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EFFECT OF TREE SPACING ON GROWTH AND FRUIT PRODUCTION OF SOME NEW CITRUS CULTIVARS IN EGYPT

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ABSTRACT

'Hernandina' clementine, 'Clemenules' clementine and 'Nova' mandarin budded on sour orange rootstock were produced in a screenhouse and planted in the field under drip irrigation system during October 1999 in a private orchard at "Wady El-Mullak" region, Ismailia Governorate (Latitude, 30°36' N; longitude, 32°14' E; Altitude, 10 m above sea level), which is one of the largest citrus production region in Egypt. All cultivars were planted at 2 x 5 m and 5 x 5 m. Annual fruit production, cumulative and average yields per tree and per feddan were estimated during five seasons, starting from 3rd year after planting (YAP) to 7th YAP (2006/2007). Tree height, canopy diameter and circumference, tree volume, and trunk girth were determined in the 6th and 7th YAP.

Trees planted at 2 x 5 m were the tallest, but the canopy diameter and circumference, and volume of trees planted at 5 x 5 m were the largest. On the other hand, trees of 'Nova' mandarin had the lowest canopy diameter and circumference, while 'Clemenules' clementine trees had more height and volume.

Initial yields per tree (3rd and 4th YAP) from planting spacing of 2 x 5 m were higher than those from the wide spacing, but starting from 5th to 7th YAP the situation was inverted. Cumulative yield for the first 5 years of production and the average annual yield per tree revealed the superiority of the wide spacing. On the contrary, the yield per feddan (4200 m^2) from trees planted at 2 x 5 m was about 454%, 221%, 137%, 76% and 90% greater than those planted at 5 x 5 m in the 3rd, 4th, 5th, 6th and 7th YAP, respectively. Cumulative yield per feddan from closely planted trees was 40 t (117%) more than from widely spaced.

'Hernandina' clementine produced more yields in the 3rd and 4th YAP compared with other cultivars; while 'Clemenules' clementine was the highest in the 5th YAP. 'Nova' mandarin produced the highest yield in the 7th YAP, while in 6th one were statistically similar to those of 'Hernandina', which produced the highest yield. Cumulative and average annual yield per tree indicated that 'Hernandina' and 'Nova' cultivars were more productive than 'Clemenules' under the conditions of this study. On the other hand, 'Clemenules', 'Hernandina' and 'Nova', as new citrus cultivars in Egypt performed satisfactory in a high-density planting (2 x 5 m) through 7 year after planting, despite of 'Nova' mandarin was the most excellent, followed by 'Hernandina' and 'Clemenules' (cumulative yields were 82, 71 and 68 t/feddan, for the three cultivars, respectively); and could continue until the productivity per feddan decrease compared to normal spacing.

Key words: *citrus, clementine, cultivars, planting density, tree growth tree spacing, yields,.*

1. INTRODUCTION

Citrus production must provide a rapid recovery of investment capital in order to provide maximum average net returns. Generally, closely-planted groves provide greater and earlier returns, and better management (Tucker *et al.*, 1994 and Wheaton *et al.*, 1995b). By facilitating more efficient fertilizer uptake from root systems and better spray interception of crop protection chemicals by tree canopies, higher density plantings provide earlier returns on investment and can help reduce energy use. One advantage of closely spaced and hedgerow systems is that they develop bearing volume more rapidly (Parsons and Wheaton, 2006).

Xian *et al.* (1994) reported that the ideal planting density is 2250 - 3000 trees/ha for 'Ponggan' mandarin; while Wheaton *et al.* (1995a) recommended planting densities of 350 to 1000 trees/ha for oranges in Florida. Furthermore, QingSheng and ShinXian (2002) suggested planting density not less than 1995 trees/ha for

'Washington Navel' orange. However, Nasir *et al.* (2006) found that planting density of 7.0 x 7.0 m for grapefruit performed better, while the planting distance of 3.5 x 3.5 m ranked last.

