Plant data values required for simple crop growth simulation models: review and bibliography

H.D.J. van Heemst

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<td>72</td>
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</tbody>
</table>

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Plant data values required for simple crop growth simulation models: review and bibliography

H.D.J. van Heemst

Introduction

In the book "Modelling of agricultural production: weather, soils and crops" (Van Keulen & Wolf, 1986) the readers are introduced into the quantitative aspects of modelling agricultural production. To run such models data on crop characteristics per species or cultivar are required, apart from data on weather and soils.

A set of default values was supplied for use if no specific data were available. That set was composed at an early stage during the development of the model and has not been updated since.

This review is a first step in the updating process of the plant data set. For theoretical aspects, symbols etc. reference is made to Van Keulen & Wolf (1986). Only aspects not treated there are discussed in this review.

References following the tabulated data may indicate that these data are found in the article as such, but many have been derived from tables or curves given by the authors of the article.

No attempt has been made to explain differences in reported values, as often environmental conditions were not reported.

Required crop characteristics

Crop characteristics required for running the simulation model for a specific crop are:

-1- Data on CO₂-assimilation characteristics of a single leaf, i.e. the initial light use efficiency, the respiration in the dark, the rate of net or gross CO₂ assimilation at light saturation, the effect of temperature, air humidity, and leaf age on the rate of CO₂ assimilation, and the extinction coefficient for diffuse light.

-2- Data on the conversion efficiency of the sugars produced in the assimilation process into structural dry mass and the requirements of sugars for maintenance processes.
Data on the partitioning of newly formed dry mass over the various plant parts in the course of the season.

Data on leaf area dynamics, as specific leaf area and leaf life span.

Data on crop phenology.

ad 1. CO₂ assimilation

The value of the maximum gross CO₂ assimilation varies with such characteristics as age of the leaf, its nitrogen concentration and its position in the canopy, the temperature during its development, the temperature during the measurement, the CO₂ concentration of the air, air humidity, the water status of the leaf etc.

Many authors have also found different values for different varieties of the same species, grown and measured under identical conditions. Wherever possible, these effects on the maximum CO₂ assimilation rate have been quantified in this review. In many cases, however, not enough detail has been provided in the reports to allow analysis of the values found.

In most cases, data on dark respiration are missing. According to De Wit et al. (1978), dark respiration is one-ninth of gross respiration. Preferably, the values of the initial light use efficiency are given in relation to photosynthetically active radiation. Most values are not very accurate, as they have been assessed from light response curves found in the literature consulted.

ad 2. Growth respiration and maintenance respiration

Growth respiration

Values for the maintenance respiration requirement and conversion efficiency of dry matter from photosynthates have been taken from the literature, whenever possible.

If no value was found, the maintenance respiration requirement was estimated from the protein concentration and the ash concentration of the material, by assuming that at 20 °C proteins require about 0.035 kg CH₂O per kg dry mass per day for maintenance and minerals about 0.07.
The conversion efficiencies have been estimated from the composition of the product, by an equation given by Vertregt & Penning de Vries (1987):

\[
\frac{1}{\text{efficiency}} = 1.221 \times \text{carbohydrates} + 1.793 \times \text{protein} + 3.030 \times \text{lipids} + 2.119 \times \text{crude fibre} + 0.906 \times \text{organic anions}
\]

in which the different components are expressed as fractions.

The concentration of organic anions is assumed to be identical to the ash concentration, and the carbohydrate concentration assumed to be the fraction not accounted for by the other components.

For example, Kay (1957) gives for mung bean seeds the following composition:

- moisture 9.1 \%, protein 22.0 \%, crude fibre 4.3 \%, ash 3.5 \%, fat 1.2 \%.

On a dry mass base the concentrations are as follows:

- protein 0.24, crude fibre 0.05, ash 0.04, organic anions 0.04 (identical to ash), lipids 0.01. Total 0.38, remainder for carbohydrates 0.62.

According to the equation the efficiency becomes 0.74. For this crop a conversion efficiency for pods + seeds is given. Assuming not much difference in composition between pod walls and stems, and 66 \% seeds in the pods (Maniruzzaman, pers. comm., 1982) results in an efficiency of 0.72 for pods + seeds.

ad 3. The method to derive these data from crop growth experiments is extensively described by Van Keulen & Wolf (1986)

ad 4. Specific leaf area

Specific leaf area follows directly from simultaneous measurements of dry weight and area of the leaf. A complication is that sometimes leaf blades are measured, sometimes leaf punches or leaf blades plus petioles. Only those values are cited here, referring to leaf blades or leaf blades plus petioles. For cereals the leaf is defined as the leaf blade without the sheath, for other crops as the leaf blade plus the petiole.

For most crops specific leaf area is not constant throughout the life cycle of the plant. In most cases leaf blades have the tendency to become thicker in the course of the season, or the fraction of petioles increases, and consequently specific leaf area becomes lower.
ad 5. Crop phenology

For the thermal unit approach used in the model, reference is made to Van Keulen & Wolf (1986). In the model phenological stage of the crop is expressed as development stage (DVS), assuming the value 0 at emergence, 1 at flowering and 2 at maturity, except for tuber and root crops, where stage 1 is defined as the beginning of tuber initiation or formation of the storage root.
Appendix I

Glossary

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVS</td>
<td>Development stage</td>
<td></td>
</tr>
<tr>
<td>HBase</td>
<td>Treshold day length for crop development</td>
<td>h</td>
</tr>
<tr>
<td>HOpt</td>
<td>Optimum day length for crop development</td>
<td>h</td>
</tr>
<tr>
<td>Hsum</td>
<td>Day length sum</td>
<td>d h</td>
</tr>
<tr>
<td>PAR</td>
<td>Photosynthetically active radiation</td>
<td>J m⁻² s⁻¹</td>
</tr>
<tr>
<td>SLA</td>
<td>Specific leaf area</td>
<td>m² kg⁻¹</td>
</tr>
<tr>
<td>SPA</td>
<td>Specific pod area</td>
<td>m² kg⁻¹</td>
</tr>
<tr>
<td>TBase</td>
<td>Treshold temperature for crop development</td>
<td>°C</td>
</tr>
<tr>
<td>Tmax</td>
<td>Maximum temperature for crop development</td>
<td>°C</td>
</tr>
<tr>
<td>TOpt</td>
<td>Optimum temperature for crop development</td>
<td>°C</td>
</tr>
<tr>
<td>TSum</td>
<td>Temperature sum</td>
<td>d °C</td>
</tr>
</tbody>
</table>

Note: a figure at the end of a symbol refers to the development stage.
Table 1. Wheat \textit{Triticum aestivum} L.

Leaf CO$_2$ assimilation:

net photosynthesis:

<table>
<thead>
<tr>
<th>temperature (°C)</th>
<th>rel. CO$_2$ ass.</th>
<th>rel. CO$_2$ ass.</th>
<th>rel. CO$_2$ ass.</th>
</tr>
</thead>
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<tr>
<td>23</td>
<td>0.34</td>
<td>0.36</td>
<td>0.36</td>
</tr>
<tr>
<td>32</td>
<td>0.75</td>
<td>1.00</td>
<td>0.75</td>
</tr>
<tr>
<td>36</td>
<td>1.00</td>
<td>1.00</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Effect of leaf age:

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<thead>
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<th>age (days)</th>
<th>rel. CO$_2$ ass.</th>
<th>rel. CO$_2$ ass.</th>
<th>rel. CO$_2$ ass.</th>
</tr>
</thead>
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<td>0</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>35</td>
<td>0.75</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>63</td>
<td>0.36</td>
<td>0.75</td>
<td>0.36</td>
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</table>

Effect of temperature:

<table>
<thead>
<tr>
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<th>rel. CO$_2$ ass.</th>
<th>rel. CO$_2$ ass.</th>
<th>rel. CO$_2$ ass.</th>
</tr>
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<tbody>
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<td>15</td>
<td>0.93</td>
<td>0.93</td>
<td>0.93</td>
</tr>
<tr>
<td>24</td>
<td>0.66</td>
<td>0.66</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Effect of air humidity:

No effect on CO$_2$ ass. of VPD 1-20 mbar (Rawson et al., 1977)
Stem, ear CO₂ assimilation:

- Gross photosynthesis stem: 0.002 kg CO₂ kg⁻¹ (dry weight) h⁻¹ (Osman, 1971)
- Gross photosynthesis ear: 0.006 (Osman, 1971)
- Net photosynthesis ears: awnless tall: 0.00007 kg CO₂ kg⁻¹ h⁻¹
  dwarf: 0.00016
  awned tall: 0.00023
  dwarf: 0.00034

(measured 15-20 days after anthesis, Olugbemi et al., 1976)

- Hexaploid wheat: 4.5 kg CO₂ ha⁻¹ h⁻¹ (Blum, 1985)
- Tetraploid: 2.7

Initial efficiency:

- 0.25 kg CO₂ J⁻¹ ha⁻¹ h⁻¹ m² s (PAR) (Marshall, 1978)
- 0.56, cv. Famos
- 0.40, cv. Kolibri (PAR) (Winzeler, 1980)

Extinction coefficient:

- 0.42 (PAR) (Osman, 1971)
- 0.44 (PAR) (Gallagher & Biscoe, 1978)
- 0.46 (PAR) cv. Avalon, before anthesis
- 0.54 (PAR) cv. Avalon, after anthesis (Thorne et al., 1988)

Specific leaf area:

- SLA = 0.0020 ha kg⁻¹ cv.'s Froid, Roughrider, Bezostaya, Mironovskaya constant over growth period. (Aase, 1978)

Leaf life span:

- Flag leaf: 63 days at 24.6 °C
  77 days at 17.7 °C (Evans, 1983)

Maintenance respiration:

- Leaves: 0.03 kg CH₂O kg⁻¹ d⁻¹
- Stems: 0.015
- Roots: 0.01
- Ears: 0.01 (Penning de Vries & Van Laar, 1982)
Conversion factors:

leaves 0.72
stems 0.69
fibrous roots 0.72 (Penning de Vries & van Laar, 1982)
ears 0.79 (Penning de Vries et al., 1983)

Dry matter distribution:

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>0</th>
<th>0.05</th>
<th>0.18</th>
<th>0.65</th>
<th>0.70</th>
<th>1.00</th>
<th>1.18</th>
<th>2.00</th>
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<td>leaves</td>
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<td>0</td>
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<td>0.27</td>
<td>0.24</td>
<td>0.09</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>stems</td>
<td>1.00</td>
<td>1.00</td>
<td>0.07</td>
<td>0.73</td>
<td>0.76</td>
<td>0.67</td>
<td>0</td>
<td>0</td>
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<tr>
<td>ears</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.24</td>
<td>1.00</td>
<td>1.00</td>
<td>0</td>
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<tr>
<td>DVS</td>
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<td>0.8</td>
<td>1.3</td>
<td>2.0</td>
<td></td>
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<tr>
<td>fibrous roots</td>
<td>0.50</td>
<td>0.15</td>
<td>0.05</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

cv. Nabawa (Williams, 1960, 1966), cv. Maris Huntsman (Gregory et al., 1978a, 1978b)

Grains 85% of inflorescence, 13% moisture content.

(Penning de Vries et al., 1983)

Crop phenology:

emergence:

Tbase = 2.6 °C, Tsum = 78 d°C (Angus et al., 1980/1981)
Tbase = 0 °C, Tsum = 100 d°C (Bauer et al., 1984)
Tbase = 4 °C, Topt = 25 °C, Tmax = 32 °C (Cardwell, 1984)

development:

Tbase1 = 3.5 °C cv. UQ189 (Angus et al., 1981)
Tbase1 = 3.1 °C, Tsum1 = 905 d°C (Davidson & Campbell, 1983)
Tbase2 = 8.9 °C cv. UQ189 (Angus et al., 1981)
Tbase2 = 6.3 °C, Tsum2 = 435 d°C (Davidson & Campbell, 1983)
Tbase2 = 9.4 °C, Tsum2 = 280 d°C (Spiertz, 1978)

Initial weight:

0.011 g per plant (Williams, 1960)
planting rate: 200000-700000 plants ha⁻¹ (Doorenbos et al., 1979)

Maximum rooting depth: 100-150 cm (Doorenbos et al., 1979)
Table 2, Barley \textit{Hordeum vulgare} L.

Leaf CO$_2$ assimilation:

**Net photosynthesis:**

- 22 kg CO$_2$ ha$^{-1}$ h$^{-1}$ cv. Spartan (Frank & Marek, 1983)
- 15 (six-row barley, flag leaf),
- 18 (two-row barley, flag leaf), (Blum, 1985)
- 36-38 cv.'s Sel.62286-1, Goudgerst
- 34-36 cv. L 98
- 32-34 cv. Zephyr
- 30-32 cv.'s Union, Impala, Quantum, Rika, Rokujyo, Brandon M75-754, L 92
- 28-30 cv.'s Pirolinke, Ceres (Dantuma, 1973)

**Effect of leaf age:**

<table>
<thead>
<tr>
<th>age</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
<th>22 days</th>
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<tr>
<td>rel. CO$_2$</td>
<td>0.53</td>
<td>0.85</td>
<td>1.00</td>
<td>0.94</td>
<td>0.72</td>
<td>0.47</td>
<td>0.36</td>
<td>0.33</td>
</tr>
<tr>
<td>cv. Numar (Friedrich &amp; Huffaker, 1980)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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**Effect of temperature:**

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<th>5</th>
<th>14</th>
<th>17</th>
<th>28</th>
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<tr>
<td>rel. CO$_2$ ass.</td>
<td>0.74</td>
<td>1.00</td>
<td>1.00</td>
<td>0</td>
</tr>
<tr>
<td>(Takeda, 1979)</td>
<td></td>
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</table>

<table>
<thead>
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<th>temperature</th>
<th>12</th>
<th>18</th>
<th>24</th>
<th>30</th>
<th>36</th>
<th>42</th>
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<td>rel. CO$_2$ ass.</td>
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<td>0.79</td>
<td>0.66</td>
<td>0.52</td>
<td>0.34</td>
</tr>
<tr>
<td>(Vong &amp; Murata, 1977)</td>
<td></td>
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</tr>
</tbody>
</table>

**Effect of air humidity:**

- No effect on CO$_2$ ass. of VPD 7-20 mbar (Rawson et al., 1977)

Ear CO$_2$ assimilation:

**Net photosynthesis ears:**

- 3 kg CO$_2$ ha$^{-1}$ h$^{-1}$ (Blum, 1985)

**Initial efficiency:**

- 0.34 kg CO$_2$ J$^{-1}$ ha$^{-1}$ h$^{-1}$ m$^2$ s (Frank & Marek, 1983)

**Extinction coefficient:**

- 0.44 (PAR) (Gallagher & Biscoe, 1978)
Specific leaf area:

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>SLA</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>0</td>
<td>0.0020</td>
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<td></td>
<td>0.29</td>
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<td></td>
<td>0.91</td>
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<td></td>
<td>1.46</td>
<td>0.0022</td>
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<tr>
<td></td>
<td>2.00</td>
<td>0.0022</td>
</tr>
</tbody>
</table>

*Proctor barley, Biscoe et al., 1975*

Leaf life span:

40 days (Kamal, 1959)

Maintenance respiration:

leaves: 0.03 kg CH$_2$O kg$^{-1}$ d$^{-1}$

stems: 0.015

roots: 0.01 (Penning de Vries & Van Laar, 1982)

ears: 0.007 (calculated from biomass composition (Geessink & Benedictus, 1973))

Conversion factors:

leaves: 0.72

stems: 0.69

fibrous roots: 0.72 (Penning de Vries & van Laar, 1982)

ears: 0.74 (calculated from biomass composition (Geessink & Benedictus, 1973))

Dry matter distribution:

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>leaves</th>
<th>stems</th>
<th>fibrous roots</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>0</td>
<td>0.60</td>
<td>0.40</td>
<td>0.45</td>
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<tr>
<td></td>
<td>0.41</td>
<td>0.70</td>
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<td></td>
<td>0.76</td>
<td>0.37</td>
<td>0.63</td>
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<td>0.00</td>
<td>0.52</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>2.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

seed weight per plant = 0.8989*(ear weight per plant) - 0.3369 g

two-row cv. Heine 4804 (Kamal, 1959)

moisture content seed 13 % (Geessink & Benedictus, 1973)
Crop phenology:

emergence: $T_{\text{base}} = 1.5 \, ^\circ\text{C}$, $T_{\text{sum}} = 100 \, \text{d}^\circ\text{C}$ (Kramer, 1954)
   $T_{\text{base}} = 3.5 \, ^\circ\text{C}$, $T_{\text{sum}} = 159 \, \text{d}^\circ\text{C}$ (Russelle & Bolton, 1980)
   $T_{\text{base}} = 4 \, ^\circ\text{C}$, $T_{\text{opt}} = 22 \, ^\circ\text{C}$, $T_{\text{max}} = 36 \, ^\circ\text{C}$ (Cardwell, 1984)
   $T_{\text{base}} = 2.6 \, ^\circ\text{C}$, $T_{\text{sum}} = 78 \, \text{d}^\circ\text{C}$ (Angus et al., 1980/1981)

Initial weight:
   0.02 g per plant (Kamal, 1959)
   planting rate: 2500000 plants ha$^{-1}$ (Kamal, 1959)

Maximum rooting depth: 125 cm (Jonker, 1958)
Table 3. Rice (Oryza sativa L.)

