How breeding can help lettuce growers manage challenges!

Germán V. Sandoya-Miranda
Importance of Lettuce as a Crop

- After China, the USA is the second biggest producer.
- In the US alone is a $3 billion dollar business.
- High profitable crop – Specialty Crop.
- California and Arizona are the biggest lettuce producer.
- Florida situates third.
Lettuce in Florida

• 15,000 acres are planted at the Everglades Agricultural Area (EAA)

• “Muck soil” rich in organic matter (>80%)

• Lettuce is a winter vegetable at the EAA (October to April)

• 60 to 70 million dollar business
Lettuce in Florida

• How many growers and what’s the area planted?
• Hydroponics
• Aquaponics
• Vertical structures
• Greenhouse
• High tunnels (Organic growers)

“Smaller Growers”
15 Host Sites
Lettuce Breeding – University of Florida

- Everglades Research and Education Center – EREC
- Mission: Improve Lettuce Cultivars for Florida Production
- History: Victor Guzman developed historical lettuce cultivars

- Short Guzmaine
- Tall Guzmaine
- Floriglade
- Floricos
- Floribibb

**Table 1** Genetic contribution of selected ancestors of lettuce cultivars registered in U.S. 2000 through 2010

<table>
<thead>
<tr>
<th>Ancestor</th>
<th>Pedigree</th>
<th>Type</th>
<th>Among leaf</th>
<th>Among romaine</th>
<th>Among crisphed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salad Bowl</td>
<td>BL 1893/BL 1885</td>
<td>Leaf</td>
<td>3.5</td>
<td>7</td>
<td>0</td>
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<tr>
<td>Walkmanns Green</td>
<td>Grand Rapids Selection</td>
<td>Leaf</td>
<td>6.1</td>
<td>7</td>
<td>0</td>
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<tr>
<td>Malibu</td>
<td>Unknown</td>
<td>Leaf</td>
<td>6.4</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Parris Island</td>
<td>PI 120965/Dark Green Cos</td>
<td>Romaine</td>
<td>13.5</td>
<td>9</td>
<td>25.9</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.6</td>
</tr>
</tbody>
</table>

**Notes**
- Lettuce type categorized as leaf (39 cultivars), romaine (47), or crisphed (60) for the 146 leaf, romaine, and crisphed cultivars registered by U.S. Plant Variety protection (PVP) or utility patent from 2000 through 2010 that had pedigree derivation available PVP/patent.
- Pedigree format written per Purdy et al. (1968). Abbreviations include breeding line (BL) and plant introduction (PI).
- Lettuce type categorized as leaf, romaine, or crisphed (crisp).
- Genetic contribution is based on pedigree analysis and is the theoretical portion of genes contributed by the respective ancestor as determined by coefficient of parentage.
- Number of lines descending from each respective ancestor.

Mikel, 2012
Lettuce Breeding Program at UF

- Improve lettuce cultivars adapted to Florida conditions
- The program aims to develop cultivars of crisphead (iceberg and boston), cos (romaine), leaf, and niche types (Latin)
Lettuce Types

*Lactuca sativa* L.

- Crisphead
- Cos
- Latin
- Cutting
- Oil
- Stem

Mary Zischke. CEO. CLGRB

Volume Trends
Iceberg and Romaine

Carton Equivalents
Lettuce Type

- New types
- New colors
- New shapes
Lettuce Market

- Fresh
  - Whole head
  - Processed lettuce
  - Baby Leaf
  - Other uses?