Yield of 'Hamlin' and 'Valencia' oranges was increased with increasing tree density (370–889 trees/ha) during the early years of production, while for tree ages 9 to 13 years there was no consistent relationship between yield and tree density (Wheaton *et al.*, 1995a). During the first 8 years, tree vigor was unimportant and production increased as tree density increased (150 - 360 trees/acre) for 'Hamlin' and 'Valencia' oranges. Trees of low vigor never fill their allocated space and thus never generate maximum economic returns if planted at wide spacing (Wheaton *et al.*, 1995b).

Tree spacing must reflect the tree vigor of a particular variety and rootstock combination as well as site, environment, and management (Wheaton *et al.*, 1995b). Because of the lack of research information about the performance of citrus trees in a high density planting under the Egyptian conditions, the present study was undertaken to compare the effect of two tree spacing on the growth and yield of 'Clemenules' and 'Hernandina' clementine's and 'Nova' mandarin as newly introduced cultivars to Egypt (Bassal, 2001), budded on sour orange as the common rootstock, in an attempt to fill allotted tree space quicker and to obtain economic yields earlier in the lifespan of the orchard.

2. MATERIALS AND METHODS

Trees of three new clementine and mandarin hybrid cultivars namely: 'Hernandina' (*Citrus clementina* Hort. ex Tan.), 'Clemenules' (*C. clementina* Hort. ex Tan.) and 'Nova' mandarin [*C. clementina* Hort. ex Tan. x Orlando Tangelo (*C. reticulata* Blanco *x C. paradisi* Macf.)], budded on sour orange rootstock were produced in a screenhouse as previously described by Bassal (2009).

Uniform 1-year-old trees of each cultivar were planted in the field (sandy soil) under drip irrigation system during October 1999 in a 3 feddans site of a private orchard at 'Wady El-Mullak' region, Ismailia Governorate (Latitude, 30°36' N; longitude, 32°14' E; Altitude, 10 m above sea level), which is one of the largest citrus production region in Egypt. All cultivars were planted at two spacing; *i.e.*, 2 x 5 m and 5 x 5 m, providing tree densities of 400 and 160 trees per feddan, respectively. Field plots were two rows x forty five trees with the center twelve trees (two rows x six trees) per each cultivar in every planting density chosen and labeled for data collection. The experiment was arranged in a randomized complete blocks design with four-trees/plot and three replicates (Steel *et al.*, 1997).

Trees were planted in north-south rows as part of a commercial grove. A regular commercial young tree care program was followed for the first 2 years, which included fertilizing on an individual tree basis. Beginning with year 3, fertilizer and foliar pesticides were applied uniformly on a land area basis. Thus, trees at different spacing all received water, fertilizer, and pest management on a land area basis, not on a per tree basis. Fertilizer was applied at recommended rates by Egyptian Ministry of Agriculture. Regular annual light manual pruning after fruit harvesting was begun in the 3^{rd} year after planting (YAP) to maintain the tree natural shape and facilitate the light penetration.

In February of 6^{th} and 7^{th} YAP (2005/2006 and 2006/2007), tree height, canopy diameter in the two tree directions (to obtain the average diameter), canopy circumference, trunk girth at 15 cm above the budding union, were measured. The canopy volume (m^3) was calculated according to Wutscher (1995) as follows.

Tree volume = (Tree diameter ^{2} x Tree height)/4

In each season, starting from 3^{rd} YAP (2002/2003) to 7^{th} YAP (2006/2007), at harvest time, the weight of harvested fruits per tree was recorded. The annual fruit productions, cumulative and average yields per tree and per feddan were estimated during five seasons.

Statistical analysis: The experimental design was randomized complete blocks with a split-block experiment (Steel *et al.*, 1997). Analysis of variance, with tree spacing as the main plot and cultivar as the subplot, and means comparison (LSD, $P<0.05$) were performed using MSTAT-C statistical package (M-STAT, 1990).

