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

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Contents

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## 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 $CO_2$-assimilation characteristics of a single leaf, i.e. the initial light use efficiency, the respiration in the dark, the rate of net or gross $CO_2$ assimilation at light saturation, the effect of temperature, air humidity, and leaf age on the rate of $CO_2$ 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.

-3- Data on the partitioning of newly formed dry mass over the various plant parts in the course of the season.

-4- Data on leaf area dynamics, as specific leaf area and leaf life span.

-5- Data on crop phenology.

ad 1. $CO_2$ assimilation

The value of the maximum gross $CO_2$ assimilation varies with such characteristics as age of the leaf, its nitrogen concentration and its postion in the canopy, the temperature during its development, the temperature during the measurement, the $CO_2$ 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. Whereever possible, these effects on the maximum $CO_2$ 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 $CH_2O$ 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):

$$1/\ \text{efficiency} = 1.221 * \text{carbohydrates} + 1.793 * \text{protein} + 3.030 * \text{lipids} + 2.119 * \text{crude fibre} + 0.906 * \text{organic anions}$$

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

| | | |
|---|---|---|
| DVS | Development stage | |
| HBase | Treshold day length for crop development | h |
| HOpt | Optimum day length for crop development | h |
| Hsum | Day length sum | d h |
| PAR | Photosynthetically active radiation | $J\ m^{-2}\ s^{-1}$ |
| SLA | Specific leaf area | $m^2\ kg^{-1}$ |
| SPA | Specific pod area | $m^2\ kg^{-1}$ |
| TBase | Treshold temperature for crop development | °C |
| TMax | Maximum temperature for crop development | °C |
| TOpt | Optimum temperature for crop development | °C |
| TSum | Temperature sum | d °C |

Note : a figure at the end of a symbol refers to the development stage.

Table 1, wheat *Triticum aestivum* L.

Leaf $CO_2$ assimilation:

net photosynthesis:

| | |
|---|---|
| 40-42 kg $CO_2$ $ha^{-1}$ $h^{-1}$, | Pilote x Mexico 63 sel. |
| 38-40 | cv.'s Opal, Gaby, Charter, Mara |
| 36-38 | cv.'s Van Hoek, Artois x mexico 43 sel., Ciano 67, Sonora 64, Reliance, Thatcher, Rex, Jufy I, Ring |
| 34-36 | Lerma Rojo 64, Bajio 67, Nepal 42 |
| 32-34 | Orca (Dantuma, 1973) |
| 50 | cv.'s Kolibri, Famos (Winzeler, 1980) |
| 41 | cv. Pavon-76 |
| 39 | cv. Sonalika |
| 35 | cv. Yavros |
| 32 | GTA TC 60 x Mexi |
| 30 | cv. Guil-S-Shipe-S |
| 25 | cv. Cando (Reddy et al., 1984) |
| 37-45 | cv. Yecora 70 (Evans, 1983) |

effect of leaf age:

| age (days) | 0 | 35 | 63 | |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 1.00 | 0 | (Evans, 1983) |

| days after max. elongation | 0 | 15 | 42 |
|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 1.00 | 0 |

(Marshall, 1978)

| days after max. elongation | 17 | 31 | 51 |
|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 0.75 | 0.34 |

(Marshall & Biscoe, 1980)

effect of temperature:

| temperature | 5 | 15 | 23 | |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.7 | 1.00 | 1.00 | (Takeda, 1979) |

| temperature | 10 | 24 | 32 | |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.67 | 1.00 | 0.75 | (Fengshan et al., 1984) |

| temperature | 12 | 18 | 24 | 30 | 36 | 42 |
|---|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.90 | 1.00 | 0.93 | 0.81 | 0.66 | 0.36 |

(Vong & Murata, 1977)

effect of air humidity:

no effect on $CO_2$ ass. of VPD 1-20 mbar (Rawson et al., 1977)

Stem, ear $CO_2$ assimilation:

gross photosynthesis stem : 0.002 kg $CO_2$ $kg^{-1}$ (dry weight) $h^{-1}$
gross photosynthesis ear : 0.006 (Osman, 1971)
net photosynthesis ears : awnless tall : 0.00007 kg $CO_2$ $kg^{-1}$ $h^{-1}$
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 $CO_2$ $ha^{-1}$ $h^{-1}$
tetraploid : 2.7 (Blum, 1985)

Initial efficiency:
0.25 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ 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 $CH_2O$ $kg^{-1}$ $d^{-1}$
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:

| DVS | 0 | 0.05 | 0.18 | 0.65 | 0.70 | 1.00 | 1.18 | 2.00 |
|---|---|---|---|---|---|---|---|---|
| leaves | 0 | 0 | 0.93 | 0.27 | 0.24 | 0.09 | 0 | 0 |
| stems | 1.00 | 1.00 | 0.07 | 0.73 | 0.76 | 0.67 | 0 | 0 |
| ears | 0 | 0 | 0 | 0 | 0 | 0.24 | 1.00 | 1.00 |

| DVS | 0 | 0.45 | 0.8 | 1.3 | 2.0 |
|---|---|---|---|---|---|
| fibrous roots | 0.50 | 0.15 | 0.05 | 0 | 0 |