Leaf CO₂ assimilation:

net photosynthesis:
- 30 kg CO₂ ha⁻¹ h⁻¹ (Sato & Kim, 1980)
- 41 - 61 extremes of a large number of indica cv.'s, (Ohno, 1976)

effect of leaf age:

<table>
<thead>
<tr>
<th>leaf number</th>
<th>0</th>
<th>1</th>
<th>3</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass.</td>
<td>0.15</td>
<td>0.59</td>
<td>1.00</td>
<td>0.12</td>
</tr>
</tbody>
</table>

leaf number 0: "developing"; 1: "young"; 3: "mature"; 6: "senescent" (Raghavendra, 1980)

effect of temperature:

<table>
<thead>
<tr>
<th>temperature</th>
<th>12</th>
<th>18</th>
<th>24</th>
<th>30</th>
<th>36</th>
<th>42</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass.</td>
<td>0.69</td>
<td>0.85</td>
<td>1.00</td>
<td>1.00</td>
<td>0.87</td>
<td>0.27</td>
</tr>
</tbody>
</table>

indica cv. IR8

<table>
<thead>
<tr>
<th>temperature</th>
<th>12</th>
<th>18</th>
<th>24</th>
<th>30</th>
<th>36</th>
<th>42</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass.</td>
<td>0.69</td>
<td>0.85</td>
<td>0.97</td>
<td>1.00</td>
<td>0.79</td>
<td>0.59</td>
</tr>
</tbody>
</table>

japonica cv. Nihonbare (Vong & Murata, 1977)

effect of air humidity:

<table>
<thead>
<tr>
<th>VPD</th>
<th>0</th>
<th>20</th>
<th>40 mbar</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass.</td>
<td>1.00</td>
<td>1.00</td>
<td>0.70 (El-Sharkawy et al., 1984b)</td>
</tr>
</tbody>
</table>

Initial efficiency:

0.30 kg CO₂ J⁻¹ ha⁻¹ h⁻¹ m² s⁻¹ (Sato & Kim, 1980)

Extinction coefficient:

0.32 (Shieh, 1977)
0.29 cv. Ketan
0.43 cv. IR36 (Taniyama et al., 1983)

Specific leaf area:

| extremes: 0.0029 - 0.0045 | average: 0.0036 ha kg⁻¹ (Ohno, 1976) |
| extremes: 0.0025 - 0.0041 | average: 0.0033 ha kg⁻¹ (Akati, 1980) |
| weeks after transplanting | 2 | 12 |
| SLA, uppermost unfolded leaf | 0.0028 | 0.0021 (first crop) |
| SLA, uppermost unfolded leaf | 0.0028 | 0.0017 (second crop) |
| (Luo, 1979) |
effect of temperature:

<table>
<thead>
<tr>
<th>temperature</th>
<th>10</th>
<th>27</th>
<th>30</th>
<th>32.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. SLA</td>
<td>0.60</td>
<td>0.94</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>cv. IR-8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rel. SLA</td>
<td>0.66</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>cv. Norin-17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Sato, 1972)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Leaf life span:
ca. 50 days at 28°C cv. IR-22 (Raghavendra, 1980)

Maintenance respiration:
leaves : 0.03 kg CH$_2$O kg$^{-1}$ d$^{-1}$
stems : 0.015
roots : 0.01 (Penning de Vries & Van Laar, 1982)
panicles : 0.0035 (calculated from biomass composition (Penning de Vries et al., 1983))

Conversion factors:
leaves 0.72
stems 0.69
fibrous roots 0.72 (Penning de Vries & van Laar, 1982)
inflorescence 0.74 (Penning de Vries et al., 1983)

Dry matter distribution:

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>0.35</th>
<th>0.80</th>
<th>1.27</th>
<th>1.38</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
<td>0.50</td>
<td>0.50</td>
<td>0.26</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>stems</td>
<td>0.50</td>
<td>0.50</td>
<td>0.74</td>
<td>0.20</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>ears</td>
<td>0.00</td>
<td>0.00</td>
<td>0.80</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

cv's Krishnasal, Pusa-33 (Kumbhar & Sonar, 1980), cv. Acorni (Van Slobbe, 1973), cv.'s IR8, Acorni (Erdman, 1972)

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>0.25</th>
<th>1.30</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>fibrous roots</td>
<td>0.40</td>
<td>0.15</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
| (Kumbhar & Sonar, 1980; Van Rossem, 1917; Van Slobbe, 1973; Erdman, 1972)

grains at harvest 0.86 of ear (Kumbhar & Sonar, 1980)
moisture content grains 11-14% (Penning de Vries et al., 1983)
Crop phenology:

emergence:

Tbase = 8 °C; Topt = 34 °C; Tsum = 65 d°C *indica* cv. Dular

(Chaudhary & Ghildyal, 1969)

development:

Tbasel = 11 °C, Tsuml = 545 d°C Transplanting – heading, average from 9 cv.'s (Morita & Murakami, 1981)

Initial weight:

bibi, 7 weeks old : 0.05 g per plant (leaves + stems + roots)

(Van Rossem, 1917)

planting rate :110000–440000 plants ha⁻¹ (Doorenbos et al., 1979)
Table 4, Millet

*Pennisetum typhoides* S. & H.

Leaf CO₂ assimilation:

net photosynthesis:

85 kg CO₂ ha⁻¹ h⁻¹, at 35 °C

effect of leaf age:

<table>
<thead>
<tr>
<th>relative leaf age</th>
<th>0</th>
<th>0.25</th>
<th>1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>relative CO₂ assimilation</td>
<td>0.46</td>
<td>1.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

effect of temperature:

<table>
<thead>
<tr>
<th>temperature</th>
<th>4</th>
<th>15</th>
<th>25</th>
<th>35</th>
<th>40</th>
<th>50</th>
<th>64</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass</td>
<td>0.00</td>
<td>0.37</td>
<td>0.72</td>
<td>1.00</td>
<td>1.00</td>
<td>0.58</td>
<td>0.00</td>
</tr>
</tbody>
</table>

(McPherson & Slatyer, 1973)

<table>
<thead>
<tr>
<th>temperature</th>
<th>12</th>
<th>18</th>
<th>24</th>
<th>30</th>
<th>36</th>
<th>42</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass</td>
<td>0.66</td>
<td>0.83</td>
<td>0.90</td>
<td>1.00</td>
<td>0.89</td>
<td>0.75</td>
</tr>
</tbody>
</table>

(Vong & Murata, 1977)

Initial efficiency:

0.38 kg CO₂ J⁻¹ ha⁻¹ h⁻¹ m² s (McPherson & Slatyer, 1973)

Extinction coefficient:

0.5 (Ong & Monteith, 1985)
0.5-0.6 (Begg et al., 1964)
0.29 cv. BK 560 (Squire et al., 1984)

Specific leaf area:

<table>
<thead>
<tr>
<th>DVS</th>
<th>0</th>
<th>0.15</th>
<th>0.40</th>
<th>0.85</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLA</td>
<td>0.0018</td>
<td>0.0020</td>
<td>0.0027</td>
<td>0.0018</td>
<td>0.0018</td>
</tr>
</tbody>
</table>

(Begg, 1965)

Leaf life span:

55-60 days at 29 °C (Begg, 1965)
71 days at 22.5 °C (McPherson & Slatyer, 1973)

Maintenance respiration:

| leaves : 0.020 kg CH₂O kg⁻¹ d⁻¹ |
| stems : 0.010                      |
| panicles : 0.007                   |
| roots : 0.007                       |

(Jansen & Gosseye, 1986)
Conversion factors:

<table>
<thead>
<tr>
<th>Component</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
<td>0.72</td>
</tr>
<tr>
<td>stems</td>
<td>0.69</td>
</tr>
<tr>
<td>fibrous roots</td>
<td>0.72 (Penning de Vries &amp; van Laar, 1982)</td>
</tr>
<tr>
<td>panicles</td>
<td>0.74 (Penning de Vries et al., 1983)</td>
</tr>
</tbody>
</table>

Dry matter distribution:

<table>
<thead>
<tr>
<th></th>
<th>0.0</th>
<th>0.2</th>
<th>1.13</th>
<th>1.30</th>
<th>1.60</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
<td>0.80</td>
<td>0.80</td>
<td>0.12</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>stems</td>
<td>0.20</td>
<td>0.20</td>
<td>0.88</td>
<td>0.64</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>panicles</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.36</td>
<td>1.1</td>
<td>1.1</td>
</tr>
</tbody>
</table>

(Carberry et al., 1985; Carberry & Campbell, 1985; Begg, 1965)

Grains 60% of panicles (Penning de Vries et al., 1983)
Moisture content grains: 10% (Penning de Vries et al., 1983)

Crop phenology:

Emergence:

$T_{base} = 12\, ^{\circ}\text{C}$, $T_{max} = 47\, ^{\circ}\text{C}$, $T_{sum} = 60\, \text{d}^{\circ}\text{C}$, $Topt = 32\, ^{\circ}\text{C}$ cv. BK-560

(Ong & Monteith, 1985; Garcia-Huidobro et al., 1985)

$T_{base} = 11.8\, ^{\circ}\text{C}$, $T_{sum} = 40\, \text{d}^{\circ}\text{C}$ (Angus et al., 1980/1981)

Development:

Most cultivars are day-neutral, the remainder short-day plants.

With cv. BJ 104 the time taken to panicle initiation of the main axis increased from 16 to 23 and 34 days as the photoperiod lengthened from 13.5 to 14.5 and 15.5 h. (Carberry & Campbell, 1985)

$T_{base 1} = 10\, ^{\circ}\text{C}$, $Topt1 = 30\, ^{\circ}\text{C}$, $T_{sum 1} = 1050\, \text{d}^{\circ}\text{C}$ cv. BK-560

$T_{base 2} = 24\, ^{\circ}\text{C}$, $T_{sum 2} = 300\, \text{d}^{\circ}\text{C}$ cv. BK-560 (Ong, 1983)

$T_{sum 1} = 1300\, \text{d}^{\circ}\text{C}$ cv. Tamrooth

$T_{sum 1} = 1500\, \text{d}^{\circ}\text{C}$ cv. MX001

$T_{sum 1} = 900\, \text{d}^{\circ}\text{C}$ inbred line (Muldoon, 1985)
Initial weight:
  estimated shoot weight 1 g per plant: (Carberry et al., 1985)
  leaves : 0.8 g per plant
  stems : 0.2
  roots : 1.5

planting rate: depends on water availability, 10000 plants ha\(^{-1}\)
in African Sahel and 175000 plants ha\(^{-1}\) in semi-arid tropical
regions of India (Carberry et al., 1985)

Growth rate roots:
  max. rate 7 cm d\(^{-1}\) (Azim-Ali et al., 1984)

Maximum rooting depth 220 cm (Azim-Ali et al., 1984)
Table 5. *Sorghum bicolor* L.

Leaf CO₂ assimilation:

**net photosynthesis:**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>CO₂ Assimilation (kg CO₂ ha⁻¹ h⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-70</td>
<td>(Peacock &amp; Heinrich, 1984)</td>
</tr>
<tr>
<td>55</td>
<td>(Ohki, 1986)</td>
</tr>
</tbody>
</table>

**effect of leaf age:**

<table>
<thead>
<tr>
<th>Leaf Age</th>
<th>CO₂ Assimilation (kg CO₂ ha⁻¹ h⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preflower</td>
<td>70</td>
</tr>
<tr>
<td>Postflower</td>
<td>48</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rel. Leaf Age</th>
<th>Rel. CO₂ Ass.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>0.3</td>
<td>0.87</td>
</tr>
<tr>
<td>0.6</td>
<td>0.62</td>
</tr>
<tr>
<td>0.9</td>
<td>0.28</td>
</tr>
<tr>
<td>1.0</td>
<td>0</td>
</tr>
</tbody>
</table>

(Krieg & Hutmacher, 1986)

(Elmore et al., 1967)

**effect of temperature:**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>CO₂ Assimilation (kg CO₂ ha⁻¹ h⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>1.00</td>
</tr>
<tr>
<td>40</td>
<td>1.00</td>
</tr>
<tr>
<td>47</td>
<td>0.82</td>
</tr>
<tr>
<td>60</td>
<td>1.00</td>
</tr>
</tbody>
</table>

(El-Sharkawy & Hesketh, 1964)

Max. rate 30-40 °C, 100 % reduction 45-48 °C, rate reduced ± 20 °C

(El-Sharkawy & Hesketh, 1964)

**effect of air humidity:**

<table>
<thead>
<tr>
<th>VPD (mbar)</th>
<th>CO₂ Assimilation (kg CO₂ ha⁻¹ h⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>21.5</td>
<td>1.00</td>
</tr>
<tr>
<td>50.0</td>
<td>0.50</td>
</tr>
<tr>
<td>81.0</td>
<td>0</td>
</tr>
</tbody>
</table>

(El-Sharkawy et al., 1984b)

No effect on CO₂ ass. of VPD 11-22 mbar (Rawson et al., 1977)

**Initial efficiency:**

0.35 kg CO₂ J⁻¹ ha⁻¹ h⁻¹ m² s (estimated identical to maize)

**Extinction coefficient:**

<table>
<thead>
<tr>
<th>Extinction Coefficient</th>
<th>Reference (Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3-0.7</td>
<td>(Peacock &amp; Heinrich, 1984)</td>
</tr>
<tr>
<td>0.4-0.7 (PAR)</td>
<td>(Muchow et al., 1984), average 0.6</td>
</tr>
<tr>
<td>0.53 (PAR)</td>
<td>(Sivakumar &amp; Virmani, 1984)</td>
</tr>
</tbody>
</table>
Specific leaf area:

\[
\begin{array}{cccc}
\text{DVS} & 0 & 0.33 & 1.0 & 2.0 \\
\text{SLA} & 0.0035 & 0.0035 & 0.0019 & 0.0019 \\
\end{array}
\]

(Sivakumar et al., 1979; McCree, 1983)

Leaf life span:

14 days at 28 °C = 400 d°C with \text{Tbase} = 0 °C, cv. RS610 (McCree, 1983),

\text{cv. Texas 610SR, cv. Dekalb DK55, cv. Pacific Monsoon (Muchow}

& Coates, 1986)

35 days, temperature range in field : 10-35 °C (Elmore et al., 1967)

Maintenance respiration:

- young plant : 0.026 g CH$_2$O g$^{-1}$ d$^{-1}$ (McCree, 1983)
- leaves : 0.03 kg CH$_2$O kg$^{-1}$ d$^{-1}$
- stems : 0.015
- roots : 0.010
- panicles: 0.010 (Penning de Vries & Van Laar, 1982)