3. RESULTS AND DISCUSSION

3.1- Vegetative growth

3.1.1. Canopy diameter and circumference:

Cultivars were statistically different, whereas trees of 'Nova' mandarin had the lowest canopy diameter and circumference as compared with those of 'Hernandina' and 'Clemenules' clementine's in the 6^{th} and 7^{th} YAP, despite of the data of tree circumference in the 7^{th} YAP which failed to show significant differences (Table 1). No significant differences were noticed between 'Hernandina' and 'Clemenules' in this respect. On the other hand, the tree spread responded

Table (1): Effect of tree spacing on vegetative growth parameters of some new citrus cultivars in Egypt

Cultivars	Growth Parameters														
	Canopy diameter (m)			Tree height (m)			Tree volume (m^3)			Canopy circum. (m)			Trunk girth (cm)		
	Tree spacing			Tree spacing			Tree spacing			Tree spacing			Tree spacing		
	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean
6th YAP															
Nova	3.20	2.98	3.09	2.81	3.40	3.10	7.20	7.56	7.38	8.79	7.77	8.28	38.67	37.00	37.83
Hernandina	3.70	3.01	3.36	2.66	2.92	2.79	9.10	6.61	7.86	10.80	8.83	9.82	39.17	36.50	37.84
Clemenules	3.87	3.04	3.46	3.10	4.15	3.63	11.58	9.61	10.60	10.62	8.92	9.77	37.83	37.33	37.58
Mean	3.59	3.01		2.86	3.49		9.29	7.93		10.07	8.50		38.56	36.94	
LSD 5% for cultivar		0.13			0.08			0.61			0.52			NS	
LSD 5% for spacing		0.46			0.23			NS			0.17			NS	
LSD 5% for interaction		0.33			0.23			1.17			0.46			NS	
7th YAP															
Nova	3.58	3.24	3.41	3.20	3.90	3.55	10.28	10.24	10.26	10.63	9.26	9.95	41.67	41.00	41.33
Hernandina	4.13	3.30	3.72	3.08	3.70	3.39	13.16	10.07	11.62	11.83	9.15	10.49	41.66	40.50	41.08
Clemenules	4.17	3.30	3.73	3.50	4.45	3.98	15.18	12.12	13.65	11.00	9.51	10.26	41.50	40.33	40.92
Mean	3.96	3.28		3.26	4.02		12.87	10.81		11.15	9.31		41.61	40.61	
LSD 5% for cultivar		0.16			0.17			0.93			NS			NS	
LSD 5% for spacing		0.25			0.13			1.76			0.25			NS	
LSD 5% for interaction		0.28			NS			1.70			NS			NS	

positively to tree spacing, whereas the trees planted at 5 x 5 m showed canopy diameter and circumference significantly higher than those planted at 2 x 5 m in the 6th and 7th YAP, probably due to the wider space between the trees in the row, and the trees in close spacing filled their allotted spaces early.

The interaction between the cultivars and tree spacing was significant in both seasons for canopy diameter, where trees of 'Hernandina' and 'Clemenules' in the wide spacing had higher diameter than those of 'Nova', while in the close spacing no significant differences were found among the three cultivars.

In this respect, results over 8 years of RongFu (1997) on 'Ponggan' mandarin indicated that the canopy of trees in wide spacing was larger than those in close one, while Nasir *et al.* (2006) found that grapefruit tree spread did not respond to planting distance. On the contrary, Stuchi *et al.* (2003) reported that trees of 'Tahiti' lime planted in the 4 x 1 m planting space had greater canopy diameters than those planted with other planting spaces (4 x 1.5 m, 4 x 2 m and 4 x 2.5 m).

3.1.2. Tree height: For 6th and 7th YAP, 'Clemenules' trees were significantly higher than those of 'Hernandina' and 'Nova' (Table 1). In the 6th YAP, the trees of 'Hernandina' were significantly shorter than those of 'Nova', but had statistically equal height in the 7th YAP.

Tree height was significantly affected by planting density, where trees planted at 2 x 5 m were significantly higher than those planted at 5 x 5 m in both seasons of this study; this was perhaps due to light competition and less space for spreading.

The interaction of tree spacing x cultivars was significant in the 6th YAP only, whereas trees of 'Clemenules' in the close spacing were the highest, while those of 'Hernandina' in the wide spacing were the shorter.

The present results fully support the finding of Nasir *et al.* (2006), who observed that grapefruit trees closely planted (3.5 x 3.5 m) were higher than those in wider spacing (7 x 3.5 m and 7 x 7 m), while Stuchi *et al.* (2003) stated that the tree height of 'Tahiti' lime was not affected by the planting spaces.

