

Performance of Grapefruit Under the Ecological Conditions of Central Sudan I. Growth, Flowering and Yield

Osman A. Sidahmed¹ and Mohamed I. Khalil

Faculty of Agricultural Sciences, University of Gezira, P.O. Box 20,
Wad Medani, Sudan

Abstract: Growth, flowering, production efficiency and fruit quality of 13 grapefruit (*Citrus paradisi*) cultivars on a sour orange rootstock were evaluated for over a 15-year-period in central Sudan. The newly introduced cultivars showed vigorous vegetative growth and were slow to come to bearing as they were nucellar line selections compared to the locally adapted cultivars. Two peaks of flowering were detected with a major peak during winter (December-March), induced by temperature rhythm, and a minor one coinciding with the rainy season (June-September). Both leafy and bouquet types of bloom were observed, but the leafy type was dominant and resulted in maximum fruit set. During early cropping seasons, the newly introduced cultivars trailed the locally adapted ones in yield. However, by the 6th cropping season (11 years after planting) all trees apparently reached full cropping capacity and the newly introduced cultivars started to excel the locally adapted ones. The yield ranged from 22.4 to 40.8 t ha⁻¹ during this cropping season.

Key words: Grapefruit, cultivar, growth, flowering, yield.

The estimated world grapefruit production in 1982 was 4484 thousand metric ton with a net income of approximately 529 dollars per metric tonne (FAO, 1982). The estimated grapefruit production in Sudan in 1982 was about 59 thousand metric tonnes (FAO, 1982). Based on these statistics the present policy for agricultural development in Sudan calls for an active role for horticultural production in the national economy. Better economic returns from citrus has encouraged many growers to look for better adapted and high yielding varieties. To achieve the growers' demands and to improve the citrus industry, several research programs have been initiated in

Sudan (Sidahmed and Genief, 1984). The central region, with its large resources of water and arable land, is considered ideal for additional citrus expansion (Sidahmed and Genief, 1984). The research on grapefruit was initiated several years back for cultivar evaluation. The research efforts over the years had culminated in identifying grapefruit cultivars with high yield capacity and excellent quality.

Materials and Methods

Four early introduced and locally adapted (Foster, White, Duncan, Marsh seedless) and nine newly introduced (Miami, Brown, Red Blush, Shamber, Little River, Carpenter Marsh, Frost Marsh, Howell, Davis seed-

1. Corresponding author : Present address, P.O. Box 439, PC III, Muscat, Sultante of Oman.

less) grapefruit cultivars, budded to a sour orange (*Citrus aurantium* L.) rootstock, were evaluated under ecological conditions of central Sudan at Sennar Horticultural Research Station (Lat. 13° 14'N, Long. 33° 34'E). The soil was non-saline, dark-gray calcareous clays with a clay content of 57%, having pH 8.5 and cation exchange capacity of 55 mg per 100 g soil. The climatic data of the area is presented in Table 1. The experimental design was a randomized complete block, replicated 5 times with 3 trees per plot. The spacing between trees was 8x8 m. Irrigation water was applied at a fortnight interval except during the rainy season (July-October). During rainy season irrigation water was applied only when necessary.

The canopy volume was measured according to Wutscher and Shull (1972) to serve as an index for tree growth, together with stem girth. The yield of the different cultivars was determined annually on the basis of both fruit number and weight per tree and the projected yield per hectare was assessed thereafter.

Results and Discussion

Growth

The trunk girth and canopy volume were determined to serve as an index for vegetative growth and yield efficiency of grapefruit cultivars. Significant differences ($P = 0.05$) in canopy volume were observed between the cultivars. The observations (Tables 2 and 3) that the newly introduced cultivars were more vigorous than the locally

adapted ones was in agreement with Sidahmed and Genief (1984), Khalil (1985) and Hamid *et al.* (1993, 1995). The trunk girth of varieties Foster, Duncan and Marsh seedless was below 38 cm, while that of the newly introduced cultivars ranged from 42.5 to 49.0 cm with Frost Marsh recording the lowest and Red Blush the highest trunk girth (Table 2). The canopy volume (Table 3) of the locally adapted cultivars ranged from 20.2 to 24.3 m³, while in newly introduced cultivars, it was 38.0 to 51.7 m³. The newly introduced cultivars were nucellar line selections, associated with juvenility, and thus were more vigorous and slower to begin bearing (Sidahmed and Genief, 1984; Hamid *et al.*, 1993). Levy *et al.* (1978) reported that tree vigor and growth cycle varied mainly due to temperature and humidity regimes. In this study, heavy vegetative flushes were observed during winter season (October-March), prior to and during flower induction, and during the rainy season (July-September). These flushes were induced by the mild winter temperatures and high relative humidity during the rainy season (Table 1). During April, May and June, when maximum temperature is always above 40°C, vegetative growth virtually ceased. Subjecting citrus trees to unfavorable high (40°C) temperature conditions would cease tree growth (Reuther, 1977 and Khalil, 1985). The canopy volume (Table 3) obtained for all cultivars under investigation were greater than those reported by Wutscher and Shull (1972) and Levy *et al.* (1978) in the U.S.A. and Israel, respectively, indicating the favorable effect of the climatic and ecological conditions of central Sudan on grapefruit tree growth.

