Effects of different fertilizers on yield and quality of foster grapefruit

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Abstract

This experiment was conducted for three consecutive seasons (1995-96, 1996-97 and 1997-98) to investigate the nutrient deficiency and to correct the nutritional status by application of appropriate fertilizers to Foster grapefruit (*Citrus paradisi* Macf.) trees grown in Sennar area. A detailed survey was carried out for 8 Foster grapefruit orchards in Sennar area (13° 37′N,-33° 37′E) representing Sudan Central Clay Plain. The survey included soil, plant and fruit analysis beside yield records for one season (1995-96). The orchards were deficient in nitrogen and zinc in both soil and plant. Urea, sheep manure and Terra-sorb (foliar), and their possible combinations were applied to the trees for two seasons (1996-97 and 1997-98) to determine their effects on fruit yield quality parameters. All treatments significantly increased average yield over control with inconsistent effects on fruit quality. Urea at the rate of 2.17 kg/tree/year exerted adverse effects on fruit quality indicated by thick peel and reduced vitamin C. Manure at the rate of 20 kg/tree/year resulted in fruits of dark green color and thick peel. The foliar treated trees at the rate of 200 ml/100 l water yielded small thick fruits of low total soluble solids, low titrable acidity and low vitamin C. The most economically feasible fertilizer treatment of best fruit quality indicated by color, thinner peel, high total soluble solids and high vitamin C was attained by a combination of urea and manure. This combination also yielded larger fruits.

Introduction

Citrus is an important cash crop in the Sudan. In addition, it is one of the major sources of human diet due to its high nutritive value, especially vitamin C (Bedri,1984). Its cultivation is native to tropical and subtropical regions. Nowadays, it is grown all over the world wherever there is sufficient rainfall and irrigation to sustain the trees.

Total area of citrus in Sudan is estimated as 100000 Fed (National Horticulture Administration, 2001). However, the productivity of this area may not satisfy the ever- increasing demand for citrus products for local consumption and export. Therefore, the national strategy of citrus expansion is directed towards the large national schemes, e.g. Gezira, Suki, Rahad and the Blue Nile Schemes in the Central Clay Plain (Sidahmed and Geneif, 1984). Soils of this area are characterized by high clay contents, low nitrogen level and high pH values (Blockhuis,1993). Citrus trees grown in this area are stunted and of low yield (Hamid, 1986). Fruit quality is also poor indicated by low total soluble solids (%TSS), low ascorbic acid (vitamin C) and high acidity (%TA). Many factors were suspected to cause the low yield and poor quality of fruits in this area. These factors may include use of local low yielding cultivars, soil problems and poor management practices such as lack of fertilizers application. Therefore, this study is an attempt to improve productivity as well as the nutritive value of citrus grown in this area through efficient use of organic and inorganic fertilizers.

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Materials and methods

This study was conducted for three seasons (1995-96, 1996-97 and 1997-98) in two phases where 8 Foster grapefruit orchards in Sennar area were selected. In phase one a nutrient deficiency survey was carried out. Phase two comprises application of appropriate fertilizers. Selected trees were budded on Sour orange (*Citrus aurantium* L.). The orchards were irrigated from the Blue Nile. The cultural practices carried out in these orchards were similar as far as irrigation, weed , pests and diseases control, pruning and fertilizers application are concerned. Trees are 18 years old. Tree spacing is 8x8 m. Selected trees were free of the major insects damages and diseases such as scale insects, leaf minor, lemon butterfly and gummosis.

Phase 1: Nutrients Deficiency Survey

A detailed survey of the selected orchards was carried out. Survey included soil, leaf and fruit sampling and analyses beside yield records for one season (1995-96).

Soil Sampling

Experimental area (8 orchards) lies between the Blue Nile and 12 km away from the Blue Nile. Each orchard was divided into three blocks in the east–west direction. Block 1 was towards the Blue Nile, block 2 in the middle and block 3 was away from the Blue Nile bank. One sampling site was selected among trees in each block as reported by Boswell *etal* (1980). The sites were 40-50 m apart. Soil samples were collected from auger pits from each site from two depths namely, 0-30, 30-60 cm according to Luiting and Ryle (1980) who reported that about 90% of the feeding roots of citrus are concentrated in the top 60 cm. .Samples were oven-dried, ground and sieved to pass a 2 mm sieve.