3.1.3. Tree volume: Trees of 'Clemenules' had significantly higher volume as compared with those of 'Hernandina' and 'Nova' in the 6th and 7th YAP (Table 1). On the other hand, trees of 'Hernandina' showed higher volume than those of 'Nova' in the 7th YAP, but in the 6th YAP, both had statistically equal volume.

Trees planted at 5 x 5 m were larger in volume than those planted at 2 x 5 m in both seasons, although the differences in the 6th YAP failed to attain significance. On the other hand, when the total canopy volume per feddan was calculated, close plantation was the highest due to the higher number of trees per feddan, indicating that the bearing volume was also higher, because when trees are small or in a narrow hedgerow, the total canopy volume may be considered to be productive (Parsons and Wheaton, 2006).

The interaction of tree spacing x cultivars for tree volume was significant in both seasons due to different response of each cultivar to the tree spacing. Trees of 'Nova' mandarin was not affected by the tree spacing in both seasons, while those of 'Clemenules' and 'Hernandina' were positively affected by the planting spaces.

These results are in harmony with those of Rodríguez *et al.* (2004), who found that citrus tree growth was lower at short distances in comparison with greater planting distances. On the contrary, Intrigliolo *et al.* (1994) mentioned that 'Valencia' orange trees planted at closer spacing (5 x 3 m) gave the largest canopy, compared with the standard spacing of 6 x 4 m.

3.1.4. Trunk girth: All cultivars had statistically similar trunk girth in the 6th and 7th YAP. Also, the tree trunk girth was not affected by tree spacing. The non significant effect of tree spacing on the trunk diameter indicated that the competition among trees at the closer spacing was nil until 7th YAP. According to Whitney *et al.* (1991), water use and root concentration per unit of land area for 7- and 8-year-old trees were similar for the lowest and highest tree densities. These results are in contrast with the finding of Nasir *et al.* (2006) on grapefruit, who reported that stem girth in the 4th YAP did not respond to tree spacing, but at 5th and 6th YAP it increased with increasing the tree spacing. On the other hand, Wheaton *et al.* (1995a) mentioned that trunk diameter of 'Valencia' and 'Hamlin' oranges on Milam rootstock was smaller with increasing tree density.

3.2. Fruit yield

3.2.1. Fruit yield per tree:

Generally, yield increased rapidly during the first four seasons of production, but declined during the 5th one (7th YAP). Largest yields were obtained during 4th season when trees were 6 year old (Table 2).

'Hernandina' trees significantly produced higher yields in the 3rd and 4th YAP as compared with those of 'Clemenules' and 'Nova' cultivars; this means that trees of 'Hernandina' were

Table (2): Effect of tree spacing on tree fruit production of some new citrus cultivars in Egypt

Cultivars	Yield (Kg/tree)																				
	3rd YAP			4th YAP			5th YAP			6th YAP			7th YAP			Cumulative yield			Average annual yield		
	Tree spacing			Tree spacing			Tree spacing			Tree spacing			Tree spacing			Tree spacing			Tree spacing		
	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean
Nova	7.6	12.8	10.2	17.5	24.9	21.2	29.7	31.5	30.6	82.7	71.2	76.9	65.8	64.0	64.9	203.3	204.4	203.8	40.7	40.9	40.8
Hernandina	9.8	18.9	14.4	30.8	26.7	28.8	33.1	32.9	33.0	112.5	54.0	83.2	51.9	45.7	48.7	238.1	178.1	208.1	47.6	35.6	41.6
Clemenules	4.0	14.0	9.0	10.8	25.8	18.3	42.3	35.5	38.9	62.8	57.4	60.1	74.9	37.3	56.1	194.9	169.9	182.4	39.0	34.0	36.5
Mean	7.1	15.2		19.7	25.8		35.0	33.3		86.0	60.9		64.2	49.0		212.1	184.2		42.4	36.8	
LSD 5% for cultivar			1.92			2.94			1.89			8.99			1.19			11.14			2.23
LSD 5% for spacing			2.52			3.80			1.38			7 74			1.74			13.79			2.76
LSD 5% for interaction			2.64			5.15			3.94			11.93			5.65			5.89			1.19

introduced in production early. 'Clemenules' trees showed the highest yield in the 5th YAP only, and 'Nova' trees had the highest yield in the 7th YAP, while in 6th one were statistically similar to those of 'Hernandina', which produced the highest yield. On the other hand, 'Nova' and 'Clemenules' trees were somewhat regular in production; while 'Hernandina' trees showed alternate bearing, especially in the 7th YAP.

