Duncan's Multiple Range Test (DMRT).

Effect of N rate on fruit chemical characteristics

The main effects of N rates on fruit chemical characteristics of tested cultivars were highly significant in both seasons (Table 5). Application of N rate had a pronounced positive effect on the chemical characteristics of fruit during both seasons. Application of N at 129 kg N/ha resulted in the highest values of ascorbic acid, pH of juice and total soluble solids(TSS), and least values of total acidity as compared to the control in both seasons. Nitrogen is of primary importance in citrus fruit quality Obreza and Morgan (2008) reported that optimizing Nitrogen improved citrus fruit quality more than any other element. Increase in fruit size and improved fruit

quality in Texas U.S.A. were observed with increasing N application to Rio Red grapefruit (Weidenfeld *et al* 2009). Recommendation for N application in Texas is 168 kg N/ha for 10 years or older grapefruit trees (Weidenfeld *et al* 2009). Our results indicated that application of N rate up to 129 kg N/ha had a positive effect on fruit Quality attributes. However further studies are needed to test the effect of N rates higher than 129 kg N/ha.

Table 5. Main effects of nitrogen rate on fruit chemical characteristics of four commercially seedless grapefruit cultivars

N	Total acidity (%)	Ascorbic acid(vit.c) (mg/100 ml)	PH of juice	TSS (%)
<u>2018/2019</u>				
0	1.19 a	38.58 d	3.48 d	6.32 d
43	1.10 b	43.16 c	3.69 c	6.96 c
86	1.04 c	47.40 b	3.95 b	7.60 b
129	0.94 d	51.72 a	4.18 a	8.11 a
Sig. level	***	***	***	***
SE ±	0.06	3.55	0.16	0.22
CV%	4.81	6.84	3.68	2.73
<u>2019/2020</u>				
0	1.18 a	41.58 d	3.18 d	6.02 d
43	1.10 b	46.16 c	3.39 c	6.66 c
86	1.03 c	50.40 b	3.65 b	7.30 b
129	0.96 d	54.72 a	3.88 a	7.81 a
Sig. level	***	***	***	***
SE ±	0.05	3.55	0.16	0.22
CV%	4.54	6.42	4.00	2.85

* Means in the same column followed by the same letter(s) are not significantly ($P \leq 0.05$) different accordingly Duncan's Multiple Range Test (DMRT)

The interaction effects of cultivars and N rate on fruit chemical characteristics of tested cultivars showed highly significant differences in TSS % and no significance in total acidity, ascorbic acid and pH of juice (Table 6).

The highest value of TSS was observed in Ray Ruby with application of 129 kg N/ha and the lowest values were observed in Frost Marsh and Shamber where no nitrogen was applied

Table.6. Interaction effect of cultivar and nitrogen on fruit chemical characteristics

of tested cultivars (2019/2020).

Cultivar	Nitrogen rate	Total acidity (%)	Ascorbic acid(vit.c) (mg/100 ml)	pH of juice	TSS (%)
Frost Marsh	0	1.15 ab	44.00 defg	3.16 fgh	5.83 i
	43	1.05 bcde	48.00 bcdefg	3.40 cdefgh	6.06ghi
	86	0.95 de	54.28 abc	3.66abcde	6.70 fg
	129	0.89 e	59.57 ab	4.10 a	7.06 def
Shamber	0	1.27 a	43.33 defg	3.00 h	5.60 i
	43	1.16 ab	48.66 bcdefg	3.26 efgh	6.76 ef
	86	1.12 abc	52.00 abcde	3.63 bcde	7.36 cde
	129	1.03 bcde	56.00 ab	3.71 abcde	8.06 ab
Rio Red	0	1.18 ab	38.66 g	3.46 cdefg	6.03 hi
	43	1.07 bcd	42.66 efg	3.60 bcdef	6.60 fgh
	86	0.99 cde	46.33 bcdefg	3.76 abcd	7.13 def
	129	0.93 de	50.33 abcdef	3.93 ab	7.66 bcd
Ray Ruby	0	1.14 abc	40.33 fg	3.10 gh	6.63 fgh
	43	1.15 ab	45.33 cdefg	3.31 defgh	7.23 def
	86	1.06 bcd	49.00 bcdef	3.56 bcdef	8.00 abc
	129	0.99 cde	53.00 abcd	3.80 abc	8.46 a
Sig.level		NS	NS	NS	**
SE±		0.05	10.00	10.00	0.64
CV%		4.54	6.42	6.42	2.85

* Means in the same column followed by the same letter(s) are not significantly ($P \leq 0.05$) different accordingly Duncan's Multiple Range Test (DMRT).

CONCULUTIONS AND RECOMONDATIONS

The study concluded that the newly introduced commercially seedless grapefruit cultivars showed excellent fruit quality under central Sudan conditions. The physico- chemical characteristics of fruits of Ray Ruby and Rio Red cultivars meets most of the regional and international maturity standards needed for grapefruit export and can be adopted by citrus producers in large scale for export and local consumption . The study also indicated

that increasing Nitrogen rates up to 129 kg/ha resulted in improved fruit quality attributes , However further studies are needed to test the effect of nitrogen rates higher than 129 kg/ha.

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