Conversion factors:

<table>
<thead>
<tr>
<th></th>
<th>leaves</th>
<th>stems</th>
<th>fibrous roots</th>
<th>panicles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.72</td>
<td>0.69</td>
<td>0.72</td>
<td>0.74</td>
</tr>
</tbody>
</table>

(Penning de Vries & van Laar, 1982)

Dry matter distribution:

\[
\begin{array}{ccccccc}
\text{DVS} & 0 & 0.56 & 0.60 & 1.35 & 1.82 & 2.00 \\
\text{leaves} & 0.60 & 0.60 & 0.57 & 0 & 0 & 0 \\
\text{stems} & 0.40 & 0.40 & 0.43 & 0.39 & 0 & 0 \\
\text{heads} & 0 & 0 & 0 & 0.61 & 1.00 & 1.00 \\
\end{array}
\]

(Roy & Wright, 1973; Kaigama et al., 1977; Hodges et al., 1979; Sivakumar et al., 1979; Chamberlin & Wilson, 1982)

\[
\begin{array}{cccc}
\text{DVS} & 0 & 0.85 & 1.45 & 2.00 \\
\text{fibrous roots} & 0.20 & 0.20 & 0 & 0 \\
\end{array}
\]

(Arrevets, 1972; Chamberlin & Wilson, 1982)

- grains = 0.60 * heads (Van Hall & Van de Koppel, 1948)
- moisture content grains : 10 % (Penning de Vries et al., 1983)
Crop phenology:

emergence:

\[ T_{\text{base}} = 5-17 \, ^\circ\text{C}, \ T_{\text{max}} = 40-48 \, ^\circ\text{C} \]
\[ T_{\text{opt}} = 22-35 \, ^\circ\text{C} \quad \text{(Peacock \& Heinrich, 1984)} \]
\[ T_{\text{base}} = 10 \, ^\circ\text{C}, \ T_{\text{opt}} = 23 \, ^\circ\text{C}, \ T_{\text{sum}} = 67 \, \text{d}^\circ\text{C}, \ 10 \text{ sorghum hybrids} \]
\[ \text{(Kanemasu et al., 1975,)} \]
\[ T_{\text{base}} = 5 \, ^\circ\text{C}, \ T_{\text{opt}} = 26 \, ^\circ\text{C}, \ T_{\text{sum}} = 97 \, \text{d}^\circ\text{C}, \ 9 \text{ cv's} \]
\[ \text{(Stickler et al., 1962)} \]
\[ T_{\text{base}} = 9 \, ^\circ\text{C}, \ T_{\text{opt}} = 33 \, ^\circ\text{C}, \ T_{\text{max}} = 40 \, ^\circ\text{C} \quad \text{(Cardwell, 1984)} \]
\[ T_{\text{base}} = 10.6 \, ^\circ\text{C}, \ T_{\text{sum}} = 48 \, \text{d}^\circ\text{C} \quad \text{(Angus et al., 1980/1981)} \]

development:

most hybrids are day-neutral in their photoperiodic response.

\[ T_{\text{basel}} = 10 \, ^\circ\text{C}, \ T_{\text{optl}} = 30 \, ^\circ\text{C} \]
\[ T_{\text{suml}} = 1200 \, \text{d}^\circ\text{C}, \ \text{cv. Pacific 303} \]
\[ T_{\text{suml}} = 1000 \, \text{d}^\circ\text{C}, \ \text{cv. Goldrush} \]
\[ T_{\text{suml}} = 730 \, \text{d}^\circ\text{C}, \ \text{cv. RS626} \quad \text{(Muldoon, 1985)} \]
\[ T_{\text{sum2}} = 600 \, \text{d}^\circ\text{C}, \ \text{cv. RS626} \quad \text{(Neild, 1982), cv. Texas 610SR} \]
\[ \text{(Muchow et al., 1982)} \quad \text{(Tbase2 and Topt2 estimated having the same value as Tbasel and Topt1)} \]

Initial weight:

16 kg ha\(^{-1}\) shoot at 180000 plants ha\(^{-1}\) \quad \text{(Sivakumar et al., 1979)}

leaves : 0.056 g per plant
stems : 0.033
roots : 0.022

planting rate : dependent on level of management 80000-400000 plants ha\(^{-1}\) \quad \text{(Muchow et al., 1982)}.

Maximum rooting depth : 150 cm \quad \text{(Kaigama et al., 1977)}
Table 6, Maize *Zea mays L.*

Leaf CO₂ assimilation:

net photosynthesis:

- 65 kg CO₂ ha⁻¹ h⁻¹ (El-Sharkawy et al., 1985)

effect of leaf age:

<table>
<thead>
<tr>
<th>rel. leaf age</th>
<th>0</th>
<th>0.25</th>
<th>0.5</th>
<th>0.75</th>
<th>1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass.</td>
<td>1.0</td>
<td>1.0</td>
<td>0.90</td>
<td>0.70</td>
<td>0</td>
</tr>
</tbody>
</table>

(Van Laar & Penning de Vries, 1972)

effect of temperature:

<table>
<thead>
<tr>
<th>temperature</th>
<th>0</th>
<th>6</th>
<th>30</th>
<th>42</th>
<th>51</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel.max.CO₂ ass.</td>
<td>0.</td>
<td>0.</td>
<td>1.</td>
<td>1.</td>
<td>0.</td>
</tr>
</tbody>
</table>

(Van Laar & Penning de Vries, 1972; Hofstra & Hesketh, 1969)

<table>
<thead>
<tr>
<th>temperature</th>
<th>12</th>
<th>18</th>
<th>24</th>
<th>30</th>
<th>36</th>
<th>42</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass.</td>
<td>0.37</td>
<td>0.62</td>
<td>0.92</td>
<td>1.00</td>
<td>0.95</td>
<td>0.56</td>
</tr>
</tbody>
</table>

(Vong & Murata, 1977)

effect of air humidity:

<table>
<thead>
<tr>
<th>VPD</th>
<th>10-15</th>
<th>35-45 mbar</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass.</td>
<td>1.00</td>
<td>0.70</td>
</tr>
</tbody>
</table>

(El-Sharkawy et al., 1985)

Initial efficiency:

- 0.35 kg CO₂ J⁻¹ ha⁻¹ h⁻¹ m² s (Van Laar & Penning de Vries, 1972)

Extinction coefficient:

- 0.6 (visible light) (Sibma, 1987)
- 0.64 (PAR) (Sivakumar & Virmani, 1984)

Specific leaf area:

<table>
<thead>
<tr>
<th>DVS</th>
<th>0</th>
<th>1.</th>
<th>2.</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLA</td>
<td>0.0035</td>
<td>0.0016</td>
<td>0.0016</td>
</tr>
</tbody>
</table>

(Sibma, 1987)

Leaf life span:

<table>
<thead>
<tr>
<th>Tbase= 9 °C</th>
<th>(Brouwer et al., 1973)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsum= 870 d°C</td>
<td>(Van Laar &amp; Penning de Vries, 1972)</td>
</tr>
</tbody>
</table>
Maintenance respiration:

leaves : 0.03 kg CH₂O kg⁻¹ d⁻¹  
stems : 0.015  
roots : 0.010  
cob : 0.010 (Penning de Vries & Van Laar, 1982)

Conversion factors:

leaves 0.72  
stems 0.69  
fibrous roots 0.72 (Penning de Vries & Van Laar, 1982)  
cob 0.72 (Penning de Vries et al., 1983)

Dry matter distribution:

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>0.48</th>
<th>0.9</th>
<th>1.25</th>
<th>1.37</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
<td>0.62</td>
<td>0.62</td>
<td>0.28</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>stems</td>
<td>0.38</td>
<td>0.38</td>
<td>0.72</td>
<td>0.24</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>cob</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.76</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

(unpublished data, trials IBS and CABO)

DVS 0 1.10 2.00

fibrous roots 0.40 0 0

grains 70% of cob

(Foth, 1962; Warnke & Barber, 1974)

moisture content grains : 13% (Penning de Vries et al., 1983)

Crop phenology:

emergence:

Tbase= 9 °C, Topt = 30 °C, Tmax= 40 °C
Tsum = 65-85 d°C (Warrington & Kanemasu, 1983)
Tbase = 9 °C, Topt = 33 °C, Tmax = 42 °C (Cardwell, 1984)
Tbase = 9.8 °C, Tsum = 61 d°C (Angus et al., 1980/1981)
development:

modern hybrids are day-neutral in their photoperiodic response.

$T_{\text{base1}} = 7-8 \degree C$ (Warrington & Kanemasu, 1983;
Derieux & Bonhomme, 1982; Becker et al., 1953)

$T_{\text{opt1}} = 28-32 \degree C$ (Warrington & Kanemasu, 1983, Derieux
& Bonhomme, 1982)

with $T_{\text{base1}}$ and $T_{\text{base2}} = 8 \degree C$, and $T_{\text{opt1}}$ and $T_{\text{opt2}} = 30 \degree C$:

$T_{\text{sum1}} = 745 \, \text{d}^{\circ} \text{C cv. Ohio 401}$

$T_{\text{sum1}} = 760 \, \text{d}^{\circ} \text{C cv. De Kalb XL-45}$

$T_{\text{sum1}} = 890 \, \text{d}^{\circ} \text{C cv. Pioneer 3306}$

$T_{\text{sum2}} = 770 \, \text{d}^{\circ} \text{C cv. Ohio 401}$

$T_{\text{sum2}} = 860 \, \text{d}^{\circ} \text{C cv. De Kalb XL-45}$

$T_{\text{sum2}} = 865 \, \text{d}^{\circ} \text{C cv. Pioneer 3306}$ (Mederski et al., 1973)

Initial weight:

leaves 0.2 g per plant

roots 0.1 g per plant

total 0.3 g per plant (Grobbelaar, 1963)

planting rate : $25000 - 60000 \, \text{plants ha}^{-1}$ (ILACO, 1981)

Maximum rooting depth : 75 cm (Foth, 1962)
Table 7, Chick pea *Cicer arietinum* L.

Leaf CO₂ assimilation:

gross photosynthesis:
- \(43 \text{ kg CO}_2 \text{ ha}^{-1} \text{ h}^{-1}\), cv. Vilmorin
- 38 cv. Gibridnyj 27
- 37 cv. A64-7-A; Cl07
- 31 cv. DZ 10-2
- 30 cv. from Greece
- 28 cv. from Spain
- 24 cv. Alemaya JM 522 B; cv. Green grain

*(Van der Maesen, 1972)*

effect of leaf age:

<table>
<thead>
<tr>
<th>age</th>
<th>7</th>
<th>14</th>
<th>21</th>
<th>28 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel.max.CO₂ ass.</td>
<td>0.90</td>
<td>1.00</td>
<td>0.41</td>
<td>0.47</td>
</tr>
</tbody>
</table>

*(Van der Maesen, 1972)*

effect of temperature:

- between 18 and 26 °C no effect *(Van der Maesen, 1972)*

<table>
<thead>
<tr>
<th>temperature</th>
<th>10</th>
<th>17</th>
<th>26</th>
<th>42</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass.</td>
<td>0.90</td>
<td>1.00</td>
<td>1.00</td>
<td>0.65</td>
</tr>
</tbody>
</table>

*(Singh et al., 1982)*

effect of air humidity:

<table>
<thead>
<tr>
<th>VPD</th>
<th>8</th>
<th>17</th>
<th>60 mbar</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass.</td>
<td>0.96</td>
<td>1.00</td>
<td>0.78</td>
</tr>
</tbody>
</table>

*(Singh et al., 1982)*

Initial efficiency:

0.30 kg CO₂ J⁻¹ ha⁻¹ h⁻¹ m² s *(Van der Maesen, 1972)*

Specific leaf area:

- 0.0020 ha kg⁻¹ throughout the growing cycle, cv. T-3
- 0.0020 ha kg⁻¹ throughout the growing cycle, cv. JG-62
  *(Sheldrake & Saxena, 1979)*
- 0.0015 ha kg⁻¹ throughout the growing cycle, cv. G-130
- 0.0016 ha kg⁻¹ throughout the growing cycle, cv. JG-62
  *(Saxena et al., 1983)*
Leaf life span:
estimated at 70 days at 23 °C (Sheldrake & Saxena, 1979)

Maintenance respiration:
leaves : 0.030 kg CH$_2$O kg$^{-1}$ d$^{-1}$
stems : 0.015
roots : 0.010 (Penning de Vries & Van Laar, 1982)
pods + seed : 0.009 (calculated from biomass composition (Penning de Vries et al., 1983))

Conversion factors:
leaves 0.72
stems 0.69
fibrous roots 0.72 (Penning de Vries & van Laar, 1982)
pods + seed 0.77 (Penning de Vries et al., 1983)

Dry matter distribution:

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>0</th>
<th>1.13</th>
<th>1.20</th>
<th>1.27</th>
<th>1.72</th>
<th>1.84</th>
<th>1.97</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
<td></td>
<td>0.60</td>
<td>0.60</td>
<td>0.60</td>
<td>0.55</td>
<td>0.12</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>stems</td>
<td></td>
<td>0.40</td>
<td>0.40</td>
<td>0.32</td>
<td>0.29</td>
<td>0.18</td>
<td>0.15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>pod wall</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0.08</td>
<td>0.16</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>seeds</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.70</td>
<td>0.85</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

(Saxena et al., 1983; Saxena & Sheldrake, 1980; Sheldrake & Saxena, 1979)

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>0</th>
<th>0.45</th>
<th>0.95</th>
<th>1.25</th>
<th>1.55</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>fibrous roots</td>
<td></td>
<td>0.40</td>
<td>0.05</td>
<td>0.05</td>
<td>0.18</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(estimated after : Saxena et al., 1983; Shanthakumari et al., 1975)

moisture content seed : 8-13 % (Van der Maesen, 1972)
10 % (Kay, 1979)
Crop phenology:

emergence:

\[
\begin{array}{cccccc}
\text{Tbase} & \text{Topt} & \text{Tmax} \\
10 & 16 & 32 & 45 & 45
\end{array}
\]

(Temperature and development rate)

(Van der Maesen, 1972)

80% germination

development:

Chickpeas are long-day plants.