Closely spaced (2 x 5 m) trees significantly produced higher yield in the 3rd and 4th YAP. Their fruit yield was 114% and 27% greater than those wide spaced (5 x 5 m) trees, in both seasons, respectively. This is probably because the trees in close spacing developed bearing volume more rapidly (Parsons and Wheaton, 2006). In addition, Wheaton *et al.* (1991) reported that many citrus scion/stock combinations will develop a canopy of 2 m in diameter and 2.5 m high through 3 - 5 years. With trees of these dimensions, the entire canopy theoretically should be bearing volume. Starting from 5th YAP to 7th YAP the attitude was inverted, where the trees in the wide spacing (5 x 5 m) produced significantly higher yields; about 5%, 41% and 31% over those in closer planting in the three seasons, respectively.

These results are in harmony with those obtained by RongFu (1997) on 'Ponggan' mandarin, who observed that the yields for the closely spaced trees were higher in the first 2 bearing years than that for the wider spacing, but from the fifth year of bearing the yield was higher for the wider spacing. In addition, Tribulato *et al.* (1994) stated that 'Navelina' orange at 1200 trees/ha (504 trees/feddan) produced the same yield/tree as those planted at 416 trees/ha (175 trees/feddan) in the first 3 years, but from 6 years onwards yield was reduced due to the trees competition. However Intrigliolo *et al.* (1994) reported that the mean yield/tree of 'Valencia' orange was higher in trees at the closer spacing (5 x 3 m). On the contrary, Rodríguez *et al.* (2004) found that citrus tree production was lower at short distances in comparison with greater planting distances, and Nasir *et al.* (2006) mentioned that trees of grapefruit in wider spacing (7 x 7 m) produced higher yields during the first 3 years of production than those in the close spacing (7 x 3.5 and 3.5 x 3.5 m).

Cumulative yield for 5 years and the average annual yield/tree were significantly lower for 'Clemenules' cultivar as compared with 'Nova' and 'Hernandina' cultivars, which were statistically similar in this respect (Table 2). On the other hand, trees planted at 5 x 5 m had significantly higher cumulative and average annual yield/tree (about 15% greater than those planted at 2 x 5 m). On the contrary, Intrigliolo *et al.* (1994) reported that 'Valencia' orange trees planted at 5 x 3 m spacing gave the highest cumulative yield/tree as compared with other spacing (6 x 4, 6 x 4 x 2 and 5 x 2.5 m).

The interaction of tree spacing x cultivars was significant for fruit yield in all seasons and for the cumulative and the average annual yield/tree. 'Nova' mandarin was not affected by the tree spacing starting from the 5th YAP, whereas the annual fruit production and the cumulative yield per tree were statistically equal in both spacing (Table 2). On the contrary, 'Clemenules' and 'Hernandina' cultivars were more affected by the tree spacing, where the cumulative yield/tree in the wide spacing was significantly higher than that in the close spacing, for both cultivars. The trees of 'Hernandina' clementine in the wide spacing had the highest cumulative yield per tree (283.1 kg/tree), while the lowest one was showed by 'Clemenules' trees in the close spacing (169.9 kg/tree).

3.2.2. Fruit yield per feddan:

Fruit production per feddan had the same trend of fruit production per tree for all cultivars because the production per feddan depends on the tree yield (Table 3).

The production per feddan increased gradually during the first four years, regardless of the tree spacing, and the highest yield was obtained in the forth year when trees were 6-year-old (24.3 and 13.8 ton/feddan in the close and wide spacing, respectively), then decreased in the next year, may be due to the alternate bearing. Wheaton *et al.* (1991) reported that yield of citrus trees in high density planting (1.5 x 3.3 m) increased rapidly during the first three seasons but was reduced during the 4th year and the largest yields were obtained when trees were 7-years-old.

