Potential yield of oil palm - an update

RHV Corley
Yield potential and potential yield

- **Site yield potential** - current material, with good management, but site-specific limitations

- **Genetic yield potential** - current material under best possible conditions

- **Potential yield** - hypothetical genotype, combining specified physiologically plausible attributes
Potential yield, genetic yield potential and national average yields

Yield of oil (t/ha.yr)

Average GYP Potential Y
Potential yield estimates

1980  Max. DMP x max. harvest index
      = 13.6 t oil/ha.yr

1983  Potential DMP x BI x O/B
      adj. for energy content  = 17 t/ha

1998  As 1983, but with max. O/B from
      bunch components  = 18.5 t/ha
Dry matter production

\[ \text{DMP} = \frac{S \cdot f \cdot e}{k} \]

- \( S \) = Total solar radiation (MJ/m².yr)
- \( f \) = Fraction of radiation intercepted
- \( e \) = Fraction incorporated into biomass
- \( k \) = Energy content of biomass (MJ/kg)
Conversion coefficient

\[ DMP = S \cdot f \cdot e \]
S in MJ/m\(^2\) \quad e \text{ in kg/MJ}

\[ DMP = S \cdot f \cdot e^* \]
\[ e^* = e \text{ adjusted for energy content of oil} \]

\[ DMP = S \cdot f \cdot e/k \]
\[ e \text{ is a fraction} \quad k \text{ in MJ/kg} \]
Palm oil production

\[ Y_{\text{oil}} = S \cdot f \cdot e \cdot \text{BI} \cdot O_{\text{dry}} / k \]

\( \text{BI} = \) Bunch index

\( O_{\text{dry}} = \) oil / dry bunch weight
S - Solar radiation

Typical figures are 6000 - 6500 MJ/m².yr

Photosynthetically active radiation (PAR) is about 50% of total

For comparisons within a trial, 6300 MJ can be assumed
f - light interception

Depends on leaf area index, L
= leaf area x leaves/palm x palms/ha

\[ \ln(1 - f) = -0.34 (L - 0.3) \]
BI - bunch index

Proportion of dry matter in fruit bunches

\[ \frac{Y_{\text{bunch}}}{(Y_{\text{bunch}} + \text{VDM})} \]

\( Y_{\text{bunch}} \) usually assumed to be 53% of FFB but will be higher if fruit/bunch and oil/bunch are high.
\[ O_{\text{dry}} - \text{oil / dry bunch weight} \]

\[ O_{\text{dry}} = O \text{ to B / bunch dry matter content} \]

Bunch dry matter may be more than 53%

- Stalk and spikelets - 30% dry matter
- Mesocarp dry matter from bunch analysis
- Shell and kernel dry matter = 100%, if nuts are dried before cracking and weighing

If F/B = 60%, M/F = 85%, DM/WM = 66%, nuts/fruit = 12%, then dry matter content = 53%
\( k \) - energy content of biomass

- Oil has higher energy content than other biomass (39.8 MJ/kg vs 18.8 MJ/kg), so \( k \) depends on BI and oil/bunch:

\[
k = 39.8 \text{ BI}.O_{\text{dry}} + 18.8 \left(1 - \text{BI}.O_{\text{dry}}\right)
\]
e - conversion efficiency

e is a residual term, after everything else has been calculated or estimated

\[
e = Y_{oil} \left( 18.8 \left( 1 - B\text{I}.O_{dry} \right) + 39.8 B\text{I}.O_{dry} \right) \]

S.f. B\text{I}.O_{dry}

or

\[
e = \left( 18.8 \left( V\text{DM} + Y_{bunch} \left( 1 - O_{dry} \right) \right) + 39.8 Y_{bunch}.O_{dry} \right) \]

S.f
Common misunderstandings

• Confusion between yield potential and potential yield -
  “maximum dry matter production of current material under good conditions” is the basis for estimating genetic yield potential, not potential yield.
Common misunderstandings

• FFB yield and oil/bunch are negatively correlated. For same gross assimilate allocated to bunches:

<table>
<thead>
<tr>
<th>O/B</th>
<th>FFB</th>
<th>Oil yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%</td>
<td>37 t</td>
<td>18.5 t</td>
</tr>
<tr>
<td>25%</td>
<td>52 t</td>
<td>13 t</td>
</tr>
</tbody>
</table>
DM120.025
Deli DM635.607 x DM742.207 Avros
Data from Pipae & Dumortier, 1996

Years 5 - 7 after planting

- FFB yield: 276 kg/palm
  33.1 t/ha
- Bunch number: 21.7 /palm.yr
- Bunch weight: 12.9 kg
- Oil/bunch: 36.1 %
- Oil yield: 11.96 t/ha
### Bunch composition, DM120.25

<table>
<thead>
<tr>
<th>Component</th>
<th>% B.Wt</th>
<th>% DM</th>
<th>Dry as % fresh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit/bunch</td>
<td>72.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stalk + spikelets</td>
<td>27.5</td>
<td>30.0</td>
<td>8.2</td>
</tr>
<tr>
<td>Mesoc. (91.2 % M/F)</td>
<td>66.1</td>
<td>65.6</td>
<td>43.4</td>
</tr>
<tr>
<td>Kernel (5% K/F)</td>
<td>3.6</td>
<td>100</td>
<td>3.6</td>
</tr>
<tr>
<td>Shell (3.9% Sh/F)</td>
<td>2.8</td>
<td>100</td>
<td>2.8</td>
</tr>
<tr>
<td><strong>Total dry matter</strong></td>
<td></td>
<td></td>
<td><strong>58.0</strong></td>
</tr>
</tbody>
</table>
Vegetative measurements, 
DM120.25
Data from Pipae & Dumortier, 1996

- Leaf area: 8.04 m²
- Planting density: 120 palms/ha
- Leaf area index: 4.34
- Leaf weight: 2.9 kg
- Leaf production: 33 /palm.yr
- Vegetative dry matter: 126 kg/palm.yr
## Dry matter production, DM120.25

<table>
<thead>
<tr>
<th>Component</th>
<th>DM120.25</th>
<th>Ideotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Y_{\text{bunch}}$ (t/ha.yr)</td>
<td>19.1</td>
<td>25.7</td>
</tr>
<tr>
<td>Total DMP (t/ha.yr)</td>
<td>34.2</td>
<td>42.1</td>
</tr>
<tr>
<td>Light interception (%)</td>
<td>75</td>
<td>91</td>
</tr>
<tr>
<td>Conversion (e, %)</td>
<td>1.89</td>
<td>2.06</td>
</tr>
<tr>
<td>VDM (kg/palm.yr)</td>
<td>126</td>
<td>91</td>
</tr>
<tr>
<td>Bunch Index (%)</td>
<td>56</td>
<td>61</td>
</tr>
<tr>
<td>Oil dry bunch (%)</td>
<td>62</td>
<td>72</td>
</tr>
<tr>
<td>Oil yield (t/ha)</td>
<td>11.96</td>
<td>18.5</td>
</tr>
</tbody>
</table>
Dry matter production and planting density
Can VDM of DM120.25 be reduced?

1. Bunch No. 22/yr, but leaf prod. 33/yr
   so reduce male flower number:
   5/palm.yr adequate for pollination

2. Increase mean bunch weight, and so
   reduce bunch number from 22 to 17

3. Therefore, reduce leaf production from
   33 to 22 per year - 3.8 t/ha

4. Reduce trunk growth by 1.5 t/ha.yr
Partitioning for “DM120.25 improved”

Reduction in VDM: 5.3 t/ha
Equivalent $Y_{\text{bunch}}$: 3.2 t/ha
Extra oil ($O_{\text{dry}} = 62\%$) 2.0 t/ha
Oil yield 14 t/ha
VDM (82 kg/palm) 9.8 t/ha
$Y_{\text{bunch}}$ (38 t FFB/ha) 22.4 t/ha
Bunch Index 70\%
Bunch index and optimal density

![Graph showing the relationship between leaf area index and dry matter production, with lines labeled for CGR, vegetative yield, and yield of crop.](image-url)
Breeding objectives

• Reduce leaf production
• High B. Wt - B. No. not too high
• Reduce trunk growth
• High oil/bunch
Conclusion

Potential yield is not just a crop physiologist’s fantasy, but can provide a useful benchmark for the plant breeder