Baby Leaf Production

- Shapes and colors
- Resistant to lettuce BLS
- Batavia Reine des Glaces

Hayes et al, 2014
Biotic Stresses
Pests and diseases in Lettuce

**Insect pests**
Lettuce aphid – *Nasonovia ribis nigrri*
The green peach aphid - *Myzus persicae*
Leaf miners – *Liryomiza trifolii*

**Diseases**
**Oomycete**
Downy mildew – *Bremia lactucae*
10 Races in the USA and 15 in Europe
Biotic Stresses
Pests and diseases in Lettuce

**Diseases**

*Fungal*
- Sclerotinia drop – *Sclerotinia sclerotiorum* *S. minor*
- Verticillium wilt – *Verticillium dahliae*
- Fusarium wilt – *Fusarium oxysporum* *f.sp. lactucae*

*Bacterial*
- Corky root rot – *Rhizomonas suberifasciens*
- Bacterial Leaf Spot – *Xanthomonas campestris pv. vitians*

*Virus*
- Dieback – *Tomato bushy stunt virus* and *lettuce necrotic stunt virus*
- Lettuce mosaic – *Lettuce Mosaic Virus*
- Big vein - *Mirafiori lettuce virus*
Abiotic Stresses

• Heat
  – Seed germination
  – Bolting
  – Low yield
• Drought
• Salt
Other problems in Lettuce

• Bolting

• Tipburn (Calcium deficiency)

• Cercospora Leaf Spot

• Post harvest quality
  – Salad Shelf-Life
  – Arrival Quality
What is a pest?

**Pest: a plant or animal detrimental to humans or human’s concerns**

- Mammals
- Birds
- Vertebrates
- Invertebrates
- Nematodes
- Parasites
- Insects
- Weeds
- Pathogens
- Fungi
- Bacteria
- Virus
- Monocot
- Dicot
Integrated Pest Management

- Cultural
- Biological
- Chemical
- Genetic
Lettuce Breeding Program at UF

The case of Bacterial Leaf Spot (BLS)

- *Xanthomonas campestris pv. vitians* – several races
- Present in lettuce production areas (subtropical - Florida)
- Sudden outbreaks have caused million dollars losses (Florida)
- No chemical pesticide is available, breeding is the most reliable option
Transfer resistance to adapted iceberg and romaine cultivars

The case of Bacterial Leaf Spot (BLS)

Crosses to PI 358001-1

PI 358001-1 (Resistant)

Iceberg

Romaine

Boston

Leaf

Latin

Sources of Resistance - CA
Lettuce Breeding Program at UF

The case of Bacterial Leaf Spot (BLS)

Backcross Selection Scheme

$\text{BC}_2\text{F}_2$
BLS resistant lettuce

- Search for additional sources of resistance
- PI 358001-1
  - Fast Bolter
  - Sensitive to Tipburn
  - Leaf characteristics are predominant
  - More than one race of BLS is known (Florida – race 1 only)
- 65 Plant Introductions (PI) and lettuce cultivars resistant to CA strains of BLS in evaluation process
Lettuce Breeding Program at UF

• Fusarium wilt – “New disease” identified in Florida

• Lettuce downy mildew

• Weed control

• Fusarium oxysporum f.sp. Lactucae

• First in California and Arizona

• New disease in Florida?

• Three races, only one in the USA

• Limited chemical control

• The disease was controlled using methyl bromide

• Breeding is the most reliable option

• Other alternatives are crop rotation, equipment sanitation, flooding
Lettuce Breeding Program at UF

- Fusarium wilt – “New disease” identified in Florida
- Lettuce downy mildew
- Weed control

- Bremia lactucae is an universal pathogen (oomycete)
- 15 races in the EU and 10 in the USA
- No information on races of the pathogen in FL
- Growers depend heavily in chemicals
- Although resistance and chemicals are available, the pathogen evolves quickly
- Collecting isolates throughout FL


**Lettuce Breeding Program at UF**

- **Fusarium wilt** – “New disease” identified in Florida
- **Lettuce downy mildew**

**Weed control**

- **Weeds are a big problem for field growers**
- **Losses are estimated to be 40%**
- **In field, lettuce is a rotational crop**
- **Not many chemicals are approved for the rotation**

**What would be a solution using breeding?**

- **Lettuce tolerant to wide spectrum herbicides are needed**
Lettuce Breeding Program at UF