Plant Sampling

Leaf samples were collected from three trees around each pit (experimental unit). According to Jones *et al.* (1970) leaf samples were taken in August which appeared to be the most stable sampling period. Leaf samples were obtained from non-fruit bearing terminals. Each leaf sample consists of 100 youngest, healthy and fully matured leaves. Samples were transported to the laboratory the same day and washed by detergent (Kleen). The leaves were then washed three times with distilled water and oven-dried for 48 hours at 65 C. The leaves were then ground in an agate ball mill and stored in polythene bags pending analysis (Chapman,1960).

Yield and Fruit Sampling

Crop yield consisted of all picks from March to early September (1995).There were two main picks in April and August. Yield per tree was recorded in tons/fed. Four fruits of mean size/tree were collected randomly for fruit quality studies.

Soil Analysis

Soil analysis followed standard procedures (Chapman and Pratt, 1961; Grigal, 1974). Analysis included particle size distribution, ECe, pH, total N, available P K, Ca , Mg, Na, Zn, Fe and Mn contents.

Leaf Analysis

Standard analytical procedures were used for plant samples (Chapman and Pratt,1961). Leaf analysis included N, P, K, Ca, Mg, Zn, Fe and Mn contents.

Quality parameters

The following parameters used for fruit quality evaluation were determined according to Rangana (1979a, 1979b) and Soule *et al.* (1967): 1. Fruit diameter and length (cm), 2. Percent green on fruit surface, 3. Juice % by weight, 4. Peel thickness (mm), 5. Total soluble solids (%TSS), mainly sugars, 6. Titrable acidity (%TA) and 7. Ascorbic acid (vitamin C) in mg/100ml juice.

Phase 11: Orchard experiment

In this phase appropriate fertilizers were applied to the same trees. The fertilizers included the following:

1. Urea (U): 46% N.
2. Sheep manure (M): 2.2% N, 0.69% P_2O_5, 0.32% K_2O, 0.86 %Ca and 0.1 % Mg. (Over 80% of sheep manure in powder form).
3. Terra-sorb foliar (F): 2.3% N, 0.05% Mg, 730 ppm Zn and 200 ppm B.

Treatments, rates and time of fertilizers application

1- (U):2.17 kg urea/tree/year (1kg N), applied in January every year.
2- (M): 20 kg sheep manure /tree/year (0.44 kg N), applied in January every year.
3- (F): 200 ml Terra-sorb/100 liters water, applied three times annually, first before blooming (January), the second after blooming and fruit setting whereas the third one month after the second one.
4- (U+M): 2.17 kg urea /tree /year + 20 kg sheep manure, applied as mentioned above.
5- (U+F): 2.17 kg urea/tree /year + 200 ml Terra-sorb/100liters water.
6- (M+F): 20kg sheep manure/tree /year + 200ml Terra-sorb/100liters water.
7- (U+M+F): 2.17 kg urea/tree/year + 20kg sheep manure /tree + 200 ml Terra-sorb/100 l water.
8- Control: No application of fertilizers was made.

Experimental Design

A randomized complete block design was adopted. The experiment comprised eight treatments with three trees per plot replicated three times (24 experimental units).

Sampling and Analytical Procedures

Soil, leaf and fruit sampling and analysis in addition to yield records followed the same procedures of phase one.

Results and discussion

Phase 1: Nutrients Deficiency Survey

Survey results showed that most orchards' soils ranged in texture between clay and clay loam. Soil reaction of the surveyed orchards ranged from neutral to alkaline (pH 7.2-8.0). Soils were non-saline, non-sodic and deficient in some elements, particularly nitrogen and zinc. Deficiencies of soil nitrogen and zinc were reflected by their low leaf contents. Yield attained in this study ranging between 0.39 and 3.26 tons/fed was low and fruit quality indicated by green fruits of low %TSS, low ascorbic acid and high titrable acidity was poor. However, the adverse conditions prevailing in these orchards such as high clay contents, high pH values beside the poor management practices, e.g. irregular irrigation and lack of fertilizer application may be the main reasons of the low yield and the poor quality of Foster grapefruit trees grown in this area.

Phase 11: Orchard Experiment

Tables 1 and 2 showed the effects of fertilizers treatments under test on yield, fruit quality and average yield of Foster grapefruit in two seasons. However, treatments were not significantly different in yield of the 1st season but significantly different ($P \geq 0.05$) in yield of the 2nd season. Average yield of all treatments was significantly higher than control. Effects of fertilizer treatments on fruit quality parameters were inconsistent.

