



## NUTRITIONAL STATUS OF FOSTER GRAPEFRUIT IN SUDAN CENTRAL CLAY PLAIN

[15]

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### ABSTRACT

A detailed survey was carried out for 8 Foster grapefruit (*Citrus paradisi* Macf.) groves in Sennar area (13° 37' N, 33° 37' E) representing Sudan Central Clay Plain. Trees were budded on Sour orange (*Citrus aurantium* L.). Soil and leaf samples were collected and analyzed according to standard procedures. Soil analyses included particle size distribution, pH (paste), ECe, SAR, N, P, K, Ca, Mg, Na, Zn, Fe and Mn. Leaf nutrient levels determination included N, P, K, Ca, Mg, Zn, Fe and Mn. Yield per tree was recorded for one season and quality parameters were measured for fruits sampled from representative trees. Results indicated that, soil texture of the orchards ranged between clay and clay loam. Although the orchards were receiving the same cultural practices, yet, they were significantly different in some soil and plant constituents. All orchards were non-saline and non-sodic of slightly to moderately alkaline reaction. Soil and plant were deficient in nitrogen and zinc with high leaf phosphorus, magnesium, iron and deficit calcium levels. Mean fruit yield ranged between 0.93 and 7.76 tons ha<sup>-1</sup> with an average of 4.35 tons ha<sup>-1</sup>, which is considered lower than world average. A low % TSS (total soluble solids), low ascorbic acid content and high % green color on fruit surface are evidents of low quality fruits. The low yield and poor quality fruits in this area were attributed to unsuitable soil conditions and the poor management practices, including lack of fertilizer application.

### INTRODUCTION

Most of the highly fertile lands along the Nile and its tributaries in Sudan have been brought under cultivation. Therefore, the Central Clay Plain, which includes the large national schemes such as Gezira, Suki, Rahad, Blue Nile and New Halfa schemes, is the area where the national strategy of citrus expansion is thought of (Sidahmed and Geneif, 1984). Citrus trees grown in this area look stunted with low yield and poor quality fruits (Hamid, 1995; Wardowski, 1990). Many factors can be suspected in this situation. These factors may include the use of local low yielding yield and poor quality fruits (Hamid, 1995; Wardowski, 1990). Many factors can be suspected in this situation. These factors may include the use of local low yielding cultivars, poor cultural practices and soil fertility factors. No studies were conducted to investigate the fertility status of citrus trees grown in this area.

Therefore, the main objective of the present survey is to study the fertility status of citrus orchards of Sudan Central Clay Plain in view of correlating soil conditions and plant nutrient status with fruit yield and quality.

### MATERIALS AND METHODS

Eight orchards of 18 years old Foster grapefruit (*Citrus paradisi* Macf.) trees budded on Sour orange (*Citrus aurantium* L.) were surveyed in Sennar area (13° 37' N, 33° 37' E) representing Sudan Central Clay Plain. The cultural practices carried out in these orchards were similar as far as weed

control, pruning and fertilizer application are concerned. Selected trees, free of the major pests and diseases such as scale insets, leaf minor, lemon butter fly and gummosis, were used in this study.

A randomized complete block design was adopted. Each orchard was divided into three blocks according to their vicinity to the Blue Nile bank. Block 1 was towards the Nile (1<sup>st</sup> terrace), block 11 in the middle (2<sup>nd</sup> terrace) and block 111 was away from the Blue Nile bank (3<sup>rd</sup> terrace). Total number of experimental units was 24.

### Sampling and analysis

In each orchard, soil samples were obtained from three sites representing the three blocks. The sites were 40-50 meters apart in the west-east direction. Soil samples were collected from the feeder root zone at two depths (0-30 and 30-60 cm) in each site according to Noling (2003). Soil samples were air dried ground and sieved to pass a 2 mm sieve.

Standard analytical procedures were used for soil physical and chemical properties (Grigal, 1974; Gough *et al* 1980 and Tandon, 1993). Soil samples were analyzed for particle size distribution, pH (paste), ECe, SAR, N, P, K, Ca, Mg, Na, Zn, Fe and Mn contents.

Three healthy trees around each sampling site were selected. Leaf samples were collected from non-fruiting terminals in August which appeared to be the most stable sampling period to be related to yield and quality. Hundred leaves per tree were collected and analyzed according to standard methods (Obreza *et al* 1999).