Table 1. Meteorological data at Sennar (average for past 30 years)

Months	Air temperature (°C)			Relative humidity (%)			Rainfall (mm)
	Maximum	Minimum	Mean	At 6 am	At noon	Mean	
January	34	15	24.5	37	17	27.0	0.0
February	36	16	26.0	33	15	24.0	0.0
March	39	19	29.0	26	13	19.5	1.0
April	41	22	31.5	24	12	18.0	1.0
May	41	25	33.0	35	16	25.0	13.0
June	39	24	31.5	52	23	37.5	63.0
July	35	22	28.5	69	33	51.0	134.0
August	33	20	26.5	73	40	56.5	162.0
September	35	22	28.5	69	36	52.5	361.0
October	37	22	29.5	38	27	32.5	25.0
November	37	20	28.5	38	20	29.0	0.0
December	34	16	25.5	39	20	29.5	0.0

Source: Sennar Meteorological Station.

Flowering

The cultivars, Foster, Duncan, White and Marsh seedless, attained flowering and fruiting stages earlier than the newly introduced cultivars. They started sporadic flowering at the age of 4 and all of them were in bearing after 5 years of planting (Table 2). The newly introduced cultivars, Howell, Little River, Brown, Red Blush, Shamber and Carpenter Marsh did not flower at the age of 5 and were considered as late bearers (Table 2). Two blooming peaks, a major peak with heavy bloom during the winter season (December-March) and a minor one during the rainy season (July-September), were observed during the growing season. The winter bloom accounted for the main crop, while the minor fall bloom partially abscised, resulting in very low yield and were not considered in this study. This observed

blooming habit was in agreement with Reuther and Rios-Castano (1969) who reported that in tropical climates with no appreciable chilling periods and ample soil moisture, either due to rainfall or supplemental irrigation, most citrus species produced some blooms in every month, but generally tended to produce three or four major, and an equal number of lesser bloom flushes annually. With orange, grapefruit and mandarin varieties in most of the U.S.A. citrus regions, small blooms are common in summer or fall setting fruits which ripen later than the main spring bloom fruits (Reuther, 1973).

Yield

The data on yield of all cultivars over three cropping seasons, i.e., the 1st, 4th and 6th cropping seasons, corresponding to a tree age of 5, 9 and 11 years after

Table 2. Yield and trunk girth of different grapefruit cultivars during the first and the fourth cropping seasons

Cultivar	First cropping season				Fourth cropping season			
	Yield/tree*		Average fruit wt. (g)	Trunk girth (cm)	Yield/tree		Average fruits wt. (g)	Projected yield (t/ha**)
	No. of fruits	Wt. of fruits (kg)			No. of fruits	Wt. of fruits (kg)		
Foster	760	442.2	555.5	37.75	211	93.55	443.4	14.59
Duncan	388	172.4	444.3	37.22	253	119.70	473.3	18.67
White	286	86.0	300.7	42.70	203	93.63	461.1	14.60
Marsh seedless	220	70.4	320.0	35.68	150	57.27	381.8	8.93
Frost Marsh	46	15.5	336.9	42.50	145	67.70	466.9	10.56
Davis seedless	32	20.9	655.5	44.77	218	95.84	439.6	14.95
Miami	9	4.2	466.6	48.66	164	74.90	456.7	11.68
Carpenter Marsh	3	1.1	350.0	46.00	159	71.30	448.4	11.12
Shamber	2	0.8	400.0	43.44	106	62.08	614.0	10.15
Red Blush	2	0.8	400.0	49.00	150	79.79	531.9	12.45
Brown	0	0.0	0.0	48.44	145	60.78	419.2	9.48
Litte River	0	0.0	0.0	44.66	143	52.12	364.4	8.13
Howell	0	0.0	0.0	42.60	61	47.45	778.6	7.40

* Total of 5 replicates of 3-tree plots.

