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

(Received: 4. 11. 2008)

By
M.A. Bassal

Department of Horticulture, Faculty of Agriculture, Suez Canal University, 41522 Ismailia, Egypt

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 m²) 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 orchard. 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 3rd year after planting (YAP) to maintain the tree natural shape and facilitate the light penetration.

In February of the 6th and 7th 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 (m³) was calculated according to Wutscher (1995) as follows.

\[
\text{Tree volume} = \frac{(\text{Tree diameter}^2 \times \text{Tree height})}{4}
\]

In each season, starting from the 3rd YAP (2002/2003) to 7th 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 6th and 7th YAP, despite of the data of tree circumference in the 7th 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

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Canopy diameter (m)</th>
<th>Tree height (m)</th>
<th>Tree volume (m³)</th>
<th>Canopy circum. (m)</th>
<th>Trunk girth (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 x 3</td>
<td>2 x 5</td>
<td>5 x 5</td>
<td>2 x 5</td>
<td>5 x 5</td>
<td>3 x 3</td>
</tr>
<tr>
<td>Nova</td>
<td>3.28</td>
<td>3.89</td>
<td>3.40</td>
<td>3.14</td>
<td>7.23</td>
</tr>
<tr>
<td></td>
<td>3.56</td>
<td>3.34</td>
<td>3.40</td>
<td>3.23</td>
<td>7.56</td>
</tr>
<tr>
<td></td>
<td>3.38</td>
<td>3.78</td>
<td>3.63</td>
<td>3.50</td>
<td>8.78</td>
</tr>
<tr>
<td></td>
<td>3.70</td>
<td>3.61</td>
<td>3.63</td>
<td>3.78</td>
<td>8.78</td>
</tr>
<tr>
<td></td>
<td>3.87</td>
<td>3.96</td>
<td>3.86</td>
<td>3.93</td>
<td>9.90</td>
</tr>
<tr>
<td></td>
<td>3.97</td>
<td>3.91</td>
<td>3.97</td>
<td>9.90</td>
<td>9.97</td>
</tr>
<tr>
<td>Mean</td>
<td>3.81</td>
<td>3.96</td>
<td>3.81</td>
<td>3.91</td>
<td>9.86</td>
</tr>
<tr>
<td>LSD 5% for cultivar</td>
<td>0.13</td>
<td>0.09</td>
<td>0.16</td>
<td>0.52</td>
<td>NS</td>
</tr>
<tr>
<td>LSD 5% for spacing</td>
<td>0.06</td>
<td>0.23</td>
<td>NS</td>
<td>0.17</td>
<td>NS</td>
</tr>
<tr>
<td>LSD 5% for interaction</td>
<td>0.07</td>
<td>0.25</td>
<td>0.65</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

8th YAP

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Canopy diameter (m)</th>
<th>Tree height (m)</th>
<th>Tree volume (m³)</th>
<th>Canopy circum. (m)</th>
<th>Trunk girth (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 x 3</td>
<td>2 x 5</td>
<td>5 x 5</td>
<td>2 x 5</td>
<td>5 x 5</td>
<td>3 x 3</td>
</tr>
<tr>
<td>Nova</td>
<td>3.58</td>
<td>3.24</td>
<td>3.41</td>
<td>3.20</td>
<td>3.53</td>
</tr>
<tr>
<td></td>
<td>3.28</td>
<td>3.28</td>
<td>3.59</td>
<td>3.20</td>
<td>3.53</td>
</tr>
<tr>
<td></td>
<td>3.19</td>
<td>3.19</td>
<td>3.19</td>
<td>3.19</td>
<td>3.19</td>
</tr>
<tr>
<td></td>
<td>3.29</td>
<td>3.29</td>
<td>3.29</td>
<td>3.29</td>
<td>3.29</td>
</tr>
<tr>
<td>Mean</td>
<td>3.26</td>
<td>3.26</td>
<td>3.26</td>
<td>3.26</td>
<td>3.26</td>
</tr>
<tr>
<td>LSD 5% for cultivar</td>
<td>0.36</td>
<td>0.17</td>
<td>0.33</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>LSD 5% for spacing</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>LSD 5% for interaction</td>
<td>0.28</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>2nd YAP</th>
<th>3rd YAP</th>
<th>4th YAP</th>
<th>5th YAP</th>
<th>Cumulative yield</th>
<th>Average annual yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tree spacing</td>
<td>Tree spacing</td>
<td>Tree spacing</td>
<td>Tree spacing</td>
<td>Tree spacing</td>
<td>Tree spacing</td>
</tr>
<tr>
<td>Variety</td>
<td>5 x 5</td>
<td>2 x 2</td>
<td>Mean</td>
<td>5 x 5</td>
<td>2 x 2</td>
<td>Mean</td>
</tr>
<tr>
<td>Navara</td>
<td>5.0</td>
<td>12.9</td>
<td>10.2</td>
<td>17.5</td>
<td>24.9</td>
<td>21.2</td>
</tr>
<tr>
<td>Hassava</td>
<td>6.8</td>
<td>18.9</td>
<td>14.4</td>
<td>30.8</td>
<td>26.7</td>
<td>23.8</td>
</tr>
<tr>
<td>Cleopatra</td>
<td>4.0</td>
<td>14.0</td>
<td>10.5</td>
<td>25.8</td>
<td>16.5</td>
<td>12.3</td>
</tr>
<tr>
<td>Mean</td>
<td>5.1</td>
<td>15.2</td>
<td>11.7</td>
<td>25.0</td>
<td>15.3</td>
<td>13.5</td>
</tr>
</tbody>
</table>