Tbase2 = 7 °C, Tsum2 = estimated at 28 °C

Tsum2 = 940 d°C, for all varieties, at every daylength

(Sheldrake & Saxena, 1979)

Initial weight:

shoot weight 0.2 g per plant

leaves : 0.6 * 0.2 = 0.12 g per plant

stems : 0.4 * 0.2 = 0.08 g per plant

roots : (0.2/0.6)*0.4 = 0.13 g per plant

Maximum rooting depth : 120 cm
Table 8, Mung bean \textit{Vigna radiata} (L.) Wilczek

Leaf CO\textsubscript{2} assimilation:

gross photosynthesis:
- 37 kg CO\textsubscript{2} ha\textsuperscript{-1} h\textsuperscript{-1} (De-Sheng Tsai & Arteca, 1985)

net photosynthesis:
- 22 kg CO\textsubscript{2} ha\textsuperscript{-1} h\textsuperscript{-1} (Phogat et al., 1984)
- 13-31 depending on cultivar (Srinivasan et al., 1985)

effect of air humidity:

<table>
<thead>
<tr>
<th>VPD</th>
<th>rel. CO\textsubscript{2} ass.</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-15</td>
<td>1.00</td>
</tr>
<tr>
<td>35-45</td>
<td>0.66</td>
</tr>
</tbody>
</table>

(El-Sharkawy et al., 1985)

Specific leaf area:

<table>
<thead>
<tr>
<th>DVS</th>
<th>SLA</th>
<th>days after planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0026</td>
<td>18</td>
</tr>
<tr>
<td>1.00</td>
<td>0.0033</td>
<td>33</td>
</tr>
<tr>
<td>2.00</td>
<td>0.0016</td>
<td>45</td>
</tr>
</tbody>
</table>

(Maniruzzaman, 1982)

<table>
<thead>
<tr>
<th>SLA</th>
<th>days after planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0030</td>
<td>18</td>
</tr>
<tr>
<td>0.0021</td>
<td>33</td>
</tr>
<tr>
<td>0.0018</td>
<td>45</td>
</tr>
<tr>
<td>0.0014</td>
<td>55</td>
</tr>
<tr>
<td>0.0018</td>
<td>66</td>
</tr>
<tr>
<td>0.0015</td>
<td>77</td>
</tr>
</tbody>
</table>

(Leaf blades, Kuo et al., 1980)

Maintenance respiration:

| leaves | 0.030 kg CH\textsubscript{2}O kg\textsuperscript{-1} d\textsuperscript{-1} |
| stems | 0.015 |
| fibrous roots | 0.010 (Penning de Vries & Van Laar, 1982) |
| pods + seed | 0.011 (calculated from biomass composition (Kay, 1979)) |

Conversion factors:

| leaves | 0.72 |
| stems | 0.69 |
| fibrous roots | 0.72 (Penning de Vries & van Laar, 1982) |
| pods + seed | 0.72 (calculated from biomass composition (Kay, 1979)) |
Dry matter distribution:

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>0.00</th>
<th>1.15</th>
<th>1.45</th>
<th>1.60</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
<td>0.65</td>
<td>0.65</td>
<td>0.45</td>
<td>0.06</td>
<td>0.04</td>
<td>0</td>
</tr>
<tr>
<td>stems</td>
<td>0.35</td>
<td>0.35</td>
<td>0.48</td>
<td>0.39</td>
<td>0.16</td>
<td>0</td>
</tr>
<tr>
<td>pods</td>
<td>0</td>
<td>0</td>
<td>0.07</td>
<td>0.55</td>
<td>0.80</td>
<td>1.00</td>
</tr>
<tr>
<td>DVS</td>
<td>0</td>
<td>1.45</td>
<td>2.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fibrous roots</td>
<td>0.45</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Maniruzzaman, 1982), cv. HB 45 (Moula & Krishnamoorthy, 1972)

seed 66 % of pods (Maniruzzaman, 1982)
moisture content seed : 9% (Kay, 1979)

Crop phenology:

emergence:

Tbase = 10.8 °C, Tsum = 50 d°C (Angus et al., 1980/1981)

development:

Tsum1 = 670 d°C cv. CES-10-2
Tsum1 = 610 cv. Berken, with assumed Tbase1 = 10°C (Muchov, 1985)
Tbase2 = 10 °C, Topt2 = 28 °C, Tsum2 = 273 d°C (Chowdhury et al., 1982)
Tsum2 = 570 d°C cv. CES-10-21
Tsum2 = 540 cv. Berken (Muchov, 1985)

Initial weight:

0.025 g per plant
roots : 0.0043, stem : 0.0093, leaves : 0.0114 g per plant
(Monsi et al., 1962)

planting rate : 100000 - 500000 plants ha⁻¹ (Kay, 1979)

Maximum rooting depth : 120 cm (Muchov, 1985)
Table 9, Cowpea *Vigna unguiculata* (L.) Walp.

Leaf CO₂ assimilation:

<table>
<thead>
<tr>
<th>net photosynthesis:</th>
<th>61-34 kg CO₂ ha⁻¹ h⁻¹, different cv.'s (Lush &amp; Rawson, 1979)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>26 (Phogat et al., 1984)</td>
</tr>
</tbody>
</table>

effect of leaf age:

- effect of age is different for plant with or without pods.
- plants with pods:
  - photosynthetic rate of 1 month old leaves = 0.60 * rate of young leaves
- plants not yet flowered:
  - photosynthetic rate of 1 month old leaves = 0.30 * rate of young leaves. (Lush & Rawson, 1979)

leaf age (days) | 0 | 13 | 40 (after attainment of final area).
rel. CO₂ ass. | 0 | 1.00 | 0.19

effect of temperature:

<table>
<thead>
<tr>
<th>temperature</th>
<th>18</th>
<th>30</th>
<th>42</th>
</tr>
</thead>
</table>
| rel. CO₂ ass. | 1.00 | 1.00 | 0.68 (Littleton et al., 1981)

effect of air humidity:

<table>
<thead>
<tr>
<th>VPD</th>
<th>10-15</th>
<th>35-45 mbar</th>
</tr>
</thead>
</table>
| rel. CO₂ ass. | 1.00 | 0.58 (El-Sharkawy et al., 1985)

Initial efficiency:

- 0.37 kg CO₂ J⁻¹ ha⁻¹ h⁻¹ m⁻² s (Lush & Rawson, 1979)
- 0.32 (Littleton et al., 1981)

Specific leaf area:

<table>
<thead>
<tr>
<th>DVS</th>
<th>0</th>
<th>2.00</th>
</tr>
</thead>
</table>
| SLA | 0.0040 | 0.0032 (Littleton et al., 1979b)

Leaf life span:

- 28 days at 27.5 °C, 36 days at 24.4 °C cv. K-2809 (Summerfield et al., 1978)
- T_base = 20 °C, death rate = 0.0039 *(T-20) d⁻¹ cv. TVu 4552 (Littleton et al., 1979a)
Maintenance respiration:
leaves: 0.030 kg CH$_2$O kg$^{-1}$ d$^{-1}$
stems: 0.015
roots: 0.010 (Penning de Vries & Van Laar, 1982)
pods + seed: 0.011 (calculated from biomass composition (Penning de Vries et al., 1983))

Conversion factors:
leaves 0.72
stems 0.69
fibrous roots 0.72 (Penning de Vries & van Laar, 1982)
pods + seed 0.81 (Penning de Vries et al., 1983)

Dry matter distribution:

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>0.60</th>
<th>0.95</th>
<th>1.50</th>
<th>1.70</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVS</td>
<td>0</td>
<td>1.00</td>
<td>1.00</td>
<td>0.61</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>leaves</td>
<td>1.00</td>
<td>1.00</td>
<td>0.61</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>stems</td>
<td>0</td>
<td>0</td>
<td>0.39</td>
<td>0.28</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>pods</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.72</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

(Littleton et al., 1979b; Ojehomon, 1970)

DVS 0 1.20 2.00
fibrous roots 0.65 0 0 (Littleton et al., 1979b)

seed 75-85% of pod
moisture content seed: 11% (Penning de Vries et al., 1983)

Crop phenology:

emergence:
80% emergence: Tbase = 11 °C, Topt > 33 °C, Tsum = 70 d°C
(Warrag & Hall, 1984)
80% germination Tbas = 9 °C; Topt = 35 °C; Tsum = 34 d°C
(Covell et al., 1986)
Tbase = 11.0 °C, Tsum = 43 d°C (Angus et al., 1980/1981)
development:

\[ T_{\text{basel}} = 8 \, ^{\circ}\text{C}, \quad T_{\text{sum1}} = 660 \, \text{d}^{\circ}\text{C} \text{ for photoperiod-insensitive genotypes;} \]

\[ T_{\text{sum1}} = 710 \, \text{d}^{\circ}\text{C} \text{ for photoperiod-sensitive genotypes, in a} \]

photo-thermal environment where flowering is determined by mean temperature. (Hadley et al., 1983)

\[ T_{\text{sum2}} = 370 \, \text{d}^{\circ}\text{C} \text{ cv. K 2809 (Summerfield et al., 1977)} \]

\[ T_{\text{max2}} = \text{about } 28 \, ^{\circ}\text{C} (\text{Hadley et al., 1983}) \]

\[ T_{\text{sum1}} = 740 \, \text{d}^{\circ}\text{C} \]

\[ T_{\text{sum2}} = 630 \, \text{d}^{\circ}\text{C} \text{ cv. Red Caloona (Muchov, 1985)} \]

Initial weight:

"seed weight 0.13 g (Martin & Leonard, 1967)"

"loss 1/3, plant weight : 0.09 g"

"planting rate : 150000-270000 plants ha^{-1} (Duke, 1981)"

Max. rooting depth : 120 cm (Muchov, 1985)
Table 10, Pigeon pea *Cajanus cajan* L.

Leaf CO₂ assimilation:

gross photosynthesis:
- 40 kg CO₂ ha⁻¹ h⁻¹ cv. Prabhat (Grover et al., 1985)

net photosynthesis:
- 24 kg CO₂ ha⁻¹ h⁻¹ cv. LRG-30 (Rao, 1985)

effect of leaf age:

<table>
<thead>
<tr>
<th>days</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass.</td>
<td>0.15</td>
<td>0.79</td>
<td>1.00</td>
<td>0.91</td>
<td>0.70</td>
<td>0.46</td>
<td>0.31</td>
</tr>
</tbody>
</table>
(days = days after unfolding; Rawson & Constable, 1981)

Initial efficiency:
- 0.51 kg CO₂ J⁻¹ ha⁻¹ h⁻¹ m⁻² s (Rawson & Constable, 1981)

Extinction coefficient:
- 0.50 (Natarajan & Willey, 1985)
- 0.69 (PAR) (Sivakumar & Virmani, 1984)

Specific leaf area:

<table>
<thead>
<tr>
<th>DVS</th>
<th>0.0020</th>
<th>0.0034</th>
<th>0.0028</th>
<th>0.0028</th>
</tr>
</thead>
</table>
| SLA | cv. Cita-1 (Tayo, 1982)

Leaf life span:
- 80 days at 31 °C (Sheldrake & Narayanan, 1979)
- 40 days, temperature unknown (Rao et al., 1984)

Maintenance respiration:
- leaves : 0.030 kg CH₂O kg⁻¹ d⁻¹
- stems : 0.015
- roots : 0.010 (Penning de Vries & Van Laar, 1982)
- pods + seed : 0.010 (calculated from biomass composition (Penning de Vries et al., 1983))
Conversion factors:

<table>
<thead>
<tr>
<th>Component</th>
<th>Conversion Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
<td>0.72</td>
</tr>
<tr>
<td>stems</td>
<td>0.69</td>
</tr>
<tr>
<td>fibrous roots</td>
<td>0.72 (Penning de Vries &amp; van Laar, 1982)</td>
</tr>
<tr>
<td>pods + seeds</td>
<td>0.78 (Penning de Vries et al., 1983)</td>
</tr>
</tbody>
</table>

Dry matter distribution:

<table>
<thead>
<tr>
<th>Component</th>
<th>0</th>
<th>0.65</th>
<th>1.00</th>
<th>1.45</th>
<th>1.85</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>leaves</td>
<td>0.50</td>
<td>0.50</td>
<td>0.43</td>
<td>0.34</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>stems</td>
<td>0.50</td>
<td>0.50</td>
<td>0.57</td>
<td>0.50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>flowers</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>pod wall</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.33</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>seed</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.67</td>
<td>0.82</td>
</tr>
</tbody>
</table>

cv. UPAS-120 (Rao et al., 1984), cv. ICP-1 (Sheldrake & Narayanan, 1979) N.B. Fallen leaves included!

DVS moisture content seed: 13% (Penning de Vries et al., 1983)

Crop phenology:

emergence:

\[ T_{base} = 12.8 \, ^{\circ}\text{C}, \quad T_{sum} = 58 \, \text{d}^\circ\text{C} \] (Angus et al., 1980/1981)

development:

\[ T_{base 1} = 11 \, ^{\circ}\text{C}, \quad T_{opt 1} = 23 - 26 \, ^{\circ}\text{C}, \quad T_{max 1} = 45 \, ^{\circ}\text{C} \]

\[ T_{sum 1} = 600 \, \text{d}^\circ\text{C} \quad \text{cv. ICRISAT 7220} \]

\[ T_{sum 1} = 685 \quad \text{cv. ICRISAT 26} \]

\[ T_{sum 1} = 725 \quad \text{cv. ICRISAT 6973} \]

\[ T_{sum 1} = 845 \quad \text{cv. ICRISAT 7120} \quad (\text{McPherson et al., 1985}) \]

\[ T_{sum 1} = 780 \quad \text{cv. Regur} \]

\[ T_{sum 1} = 1150 \quad \text{cv. ICP7179} \]

\[ T_{sum 1} = 585 \quad \text{cv. Regur} \]

\[ T_{sum 2} = 565 \quad \text{cv. ICP7179} \quad (\text{Muchov, 1985}) \]
Initial weight:
    seed weight 0.06 g (Martin & Leonard, 1967)
    loss 1/3, plant weight : 0.04 g
    planting rate : 3000-90000 plants ha$^{-1}$ (Kay, 1979)

Maximum rooting depth:
    97 % of roots in first 120 cm, 76 % in first 75 cm.
    maximum rooting depth : 180 cm (Rivera et al., 1983; Muchov, 1985)
Table 11, Lentil *Lens culinaris* Medic.

Leaf CO₂ assimilation:

gross photosynthesis:
- 32 kg CO₂ ha⁻¹ h⁻¹, cv. Large blonde
- 23 kg cv. Anica (Saint-Clair, 1972)

effect of temperature:
- no effect between 18-30 °C (Saint-Clair, 1972)

Specific leaf area:

<table>
<thead>
<tr>
<th>DVS</th>
<th>0</th>
<th>0.45</th>
<th>0.75</th>
<th>1.3</th>
<th>1.57</th>
<th>2.</th>
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<tbody>
<tr>
<td>SLA</td>
<td>0.0037</td>
<td>0.0037</td>
<td>0.0028</td>
<td>0.0039</td>
<td>0.0032</td>
<td>0.0032</td>
</tr>
</tbody>
</table>

(Maniruzzaman, 1982)

Maintenance respiration:

<table>
<thead>
<tr>
<th></th>
<th>leaves: 0.030 kg CH₂O kg⁻¹ d⁻¹</th>
<th>stems: 0.015</th>
<th>roots: 0.010 (Penning de Vries &amp; Van Laar, 1982)</th>
<th>pods + seed: 0.013 (calculated from biomass composition (Geessink &amp; Benedictus, 1973))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td></td>
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</tbody>
</table>

Conversion factors:

<table>
<thead>
<tr>
<th></th>
<th>leaves 0.72</th>
<th>stems 0.69</th>
<th>fibrous roots 0.72 (Penning de Vries &amp; van Laar, 1982)</th>
<th>pods + seed 0.71 (calculated from biomass composition (Geessink &amp; Benedictus, 1973))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
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</tbody>
</table>

Dry matter distribution:

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>leaves</th>
<th>stems</th>
<th>pods</th>
<th>DVS</th>
<th>leaves</th>
<th>stems</th>
<th>pods</th>
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</thead>
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<tr>
<td></td>
<td>0</td>
<td>0.85</td>
<td>1.00</td>
<td>1.60</td>
<td>0</td>
<td>0.60</td>
<td>0.51</td>
<td>0.56</td>
</tr>
<tr>
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<td>0.60</td>
<td>0.51</td>
<td>0.56</td>
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<td>0.40</td>
<td>0.49</td>
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</tr>
<tr>
<td></td>
<td>0.40</td>
<td>0.40</td>
<td>0.49</td>
<td>0.30</td>
<td>0</td>
<td>0.40</td>
<td>0.49</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
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<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0</td>
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<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
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<td>1.00</td>
<td>1.60</td>
<td>0</td>
<td>0.85</td>
<td>1.00</td>
<td>1.60</td>
</tr>
<tr>
<td></td>
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<td>0.51</td>
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<td>0.49</td>
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<td>0.51</td>
<td>0.49</td>
<td>0.49</td>
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<tr>
<td></td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
</tr>
</tbody>
</table>

seed 78% of pods (Maniruzzaman, 1982)
mobility content seed: 13% (Geessink & Benedictus, 1973)
Crop phenology:

emergence:

\[ T_{\text{base}} = 13 \, ^\circ\text{C}; \quad T_{\text{opt}} = 18-20 \, ^\circ\text{C}; \quad T_{\text{max}} = 25 \, ^\circ\text{C}; \quad T_{\text{sum}} = 14 \, \text{d}^\circ\text{C} \]  
(Pilet & Went, 1956)