- Postharvest
- Nutrient use efficiency
- Heat tolerance

- Shelf-life is needed for lettuce in any type of market
- Pinking and Browning are big issues for growers
- Poor shelf-life in modified atmosphere

- Fertilizers are costly
- Environmental concerns
- In the future, lettuce production will happen in smaller operations

- Heat causes bolting, low yield, losses
- Heat tolerance is needed for field production
- Heat tolerance is needed for greenhouse production
Future of Lettuce Breeding

• What other lettuce types will be in the market?
  – Baby Leaf?
  – Hydroponic Lettuce?
  – Other protected structures?
  – Novel head architecture and head traits?
Lettuce as Source of Vitamins and other Minerals

<table>
<thead>
<tr>
<th>Nutrient and units</th>
<th>Lettuce type</th>
<th></th>
<th></th>
<th>Cutting&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Cutting&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Stalk</th>
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<tr>
<td></td>
<td>Butterhead</td>
<td>Cos</td>
<td>Crisphead</td>
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<tr>
<td>Protein (g)</td>
<td>1.35</td>
<td>1.23</td>
<td>0.90</td>
<td>1.36</td>
<td>1.33</td>
<td>0.85</td>
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<td>Sugars, total (g)</td>
<td>0.94</td>
<td>1.19</td>
<td>1.76</td>
<td>0.78</td>
<td>0.48</td>
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<td>Lipids</td>
<td></td>
<td></td>
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<tr>
<td>Fatty acids, total saturated (mg)</td>
<td>29</td>
<td>39</td>
<td>18</td>
<td>20</td>
<td>–</td>
<td>–</td>
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<td>Fatty acids, total monounsaturated (mg)</td>
<td>8</td>
<td>12</td>
<td>6</td>
<td>6</td>
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<td>–</td>
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<tr>
<td>Fatty acids, total polyunsaturated (mg)</td>
<td>117</td>
<td>167</td>
<td>74</td>
<td>82</td>
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<td>Phytosterols (mg)</td>
<td>–</td>
<td>–</td>
<td>10</td>
<td>38</td>
<td>–</td>
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<td>Minerals</td>
<td></td>
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<td>Calcium (mg)</td>
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<td>33</td>
<td>18</td>
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<td>Iron (mg)</td>
<td>1.24</td>
<td>0.97</td>
<td>0.41</td>
<td>0.86</td>
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<td>Magnesium (mg)</td>
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<td>14</td>
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<td>Phosphorous (mg)</td>
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<td>30</td>
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<td>29</td>
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<td>39</td>
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<td>Potassium (mg)</td>
<td>238</td>
<td>247</td>
<td>141</td>
<td>194</td>
<td>187</td>
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<td>Sodium (mg)</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>28</td>
<td>25</td>
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<td>Zinc (mg)</td>
<td>0.20</td>
<td>0.23</td>
<td>0.15</td>
<td>0.18</td>
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<td>0.27</td>
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<td>Copper (mg)</td>
<td>0.016</td>
<td>0.048</td>
<td>0.025</td>
<td>0.029</td>
<td>0.028</td>
<td>0.040</td>
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<td>Manganese (mg)</td>
<td>0.179</td>
<td>0.155</td>
<td>0.125</td>
<td>0.250</td>
<td>0.203</td>
<td>0.688</td>
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<tr>
<td>Selenium (mcg)</td>
<td>0.6</td>
<td>0.4</td>
<td>0.1</td>
<td>0.6</td>
<td>1.5</td>
<td>0.9</td>
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<tr>
<td>Vitamins</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>Ascorbic acid (mg)</td>
<td>3.7</td>
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<td>2.8</td>
<td>18</td>
<td>3.7</td>
<td>19.5</td>
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<td>Thiamin (mg)</td>
<td>0.057</td>
<td>0.072</td>
<td>0.041</td>
<td>0.070</td>
<td>0.064</td>
<td>0.055</td>
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<tr>
<td>Riboflavin (mg)</td>
<td>0.062</td>
<td>0.067</td>
<td>0.025</td>
<td>0.080</td>
<td>0.077</td>
<td>0.070</td>
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<tr>
<td>Niacin (mg)</td>
<td>0.357</td>
<td>0.313</td>
<td>0.123</td>
<td>0.375</td>
<td>0.321</td>
<td>0.550</td>
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<tr>
<td>Pantothenic acid (mg)</td>
<td>0.150</td>
<td>0.142</td>
<td>0.091</td>
<td>0.134</td>
<td>0.144</td>
<td>0.183</td>
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<tr>
<td>Vitamin B-6 (mg)</td>
<td>0.082</td>
<td>0.074</td>
<td>0.042</td>
<td>0.090</td>
<td>0.100</td>
<td>0.050</td>
</tr>
<tr>
<td>Folate, total (mce)</td>
<td>73</td>
<td>136</td>
<td>29</td>
<td>38</td>
<td>36</td>
<td>46</td>
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<tr>
<td>Vitamin A (IU)</td>
<td>3312</td>
<td>5807</td>
<td>502</td>
<td>7405</td>
<td>7492</td>
<td>3500</td>
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<tr>
<td>Vitamin E (mg)</td>
<td>0.18</td>
<td>0.15</td>
<td>0.18</td>
<td>0.29</td>
<td>0.15</td>
<td>–</td>
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<tr>
<td>Tocopherol, gamma (mg)</td>
<td>0.27</td>
<td>0.36</td>
<td>0.08</td>
<td>0.37</td>
<td>0.24</td>
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<tr>
<td>Vitamin K (phyloquinone) (mg)</td>
<td>102.3</td>
<td>102.5</td>
<td>24.1</td>
<td>173.6</td>
<td>140.3</td>
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<tr>
<td>Carotenoids</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Carotene, beta (mcg)</td>
<td>1987</td>
<td>3484</td>
<td>299</td>
<td>4443</td>
<td>4495</td>
<td>–</td>
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<tr>
<td>Lutein + zeaxanthin (mcg)</td>
<td>1223</td>
<td>2312</td>
<td>277</td>
<td>1730</td>
<td>1724</td>
<td>–</td>
</tr>
</tbody>
</table>