1. Urea effects

The high significant rise in yield of urea treated trees was in harmony with the records of Dinar (1987) in Northern Sudan. He reported that yield of grapefruit started to increase significantly from 0.8 kg N/tree/year and above. Similar results were reported by Shawky *et al.* (1979) in Egypt. This may be due to the high coefficient nitrogen utilization on clay soils. On the other hand, the attained result in this study was not in line with those of Hong and Chung (1979) in China and Lay and Wang (1997) in Taiwan. They reported a decline or an insignificant rise in yield as a result of nitrogen fertilization. However, Mengel and Kirkby (1987) related the low yield as a result of nitrogen fertilizer application to the presence of excess soluble amino acids which can not be used for growth process because of the relative shortage of the other nutrients. Discrepancies in results may be due to the environmental conditions, especially temperature at fruit setting period (Embleton and Cree, 1965) or due to the method of urea application, whether single or split (Jones and Embleton, 1967) or most probably due to varietal differences (Jones *et al.*, 1970). The adverse effect of urea on fruit quality reflected by the thicker peel and the reduced vitamin C is in agreement with the findings of Obreza (1995) who recorded an increase of nitrogen in the juice as a result of urea application. Generally fruit quality is inversely related to nitrogen contents of the fruit.

2. Manure effects

Manure increased the average yield significantly over the control. .Manure gave the highest yield at 1.54% (average) leaf nitrogen level (optimum leaf N≥ 2.3%) This suggests that yields were not associated with leaf nitrogen level. However, the effect of manure on yield is not largely due to its nutrient contents. Most research workers related this to the cumulative effects of one dressing after another on the structural improvement of the soil. In addition, the nitrogen supplying power of the soil will be improved by long-term manure application. Studies showed the superiority of these organic manures when applied in equivalent amounts to inorganic fertilizers (Cook, 1977). This confirmed the previous findings of Branson (1972). He indicated that one of the major limiting factors of fruit yield is water infiltration. It is clear that trees responded to improvement of soil structure and soil-plant-water relationships that resulted from manure application and not nitrogen rate per se.

Manure yielded small fruits, intensified the green color on fruit surface, increased peel thickness and the total soluble solids (%TSS). Other studies gave better fruit quality (Huang *et al.*, 1996), which may be attributed to different types of manure and different rates of application and decomposition.

3. Foliar effects

Terra-sorb foliar increased the average yield significantly over the control. Yield increment may be in response to nitrogen of the spray. Results were in conformity with those of Jones *et al*. (1970). However, the foliar spraying of nitrogen with magnesium, zinc and boron exerted adverse effects on fruit quality. The measured fruit quality parameters were almost below the standards, possibly because of the specific utilization of nitrogen by fruits. However, results disagreed with those of Qin (1996) who applied a foliar fertilizer containing magnesium, zinc and boron only. He related the improvement of fruit quality to the greater elongation of the pollen tube in magnesium, zinc and boron treatment favoring fertilization and improving fruit setting. According to Spencer and Wander (1960), magnesium exerted no positive effect on yield or fruit quality. Similarly, micronutrients had no effect on yield and fruit quality as suggested by Leyden and La Duke (1984). It is clear from the foregoing discussion that yield and fruit quality are mush more affected by the presence or absence of nitrogen in the foliar.

4. Combined effects of urea and manure

Average increase of yield as a result of this combination was significant. The effect of this interaction on fruit quality was the best indicated by the favorable fruit characteristics such as fruit color, thinner peel, higher % TSS and vitamin C. This may be due to the more suitable soil physical conditions and the better supply of phosphorus, potassium and other essential nutrients resulting from manure application (Brady and Weil , 2000). Calcium from manure can compensate the calcium removed by actively growing vegetative tissues due to urea application. So calcium can be translocated in storage tissues and fruits favoring improvement of fruit quality. Improvement of fruit quality may be also due to the absence of the foliar in this treatment (Papanikoleau *et al.,* 1988). Similar results were obtained by Abaev (1973) who reported a significant high yield and best quality as a result of combination of organic and inorganic fertilizers.