Leaf analysis included N, P, K, Ca, Mg, Zn, Fe and Mn contents.

Crop yield consisted of all picks (April to August). Yield was recorded in tons ha<sup>-1</sup>.

Four fruits of mean size per tree were randomly sampled in August for quality studies. The following parameters which were determined for fruit samples according to standard procedure (Wardowski, 1990) were used for quality evaluation. These parameters included fruit diameter, peel thickness, fruit juice, total soluble solids (% TSS), titrable acidity (% TA) and ascorbic acid (vitamin C).

Statistical analysis was carried out using Gomez and Gomez (1984) and Irristat (2005) computer software method.

### RESULTS AND DISCUSSION

Data obtained from the survey revealed that, soil texture of the orchards ranged between clay and clay loam (Table 1). Although the orchards were significantly different at ( $P \geq 0.05$ ) and ( $P \geq 0.01$ ) in sodium adsorption ratio in surface and sub surface samples, respectively, yet, all orchards were non-saline, non-sodic of slightly to moderately alkaline reaction (pH = 7.3-7.8) according to Ghassemi *et al* (1995) (Table 2). Table (3a) showed soil total N, available P and soluble K. The orchards were significantly different at ( $P \geq 0.01$ ) and ( $P \geq 0.05$ ) in N of surface and subsurface, respectively and significantly different ( $P \geq 0.01$ ) in soil K in the two depths. Table (3 a & b) on the other hand, indicated that the orchards were significantly different at ( $P \geq 0.05$ ) in Mg of surface and Na in the two depths. Table (4) depicted significant difference ( $P \geq 0.05$ ) in soil Mn of the surface. However, the orchards were of deficit soil nitrogen and zinc levels. Tables (5 & 6) illustrated plant nutrient levels. The orchards were significantly different at ( $P \geq 0.01$ ) in leaf N and ( $P \geq 0.05$ ) in leaf K, Mg and Mn. According to He *et al* (2003) and Obreza *et al* (1992), the orchards were deficient in leaf nitrogen, calcium and zinc with high levels of phosphorus, magnesium and iron. Tables (7a & 7b) showed mean fruit yield and quality parameters of the surveyed orchards. The orchards were significantly different at ( $P \geq 0.01$ ) in yield, peel thickness and % green color on fruit surface and significantly different ( $P \geq 0.05$ ) in juice % by weight and mean fruit weight. Mean yield ranged between 0.93 and 7.76 tons ha<sup>-1</sup> with an average of 4.35 tons ha<sup>-1</sup> which is considered lower than average of worlds similar areas (10.7 tons ha<sup>-1</sup>) (FASS, 2000). Surveyed orchards were of low % TSS contents, low ascorbic acid and of high % green color on fruit surface according to standard levels (Wardowski, 1990). The low yield and poor quality fruits may be due to the increased clay contents in the root zone which may have contributed to very high water contents, hence, poor aeration that might have resulted in decreased or low root density and unfavorable growth conditions. Poor aeration conditions may also lead to upset of nutrients absorption and formation of toxic compounds resulting from low decomposition of organic matter such as lactic, butyric and citric acids as reported by Brady and Weil (2000). In addition, the high clay contents may increase Zn and other micronutrients fixation. Under such conditions, the capacity of the feeder

Table 1. Surface and subsurface soil particle size distribution and textural class of the surveyed 8 Foster grapefruit orchards in Sennar area

Orchard	0-30 cm				30-60 cm			
	Sand %	Silt %	Clay %	Texture Class	Sand %	Silt %	Clay%	Texture Class
1	37	24	39	Clay loam	38	22	40	clay loam
2	37	14	49	Clay	38	14	48	Clay
3	25	28	47	Clay loam	34	25	41	Clay loam
4	32	25	43	Clay loam	34	23	43	Clay loam
5	36	25	39	Clay loam	27	24	49	Clay loam
6	26	28	46	Clay	25	25	50	Clay
7	30	24	46	Clay	27	19	54	Clay
8	37	17	46	Clay	39	12	49	Clay

Table 2. Some soil chemical properties of the surveyed 8 Foster grapefruit orchards in Sennar area

