Growing cactus pear *O. ficus-indica* (L.) Mill. 
The contribution of the scientific research on plant ecophysiology and biology

Inglese P., Liguori G.

*Agadir, Morocco – October 17-22, 2010*
In 1993, when the CACTUSNET was created, international cooperation among Scientists working on cacti was nihil.

Scientific information delivered to growers was not consistent and updated.

Many questions have been addressed concerning all major aspects related to fruit production and quality.
Numbers for cactus Research in the last 20 years

- **360** papers in the ISI web of science (1990-2010).
- **573** citations for “*Opuntia ficus-indica*” in the CAB (2000-2010).

### Numbers for cactus Research in the last 20 years (Symposia)

<table>
<thead>
<tr>
<th>Country</th>
<th>Papers</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>28</td>
<td>37</td>
</tr>
<tr>
<td>S. Africa</td>
<td>23</td>
<td>46</td>
</tr>
<tr>
<td>Tunisia</td>
<td>40</td>
<td>91</td>
</tr>
<tr>
<td>Mexico</td>
<td>42</td>
<td>80</td>
</tr>
<tr>
<td>Brazil</td>
<td>59</td>
<td>178</td>
</tr>
</tbody>
</table>

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MAJOR INNOVATIONS:

Genetic Resources:

✓ genotype identification and description;
✓ morphological and biological analysis worldwide;
✓ genotype characterization (from isozymes to microarrays and DNA analysis);
✓ breeding;
✓ germplasm collections.

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MAJOR INNOVATIONS:

Orchard lay out and management:

- orchard planting and lay-out;
- tree pruning;
- LAI measurement;
- plant nutrition and fertilization;
- water requirement and irrigation management;
- orchard floor management.

Planting Density

**Sicily**: 4 m in the row and 6 m between the rows  
*416 plants/hectares (22 ton/ha)*

**Mexico**: 2 m in the row and 4 m between the rows  
*1250 plants/hectares (20 ton/ha)*

**Israel**: 1.5 m in the row and 4 m between the rows  
*1600 plants/hectares (21 ton/ha)*
MAJOR INNOVATIONS:

Reproductive biology:

✓ reflowering potential;
✓ environmental factors affecting reproductive potential;
✓ plant architecture and reproductive sites;
✓ biennial bearing;
✓ variability of fruit yield.
Relative cladode contribution to plant yield in relation to its fertility

Number of fruit per cladode

Percentage of total plant yield

Number of fruit per cladode
Number of fertile cladodes needed to get a crop yield of 20 t ha$^{-1}$, given 6 fruits (120 g) per cladode, in relation to orchard density.
Cladode dry weight in excess of the minimum dry weight for its surface area vs number of fruits on that cladode.

Figure 15
Relationship between fruit weight and n° of fruit per tree in *O. ficus-indica* trees, cultivar *Gialla*.
Carbon flux in cladode of *O. ficus-indica* with and without fruit, during fruit growth.
GROWTH OF SUMMER AND LATE RIPENING FRUITS
Relationship between cladode natural fertility and its reflowering aptitude *O. ficus-indica*
Evolution of GA$_3$ content in flowers of *O. ficus-indica* at different bloom stages

![Graph showing GA$_3$ content in flowers at different bloom stages](image)
MAJOR INNOVATIONS:

Fruit characteristics:

✓ fruit growth and ripening pattern;
✓ fruit ripening period (out-of-season crop);
✓ fruit harvest and quality index;
✓ fruit quality parameters;
✓ fruit nutraceutical potential;
✓ fruit minimal processing;
✓ post harvest physiology and management.

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Analysis of variance of quality parameters of *O. ficus-indica* fruits, cultivar *Gialla* and *Rossa*, coming from three different growing sites, in Sicily.

<table>
<thead>
<tr>
<th></th>
<th>Weight (g)</th>
<th>TSS (% Brix)</th>
<th>Percent Flesh (%)</th>
<th>pH</th>
<th>Titratable Acidity (% NaOH)</th>
<th>Height/Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site</td>
<td>**</td>
<td>**</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>*</td>
</tr>
<tr>
<td>Cultivar</td>
<td>**</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Altitude</td>
<td>**</td>
<td>**</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>**</td>
</tr>
<tr>
<td>Site x</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Cultivar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*=significant at p<0.05; **=significant at p<0.01; ns=non significant (Tukey’s test).
Variability of fruit fresh weight and TSSC in five 8-years-old *Opuntia ficus-indica* trees, cultivar *Gialla*.

Figure 7
Relationship between average fruit weight and number of fruit per tree in five 8-years-old *Opuntia ficus-indica* trees, cultivar *Gialla*.