Trees planted at 2 x 5 m produced significantly higher yields per feddan through the first five years of production as compared with those planted at 5 x 5 m. In the first season of production (3rd YAP), the yield from higher density planting was about 454% greater than that from lower density. The difference in production between the two planting densities was decreased with tree age, whereas the increment in production in the closely planted trees was about 221%, 137%, 76% and 90% in 4th, 5th, 6th and 7th YAP, respectively. This productivity increment in the closely planting was a result of the higher number

Table (3): Effect of tree spacing on fruit production (ton/feddan) of some new citrus cultivars in Egypt

Cultivars	Production (t/feddan)																				
	3rd YAP			4th YAP			5th YAP			6th YAP			7th YAP			Cumulative yield			Average annual yield		
	Tree spacing			Tree spacing			Tree spacing			Tree spacing			Tree spacing			Tree spacing			Tree spacing		
	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean	5 x 5	2 x 5	Mean
Nova	1.2	5.1	3.2	2.8	9.9	6.4	4.8	12.6	8.7	13.2	28.5	20.9	10.5	25.6	18.1	32.5	81.8	57.1	6.5	16.4	11.4
Hernandina	1.6	7.6	4.6	4.9	10.7	7.8	5.3	13.2	9.2	18.0	21.6	19.8	8.3	18.3	13.3	38.1	71.3	54.7	7.6	14.3	10.9
Clemenules	0.6	5.6	3.1	1.7	10.3	6.0	6.8	14.2	10.5	10.1	23.0	16.5	12.0	14.9	13.5	31.2	67.9	49.6	6.2	13.6	9.9
Mean	1.1	6.1		3.2	10.3		5.6	13.3		13.8	24.3		10.3	19.6		33.9	73.7		6.8	14.7	
LSD 5% for cultivar			0.54			0.88			0.32			2.62			0.63			2.98			0.60
LSD 5% for spacing			0.81			1.60			0.49			2.24			0.31			5.19			1.04
LSD 5% for interaction			0.90			NS			NS			3.92			1.78			2.36			0.47

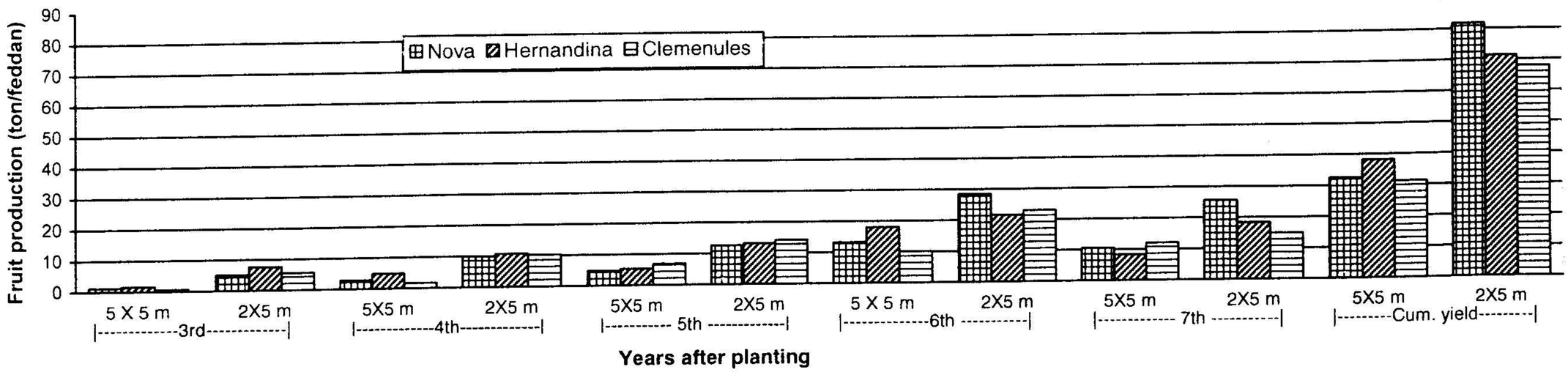

Fig. (1): Effect of tree spacing (5 x 5 m and 2 x 5 m) on annual and cumulative fruit production (3rd to 7th YAP) of Nova, Hernandina and Clemenules cultivars.

of trees per feddan (higher canopy volume, otherwise bearing volumes).