LSD (5%) for cultivars: 1.92, 3.14
LSD (5%) for spacing: 2.52, 3.30
LSD (5%) for interaction: 2.68, 5.12
introduced in production early. 'Clemeneules' 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 'Clemeneules' 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 'Clemeneules' 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, 'Clemeneules' 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 'Clemeneules' 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 1: Effect of tree spacing on fruit production (ton/field) of some citrus cultivars in Egypt

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>1st YAP</th>
<th>2nd YAP</th>
<th>3rd YAP</th>
<th>4th YAP</th>
<th>5th YAP</th>
<th>Cumulative yield</th>
<th>Average annual yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td>Nova</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Jerusalem</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Clementine</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

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, Jerusalem, and Clementine 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 7th and 8th YAP, and favored the 6 x 4.5 m spacing in the 9th 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 3rd, 5th and 7th 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.

4. REFERENCES


بدءاً من السنة الثالثة وحتى السنة السابعة ستمتد المحصول الزراعي لمدة 5 متواسم متلازماً وذلك متوسط المحصول السنوي على مستوى الشجرة والفدان. أيضاً تم اخذ قياسات النمو الخضري للأشجار (الارتفاع - قطر - المحيط - الحجم - محيط الجذع) في السنة السادسة والسابعة من الزراعة.

وكان أحد النتائج المكتشف عليها ما يلي:

- كانت الأشجار المنزرعة على 2 x 5 م أكثر ارتفاعاً ولكن كانت الأقل في القطر والمحيط وكذلك الحجم. واجتازت الأصناف فيما بينها من حيث النمو الخضري. كانت أشجار الصنف نوفا هي الأقل في كل من القطر والمحيط، بينما أشجار الكليمينولس كانت الأ أكثر ارتفاعاً والأكبر حجماً.

- كانت الأشجار المنزرعة على 2 x 5 م الأعلى إنتاجاً في السنة الثالثة والرابعة من الزراعة (2442 و 262كم/شجرة). مقاومة بتلك المنتزعة على 5 x 5 م (20.7 كجم/شجرة) ولكن بدأ من السنة الخامسة وحتى السنة السابعة انعكس الوضع وتقوف الزراعة الواسعة. أيضاً المحصول التركمي لمدة 5 مaways وكذلك متوسط محصول الشجرة أظهر تفوق الزراعة الواسعة بزيادة قدرها 15% تقريباً.

- كانت إنتاجية ال دان في الزراعة الكثيفة أعلى منها في الزراعة الأقل كثافة وذلك خلال سنوات الدراسة. حيث كانت نسبة الزيادة حوالي 454%، 211%، 76%، 90% في السنوات الثلاثة والرابعة والسادسة والثامنة والرابعة وتعادل الزراعة على التوالي. أيضاً المحصول التركمي للدان كان أعلى في الزراعة الكثيفة بحوالي 40 طن/فدان (1176%). حسب الزراعة الأوسع.

- أعطي الصنف إيررانديا أعلى محصول في السنوات الثلاثة والرابعة بعد الزراعة، بينما الكليمينولس كان الأعلى في السنة الخامسة والثامنة. كان هو الأعلى إنتاجاً في السنة السادسة بعد الزراعة أما في السنة السابعة فلم يختلف منهما عن الإيرنانديا الذي أعطي أعلى محصول. أيضاً المحصول التركمي لمدة 5 مaways وكذلك متوسط محصول الشجرة أظهر أن الكليمينولس كان أقل إنتاجية تحت ظروف هذا الدراسة.

اما بالنسبة لسلوك الأصناف في الزراعة الكلية (2 x 5 م) فقد أعطي الصنف نوفا أعلى محصول تراكمي (82 طن/فدان) تلاه في كل الصنف الإيرنانديا (71 طن/فدان) بينما الكليمينولس كان الأقل في هذا الفئة (68 طن/فدان).

على ضوء النتائج المحققة تسكينة تحت ظروف هذه الدراسة يصبح بزراعة هذه الأصناف زراعة تراكمية حيث تنتظم متواسم المحصول استمرار تكاثف الإنشاء في أسرع وقت، ويمكن استمرار المزرعة بهذه الكثافة العالية (400 شجرة/فدان) لأكثر من 7 سنوات وحتى تتساوى إنتاجية الفدان مع الكثافة الأقل.