Orchard	pH		ECe (dSm <sup>-1</sup> )		SAR	
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
1	7.3	7.3	0.49a	0.72a	0.23ab	0.20ab
2	7.5	7.6	0.48a	0.70a	0.41a	0.42a
3	7.8	7.6	0.42a	0.81a	0.12b	0.14b
4	7.7	7.7	0.47a	0.46a	0.13b	0.15b
5	7.7	7.7	0.66a	0.88a	0.14b	0.12b
6	7.4	7.5	0.50a	0.60a	0.13b	0.12b
7	7.5	7.8	0.69a	0.64a	0.23ab	0.41a
8	7.4	7.5	0.45a	0.38a	0.18b	0.20ab
F-value			NS	NS	*	**
SE±			0.29	0.19	0.76	0.07
LSD			0.62	0.41	0.16	0.15

-Each value is a mean of 3 replicates

-NS = Not significant

-Means within a column followed by same letters are significantly different

Table 3a. Soil total nitrogen, available phosphorus and soluble potassium contents of the surveyed 8 Foster grapefruit orchards in Sennar area

Orchard	Total N (%)		Available P (ppm)		Soluble K (meq/L)	
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
1	0.016b	0.062b	1.9a	1.23a	0.13bc	0.02a
2	0.026d	0.036b	0.41a	2.4a	0.01d	0.01b
3	0.070ab	0.045ab	4.79a	3.92a	0.16ab	0.19a
4	0.090a	0.074a	5.05a	4.0a	0.26a	0.23a
5	0.070ab	0.074a	4.13a	4.7a	0.23c	0.04b
6	0.093a	0.049b	4.88a	2.4a	0.14b	0.01b
7	0.057bc	0.035b	1.5a	0.92a	0.02c	0.01b
8	0.032c	0.024b	0.63a	1.28a	0.01d	0.01b
Sig.level	**	*	NS	NS	**	**
SE±	0.01	0.014	1.11	1.92	0.05	0.03
LSD	0.021	0.03	2.38	4.11	0.1	0.06

-Each value is a mean of 3 replicates

-NS=Not significantly different

- Means followed by same letters are not significantly different.

Table 3b. Soil soluble calcium, magnesium and sodium levels (meq/L) of the surveyed 8 Foster grapefruit orchards in Sennar area

Orchard	Ca		Mg		Na	
	0-30cm	30-60m	0-30cm	30-60cm	0-30cm	30-60cm
1	3.33a	6.5a	3.33a	3.67a	0.42ab	0.44ab
2	3.0a	2.5a	3.0a	2.67a	0.73a	0.69a
3	4.0a	4.5a	2.33ab	4.67a	0.22b	0.29b
4	4.83a	3.5a	1.17b	1.70a	0.22b	0.22b
5	5.17a	4.83a	1.5b	2.33a	0.25b	0.22b
6	3.0a	4.17a	3.0a	2.33a	0.22b	0.22b
7	4.17a	2.17a	1.5b	0.83a	0.37b	0.50a
8	2.5a	3.0a	3.5a	5.0a	0.31b	0.34b
Sig.level	NS	NS	*	NS	*	*
SE±	1.32	1.7	0.65	1.39	0.14	0.12
LSD	2.82	3.65	1.4	2.98	0.3	0.26

-Each value is a mean of 3 replicates

-NS=Not significantly different

- Means followed by same letters are not significantly different

Table 4. Soil EDTA extractable zinc, iron and manganese levels (ppm) of the surveyed 8 Foster grapefruit orchards in Sennar area

Orchard	Zn		Fe		Mn	
	0-30cm	30-60cm	0-30cm	30-60cm	0-30cm	30-60cm
1	1.61a	1.32a	14.6a	21.5a	6.53a	6.54bc
2	2.01a	1.67a	13.0a	14.9a	5.07a	6.58b
3	0.84a	0.99a	10.7a	12.3a	6.76a	6.92ab
4	2.67a	2.60a	18.6a	32.1a	7.36a	7.40a
5	2.53a	1.75a	14.6a	11.6a	6.81a	6.73b
6	1.55a	1.34a	17.7a	20.6a	6.84a	6.93a
7	2.10a	1.00a	15.8a	16.8a	6.72a	6.54bc
8	1.45a	1.33a	25.1a	17.7a	6.77a	6.28c
F.value	NS	NS	NS	NS	NS	*
SE±	0.94	0.37	3.72	3.6	0.73	0.23
LSD	2.01	1.33	8.1	7.72	1.57	0.49

-Each value is a mean of 3replicates

-NS= Not significant

-Means followed by same letters are not significantly different.