80% germination

\[ T_{\text{base}} = 3 \, ^\circ\text{C}; \quad T_{\text{opt}} = 25 \, ^\circ\text{C}; \quad T_{\text{max}} = 33 \, ^\circ\text{C}; \quad T_{\text{sum}} = 23 \, \text{d}^\circ\text{C} \]  
(Covell et al., 1986)

\[ T_{\text{base}} = 1.9 \, ^\circ\text{C}, \quad T_{\text{sum}} = 89 \, \text{d}^\circ\text{C} \]  
(Angus et al., 1980/1981)

development:

\[ T_{\text{base}} = 0 \, ^\circ\text{C} \]  
(Summerfield et al., 1985)

Initial weight:

seed weight 0.05 g  
(Martin & Leonard, 1967)

loss 1/3, plant weight : 0.03 g

planting rate : 50000-150000 plants ha\(^{-1}\)  
(Duke, 1981)
Table 12, Soybean *Glycine max* (L.) Merrill

Leaf CO₂ assimilation:

**gross photosynthesis:**
- 37 kg CO₂ ha⁻¹ h⁻¹ (Elmore et al., 1967)
- 29 (Woodward, 1976)
- 34 (Singh et al., 1974)

**effect of leaf age:**

<table>
<thead>
<tr>
<th>rel. leaf age</th>
<th>0</th>
<th>0.13</th>
<th>1.</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass.</td>
<td>0.17</td>
<td>1.00</td>
<td>0</td>
</tr>
</tbody>
</table>

**effect of temperature:**

<table>
<thead>
<tr>
<th>temperature</th>
<th>0</th>
<th>32</th>
<th>39</th>
<th>49</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass.</td>
<td>0</td>
<td>1.00</td>
<td>1.00</td>
<td>0</td>
</tr>
</tbody>
</table>

(Hofstra & Hesketh, 1969)

<table>
<thead>
<tr>
<th>temperature</th>
<th>12</th>
<th>18</th>
<th>24</th>
<th>30</th>
<th>36</th>
<th>42</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass.</td>
<td>0.77</td>
<td>0.91</td>
<td>1.00</td>
<td>0.94</td>
<td>0.84</td>
<td>0.63</td>
</tr>
</tbody>
</table>

(Vong & Murata, 1977)

**effect of air humidity:**

- no effect on CO₂ ass. of VPD 8-22 mbar (Rawson et al., 1977)

**Pod CO₂ assimilation:**

Pods are capable of gross photosynthesis, but found to be incapable of net photosynthesis. Rate of gross photosynthesis, dependent on development stage between 2.8 and 11.0 micro-moles CO₂ h⁻¹ per g fresh weight (Qwebedeaux & Chollet, 1975)

- no pod assimilation below 5 °C (Spaeth & Sinclair, 1983a; 1983b)
- on fresh weight base, pod gross photosynthesis is 1/7 of leaf gross photosynthesis (Andrews & Svec, 1975)

**Initial efficiency:**

- 0.60 (Singh et al., 1974)
- 0.42 (PAR) (Harley et al., 1985)
Extinction coefficient:

0.41 (Global radiation; Taylor et al., 1982)
0.804 (PAR), 0.474 (Total radiation) cv. Tachisuzunari
0.787 (PAR), 0.525 (Total radiation) cv. Yamabedaizu
(Kumura, 1969)

Specific leaf area:

<table>
<thead>
<tr>
<th>DVS</th>
<th>SLA</th>
<th>SLA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0.90</td>
</tr>
</tbody>
</table>
| 0.45| 0.0020 | 0.0037 | 0.0037 | 0.0010 ha kg\(^{-1}\) (leaf blades)
| 0.78 | 0.0014 | 0.0025 | 0.0025 | 0.0007 ha kg\(^{-1}\) (leaf blades + petioles)

leaf blade = 0.68 * (leaf blades + petioles)
(Lugg & Sinclair, 1979; Sivakumar et al., 1977)

Leaf life span:

about 40 days at 20 °C on average (Hanway & Weber, 1971)

Maintenance respiration:

leaves: 0.03 kg CH\(_2\)O kg\(^{-1}\) d\(^{-1}\)
stems: 0.015
roots: 0.010 (Penning de Vries & Van Laar, 1982)

pods + seed: 0.017 (calculated from biomass composition (Penning de Vries et al., 1983))

Conversion factors:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
<td>0.72</td>
</tr>
<tr>
<td>stems</td>
<td>0.69</td>
</tr>
<tr>
<td>fibrous roots</td>
<td>0.72 (Penning de Vries &amp; van Laar, 1982)</td>
</tr>
<tr>
<td>pod + seed</td>
<td>0.68 (Penning de Vries et al., 1983)</td>
</tr>
</tbody>
</table>
Dry matter distribution:

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>0</th>
<th>1.00</th>
<th>1.15</th>
<th>1.30</th>
<th>1.50</th>
<th>1.70</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
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<td>0.75</td>
<td>0.75</td>
<td>0.60</td>
<td>0.46</td>
<td>0.27</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>stems</td>
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<td>0.25</td>
<td>0.27</td>
<td>0.27</td>
<td>0.28</td>
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<td>0</td>
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<tr>
<td>pod wall</td>
<td></td>
<td>0</td>
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<td>0.19</td>
<td>0.27</td>
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<td>seeds</td>
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<td>0</td>
<td></td>
<td>0.08</td>
<td>0.18</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

N.B. Fallen leaves included
(Hanway & Weber, 1971; Sivakumar et al., 1977)

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>0</th>
<th>0.75</th>
<th>1.50</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>fibrous roots</td>
<td>0.50</td>
<td>0.10</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

(Sivakumar et al., 1977; Courpront & Tauzin, 1975)

moisture content seed : 10 % (Penning de Vries et al., 1983)

Crop phenology:

devolution:

almost all cultivars are short-day plants, in which flowering occurs earlier in shorter than in longer photoperiods. There is considerable variability in the relative sensitivity of soybean genotypes to differences in photoperiod; later maturing cultivars are generally more sensitive than early maturing ones.

Tbase = 7 °C, Topt = 30 °C (Brown, 1960)
Tsum1 = 700 d°C
Tsum2 = 1050 d°C cv. Wayne (Sivakumar et al, 1977)
Tsum1 = 690 d°C cv. Durack
Tsum1 = 450 d°C cv. Buchanan
Tsum2 = 1080 d°C cv.'s Durack, Buchanan (Muchov, 1985)
Initial weight:

about 0.4 g per plant (Hanway & Weber, 1971)
leaves : 0.2 g per plant
roots : 0.2
planting rate : 300000–750000 plants ha$^{-1}$ (Godin & Spensley, 1971)

Maximum rooting depth : 120 cm (Muchov, 1985)
Table 13, **Peanut Arachis hypogaea L.**

**Leaf CO₂ assimilation:**

**gross photosynthesis:**

**field plants:**

- 22-28 kg CO₂ ha⁻¹ h⁻¹, cv. Florunner (Henning et al., 1979)
- 30, cv. Florunner
- 27, cv. Florigiant (Bhagsari & Brown, 1976a)

**greenhouse plants:**

- 28 kg CO₂ ha⁻¹ h⁻¹, cv. Tang
- 33, cv. Florunner (Bhagsari & Brown, 1976b)
- 41, cv. Florunner
- 27, cv. Florigiant (Bhagsari & Brown, 1976a)
- 43, cv. Florunner
- 50, cv. Tift-8 (Bhagsari et al., 1976)
- 66-53, cv. 's Florida 70115, Florunner, Dixi Runner, resp. mainstem and cotyledonary branch (Trachtenberg & McCloud, 1976)

**effect of leaf age:**

<table>
<thead>
<tr>
<th>relative leaf age</th>
<th>0</th>
<th>0.2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>relative CO₂ ass.</td>
<td>1.00</td>
<td>0.99</td>
<td>0.88</td>
</tr>
<tr>
<td>age (days)</td>
<td>10</td>
<td>20</td>
<td>30</td>
</tr>
</tbody>
</table>
| rel. CO₂ ass.     | 0.77  | 0.65  | 0.56  | (Trachtenberg & McCloud, 1976)

**effect of temperature:**

<table>
<thead>
<tr>
<th>temperature</th>
<th>0</th>
<th>7</th>
<th>30</th>
<th>45</th>
</tr>
</thead>
</table>
| relative CO₂ ass. | 0     | 0     | 1.00  | 0.78  | (Paz & Pallas, 1986)

**effect of air humidity:**

<table>
<thead>
<tr>
<th>VPD</th>
<th>10-15</th>
<th>35-45</th>
<th>mbar</th>
</tr>
</thead>
</table>
| rel. CO₂ ass.     | 1.00  | 0.57  | (El-Sharkawy et al., 1985)

**Initial efficiency:**

0.42 kg CO₂ J⁻¹ ha⁻¹ h⁻¹ m⁻² s (Pallas & Samish, 1974)

**Extinction coefficient:**

0.6 (Global radiation) cv. Robut 33-1 (Reddy & Willey, 1981)
Specific leaf area:

0.0018 ha kg\(^{-1}\) (Rao & Rama Das, 1981; Pallas & Samish, 1974; Bhagsari & Brown, 1976a, 1976b)

Leaf life span:

\[ \text{Tbase} = 10 \, ^\circ\text{C}, \text{Tsum} = 1000 \, \text{d}^\circ\text{C} \text{ estimated} \] (Leong & Ong, 1983)

Maintenance respiration:

- leaves: \(0.030 \, \text{kg CH}_2\text{O kg}^{-1} \text{d}^{-1}\)
- stems: \(0.015\)
- roots: \(0.010\) (Penning de Vries & Van Laar, 1982)
- pods + seed: \(0.012\) (calculated from biomass composition (Penning de Vries et al., 1983)

Conversion factors:

- leaves: 0.72
- stems: 0.69
- fibrous roots: 0.72 (Penning de Vries & van Laar, 1982)
- pod with seed: 0.50 (Penning de Vries et al., 1983)

Dry matter distribution:

\[
\begin{array}{cccccccc}
\text{DVS} & 0 & 1.00 & 1.10 & 1.30 & 1.60 & 1.70 & 2.00 \\
\text{leaves} & 0.50 & 0.50 & 0.50 & 0.34 & 0.10 & 0.10 & 0.10 \\
\text{stems} & 0.50 & 0.50 & 0.40 & 0.56 & 0.32 & 0.15 & 0.15 \\
\text{nuts} & 0 & 0 & 0.03 & 0.03 & 0.51 & 0.68 & 0.68 \\
\text{flowers} & 0 & 0 & 0.07 & 0.07 & 0.07 & 0.07 & 0.07 \\
(\text{Bouyer, 1949}; \text{McCord, 1974}; \text{Ong, 1984}) \\
\text{DVS} & 0 & 0.20 & 1.50 & 2.00 \\
\text{fibrous roots} & 0.20 & 0.08 & 0 & 0 & \text{(Bouyer, 1949)} \\
\end{array}
\]

seed 60-75 % of nuts

moisture content nuts: 5 % (Penning de Vries et al., 1983)
Crop phenology:

emergence:

\[ T_{\text{base}} = 10 \, ^\circ C, \quad T_{\text{opt}} = 30 \, ^\circ C, \quad \text{cv. Robut 33-1} \]

\[ T_{\text{sum}} = 120 \, \text{d}^\circ C \text{ for } 70 \% \text{ emergence.} \]

Note: serious reduction in germination below 18 \, ^\circ C, probably a consequence of attack by soil pathogens. (Leong & Ong, 1983)

\[ T_{\text{base}} = 13 \, ^\circ C, \quad T_{\text{opt}} = 20 \, ^\circ C, \quad T_{\text{max}} = 38 \, ^\circ C \] (Cardwell, 1984)

\[ T_{\text{base}} = 13.3 \, ^\circ C, \quad T_{\text{sum}} = 76 \, d^\circ C \] (Angus et al., 1980/1981)

development:

peanut is a short-day plant, but there are many day-neutral cultivars.

\[ T_{\text{base1}} = 10 \, ^\circ C, \quad T_{\text{opt1}} = 30 \, ^\circ C \]

\[ T_{\text{sum1}} = 600 \, d^\circ C, \quad \text{cv. Robut 33-1} \]

\[ T_{\text{sum2}} = 750 \, d^\circ C, \quad \text{cv. Robut 33-1} \] (Leong & Ong, 1983; Ong, 1984)

Initial weight:

leaves: 0.050 g per plant at emergence

stems: 0.050

roots: 0.025 (Bouyer, 1949)

planting rate: 40000 - 110000 plants ha\(^{-1}\) (Godin & Spensley, 1971)

Maximum rooting depth: 60 cm (Doorenbos et al., 1979)
Table 14, Sesame *Sesamum indicum* L.

Leaf CO₂ assimilation:

**net photosynthesis:**
- 22 kg CO₂ ha⁻¹ h⁻¹ cv. TMV-1 (Rao, 1985)
- 29 cv. Glauc (Hall & Kaufmann, 1975)

**effect of temperature:**
- temperature: 20, 30, 34
- rel. CO₂ ass.: 0.79, 1.00, 1.00 (Hall & Kaufmann, 1975)

**Specific leaf area:**

<table>
<thead>
<tr>
<th>DVS</th>
<th>SLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.00</td>
</tr>
</tbody>
</table>
| 0.0030 | 0.0021 | (Lazim & El-Nadi, 1974)

**Maintenance respiration:**

<table>
<thead>
<tr>
<th></th>
<th>leaves: 0.030 kg CH₂O kg⁻¹ d⁻¹</th>
<th>stems: 0.015</th>
<th>roots: 0.010 (Penning de Vries &amp; Van Laar, 1982)</th>
<th>capsules: 0.012 (calculated from biomass composition (Geessink &amp; Benedictus, 1973))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Conversion factors:**

<table>
<thead>
<tr>
<th></th>
<th>leaves: 0.72</th>
<th>stems: 0.69</th>
<th>fibrous roots: 0.72 (Penning de Vries &amp; van Laar, 1982)</th>
<th>capsules: 0.62 (calculated from biomass composition (Geessink &amp; Benedictus, 1973))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Dry matter distribution:**

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>leaves</th>
<th>stems</th>
<th>capsules</th>
<th>DVS</th>
<th>leaves</th>
<th>stems</th>
<th>capsules</th>
<th>DVS</th>
<th>leaves</th>
<th>stems</th>
<th>capsules</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0.90</td>
<td>1.00</td>
<td>1.30</td>
<td>1.70</td>
<td>1.90</td>
<td>2.00</td>
<td></td>
<td>0</td>
<td>0.05</td>
<td>0.67</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>0.80</td>
<td>0.80</td>
<td>0.70</td>
<td>0.40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>0.05</td>
<td>0.67</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>0.20</td>
<td>0.20</td>
<td>0.30</td>
<td>0.55</td>
<td>0.33</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>0.05</td>
<td>0.67</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>2.00</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>0.05</td>
<td>0.67</td>
<td>1.00</td>
</tr>
</tbody>
</table>

(Narasayan & Reddy, 1982; Patarroyo Murcia, 1980; Saha & Bhargava, 1980; Weiss, 1971)
seed = 0.30 * capsule weight (Saha & Bhargava, 1980)
moisture content seed : 6 % (Geessink & Benedictus, 1973)

Crop phenology:

emergence:
no germination when soil temp. ± 21 °C (Godin & Spensley, 1971)

Initial weight:
seed weight 0.01 g (Martin & Leonard, 1967)
loss 1/3, plant weight : 0.007 g
planting rate : 90000 - 1110000 plants ha⁻¹ (Godin & Spensley, 1971)
### Table 15. Oilseed rape *Brassica campestris* L.