This trend is in accordance with the finding of Gallasch (1983) on 'Washington Navel' orange, who mentioned that at six years, the yield/ha from closely planted trees was 121% greater than from widely spaced. Also, Whitney *et al.* (1991) found that fruit yields/ha of 'Hamlin' orange were greater for the 4.5 x 2.5 m spacing in the early years; were comparable for both spacing during the 7^{th} and 8^{th} YAP, and favored the 6 x 4.5 m spacing in the 9^{th} year. In addition, Intrigliolo *et al.* (1994) showed that 'Valencia' orange trees in closer planting (5 x 2.5 m) produced a 123% increase in yield/ha compared with standard spacing. On the other hand, Rodríguez *et al.* (2004) reported that the yield of citrus trees was increased proportionally to the increase in the number of trees per unit of area during the first years, and later went similar or superior to those obtained at shorter distances.

Cumulative yield per feddan for first 5 years of production (tree age 3 to 7 years) from trees planted at 2 x 5 m was about 40 t (117%) more than that from those planted at 5 x 5 m. Average annual yield per feddan (Table 3) reached to 14.7 t/feddan in closely planted trees, about 8 t over that in widely spaced trees annually.

On the other hand, the interaction of tree spacing x cultivars was significant for fruit production per feddan in the 3^{rd}, 5^{th} and 7^{th} YAP and for the cumulative and the average annual yield/feddan. The response of the cultivars to planting spacing were different, where data of the cumulative yield/feddan indicated that 'Nova' mandarin was the most excellent in the narrow spacing, while 'Hernandina' was the best in the wide spacing, and 'Clemenules' had the lowest cumulative yield/feddan (Fig 1).

Tribulato *et al.* (1994) found that the cumulative yield of 'Navelina' orange after 13 years in high-density planting was 71% over that in normal density (416 trees/ha; or 175 trees/feddan), also 'Tarocco' orange in high-density planting (832 trees/ha; or 349 trees/feddan) after 5 years produced 36% higher yield than that in normal density (416 trees/ha), while for lemons, cumulative yield over 4 years from high-density planting was 115% higher than from normal density. Also, average annual yield (t/ha) for the first 5 years of production increased substantially with increasing tree density (Wheaton *et al.*, 1995a, on oranges). In addition, Stuchi *et al.* (2003) found that average fruit yield/ha of 'Tahiti' lime trees over 3 years in close space planting was 65% greater than those in wider space planting.

Conclusions:

The growers look for earlier net returns on their investment. The obtained results in this study showed that the trees planted at 2 x 5 m produced from 5 to 10.5 t per feddan annually greater than those planted at 5 x 5 m through 7 years. This productivity increment in the closely planting was due to the higher trees number per feddan (higher canopy volume, otherwise bearing volumes). This means that the growers can obtain about 117% annually over economic return from the same land area with, approximately the same cost of production.

On the other hand, 'Clemenules', 'Hernandina' and 'Nova', as new citrus cultivars in Egypt performed satisfactory in a high-density planting (2 x 5 m) through 7 year after planting, despite of 'Nova' mandarin was the most excellent followed by 'Hernandina' and 'Clemenules' (cumulative yields were 82, 71 and 68 t/feddan, for the three cultivars, respectively); and could continue until the productivity per feddan decrease compared to normal spacing.

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تأثير مسافات الزراعة على نمو وإثمار بعض أصناف الموالح الجديدة في مصر

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ملخص

يهدف هذا البحث إلى الحصول على أعلى عائد اقتصادي خاصة في السنوات الأولى من عمر المزرعة من ثلاثة أصناف من الموالح الجديدة في مصر هي: إرناندينا – كليمينولس – نوفا وذلك عن طريق زيادة كثافة الزراعة. أجريت هذه الدراسة في مزرعة خاصة بمنطقة وادي الملاك بمحافظة الإسماعيلية. حيث تم إنتاج شتلات من هذه الأصناف على أصل النارنج تحت الصوب.