Table 5. Leaf macronutrient levels (%) of the surveyed 8 Foster grapefruit orchards in Sennar area

Orchard	N	P	K	Ca	Mg
1	1.93a	0.60a	0.36b	2.7a	1.02a
2	1.83b	0.62a	0.44b	3.2a	1.00a
3	1.91a	0.67a	0.50a	2.9a	1.01a
4	1.80b	0.63a	0.60a	2.9a	0.51b
5	1.75b	0.62a	0.54a	2.7a	0.56b
6	1.57b	0.59a	0.52a	2.7a	0.69b
7	1.57b	0.51a	0.35b	2.5a	0.82ab
8	1.29b	0.56a	0.43b	3.2a	0.63b
F.value	**	NS	*	NS	*
SE±	0.03	0.06	0.07	0.03	0.27
LSD	0.06	0.14	0.15	0.64	0.58
CV%	1.74	10.5	10.2	10.5	13.8

-Each value is a mean of 3 replicate

-NS= Not significant

-Means followed by same letters are not significantly different

Table 6. Leaf micronutrient levels (ppm) of the surveyed 8 Foster grapefruit orchards in Sennar area

Orchard	Zn	Fe	Mn
1	16.2a	233.4a	23.0b
2	19.4a	255.6a	24.5b
3	13.8a	220.4a	20.9b
4	16.1a	144.9a	19.6b
5	12.2a	169.9a	19.1b
6	15.5a	190.8a	22.2b
7	15.5a	139.9a	16.6b
8	13.1a	165.7a	36.1a
F. value	NS	NS	*
SE±	4.04	45.9	4.15
LSD	8.67	98.5	8.9
CV%	26.5	24.2	18.3

-Each value is a mean of 3 replicate

-NS= Not significant

-Means followed by same letters are not significantly different

Table 7a. Mean fruit yield and quality parameters of the surveyed 8 Foster grapefruit orchards in Sennar area

Orchard	Yield (tonha <sup>-1</sup> )	Fruit diameter (cm)	Fruit length/width	Peel thickness (mm)	% green color on fruit surface	Juice % by weight
1	7.76a	7.9a	0.92a	7.9c	35.7d	26.1b
2	0.93d	6.7a	1.01a	12.9ab	75.0ab	16.5b
3	3.8b	6.8a	0.97a	7.54c	58.3bc	26.3a
4	4.26b	6.5a	0.94a	7.1cd	40.1d	31.1a
5	4.45b	7.2a	0.92a	8.3c	6.0b	25.9a
6	3.73b	7.5a	0.94a	9.7bc	48.7cd	32.0a
7	3.18bc	6.2a	0.93a	6.0d	35.0d	25.7ab
8	1.65c	7.2a	1.00a	13.3a	81.0a	20.5b
F. value	**	NS	NS	**	**	*
SE±	0.8	0.64	0.03	1.46	7.44	4.15
LSD	1.72	1.37	0.07	3.32	15.9	8.9
CV%	21.5	9.1	3.4	16.1	13.7	16.3

1 hectare = 156 trees

-Each value is a mean of 9 replicates

- Mean values with different subscript letters are significantly different.

Table 7b. Quality parameters of the surveyed 8 Foster grapefruit orchards in Sennar area

Orchard	TSS (%)	(%TA)	Maturity ratio (TSS/TA)	Ascorbic acid (vit C) (mg/100cc)	Mean fruit weight (g)
1	9.3a	0.98a	10.1a	32.9a	281.7a
2	8.8a	1.00a	8.8a	41.4a	151.3b
3	10.4a	1.16a	9.0a	39.6a	170.7b
4	10.8a	0.96a	12.1a	35.5a	277.7a
5	11.0a	1.12a	9.8a	45.3a	268.7a
6	9.1a	1.21a	7.6a	36.0a	292.7a
7	11.7a	1.10a	12.5a	45.1a	216.7a
8	8.5a	0.97a	8.9a	39.0a	186.3ab
F.value	NS	NS	NS	NS	*
SE±	1.05	0.18	2.26	6.74	47.5
LSD	2.25	0.39	4.85	14.5	101.9
CV%	10.6	17	22.9	17.1	20.7

- Each value is a mean of 9 replicates

- Mean values with different subscript letters are significantly different.