5-Combined effects of urea and foliar

This interaction increased the average grapefruit yield significantly and yielded large fruits but had no consistent effects on the other quality parameters. Results were obtained at 1.66% leaf nitrogen level (optimum leaf N level ≥2.3%). This is supported by Jones *et al.* (1970) who showed that, the larger fruit size was attained at lower leaf nitrogen level but was associated with yield reduction. It was indicated that, high nitrogen supply as a result of urea and foliar application mostly exerted a negative effect on fruit quality (Jones and Embleton, 1960). Other workers recorded increment of %TSS, fruit juice and TSS/TA ratio at high nitrogen supply (Reuther *et al.*, 1958). It seems that, disparity in results concerning fruit quality may be ascribed to effect of rate and time of application of nitrogen fertilizer where high rates at summer were more detrimental to fruit than lower rates at spring (Jones and Embleton, 1967).

6-Effects of manure and foliar

Average increase of yield as a result of this combination was significant. When compared with the increase of yield in urea and foliar treatment, the effect of manure addition is obvious.

The adverse effects of this combination on fruit quality were reflected by small fruits, intensive green color on fruit surface and low %TA. This was related to the foliar and the specific utilization of nitrogen by fruits (Papanikoleau *etal,*1988).

.7- Combined effects of urea, manure and foliar

Interaction of urea, sheep manure and Terra-sorb gave a high significant increase of yield but adversely affected fruit quality. It is well known that nitrogen encourages the vegetative growth (Brady and Weil, 2000) hence, yield will increase. On the other hand, calcium within the plant moves preferentially to actively growing tissues rather than to storage tissues e.g. fruits. Shoot growth may therefore, compete with the storage tissues for the available calcium in the plant ,hence, induce calcium deficiency in fruit which affects fruit quality adversely. This effect may be brought about by high levels of nitrogen and account for the well-known observation that calcium disorders were stimulated by high levels of nitrogen fertilization (Mengel and kirkby,1987).In this context, Shear (1975) noted many calcium disorders in calcium deficient fruits and vegetables such as high %TA and low vitamin C. This demonstrates that fruits and vegetables are largely affected in quality by conditions of localized calcium deficiency within the plant. According to Bould and Chiu (1976) a continuous flow of calcium is required in fruits for normal crop production. Shortage of calcium during fruit development will induce fruit disorders because calcium reserved are not mobile.

8. Economic Evaluation

Results of the experiment have been subjected to economic evaluation. The objective being to test the economic viability of different fertilizers used for grapefruit production. Economic evaluation comprises data on experiments carried out on Foster grapefruit (*Citrus paradisi* Macf.) in Sennar area during two seasons (1996-97, 1997-98). Partial budget analysis was used for the fertilizer experiment as described by CIMMYT (1988). Average yield for the two seasons, average costs and average prices (as prevailed in 2005) were used in the economic analysis. In the case of improved fruit quality, a premium price, which is about 25% higher, was used. Net benefit from applying different fertilizers and those without fertilization were compared. Net benefits of fertilizer treatments are the differences between the benefit and the cost of the treatment in question. Gross benefit of a fertilizer treatment is the product of yield of tree fruits and the field price of the fruits. Cost on the other hand, comprised the cost of fertilizer and its application. The field price was derived by subtracting harvest and post harvest costs associated with extra yield from the farm gate price, which was the whole price in this case.

Partial budget was computed for the fertilizer experiment and average yield, gross benefits, costs that vary and benefits for treatments are shown in Table 3.

For the sake of comparison between treatments, dominance and marginal analyses were carried out. Dominance analysis was done by first listing the treatments in order of increasing cost that vary. Any treatment that has net benefit less than or equal to those of a treatment with lower costs that vary, was dominated (Marked with a "D" in Table 4). Such treatment can be eliminated from further consideration because it does not represent a feasible option to the farmer or producer. Results of the dominance and marginal analyses were shown in Tables 4 and 5, respectively.

It is clear from Table 4 that treatments F, M, (M+F) and (U+M) were undominated and will be subjected to further analysis.

Marginal analysis shows the relative profitability of the promising (undominated) treatments. The purpose of marginal analysis is to reveal how the net benefits from an investment increase as the amount invested increases. The idea is to see the level of improvement. The marginal rate of return (MRR) shows return to investment in different treatments (Table 5). Treatment (U+M) gave the highest net benefit with substantial MRR (1861%). This means that for every SD1 invested in treatment (U+M), grapefruit producer can expect to get back that SD1 plus an additional SD19. Other treatments, namely, (M+F), M and F were also profitable with very high marginal rates of returns compared to the control treatment. They represent, thus, feasible options to grapefruit producer in case of capital shortage or unavailability of fertilizer imputs.