Leaf CO₂ assimilation:

<table>
<thead>
<tr>
<th>gross photosynthesis:</th>
<th>40 kg CO₂ ha⁻¹ h⁻¹ cv. Jet neuf (Duivenvoorde &amp; Backx, 1984)</th>
</tr>
</thead>
<tbody>
<tr>
<td>net photosynthesis:</td>
<td>15 kg CO₂ ha⁻¹ h⁻¹ cv. BSH-1 B. juncea: cv. Parkash (Dabas &amp; Sheoran, 1984)</td>
</tr>
</tbody>
</table>

**effect of leaf age:**

<table>
<thead>
<tr>
<th>leaf age</th>
<th>rel. CO₂ ass.</th>
<th>cv. Brutor (Rode et al., 1983)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>13</td>
<td>1.00</td>
<td>0</td>
</tr>
<tr>
<td>30 days</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**effect of temperature:**

<table>
<thead>
<tr>
<th>temperature</th>
<th>rel. CO₂ ass.</th>
<th>cv. Zollerngold Zollerngold (Tayo &amp; Morgan, 1975)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>24</td>
<td>0.98</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>0.90</td>
<td></td>
</tr>
</tbody>
</table>

Pod CO₂ assimilation:

<table>
<thead>
<tr>
<th>gross photosynthesis:</th>
<th>40 kg CO₂ ha⁻¹ (pods) h⁻¹ cv. Jet neuf (Duivenvoorde &amp; Backx, 1984)</th>
</tr>
</thead>
<tbody>
<tr>
<td>net photosynthesis:</td>
<td>14 kg CO₂ ha⁻¹ (pods) h⁻¹ (Inanaga et al., 1979)</td>
</tr>
</tbody>
</table>

**effect of pod age:**

<table>
<thead>
<tr>
<th>DVS</th>
<th>rel. CO₂ ass.</th>
<th>cv. Zollerngold Zollerngold (Tayo &amp; Morgan, 1975)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Initial efficiency:**

0.5 kg CO₂ J⁻¹ ha⁻¹ h⁻¹ m² s⁻¹ (Duivenvoorde & Backx, 1984)

**Extinction coefficient:**

0.54 (Chartier et al., 1983)

**Specific leaf area:**

<table>
<thead>
<tr>
<th>DVS</th>
<th>SLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0022</td>
</tr>
<tr>
<td>2.00</td>
<td>0.0019</td>
</tr>
</tbody>
</table>

Specific pod area:

DVS 1.00 2.00
SPA 0.0016 0.0008

(Tayo & Morgan, 1975)

DVS 1.00 1.48 2.00
SPA 0.00226 0.00054 0.00054 (Inanaga et al., 1979)

N.B. in pod weight seed weight is included

Leaf life span:

30 days (estimated from Clarke & Simpson, 1978)

Maintenance respiration:

leaves : 0.030 kg CH$_2$O kg$^{-1}$ d$^{-1}$
stems : 0.015
roots : 0.010 (Penning de Vries & Van Laar, 1982)
pods + seed : 0.012 (calculated from biomass composition (Geessink & Benedictus, 1973))

Conversion factors:

leaves 0.72
stems 0.69
fibrous roots 0.72 (Penning de Vries & van Laar, 1982)
pod wall 0.67 (estimated identical to stems)
seed 0.46 (calculated from biomass composition (Geessink & Benedictus, 1973))

Dry matter distribution:

DVS 0 0.55 1.00 1.22 1.33 1.45 1.70 2.00
leaves 0.85 0.85 0.43 0.22 0.12 0 0 0
stems 0.15 0.15 0.57 0.46 0.41 0.37 0 0
pod wall 0 0 0 0.32 0.37 0 0 0
seed 0 0 0 0 0.10 0.63 1.00 1.00
DVS 0 1.20 1.60 0
fibrous roots 0.14 0.14 0 0

cv.'s Toria, Yellow Sarson, Brown Sarson (Chauhan & Bhargava, 1984; Duivenvoorde & Backx, 1984), cv. Span (Rood et al., 1984a; Tayo & Morgan, 1975)

moisture content seed : 8 % (Geessink & Benedictus, 1973)
Crop phenology:

emergence:

Tbase = 2.6 °C, Tsum = 79 d°C (Angus et al., 1980/1981)

development:

Tbasel and Tbase2 = 4 °C, winter oilseed rape (Duivenvoorde & Backx, 1984)

Tbasel and Tbase2 = 5 °C, spring oilseed rape (Rood et al., 1984b)

Tsum1 = 1000 d°C

Tsum2 = 1300 d°C, cv. Jet neuf (Duivenvoorde & Backx, 1984)

Tsum1 = 450 d°C

Tsum2 = 650 d°C, cv. Span (Rood et al., 1984b)

Note: day-degree sums obtained under the prevailing daylength conditions.

photoperiodic response:

Hbase = 6 h, Hopt = 18 h, Hsum = 330 dh mean for 10 cv.'s at 20 °C (King & Kandra, 1986)

Initial weight:

0.5 g per plant (estimated after Duivenvoorde & Backx, 1984)

roots: 0.07; leaves: 0.37; stems: 0.06 g per plant

planting rate: 500000 – 800000 plants ha⁻¹ (Bernelot Moens & Wolfert, 1975)

Maximum rooting depth: 125 cm (Jonker, 1985)
Table 16. Sunflower *Helianthus annuus* L.

Leaf CO\(_2\) assimilation:

net photosynthesis:

\(30-33 \text{ kg CO}_2 \text{ ha}^{-1} \text{ h}^{-1}\) (Van Laar & Penning de Vries, 1972)

effect of temperature:

<table>
<thead>
<tr>
<th>temperature</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO(_2) ass.</td>
<td>1.00</td>
<td>0.92</td>
<td>0.82</td>
<td>0.68</td>
<td>0.50</td>
</tr>
<tr>
<td>(Hew et al., 1969)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>temperature</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO(_2) ass.</td>
<td>0.50</td>
<td>1.00</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>(Horie, 1977)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

effect of leaf age:

<table>
<thead>
<tr>
<th>age</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>45 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO(_2) ass.</td>
<td>1.00</td>
<td>0.96</td>
<td>0.77</td>
<td>0.54</td>
<td>0.19</td>
<td>0</td>
</tr>
<tr>
<td>(Elmore et al., 1967)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Initial efficiency:

\(0.27-0.30 \text{ kg CO}_2 \text{ J}^{-1} \text{ ha}^{-1} \text{ h}^{-1} \text{ m}^2\) \(\text{s}\)  
(Van Laar & Penning de Vries, 1972)

Extinction coefficient:

0.8 - 0.9 (Stern, 1962)  
0.9 (Rawson et al., 1984)

Specific leaf area:

<table>
<thead>
<tr>
<th>DVS</th>
<th>0</th>
<th>1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLA</td>
<td>0.0035</td>
<td>0.0025</td>
</tr>
</tbody>
</table>

Maintenance respiration:

<table>
<thead>
<tr>
<th>leaves</th>
<th>0.05 \text{ kg CH}_2\text{O kg}^{-1} \text{ d}^{-1}</th>
</tr>
</thead>
<tbody>
<tr>
<td>stems</td>
<td>0.0075</td>
</tr>
<tr>
<td>roots</td>
<td>0.01</td>
</tr>
<tr>
<td>inflorescence</td>
<td>0.023  (Horie, 1977)</td>
</tr>
</tbody>
</table>


Conversion factors:

leaves 0.59
stems 0.73
fibrous roots 0.71
inflorescence 0.71 (Horie, 1977)

Dry matter distribution:

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>0.85</th>
<th>0.91</th>
<th>1.22</th>
<th>1.35</th>
<th>1.72</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
<td>0.50</td>
<td>0.50</td>
<td>0.41</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>stems</td>
<td>0.50</td>
<td>0.50</td>
<td>0.59</td>
<td>0.28</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>capitulum</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.34</td>
<td>0.46</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>seed</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.38</td>
<td>0.54</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

(Gimenez & Fereres, 1986; Hocking & Steer, 1983)

moisture content seed 6 % (Penning de Vries et al., 1983)

Crop phenology:

emergence:

| temperature | 13 | 37 |
| days        | 13 | 4  |

Tbase = 3 °C; Topt = 37 °C, Tsum = 130 d°C (Singh & Singh, 1976)
Tbase = 1 °C; Tsum = 133 d°C cv. Stepniak (Doyle, 1975)

development:

Tbasel = 2 °C,
Topt1 = 18 - ≥ 27 °C, Tsum1 = 910 d°C
Topt2 = 18 - ≥ 27 °C, Tsum2 = 640 d°C cv. Suncros 150
Topt1 = 23 - ≥ 27 °C, Tsum1 = 1190 d°C
Topt2 = 18 - ≥ 27 °C, Tsum2 = 640 d°C cv. Hysun 31

(Rawson et al., 1984)

Tbasel = 1 °C, Tsum1 = 1250 d°C cv. Stepniak (Doyle, 1975)
Tbasel = 5 °C, Tsum1 = 1300 d°C cv. Mammoth Russian (Horie, 1977)

Plating rate : 60000 plants ha⁻¹ (Doorenbos et al., 1979)

Maximum rooting depth : 150 cm (Doorenbos et al., 1979)
Table 17, Cassava  

*Manihot esculenta Crantz*

Leaf CO₂ assimilation:

**gross photosynthesis:**

30 kg CO₂ ha⁻¹ h⁻¹, no significant clonal differences (Veltkamp, 1985)

**net photosynthesis:**

35-41 kg CO₂ ha⁻¹ h⁻¹ (El-Sharkawy et al., 1984a)

**effect of leaf age:**

reduction of photosynthetic rate up to 0.45 of maximum for leaves of 8 weeks old.

**effect of temperature:**

no effects between 25 and 35 °C (Tsuno et al., 1983)

<table>
<thead>
<tr>
<th>temperature</th>
<th>15</th>
<th>23</th>
<th>35</th>
<th>45</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO₂ ass.</td>
<td>0.69</td>
<td>1.00</td>
<td>1.00</td>
<td>0.31 (El-Sharkawy et al., 1984a)</td>
</tr>
</tbody>
</table>

**effect of air humidity:**

VPD 0 16 53 mbar

<table>
<thead>
<tr>
<th>rel. CO₂ ass.</th>
<th>1.00</th>
<th>1.00</th>
<th>0</th>
</tr>
</thead>
</table>

**Initial efficiency:**

0.39 kg CO₂ J⁻¹ ha⁻¹ h⁻¹ m² s (Veltkamp, 1985)

**Extinction coefficient:**

0.7 (Tsuno et al., 1983)

0.88 cv. M Col 22

0.86 cv. M Col 1684

0.84 cv. M Ptr 26

0.72 cv. M Ven 77 (Veltkamp, 1985)

**Specific leaf area:**

0.0023 ha kg⁻¹ for leaf blades (Tsuno et al., 1983; Aslam et al., 1977)

leaf blade = 0.79 * (leaf blade + petiole) (Howeler & Cadavid, 1983)

0.0018 ha kg⁻¹ for leaves (Veltkamp, 1985; Howeler & Cadavid, 1983)
Leaf life span:
- between 20 and 210 days. On average at 24 °C and under moisture stress 80-100 days (Veltkamp, 1985)
- dependent on cv. 36-54 days, on average 45 days (Ramanujam & Indira, 1983)
- Start leaf fall at 110 days after planting, mean leaf age at falling 80 days after leaf appearance (Conner & Cock, 1981)

Maintenance respiration:
- leaves: \(3.81 \text{ mg CO}_2 \text{ g}^{-1} \text{ h}^{-1}\) = 0.030 kg CH\(_2\)O kg\(^{-1}\) d\(^{-1}\)
- stems: 0.25 = 0.004
- tubers: 0.20 = 0.003 (Tsuno et al., 1983)
- fibrous roots: = 0.010 (Penning de Vries & Van Laar, 1982)

Conversion factors:
- leaves 0.72
- stems 0.69
- fibrous roots 0.72 (Penning de Vries & van Laar, 1982)
- tubers 0.81 (Penning de Vries et al., 1983)

Dry matter distribution:
- DVS 0 1.00 1.29 2.00
- leaves 0.75 0.60 0.16 0.16
- stems 0.25 0.40 0.29 0.29
- tubers 0 0 0.55 0.55
(Veltkamp, 1985; Howeler & Cadavid, 1983)
- fibrous roots ca. 0.03 throughout the crop cycle (Connor et al., 1981)
- Moisture content tubers: 62 % (Penning de Vries et al., 1983)

Crop phenology:

emergence:
- \(T_{base} = 13 \degree C\), \(T_{max} = 36-40 \degree C\), \(T_{sum} = 220 \degree d\text{C}\)
- \(T_{opt} = 30 \degree C\) cv. Maus 10
- = 28.5 \degree C cv. Maus 7 (Keating & Evenson, 1979)
development:
cassava is a short day plant and less productive in day lengths exceeding 12 hours. Therefore the crop is most productive when grown in areas between latitudes 15 N and 15 S.
The growth cycle of cassava lacks major phenological events, and timing and extent of storage root development is not greatly affected by environment.
Development stage 1.00 is assumed to be tuber initiation, the crop is supposed to mature in one year.
assumed $T_{\text{base}} = 10 \, ^\circ\text{C}$
assumed time till tuber initiation 30 days: $T_{\text{sum1}} = 420 \, \text{d}^\circ\text{C}$
rest of the year, 314 days: $T_{\text{sum2}} = 4400 \, \text{d}^\circ\text{C}$ (Veltkamp, 1985)

Initial weight:
stem cuttings (20 cm) 14 g dry matter each
initial weight leaves 10 g per plant
initial weight stems 12 g per plant (Howeler & Cadavid, 1983)
planting rate : 7000–20000 plants ha$^{-1}$ (Kay, 1973)

Maximum rooting depth : 260 cm (Connor et al., 1981)
95 % of roots in first 75 cm, 75 % in first 30 cm
(Rivera et al., 1983)
Table 18. Sweet potato *Ipomoea batatas* (L.) Lam

Leaf CO₂ assimilation:

net photosynthesis:
31 kg CO₂ ha⁻¹ h⁻¹ (average for 36 genotypes, Bhagsari, 1981; Bhagsari & Harmon, 1982)

effect of leaf age:

<table>
<thead>
<tr>
<th>leaf age</th>
<th>rel. CO₂ ass.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 days</td>
<td>0.97</td>
</tr>
<tr>
<td>90 days</td>
<td>0.29</td>
</tr>
</tbody>
</table>

(Fujise & Tsuno, 1962)

effect of temperature:

<table>
<thead>
<tr>
<th>temperature</th>
<th>rel. CO₂ ass.</th>
<th>(Tsuno &amp; Fujise, 1965)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>32</td>
<td>1.00</td>
<td>0.81</td>
</tr>
<tr>
<td>36</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>temperature</th>
<th>rel. CO₂ ass.</th>
<th>temperature</th>
<th>rel. CO₂ ass.</th>
<th>rel. CO₂ ass.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.29</td>
<td>15</td>
<td>0.45</td>
<td>1.00</td>
</tr>
<tr>
<td>25</td>
<td>0.93</td>
<td>35</td>
<td>0.95</td>
<td>1.00</td>
</tr>
</tbody>
</table>

cv. Tai-lung 57

(Wu et al., 1974)

Extinction coefficient:
0.45 (Fujise & Tsuno, 1962)

Specific leaf area:

<table>
<thead>
<tr>
<th>days after planting</th>
<th>SLA</th>
<th>SLA</th>
<th>leaf blade = 0.68 * (leaf blade + petiole)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0017</td>
<td>0.0012</td>
<td>(leaf blade)</td>
</tr>
<tr>
<td>57</td>
<td>0.0031</td>
<td>0.0021</td>
<td>(leaf blade + petiole)</td>
</tr>
<tr>
<td>150</td>
<td>0.0020</td>
<td>0.0014</td>
<td>(leaf blade + petiole)</td>
</tr>
</tbody>
</table>

(Tsuno & Fujise, 1965)

Leaf life span:
60–80 days (Tsuno & Fujise, 1965);
45 days at 25 °C (Bhattacharya et al., 1985)

Maintenance respiration:

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
<td>0.028 kg CH₂O kg⁻¹ d⁻¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>stems</td>
<td>0.020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fibrous roots</td>
<td>0.025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tubers</td>
<td>0.005 (Tsuno &amp; Fujise, 1965)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Conversion factors:

- leaves: 0.72
- stems: 0.69
- fibrous roots: 0.72 (Penning de Vries & van Laar, 1982)
- tubers: 0.80 (Penning de Vries et al., 1983)

Dry matter distribution:

<table>
<thead>
<tr>
<th>DVS</th>
<th>0</th>
<th>1.00</th>
<th>1.55</th>
<th>1.65</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
<td>0.60</td>
<td>0.60</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>stems</td>
<td>0.40</td>
<td>0.40</td>
<td>0.15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>tubers</td>
<td>0</td>
<td>0</td>
<td>0.85</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

(Agata, 1982; Bhattacharya et al., 1985; Bourke, 1985; Fabro et al., 1976; Tsuno & Fujise, 1965)

<table>
<thead>
<tr>
<th>DVS</th>
<th>0</th>
<th>1.50</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>fibrous roots</td>
<td>0.35</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(Bhattacharya et al., 1985; Bourke, 1985)

Moisture content of tubers: 70% (Penning de Vries et al., 1983)

Crop phenology:

Development:
- planting – tuber initiation: 38 days at 24.9 °C;
- tuber initiation – maturity: 109 days at 23.2 °C
(Agata, 1982)

Initial weight:
- 3 g per plant, 20 days after planting (Bhattacharya et al., 1985), giving about 0.33 g on day of emergence.
- planting rate: 25000 – 125000 plants ha⁻¹ (Kay, 1973)
Table 19, Potato *Solanum tuberosum* L.