*Figure 10*

![Graph showing the relationship between average fruit weight and number of fruits per tree. The graph includes data points and a trend line with a correlation coefficient of $R^2 = 0.80$.](image-url)
Relationship between total soluble solid content (TSSC) and cladode crop load

![Graph showing the relationship between TSSC and number of fruits per cladode. The graph indicates a negative correlation with an R^2 value of 0.9741.]
Relationship between average fruit fresh weight and number of fruits per cladode in five 8-years-old *Opuntia ficus-indica* trees, cultivar *Gialla*.
Quality parameters for *O. ficus-indica, cv Gialla* fruits, in relation to canopy site and intercepted Photosynthetic Active Radiation (PAR)

<table>
<thead>
<tr>
<th>Fruit parameters</th>
<th>Canopy site</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bottom (0-1 m)</td>
</tr>
<tr>
<td></td>
<td>PAR = 15 mol m⁻² day⁻¹</td>
</tr>
<tr>
<td>Fruit weight (g)</td>
<td>127.0 a</td>
</tr>
<tr>
<td>TSSC* (° Brix)</td>
<td>14.9 ns</td>
</tr>
<tr>
<td>Percent flesh (%)</td>
<td>55.1 ns</td>
</tr>
</tbody>
</table>

TSSC= Total Soluble Solids Content. Different letters indicate significant differences and ns = not significant differences within the row at p=0.05 (Tukey’s test).
Ecophysiology and environmental aspects:

- environmental aspects of plant and fruit growth;
- Carbon balance at cladode, plant and orchard level;
- Plant response to global change;
- organic production.

MAJOR INNOVATIONS:

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**Dry matter cumulated in one year in a 8-year-old cactus pear tree**

<table>
<thead>
<tr>
<th>Vegatative flush</th>
<th>Flowers and Fruit (kg dm)</th>
<th>Current-year-cladodes (kg dm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>± SE</td>
</tr>
<tr>
<td>I</td>
<td>3,06</td>
<td>0,64</td>
</tr>
<tr>
<td>II</td>
<td>6,34</td>
<td>0,25</td>
</tr>
<tr>
<td>TOTAL</td>
<td>9,40</td>
<td>0,34</td>
</tr>
</tbody>
</table>

**Secondary growth of 1-year-, 2-year- and >2-year-old cladodes**

<table>
<thead>
<tr>
<th></th>
<th>1-year-old</th>
<th>2-year-old</th>
<th>&gt;2-year-old</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>±SE</td>
<td>Mean</td>
<td>± SE</td>
</tr>
<tr>
<td>Whole tree (kg dm)</td>
<td>26,06</td>
<td>3,20</td>
<td>5,86</td>
<td>0,34</td>
</tr>
<tr>
<td>Single cladode (g dm)</td>
<td>150,21</td>
<td>13,2</td>
<td>60,13</td>
<td>5,54</td>
</tr>
</tbody>
</table>
### Seasonal dry matter accumulation

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(kg tree(^{-1}))</td>
<td>58,7</td>
<td>6,0</td>
</tr>
<tr>
<td>(t ha(^{-1}))</td>
<td>16,2</td>
<td>1,7</td>
</tr>
</tbody>
</table>
### Tree (m²) and Cladode (cm²) surface area

<table>
<thead>
<tr>
<th>Surface area</th>
<th>Current-year</th>
<th>1-year-old</th>
<th>2-year-old</th>
<th>&gt;2-year-old</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>± SE</td>
<td>mean</td>
<td>± SE</td>
<td>mean</td>
</tr>
<tr>
<td>tree (m²)</td>
<td>33,4</td>
<td>5,1</td>
<td>25,6</td>
<td>3,2</td>
<td>14,6</td>
</tr>
<tr>
<td>Cladode (cm²)</td>
<td>1370,2</td>
<td>32,1</td>
<td>1553,8</td>
<td>17,8</td>
<td>1706,0</td>
</tr>
</tbody>
</table>

### Stem Area Index (SAI)

<table>
<thead>
<tr>
<th>SAI</th>
<th>Current-year</th>
<th>1-year-old</th>
<th>2-year-old</th>
<th>&gt;2-year-old</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>± SE</td>
<td>mean</td>
<td>± SE</td>
<td>mean</td>
</tr>
<tr>
<td>tree</td>
<td>1,70</td>
<td>0,3</td>
<td>1,3</td>
<td>0,2</td>
<td>0,74</td>
</tr>
<tr>
<td>orchard</td>
<td>0,95</td>
<td>0,1</td>
<td>0,73</td>
<td>0,1</td>
<td>0,42</td>
</tr>
</tbody>
</table>
MAJOR RELEVANT QUESTIONS:

☑️ How to increase fruit yield potential?
   - plant fertility vs Cladode fertility
   - tree spacing vs plant architecture

☑️ How to reduce production costs?
   - mechanization vs plant breeding

☑️ How to increase fruit quality and value?
   - seasonal offer
   - fruit shape and color
   - seed number
   - fruit organolpetic and nutraceutical value

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MAJOR RELEVANT QUESTIONS:

✓ Plant nutrition and N balance
✓ Water requirement and irrigation management
✓ C balance and environmental impact of cactus pear orchard