في أكتوبر ١٩٩٩ تم زراعة شتلات متجانسة عمر سنة من هذه الأصناف في الأرض المستديمة على مسافتي زراعة هما ٢ x ٥ م (٤٠٠ شجرة/فدان) و٥ x ٥ م (١٦٠ شجرة/فدان) تحت ظروف الري بالتنقيط. وقد خضعت جميع الأشجار لنفس المعاملات الزراعية.

بدءاً من السنة الثالثة وحتى السنة السابعة بعد الزراعة (٢٠٠٢/٢٠٠٣ – ٢٠٠٦/٢٠٠٧) تم تقدير محصول الأشجار سنويا عند الجمع وتم حساب المحصول التراكمي لمدة ٥ مواسم متتالية وكذلك متوسط المحصول السنوى على مستوى الشجرة والفدان. أيضا تم اخذ قياسات النمو الخضرى للأشجار (الارتفاع – القطر – المحيط – الحجم – محيط الجذع) في السنة السادسة والسابعة من الزراعة.

وكانت أهم النتائج المتحصل عليها ما يلي:

- كانت الأشجار المنزرعة على ٢ x ٥م الأكثر ارتفاعا ولكن كانت الأقل فى القطر والمحيط وكذلك الحجم. واختلفت الأصناف فيما بينها من حيث النمو الخضرى فكانت أشجار الصنف نوفا هي الأقل في كل من القطر والمحيط، بينما أشجار الكليمينولس كانت الأكثر ارتفاعاً والأكبر حجماً.
- كانت الأشجار المنزرعة على ٢ x ٥م الأعلى إنتاجاً في السنة الثالثة والرابعة من الزراعة (١٢ و ٢٦كجم/شجرة) مقارنة بتلك المنزرعة على ٥ x ٥م (٢٠.٧ كجم/شجرة)، ولكن بدءاً من السنة الخامسة وحتى السنة السابعة انعكس الوضع وتفوقت الزراعة الواسعة. أيضا المحصول التراكمي لمدة ٥ مواسم وكذلك متوسط محصول للشجرة أظهر تفوق الزراعة الواسعة بزيادة قدرها ١٥% تقريباً.
- كانت إنتاجية الفدان في الزراعة الكثيفة أعلى منها في الزراعة الأقل كثافة وذلك خلال جميع سنوات الدراسة، حيث كانت نسبة الزيادة حوالي ٤٥٤% ، ٢٢١% ، ١٣٧% ، ٧٦% ، ٩٠% في السنوات الثالثة والرابعة والخامسة والسادسة والسابعة بعد الزراعة على التوالي. أيضا المحصول التراكمي للفدان كان أعلى في الزراعة الكثيفة بحوالي ٤٠ طن/فدان (١١٧%) عنه في الزراعة الأوسع.
- أعطى الصنف إيرناندیا أعلى محصول في السنوات الثالثة والرابعة بعد الزراعة، بينما الكليمينولس كان الأعلى في السنة الخامسة والنوفا كان هوالأعلى إنتاجية في السنة السابعة بعد الزراعة أما فى السنة السادسة فلم يختلف معنويا عن الإيرناندیا الذى أعطى أعلى محصول. أيضا المحصول التراكمي لمدة ٥ مواسم وكذلك متوسط محصول الشجرة أظهرا أن الكليمينولس كان الأقل إنتاجية تحت ظروف هذه الدراسة.
- اما بالنسبة لسلوك الأصناف فى الزراعة الكثيفة (٢ x ٥م) فقد أعطى الصنف نوفا أعلى محصول تراكمى (٨٢ طن/فدان) تلاه فى ذلك الصنف إيرناندیا (٧١ طن/فدان) بينما الكليمينولس كان الأقل فى هذا الشأن (٦٨ طن/فدان).

على ضوء النتائج المتحصل عليها تحت ظروف هذه الدراسة ينصح بزراعة هذه الأصناف زراعة كثيفة للحصول على أعلى عائد اقتصادى ممكن في السنوات الأولى من عمر المزرعة وحتى يستطيع المزارع استرداد تكاليف الإنشاء في أسرع وقت، ويمكن استمرار المزرعة بهذه الكثافة العالية (٤٠٠ شجرة/فدان) لأكثر من ٧ سنوات وحتى تتساوى إنتاجية الفدان مع الكثافة الأقل.