Leaf CO₂ assimilation:

**net photosynthesis:**

<table>
<thead>
<tr>
<th>Value (kg CO₂ ha⁻¹ h⁻¹)</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>cv. W729R (Ku et al., 1977)</td>
</tr>
<tr>
<td>26-28</td>
<td>cv. Russet Burbank</td>
</tr>
<tr>
<td>35</td>
<td>cv. Lemhi</td>
</tr>
<tr>
<td>29-50</td>
<td>cv. A66107-51</td>
</tr>
<tr>
<td>28-40</td>
<td>cv. A6948-4 (Dwelle et al., 1983)</td>
</tr>
<tr>
<td>15</td>
<td>cv. Bintje (Teubner, 1985)</td>
</tr>
<tr>
<td>9</td>
<td>cv. Lenino</td>
</tr>
<tr>
<td>7</td>
<td>cv. Sowa</td>
</tr>
<tr>
<td>8</td>
<td>cv. Nysa (Markowski et al., 1979)</td>
</tr>
</tbody>
</table>

**effect of leaf age:**

<table>
<thead>
<tr>
<th>Days after full expansion</th>
<th>Relative CO₂ assimilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>25</td>
<td>0</td>
</tr>
</tbody>
</table>

**effect of temperature:**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Relative CO₂ assimilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>7</td>
<td>0.38</td>
</tr>
<tr>
<td>19</td>
<td>0.38</td>
</tr>
<tr>
<td>29</td>
<td>1.00</td>
</tr>
<tr>
<td>37</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**Initial efficiency:**

0.38 kg CO₂ J⁻¹ ha⁻¹ h⁻¹ m⁻² s (Teubner, 1985)

**Extinction coefficient:**

0.48 (total radiation) cv. Majestic (Allen & Scott, 1980)

**Specific leaf area:**

<table>
<thead>
<tr>
<th>Method</th>
<th>DVS</th>
<th>SLA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0.0032</td>
</tr>
<tr>
<td></td>
<td>1.30</td>
<td>0.0032</td>
</tr>
<tr>
<td></td>
<td>2.00</td>
<td>0.0015</td>
</tr>
</tbody>
</table>

**Leaf life span:**

T_base = 0 °C, cv. Sebagó: T_sum = 325 d°C; cv. Monano: T_sum = 410 d°C (Ingram, 1980)
Maintenance respiration:

leaves: 0.03 kg CH$_2$O kg$^{-1}$ d$^{-1}$
stems: 0.015
roots: 0.01 (Penning de Vries & Van Laar, 1982)
tubers: 0.007 (Sale, 1974)

Conversion factors:

leaves: 0.72
stems: 0.69
fibrous roots: 0.72 (Penning de Vries & van Laar, 1982)
tubers: 0.85 (Penning de Vries et al., 1983)
Dry matter distribution:

<table>
<thead>
<tr>
<th>cv.</th>
<th>DVS</th>
<th>leaves</th>
<th>stems</th>
<th>tubers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dore</td>
<td>0.00</td>
<td>0.80</td>
<td>0.20</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>0.79</td>
<td>0.17</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>1.57</td>
<td>0.00</td>
<td>0.16</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>1.68</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>2.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>cv.</th>
<th>DVS</th>
<th>leaves</th>
<th>stems</th>
<th>tubers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Favorita</td>
<td>0.00</td>
<td>0.80</td>
<td>0.20</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>0.77</td>
<td>0.15</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>1.52</td>
<td>0.00</td>
<td>0.15</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>1.62</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>cv.</th>
<th>DVS</th>
<th>leaves</th>
<th>stems</th>
<th>tubers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marijke</td>
<td>0.00</td>
<td>0.80</td>
<td>0.20</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>0.80</td>
<td>0.20</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>1.39</td>
<td>0.00</td>
<td>0.24</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>1.51</td>
<td>0.00</td>
<td>0.24</td>
<td>1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>cv.</th>
<th>DVS</th>
<th>leaves</th>
<th>stems</th>
<th>tubers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irene</td>
<td>0.00</td>
<td>0.80</td>
<td>0.20</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>0.53</td>
<td>0.80</td>
<td>0.42</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>0.80</td>
<td>0.42</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>1.33</td>
<td>0.00</td>
<td>0.42</td>
<td>1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>cv.</th>
<th>DVS</th>
<th>leaves</th>
<th>stems</th>
<th>tubers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mara</td>
<td>0.00</td>
<td>0.80</td>
<td>0.20</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>0.81</td>
<td>0.80</td>
<td>0.24</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>0.80</td>
<td>0.23</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>1.34</td>
<td>0.00</td>
<td>0.23</td>
<td>1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>cv.</th>
<th>DVS</th>
<th>leaves</th>
<th>stems</th>
<th>tubers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multa</td>
<td>0.00</td>
<td>0.80</td>
<td>0.20</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>0.81</td>
<td>0.80</td>
<td>0.24</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>0.80</td>
<td>0.23</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>1.33</td>
<td>0.00</td>
<td>0.23</td>
<td>1.00</td>
</tr>
</tbody>
</table>

(Van Heemst, 1986)

<table>
<thead>
<tr>
<th>cv.</th>
<th>DVS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mara</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>0.81</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>1.44</td>
</tr>
<tr>
<td></td>
<td>2.00</td>
</tr>
</tbody>
</table>

Fibrous roots: 0.30 0.10 0.00 0.00

Moisture content tubers: 76% (Penning de Vries et al., 1983)
Crop phenology:

emergence:

\[ T_{\text{base}} = 2 \degree C, \quad T_{\text{opt}} = 25 \degree C, \quad T_{\text{max}} = 33 \degree C, \quad T_{\text{sum}} = 385 \text{ d} \degree C \]


development:

\[ T_{\text{basel}} = 7 \degree C \] (Gutierrez et al., 1985; Van Heemst, 1986)

\[ T_{\text{optl}} = 18 \degree C, \]

\[ T_{\text{maxl}} = 29 \degree C \]

\[ T_{\text{suml}} = 0 \text{ d} \degree C, \text{ cv.'s Dore, Favorita} \]

\[ T_{\text{suml}} = 30 \text{ d} \degree C, \text{ cv. Marijke} \]

\[ T_{\text{suml}} = 170 \text{ d} \degree C, \text{ cv. Irene on sandy soil} \]

\[ T_{\text{suml}} = 80 \text{ d} \degree C, \text{ cv.'s Mara, Multa (Van Heemst, 1986)} \]

N.B. Development stage 1.00 is tuber initiation.

\[ T_{\text{sum2}} = 500 \text{ d} \degree C, \text{ cv. Dore} \]

\[ T_{\text{sum2}} = 530 \text{ d} \degree C, \text{ cv. Favorita} \]

\[ T_{\text{sum2}} = 690 \text{ d} \degree C, \text{ cv. Marijke} \]

\[ T_{\text{sum2}} = 625 \text{ d} \degree C, \text{ cv. Irene on sandy soil} \]

\[ T_{\text{sum2}} = 800 \text{ d} \degree C, \text{ cv. Mara} \]

\[ T_{\text{sum2}} = 810 \text{ d} \degree C, \text{ cv. Multa (Gmelig Meyling, 1981)} \]

Initial weight:

roots: 0.7 g; leaves: 1.3 g; stems: 0.3 g per plant (unpublished data, trial 42B460, 1969)

planting rate: 28000–66000 plants ha\(^{-1}\) (Kay, 1973)

Maximum rooting depth: 40–60 cm (Doorenbos et al., 1979)
Table 20, Sugar beet \textit{Beta vulgaris} L.

Leaf CO$_2$ assimilation:

**gross photosynthesis:**
- 27 kg CO$_2$ ha$^{-1}$ h$^{-1}$ cv. Bush Mono G (Lawrence & Ridley, 1984)

**net photosynthesis:**
- 29 kg CO$_2$ ha$^{-1}$ h$^{-1}$ cv. Otofte (Hansen, 1971)
- 24 kg CO$_2$ ha$^{-1}$ h$^{-1}$ cv. Sharpe's Klein E monobeet (Milford & Pearman, 1975)
- 17 cv. Dobrovicka A (Hodanova, 1979)
- 50 cv. MS NB1 x NB4 (Nevins & Loomis, 1970)
- 17 cv. Hillashogn (Hofstra & Hesketh, 1969)

**dark respiration:**
- 3 kg CO$_2$ ha$^{-1}$ h$^{-1}$ (Cary, 1977)

**effect of leaf age:**

<table>
<thead>
<tr>
<th>age</th>
<th>20</th>
<th>55 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO$_2$ ass.</td>
<td>1.00</td>
<td>0</td>
</tr>
</tbody>
</table>

**effect of temperature:**

<table>
<thead>
<tr>
<th>temperature</th>
<th>20</th>
<th>28</th>
<th>41</th>
<th>45</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO$_2$ ass.</td>
<td>0.80</td>
<td>1.00</td>
<td>1.00</td>
<td>0</td>
</tr>
</tbody>
</table>

cv. Hillashogn (Hofstra & Hesketh, 1969)

**Initial efficiency:**

- 0.31 kg CO$_2$ J$^{-1}$ ha$^{-1}$ h$^{-1}$ m$^{-2}$ s $^1$ cv. F58-554H
  (Taylor & Terry, 1984)

**Extinction coefficient:**

- 0.65 (PAR) (Clark & Loomis, 1978)
Specific leaf area:

<table>
<thead>
<tr>
<th>age (days)</th>
<th>0</th>
<th>25</th>
<th>85</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLA</td>
<td>0.0030</td>
<td>0.0012</td>
<td>0.0007</td>
<td>0.0007</td>
</tr>
</tbody>
</table>

(Leaf blades + petioles)  

if dry weight of leaf blades + petioles < 17 g per plant:
leaf blades = 0.70 * (leaf blades + petioles)

if dry weight of leaf blades + petioles ≥ 17 g per plant:
leaf blades = 0.34 * (leaf blades + petioles)

(Boonstra, 1940; unpublished data, CABO-457, 1981; Houba, 1973)

Leaf life span:

leaves differ in their life span:

<table>
<thead>
<tr>
<th>leaf number</th>
<th>1</th>
<th>25</th>
<th>65</th>
</tr>
</thead>
</table>
| life span   | 16 | 67 | 28 days cv. Dobrovicka (Hodanova, 1981)

The first leaves are small, at the end of the growing season only about 12-15 leaves have died. Average life span of 42 days looks reasonable. (Houba, 1973)

Maintenance respiration:

leaves : 0.03 kg CH₂O kg⁻¹ d⁻¹

fibrous roots : 0.01  
(Penning de Vries & Van Laar, 1982)

storage roots : 0.005  
(calculated from biomass composition (Penning de Vries et al., 1983))

Conversion factors:

<table>
<thead>
<tr>
<th>leaves</th>
<th>0.72</th>
</tr>
</thead>
<tbody>
<tr>
<td>fibrous roots</td>
<td>0.72 (Penning de Vries &amp; van Laar, 1982)</td>
</tr>
<tr>
<td>storage roots</td>
<td>0.82 (Penning de Vries et al., 1983)</td>
</tr>
</tbody>
</table>

Dry matter distribution:

<table>
<thead>
<tr>
<th>DVS</th>
<th>0</th>
<th>1(20 d)</th>
<th>1.88(135 d)</th>
<th>2.(150 d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
<td>0.95</td>
<td>0.95</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>storage roots</td>
<td>0.05</td>
<td>0.05</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

(Boonstra, 1940; unpublished data, CABO-457, 1981; Fick et al., 1971; Snyder & Carlson, 1978)

<table>
<thead>
<tr>
<th>DVS</th>
<th>0</th>
<th>1(20 d)</th>
<th>1.46(d)</th>
<th>2.(150 d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>fibrous roots</td>
<td>0.15</td>
<td>0.11</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

(Boonstra, 1940; Fick et al., 1971)
crown = 0.08 * storage root (Houba, 1973)
moisture content storage root: 77% (Penning de Vries et al., 1983)
sugar content 16% of fresh weight, 70% of dry weight

Crop phenology:

emergence:
T_{\text{base}} = 2 \degree \text{C} \ (\text{Dubetz et al., 1962}) \ ; \ T_{\text{opt}} = 23 \degree \text{C}, \ T_{\text{sum}} = 189 \ \text{d}^\circ \text{C} \ (\text{Radke & Bauer, 1969})
T_{\text{base}} = 3 \degree \text{C}, \ T_{\text{sum}} = 80 \ \text{d}^\circ \text{C} \ \text{for} \ 50\% \ \text{emergence} \ (\text{Gummerson & Jaggard, 1985})
T_{\text{max}} = 30 \degree \text{C} \ (\text{Cardwell, 1984})

development:
It is difficult to define development stages. Arbitrarily a choice has been made to define development stage 1 at 20 days after emergence, when the storage roots are starting to thicken, and development stage 2 at 150 days after emergence as harvest date.

Maximum rooting depth: 120 cm (Brown & Biscoe, 1985)

Initial weight:
0.008 g per plant (Snyder & Carlson, 1978)
planting rate: 80000 plants ha\(^{-1}\) (ILACO, 1981)
Table 21, Sugar cane *Sacharum officinarum* L.