<sup>a</sup> Greenleaf
<sup>b</sup> Redleaf

Still, 2007
Interaction Industry – UF Lettuce

GET TO KNOW YOUR GROWERS BECAUSE YOU NEED TO KNOW THEIR NEEDS

FIELD SELECTIONS AT THEIR FACILITY

PLANT ADVANCED BREEDING LINES AND GET FEEDBACKS

TARGET ALL GROWERS IN THE STATE
Future of Lettuce Breeding

• What other alternatives do we have in lettuce breeding?
  – Molecular Markers for MAS
    Lettuce genome is sequenced – Version 9
    Newer sequencing technologies - GBS
    Several traits in lettuce have been mapped
    Vegetable breeding companies are likely using MAS
    No many markers have been developed in academia
      Corky Cork Root – Cor gene
      Lettuce Dieback – Tvr1 gene
      Verticillium resistance 1 – Vrl gene
      Bacterial Leaf Spot – Xar1 or Xcyr gene
Future of Lettuce Breeding

• What other alternatives do we have in lettuce breeding?
  – “GMOs” – Genetically engineered?
  – Gene editing?
    • First lettuce mutated lines able to germinate at >35°C

Bertier et al., 2018
Recommendations

• Seed-borne pathogens
  ➢ Sclerotinia drop
  ➢ Verticillium wilt
  ➢ Fusarium wilt
  ➢ Bacterial Leaf Spot
  ➢ Lettuce mosaic

• Limited pesticides

➢ Use clean seed

➢ Think of breeding as part of an IPM
  ▪ Use as many resources as you have

➢ Test your seed for pathogens
Recommendations

• Bolting

• Heat Tolerance

➢ Use cultivars bred for the specific environment

➢ Talk to your specialist
How breeding can help lettuce growers manage challenges!

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