**Number of trees/ha = 156.

planting, are presented in Tables 2 and 3. The yield was low at earlier cropping seasons and the locally adapted cultivars out yielded the introduced ones. The yield progressively increased over the years and by the 6th cropping season (11 years after planting) the trees apparently reached their full cropping capacity and the newly introduced cultivars started to excel the adapted local ones (Table 3). This could be explained on the basis that the newly introduced cultivars were nucellar line selections exhibiting juvenile characteristics of vigorous growth and late bearing ability compared to old adapted local cultivars. Furthermore, the large canopy volume (Table 3) of the newly introduced cultivars resulted in more photosynthates that sus-

tained large number of flowers and fruits. Good correlation between canopy volume and yield was reported by several investigators (Levy *et al.*, 1978; Sidahmed and Genief, 1984; Hamid *et al.*, 1993, 1995). No alternate bearing phenomenon was observed during this period. Levy *et al.* (1978) also did not detect regular alternate bearing pattern on 12-year-old grapefruit trees. The high yield obtained during the 6th cropping season (Table 3) is conceivable since all trees approached the age of maximum productivity. At this stage, significant differences in yield were not observed among various cultivars. However, Miami numerically out yielded all cultivars in both number and weight of fruits produced, while Marsh seedless trailed all of them. The yield per

Table 3. Yield, canopy volume and tree efficiency of different grapefruit cultivars during the 6th cropping season

Cultivar	Canopy* volume (m ³)	Yield*			Projected** yield (t/ha)
		No. of fruits/plant	Fruit (kg/tree)	Canopy (kg/m ³)	
Marsh seedless	20.21 a	318	141.63	7.00 ab	22.09
Little River	29.69 ab	411	156.75	5.29 ab	24.43
Davis seedless	38.05 abc	505	179.33	4.71 ab	27.98
Frost Marsh	40.13 abc	418	181.04	4.51 a	28.24
Foster	20.91 a	397	186.74	9.93 c	29.31
Howell	48.04 bc	393	190.54	3.97 a	29.72
Duncan	21.10 a	485	198.76	9.41 c	31.01
Carpenter Marsh	51.73 c	438	218.06	4.21 a	32.77
Shamber	50.24 c	505	212.84	4.24 a	33.20
Red Blush	49.50 bc	529	213.89	4.32 a	33.37
White	24.30 a	480	216.48	8.90 cb	33.77
Brown	41.25 abc	545	228.58	5.54 ab	35.66
Miami	48.32 bc	565	261.80	5.41 ab	40.81
		NS	NS		

* Within a column means with a letter in common do not differ significantly according to Duncan's multiple range,

NS = No significant difference,

** At the spacing of this experiment the number of trees/ha = 156.

unit canopy volume showed that cultivars Foster, Duncan, White and Marsh seedless used the space they occupy more efficiently than the newly introduced cultivars. The yield per metre cube canopy volume ranged from 7.0 to 9.9 kg for the local adapted cultivars and from 3.9 to 5.5 kg for the newly introduced cultivars (Table 3).

Commercial yields for citrus in the tropics were reported to be well below those of subtropics, with an average yield of 12.8 t ha⁻¹ in Trinidad (Reuther, 1977; Samson, 1986), 10.7 t ha⁻¹ in Jamaica (Samson, 1986) and 13.0 t ha⁻¹ in Ethiopia (Haile-Mariam, 1983). The yield (Table 3) obtained during the 6th cropping season of

this study (22.4 to 40.8 t ha⁻¹) compared well with the yield (30.7 to 44.0 t ha⁻¹) reported for Florida grapefruit (Reuther, 1977). Given that grapefruit trees in Florida reached their maximum productivity at the age of 28 to 34 years (Sinclair, 1972; Hamid *et al.*, 1993), while the trees under the current investigation were only 11 years old, further improvement in yield could be expected with age, provided optimum cultural practices are adopted. Moreover, the cultivar Miami gave a high yield of 40.8 t ha⁻¹ and the yield of six other cultivars were above 30 t ha⁻¹.

The spacing (8x8 m) used in this study was fairly wide and resulted in a reduced

plant population of 156 trees per hectare. High early yields than these could be obtained if spacing is reduced, especially in the case of the local adapted cultivars with small canopy volumes. Levy *et al.* (1978) reported yields of 70 t ha⁻¹ at a tree spacing of 6x6 m. These yields, obtained without regular fertilization or crop protection measures, reflected the potentiality of the central clay plains of the Sudan for commercial production of grapefruit.

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