Leaf CO$_2$ assimilation:

net photosynthesis:
- 49 kg CO$_2$ ha$^{-1}$ h$^{-1}$ (Hesketh & Moss, 1963)
- 34-86 different cv.'s (Irvine, 1967)
- 70 (Varlet-Grancher et al., 1981)

effect of leaf age:
- rel. leaf age 0 0.12 0.71 1.00 (after full development)
- rel. CO$_2$ ass. 0.95 1.00 0.73 0
(Varlet-Grancher et al., 1981; average age: 113 days; it takes about 21 days from emergence till full development)

effect of plant age:
each subsequently developed leaf has a lower maximum photosynthetic rate than the previous one, so the age of the plant has a greater effect on photosynthesis than the age of the leaf. This is confirmed by Kortschak & Forbes (1969) and Hartt & Burr (1967)

<table>
<thead>
<tr>
<th>plant age</th>
<th>50</th>
<th>300 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO$_2$ ass.</td>
<td>1.00</td>
<td>0.60</td>
</tr>
</tbody>
</table>
(Varlet-Grancher et al., 1981)

<table>
<thead>
<tr>
<th>plant age</th>
<th>3</th>
<th>8</th>
<th>15</th>
<th>21 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO$_2$ ass.</td>
<td>1.00</td>
<td>0.60</td>
<td>0.43</td>
<td>0.43</td>
</tr>
</tbody>
</table>
(measured at blade 4, average of twelve varieties, Hartt & Burr, 1967)

<table>
<thead>
<tr>
<th>plant age</th>
<th>3</th>
<th>5</th>
<th>15</th>
<th>21 month</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO$_2$ ass.</td>
<td>1.00</td>
<td>1.00</td>
<td>0.69</td>
<td>0.69</td>
</tr>
</tbody>
</table>
(measured at leaves of one month old, Kortschak & Forbes, 1969)

effect of temperature:

<table>
<thead>
<tr>
<th>temperature</th>
<th>9</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>rel. CO$_2$ ass.</td>
<td>0.76</td>
<td>1.00</td>
</tr>
</tbody>
</table>
(Waldron et al., 1967)

Initial efficiency:
- 0.51 kg CO$_2$ J$^{-1}$ ha$^{-1}$ h$^{-1}$ m$^2$ s (Varlet-Grancher et al., 1981)
- 0.26 (Hartt & Burr, 1967)

Extinction coefficient:
- 0.48 (PAR)
- 0.31 (Total) (Varlet-Grancher & Bonhomme, 1979)
Specific leaf area:

<table>
<thead>
<tr>
<th>age (months)</th>
<th>0</th>
<th>9</th>
<th>17.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVS</td>
<td>0.21</td>
<td>0.29</td>
<td>0.64</td>
</tr>
<tr>
<td>SLA</td>
<td>0.00089</td>
<td>0.00116</td>
<td>0.00079</td>
</tr>
<tr>
<td>(Rege &amp; Sannabhadri, 1943)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Leaf life span:
- 21 days from emergence till full development, 113 days from full development till death (Varlet-Grancher et al., 1981)
- days after emergence: 0, 165, 365
- leaf life span: 40, 105, 105 days (Ayres, 1936)

Maintenance respiration (at 20 °C):
- leaves: 0.0034 kg CH₂O kg⁻¹ d⁻¹
- stems: 0.0029 (Glover, 1973)
- roots: 0.010 (Penning de Vries & Van Laar, 1982)

Conversion factors:
- leaves: 0.72
- fibrous roots: 0.72 (Penning de Vries & van Laar, 1982)
- stems: 0.72 (Penning de Vries et al., 1983)

Dry matter distribution:

<table>
<thead>
<tr>
<th>days after emergence</th>
<th>0</th>
<th>12</th>
<th>56</th>
<th>84</th>
<th>174</th>
<th>365</th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
<td>1.00</td>
<td>1.00</td>
<td>0.79</td>
<td>0.66</td>
<td>0.24</td>
<td>0.24</td>
</tr>
<tr>
<td>stems</td>
<td>0</td>
<td>0</td>
<td>0.21</td>
<td>0.34</td>
<td>0.76</td>
<td>0.76</td>
</tr>
<tr>
<td>(Ayres, 1936)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fibrous roots</td>
<td>0.67</td>
<td>0.67</td>
<td>0.67</td>
<td>0.16</td>
<td>0.16</td>
<td>0.16</td>
</tr>
<tr>
<td>(Borden, 1944)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sugar content: 10 - 12 % of cane fresh weight; moisture content cane ca. 80 %. 
Crop phenology:

emergence:

80% emergence after 6 weeks (Rege & Sannabhadti, 1943);
40 days (Ayres, 1936).

Tbase = 10 °C, Topt = 27-32 °C, Tsum = 200 d°C at 27 °C cv. H44-3098;
(Clements & Nakata, 1967)

Initial weight:
Bibit 70 cm, 382 g fresh, 77 g dry (Diez et al., 1962)
About 67% carbohydrates, about 1/3 loss by respiration, gives
34 g plant weight at emergence.
planting rate: 20000 - 35000 sets ha⁻¹ (Doorenbos et al., 1979)

Maximum rooting depth: 150-200 cm (Doorenbos et al., 1979)
Table 22, Cotton \textit{Gossypium hirsutum} L.

Leaf CO$_2$ assimilation:

\begin{verbatim}
gross photosynthesis:  
40 - 50 kg CO$_2$ ha$^{-1}$ h$^{-1}$ (Mutsaers, 1982) 
effect of leaf age:  
rel. leaf age | 0 | 0.2 | 0.3 | 0.7 | 1. 
rel. CO$_2$ ass. | 0.68 | 1. | 1. | 0.25 | 0 
cv. Deltapine 16 (Constable & Rawson, 1980; Nagarajah, 1975) 
effect of temperature:  
temperature | 14 | 26 | 38 | 46 
rel. CO$_2$ ass. | 0 | 1. | 1. | 0 
cv. Deltapine Smoothleaf (interpretation of data by Downton & Slatyer, 1972) 
temperature | 23 | 34 | 50 | 55 
rel. CO$_2$ ass. | 0.82 | 1.00 | 0.67 | 0 
cv. Deltapine Smoothleaf (El-Sharkawy & Hesketh, 1964) 
effect of air humidity:  
VPD | 10-15 | 35-45 mbar 
rel. CO$_2$ ass. | 1.00 | 0.62 (El-Sharkawy et al., 1985) 
\end{verbatim}

Initial efficiency:  
0.41 kg CO$_2$ J$^{-1}$ ha$^{-1}$ h$^{-1}$ m$^2$ s 

Extinction coefficient:  
0.62 (300-2500 nm) cv. Deltapine Smoothleaf (Baker & Meyer, 1966)

Specific leaf area:  

dvs | 0 | 1.00 | 2.00 
sla | 0.00164 | 0.00220 | 0.00136 | 12 cv.'s, half of the Stoneville 
and half of the Deltapine lineage (Wells & Meredith, 1984)
Leaf life span:
112 days at 23 °C cv.'s Acala 1517-C and Acala 4-42 (Halevy, 1976)
110 days at 23 °C cv. Acala 1517C (Merani & Aharonov, 1964)
85 days at 27 °C cv. Wild's early (Hearn, 1969a, 1969b)
estimated Tbase = 10 °C, Tsum = 1450 d°C

Maintenance respiration:
leaves: 0.030 kg CH₂O kg⁻¹ d⁻¹
stems: 0.015
fibrous roots: 0.010 (Penning de Vries & Van Laar, 1982)
bolls: 0.010 (calculated from biomass composition
(Penning de Vries et al., 1983))

Conversion factors:
leaves 0.72
stems 0.69
fibrous roots 0.72 (Penning de Vries & van Laar, 1982)
bolls 0.61 (Penning de Vries et al., 1983)

Dry matter distribution:
<table>
<thead>
<tr>
<th>DVS</th>
<th>0</th>
<th>0.90</th>
<th>1.03</th>
<th>1.70</th>
<th>1.77</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>leaves</td>
<td>0.60</td>
<td>0.60</td>
<td>0.50</td>
<td>0.10</td>
<td>0.90</td>
<td>1.00</td>
</tr>
<tr>
<td>stems</td>
<td>0.40</td>
<td>0.40</td>
<td>0.50</td>
<td>0.10</td>
<td>0.90</td>
<td>1.00</td>
</tr>
<tr>
<td>bolls</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.00</td>
</tr>
</tbody>
</table>
(Merani & Aharonov, 1964; Halevy, 1976; Hearn, 1969b; Wells & Meredith, 1984)

Final dry matter distribution over boll components:
bur : 0.27
seeds : 0.43
fibre : 0.30 (Mutsaers, 1976)
moisture content seed : 8 % (Penning de Vries et al., 1983)
Crop phenology:

emergence:
ca. 7 days at 30 °C doubled-haploid strain M-8 (Mauney, 1966)
Tbase = 14 °C, Topt = 18-30 °C, Tmax = 40 °C (Doorenbos et al., 1979)
Tbase = 15 °C, Topt = 34 °C, Tmax = 39 °C (Cardwell, 1984)

development:
Tbase1 = 15 °C, Topt1 = 27 °C, Tmax1 = 35 °C, Tsum1 = 240 d°C
(Mauney, 1966)
Tbase2 = 10 °C, Topt2 33 °C, Tsum2 = 690 d°C at 33 °C
(Mutsaers, 1976)

Initial weight:
1 seed = 0.13 g (Martin & Leonard, 1967)
loss 1/3, initial weight per plant 0.09 g
roots 0.33 * 0.09 = 0.03 g
shoot = 0.10 g, leaves 0.60 * 0.10 = 0.06 g
stems 0.40 * 0.10 = 0.04 g
planting rate: 20000-65000 plants ha⁻¹ (Doorenbos et al., 1979)

Maximum rooting depth: 100-170 cm (Doorenbos et al., 1979)
Table 23, white jute *Corchorus capsularis* L.

tossa jute *Corchorus olitorius* L.

Leaf CO$_2$ assimilation:

net photosynthesis:

- 17 kg CO$_2$ ha$^{-1}$ h$^{-1}$ *C. capsularis* (Jin-qiang & Ming-qi, 1983)
- 12 *C. olitorius* (Palit & Bhattacharyya, 1984b)

Specific leaf area:

No significant differences between cultivars.

\[
\begin{array}{cccc}
\text{age} & 0 & 30 & 125 \\
\text{SLA} & 0.0029 & 0.0033 & 0.0033 \\
\text{SLA} & 0.0028 & 0.0031 & 0.0031 \\
\end{array}
\]

*C. capsularis* (Palit & Bhattacharyya, 1984a)

Leaf life span:

- 31 days (Sarma, 1969); about 30 days (Palit & Bhattacharyya, 1984a)
- 30-34 days, *C. olitorius*
- 40-50 days, *C. capsularis* (Palit & Bhattacharyya, 1982)

Maintenance respiration:

- leaves : 0.030 kg CH$_2$O kg$^{-1}$ d$^{-1}$
- stems : 0.015
- roots : 0.010 (Penning de Vries & Van Laar, 1982)

Conversion factors:

- leaves 0.72
- stems 0.69
- fibrous roots 0.72 (Penning de Vries & van Laar, 1982)
Dry matter distribution:

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>leaves</th>
<th>stems</th>
<th>fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVS</td>
<td>0</td>
<td>0.18</td>
<td>0.40</td>
<td>1.00</td>
</tr>
<tr>
<td>leaves</td>
<td>0.83</td>
<td>0.83</td>
<td>0.40</td>
<td>0.71</td>
</tr>
<tr>
<td>stems</td>
<td>0.17</td>
<td>0.17</td>
<td>0.60</td>
<td>0.29</td>
</tr>
<tr>
<td>fruit</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.10</td>
</tr>
</tbody>
</table>

DVS    | 0   | 0.16    | 0.37   | 1.00  |
leaves | 0.81| 0.81    | 0.35   | 0.67  |
stems  | 0.19| 0.19    | 0.65   | 0.33  |
fruit  | 0   | 0       | 0      | 0     |

1.00 C. capsularis (Johansen et al., 1985b, with estimated shed of leaves with a life span of 30 days)

<table>
<thead>
<tr>
<th></th>
<th>DVS</th>
<th>fibrous roots</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVS</td>
<td>0</td>
<td>0.10</td>
</tr>
<tr>
<td>leaves</td>
<td>0.50</td>
<td>0.30</td>
</tr>
</tbody>
</table>

1.00 C. olitorius (Sen & Banerjee, 1960; Ghose & Chattopadhyay, 1977)

The proper time for harvesting is when the fruits have just commenced to form.

Crop phenology:

Development:

Jute is a short-day plant, critical daylength being about 12 h for C. capsularis and 12.5 h for C. olitorius (Johansen et al., 1985a)

Short-day photoperiods induce flowering in 30-35 days. (Sarma, 1969; Alim, 1978)

Initial weight:

Seed weight: 0.0033 g (C. capsularis); 0.0020 g (C. olitorius) (Alim, 1978)

Planting rate: 250000-400000 plants ha⁻¹, after thinning (Alim, 1978)

Note: White jute can stand a few feet of water at maturity, tossa jute cannot stand waterlogging.
Table 24, Tobacco Nicotiana tabacum L.

Leaf CO₂ assimilation:

gross photosynthesis:
25 kg CO₂ ha⁻¹ h⁻¹ cv. Havanna seed 211 (Turner & Incoll, 1971)

net photosynthesis:
18-25 kg CO₂ ha⁻¹ h⁻¹ (Hackett, 1973)
17-21 (Hesketh & Moss, 1963)
34 (Rawson & Woodward, 1976)
25 (Rawson & Hackett, 1974)
15-20 (Peterson & Zelitch, 1985)

effect of leaf age:

<table>
<thead>
<tr>
<th>age</th>
<th>rel CO₂ ass.</th>
<th>cv. Mammoth (Rawson &amp; Hackett, 1974)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>14 6 (days)</td>
</tr>
<tr>
<td>0</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>rel. CO₂ ass.</th>
<th>cv.'s Consolation 402, Bright Yellow (Wada et al., 1967)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.72</td>
<td>1.00 0.16</td>
</tr>
</tbody>
</table>

effect of temperature:

<table>
<thead>
<tr>
<th>temperature</th>
<th>rel. CO₂ ass.</th>
<th>young leaves</th>
<th>old leaves cv. Bright Yellow</th>
<th>young leaves</th>
<th>old leaves cv. Burley 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>1.00</td>
<td>0.86 0.81</td>
<td>1.00 0.90</td>
<td>1.00 0.52</td>
<td>1.00 0.79</td>
</tr>
<tr>
<td>20</td>
<td>1.00</td>
<td></td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>1.00</td>
<td></td>
<td></td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>temperature</th>
<th>rel. CO₂ ass.</th>
<th>(Zioni &amp; Itai, 1972)</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

Initial efficiency:
0.83 kg CO₂ J⁻¹ ha⁻¹ h⁻¹ m² s (Vaclavik, 1973)

Specific leaf area:

<table>
<thead>
<tr>
<th>DVS</th>
<th>SLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0010</td>
</tr>
<tr>
<td>0.30</td>
<td>0.0031</td>
</tr>
<tr>
<td>1.00</td>
<td>0.0031</td>
</tr>
<tr>
<td>2.00</td>
<td>0.0023</td>
</tr>
</tbody>
</table>

(Raper et al., 1977; Tejwani et al., 1957)
Leaf life span:
56 days at 24 °C (Rawson & Hackett, 1974)
resp. at high and low light.

Maintenance respiration:
leaves: 0.030 kg CH₂O kg⁻¹ d⁻¹
stems : 0.015
fibrous roots: 0.010 (Penning de Vries & Van Laar, 1982)

Conversion factors:
leaves 0.72
stems 0.69
fibrous roots 0.72 (Penning de Vries & van Laar, 1982)

Dry matter distribution:

<table>
<thead>
<tr>
<th>Item</th>
<th>0.3</th>
<th>0.45</th>
<th>1.0</th>
<th>2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVS</td>
<td>0.70</td>
<td>0.85</td>
<td>0.85</td>
<td>0.40</td>
</tr>
<tr>
<td>leaves</td>
<td>0.30</td>
<td>0.15</td>
<td>0.15</td>
<td>0.60</td>
</tr>
<tr>
<td>stems</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>pods</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Connecticut Shadegrown wrapper tobacco (Bertinuson et al., 1970),
cv. NC 2326 (Flynt et al., 1978), Havanna seed tobacco (Morgan &
Street, 1935), cv. NC 2326 (Raper et al., 1977), cv. Vellavazhai
(Tejwani et al., 1957)

Crop phenology:

development:

<table>
<thead>
<tr>
<th>Tbasel = 0 °C, Toptl = 22-26 °C, Tmaxl = 39 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsuml = 785 d°C (transplanting - flowering)</td>
</tr>
<tr>
<td>cv. NC2326 (Haroon et al., 1972), cv.'s Burley 21, Ky 151, Hicks</td>
</tr>
<tr>
<td>(Kasperbauer, 1970)</td>
</tr>
</tbody>
</table>
Initial weight (at transplanting, 40-60 days after sowing):
6.5 g per plant,
1.3 g roots, 1.6 g stalks, 3.6 g leaves. (Bertinuson et al., 1970)
planting rate: 9000-19000 plants ha$^{-1}$ (Doorenbos et al., 1979)

Maximum rooting depth: 50-100 cm (Doorenbos et al., 1979)
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a wide range of warm climate species. Photosynthesis Research 7,
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