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 *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 Piroline, Ceres (Dantuma, 1973) |

effect of leaf age:

| age | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 days |
|---|---|---|---|---|---|---|---|---|
| rel.$CO_2$ | 0.53 | 0.85 | 1.00 | 0.94 | 0.72 | 0.47 | 0.36 | 0.33 |

cv. Numar (Friedrich & Huffaker, 1980)

effect of temperature:

| temperature | 5 | 14 | 17 | 28 | |
|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.74 | 1.00 | 1.00 | 0 | (Takeda, 1979) |

| temperature | 12 | 18 | 24 | 30 | 36 | 42 |
|---|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.88 | 1.00 | 0.79 | 0.66 | 0.52 | 0.34 |

(Vong & Murata, 1977)

effect of air humidity:

no efffect 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:

| | | | | | |
|---|---|---|---|---|---|
| DVS | 0 | 0.29 | 0.91 | 1.46 | 2. |
| SLA | 0.0020 | 0.0055 | 0.0029 | 0.0022 | 0.0022 (Kamal, 1959) |
| DVS | 0 | 0.45 | 1.05 | 2.00 | |
| SLA | 0.0022 | 0.0027 | 0.0027 | 0.0018 | |

(Proctor barley, Biscoe et al., 1975)

Leaf life span:

40 days (Kamal, 1959)

Maintenance respiration:

leaves : 0.03 kg $CH_2O$ $kg^{-1}$ $d^{-1}$
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:

| | | | | | | |
|---|---|---|---|---|---|---|
| DVS | 0 | 0.41 | 0.76 | 1.21 | 1.69 | 2. |
| leaves | 0.60 | 0.70 | 0.37 | 0 | 0 | 0 |
| stems | 0.40 | 0.30 | 0.63 | 0.48 | 0 | 0 |
| ears | 0 | 0 | 0 | 0.52 | 1.00 | 1.00 |

| | | | | |
|---|---|---|---|---|
| DVS | 0 | 0.45 | 1.46 | 2. |
| fibrous roots | 0.45 | 0.04 | 0 | 0 |

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: Tbase = 1.5 °C, Tsum = 100 d°C (Kramer, 1954)
Tbase = 3.5 °C, Tsum = 159 d°C (Russelle & Bolton, 1980)
Tbase = 4 °C, Topt = 22 °C, Tmax = 36 °C (Cardwell, 1984)
Tbase = 2.6 °C, Tsum = 78 d°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 $CO_2$ assimilation:

net photosynthesis:

30 kg $CO_2$ $ha^{-1}$ $h^{-1}$ (Sato & Kim, 1980)

41 - 61 extremes of a large number of *indica* cv.'s, (Ohno, 1976)

effect of leaf age:

| leaf number | 0 | 1 | 3 | 6 |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.15 | 0.59 | 1.00 | 0.12 |

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

effect of temperature:

| temperature | 12 | 18 | 24 | 30 | 36 | 42 |
|---|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.69 | 0.85 | 1.00 | 1.00 | 0.87 | 0.27 |

*indica* cv. IR8

| temperature | 12 | 18 | 24 | 30 | 36 | 42 |
|---|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.69 | 0.85 | 0.97 | 1.00 | 0.79 | 0.59 |

*japonica* cv. Nihonbare (Vong & Murata, 1977)

effect of air humidity:

| VPD | 0 | 20 | 40 | mbar |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 1.00 | 0.70 | (El-Sharkawy et al., 1984b) |

Initial efficiency:

0.30 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ s (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:

| temperature | 10 | 27 | 30 | 32.5 | |
|---|---|---|---|---|---|
| rel. SLA | 0.60 | 0.94 | 1.00 | 1.00 | cv. IR-8 |
| rel. SLA | 0.66 | 1.00 | 1.00 | 1.00 | cv. Norin-17 |

(Sato, 1972)

Leaf life span:

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

Maintenance respiration:

leaves : 0.03 kg $CH_2O$ $kg^{-1}$ $d^{-1}$
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:

| DVS | 0 | 0.35 | 0.80 | 1.27 | 1.38 | 2.00 |
|---|---|---|---|---|---|---|
| leaves | 0.50 | 0.50 | 0.26 | 0 | 0 | 0 |
| stems | 0.50 | 0.50 | 0.74 | 0.20 | 0 | 0 |
| ears | 0 | 0 | 0 | 0.80 | 1.00 | 1.00 |

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

| DVS | 0 | 0.25 | 1.30 | 2.00 |
|---|---|---|---|---|
| fibrous roots | 0.40 | 0.15 | 0 | 0 |

(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 :

Tbase1 = 11 °C, Tsum1 = 545 d°C Transplanting - heading, average from 9 cv.'s (Morita & Murakami, 1981)