TSS= Total soluble solids (mainly sugars)

%TA= Percent titrable acidity

roots to take up nutrients can be reduced. Similar results were reported by Wiedendfeld *et al* (1982). Besides, the trees are subject to short supply of the most necessary nutrients. This may be related to the fact that, most of these soils are inherently deficient in nitrogen (Blockhuis, 1993) and of high pH values which adversely affect the availability of micronutrients in particular (Sims, 1986). These results were supported by the findings of Hamid (1995). He related the low yield and poor quality of fruit crops in this area to micronutrients deficiency and that was reflected by tree response to micronutrients application. In addition, Ali (1998) suggested that this low yield is due to absence of proper fertilization programs, removal of leaf litters from surface and use of herbicides or hand hoeing in Central Sudan depriving the soil from any organic residues which may aggravate the situation of plant nutrition. However, the conditions prevailing in these orchards are conducive to imbalanced nutritional status within the plant tissue indicated by low leaf nitrogen, calcium, zinc and high phosphorus, magnesium and iron levels. Consequently, tree growth, yield and quality were adversely affected. It is well known that nitrogen and zinc are essential to plant growth from early stages to har-

vest by affecting development of root system, leaves, flowers and fruits (Zekri and Obreza, 2008). The low quality may also be related to calcium deficiency levels in the plant tissue. It is known that fruits and vegetables are affected in quality by conditions of localized calcium deficiencies. Shortage of calcium during fruit development was found to cause fruit disorders because calcium reserves are not mobile (Zekri and Obreza, 2009).

It can be concluded that, the high clay contents and the relatively high soil pH values in some orchards may be the cause of poor root density and low permeability to water and air, which, in turn adversely affect availability and uptake of plant nutrients. Besides, lack of proper management practices including irrigation, pruning and fertilization could be one of the major factors of the stunted growth, low yield and poor quality of citrus grown in Sudan Central Clay Plain. Therefore, the present study suggested proper management practices to improve soil physical and chemical conditions for better growth, such as keeping and incorporation of leaf litters in soil and application of organic and inorganic fertilizers frequently.

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## الوضع الغذائي للجريب فروت الفوستر في سهل السودان الطيني الأوسط

[١٥]

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### الموجز

العمليات الفلاحية في هذه المزارع متشابهة ، إلا أن هنالك فروقات معنوية في بعض مكونات التربة والنبات . كما أوضحت النتائج أن أراضي هذه المزارع خالية من الملوحة والصودية ، وأنها تميل نحو القلوية الخفيفة إلى المتوسطة . التربة والنبات يعانيان من نقص النيتروجين والزنك ، بينما تعاني النباتات من ارتفاع الفسفور والمغنيسيوم والحديد ونقص الكالسيوم في الأوراق . وتتراوح الإنتاجية ما بين ٠,٩٣ و ٧,٧٦ طن للهكتار ، بينما بلغ متوسط الإنتاجية ٤,٣٥ طن للهكتار والذي يعتبر أقل من متوسط الإنتاج العالمي . تدنى السكريات وفيتامين ج وزيادة اللون الأخضر على سطح ثمار الموالح ، يعتبر دليلاً على تدنى هذه الثمار . تدنى الإنتاجية وتدنّى جودة الثمار في هذه المنطقة ، تم إرجاعها إلى ظروف التربة غير المناسبة ، وإلى سوء إدارة العمليات الفلاحية ، خاصة عدم إضافة الأسمدة في هذه المزارع .

تم إجراء مسح تفصيلي لعدد ثمانية مزارع للجريب فروت الفوستر في منطقة سنار (33° 37' N, 13° 37' E) ، ممثلة لسهل السودان الطيني الأوسط . الأشجار مطعومة على النارنج . تم جمع وتحليل عينات التربة والنبات حسب الطرق القياسية . شمل تحليل التربة توزيع حبيبات التربة ، الأس الهيدروجيني ، درجة الملوحة والصودية ، ومحتويات التربة من النيتروجين ، الفسفور ، البوتاسيوم ، الكالسيوم ، المغنيسيوم ، الصوديوم ، الزنك ، الحديد والمغنيسيوم . وشمل تحليل النبات محتوياته من النيتروجين ، الفسفور ، البوتاسيوم ، المغنيسيوم ، الزنك ، الحديد والمغنيز . تم تسجيل إنتاجية الأشجار لموسم واحد كما تم تحديد الجودة لثمار ممثلة للأشجار . أوضحت النتائج أن قوام التربة لهذه المزارع يتراوح بين الطيني والطيني اللومي . بالرغم من أن