Recommendations

Based on yield and quality data, and economic evaluation the following recommendations are suggested:

1- Urea at the rate of 2.17 kg/tree/year + sheep manure at the rate of 20 kg/tree/year (equivalent to 1.3 tons sheep manure/fed + 141 kg urea/fed where 1 feddan = 65 trees. Urea to be applied in January and manure to be incorporated into the top soil in January.

1. Sheep manure at the rate of 20 kg /tree/year (equivalent to 1.3 tons/fed)

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Table 1. Effects of fertilizer treatments on mean yield and fruit quality of Foster grapefruit in Sennar area (1st season,1996/97)

Treatment	Yield Ton/fed	Peel thickness (mm)	Juice% by weight	%Titrable acidity
U	2.37a	4.5c	19.8b	1.70c
M	3.09a	6.7b	17.2bc	0.94ab
F	1.24a	5.3c	19.0b	0.75bc
U+M	3.25a	5.4bc	19.7b	1.01a
U+F	3.50a	7.5b	16.3c	0.69c
M+F	3.40a	6.3b	15.5c	0.59c
U+M+F	3.87a	12.5a	16.1c	0.77b
Control	1.09a	5.7b	26.3a	0.63c
F-value	NS	**	**	**
SE±	1.13	0.87	1.29	0.08
LSD	2.42	1.84	2.77	0.17
CV%	41.5	12.9	7.0	10.5

-Each value is a mean of 9 replicates
-Means followed with different subscript letter are not significantly different

Table 2. Effect of fertilizer treatments on mean yield and Fruit quality of Foster grapefruit in Sennar area (2nd season 97/98)

Treatment	Yield Ton/fed	Peel thickness (mm)	Juice % by weight	Titrable acidity (%TA)	Ascorbic acid (vitC mg/100)
U	5.43a	5.5b	19.3b	0.36b	62.8a
M	4.80a	13.0a	28.1b	0.38b	92.5a
F	2.55b	6.4b	26.7ab	0.34b	54.2ab
U+M	6.63a	6.6b	24.6b	0.34b	63.7a
U+F	4.55ab	8.0b	42.1a	0.42b	42.8b
M+F	6.15a	6.8b	38.8a	0.37b	63.6a
U+M+F	7.24a	12.5a	26.8a	0.35b	51.4b
Control	1.60b	5.5b	15.5b	0.63a	50.9b
F-value	*	**	*	**	**
SE±	1.47	1.09	6.73	0.06	4.9
LSD	3.14	2.34	14.4	0.14	10.7
CV%	30.1	13.5	24.2	16.00	8.8

-Each value is amean of 9 replicates
- Means followed by same letters are not significantly different.

Table 3. Partial budget of the effects of different fertilizers on yield and quality of Foster grapefruit experiment, average yield (1996-97 and 1997-98), Sennar area

Treatment	Average yield (ton/fed)	Gross return(SD/fed)	Variable cost(SD/fed)	Net return(SD/fed)
U	3.90a	312000	4852	296890
M	3.95a	316000	1411	309700
F	1.89a	151200	27070	146860
U+M	4.94a	592800	6263	571390
U+F	4.02a	321600	7560	302150
M+F	4.77a	381600	4118	370960
U+M+F	5.55a	444000	8970	418150
Control	1.34b	107200	0	107200

SD =Sudanese Dinar

1US $ =250 SD(March 2005)

Table 4. Dominance analysis of fertilizer treatments experiment

Treatment	Cost that vary(SD/fed)	Net benefits(SD/fed)	
Control	0	107200	
F	4340	146860	
M	6300	309700	
M+F	10640	370960	
U	15110	296890	D
U+F	19450	302150	D
U+M	21410	571390	
U+M+F	25850	418150	D

D = Dominated

Table 5. Marginal analysis of undominated treatments

Treatment	Costs that vary (SD/fed)	Marginal cost (SD/fed)	Net benefits (SD/fed)	Marginal net benefits (SD/fed)	Marginal rate of return (MRR)
Control	0	-	107200	-	-
F	4340	4340	146860	39660	913%
M	6300	1960	309700	162840	8308%
M+F	10640	4340	370960	61260	1411%
U+M	21410	10770	571390	200430	1861%