Initial weight:

bibit, 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 $CO_2$ assimilation:

net photosynthesis:

85 kg $CO_2$ $ha^{-1}$ $h^{-1}$ , at 35 °C

effect of leaf age:

| relative leaf age | 0 | 0.25 | 1.00 |
|---|---|---|---|
| relative $CO_2$ assimilation | 0.46 | 1.00 | 0 |

effect of temperature:

| temperature | 4 | 15 | 25 | 35 | 40 | 50 | 64 |
|---|---|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0 | 0.37 | 0.72 | 1. | 1. | 0.58 | 0 |

(McPherson & Slatyer, 1973)

| temperature | 12 | 18 | 24 | 30 | 36 | 42 |
|---|---|---|---|---|---|---|
| rel. $CO_2$ ass | 0.66 | 0.83 | 0.90 | 1.00 | 0.89 | 0.75 |

(Vong & Murata, 1977)

Initial efficiency:

0.38 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ 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:

| DVS | 0 | 0.15 | 0.40 | 0.85 | 2. | |
|---|---|---|---|---|---|---|
| SLA | 0.0018 | 0.0020 | 0.0027 | 0.0018 | 0.0018 | ha $kg^{-1}$ |

(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 $CH_2O$ $kg^{-1}$ $d^{-1}$ | |
| stems | : 0.010 | |
| panicles | : 0.007 | |
| roots | : 0.007 | (Jansen & Gosseye, 1986) |

Conversion factors:

| | | |
|---|---|---|
| leaves | 0.72 | |
| stems | 0.69 | |
| fibrous roots | 0.72 | (Penning de Vries & van Laar, 1982) |
| panicles | 0.74 | (Penning de Vries et al., 1983) |

Dry matter distribution:

| DVS | 0 | 0.2 | 1.13 | 1.30 | 1.60 | 2.00 |
|---|---|---|---|---|---|---|
| leaves | 0.80 | 0.80 | 0.12 | 0 | 0 | 0 |
| stems | 0.20 | 0.20 | 0.88 | 0.64 | 0 | 0 |
| panicles | 0 | 0 | 0 | 0.36 | 1. | 1. |

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

| DVS | 0 | 1. | 1.3 | 2. |
|---|---|---|---|---|
| roots | 0.60 | 0.14 | 0 | 0 (Gregory & Squire, 1979) |

grains 60 % of panicles (Penning de Vries et al., 1983)

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

Crop phenology:

emergence:

Tbase = 12 °C, Tmax = 47 °C, Tsum = 60 d°C, Topt = 32 °C cv. BK-560 (Ong & Monteith, 1985; Garcia-Huidobro et al., 1985)

Tbase = 11.8 °C, Tsum = 40 d°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)

Tbase1 = 10 °C, Topt1 = 30 °C, Tsum1 = 1050 d°C cv. BK-560

Topt2 = 24 °C, Tsum2 = 300 d°C cv. BK-560 (Ong, 1983)

Tsum1 = 1300 d°C cv. Tamrooth

Tsum1 = 1500 d°C cv. MX001

Tsum1 = 900 d°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 *Sorghum bicolor* L.

Leaf $CO_2$ assimilation:

net photosynthesis:

30-70 kg $CO_2$ $ha^{-1}$ $h^{-1}$ (Peacock & Heinrich, 1984)

55 (Ohki, 1986)

effect of leaf age:

70 kg $CO_2$ $ha^{-1}$ $h^{-1}$ preflower

48 postflower, about 40 days later

(Krieg & Hutmacher, 1986)

| rel. leaf age | 0 | 0.3 | 0.6 | 0.9 | 1.0 |
|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 0.87 | 0.62 | 0.28 | 0 |

(Elmore et al., 1967)

effect of temperature:

| temperature | 30 | 40 | 47 | 60 |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.82 | 1.00 | 1.00 | 0 |

(El-Sharkawy & Hesketh, 1964)

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

(Peacock & Heinrich, 1984)

| temperature | 12 | 18 | 24 | 30 | 36 | 42 |
|---|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.51 | 0.71 | 0.90 | 1.00 | 0.98 | 0.84 |

(Vong & Murata, 1977)

effect of air humidity:

| VPD | 0 | 21.5 | 50. | 81. | mbar |
|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 1.00 | 0.50 | 0 | (El-Sharkawy et al., 1984b) |

No effect on $CO_2$ ass. of VPD 11-22 mbar (Rawson et al., 1977)

Initial efficiency:

0.35 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ s (estimated identical to maize)

Extinction coefficient:

0.3-0.7 (Peacock & Heinrich, 1984)

0.4-0.7 (PAR) (Muchow et al., 1984), average 0.6

0.53 (PAR) (Sivakumar & Virmani, 1984)

Specific leaf area:

| DVS | 0 | 0.33 | 1.0 | 2.0 | |
|---|---|---|---|---|---|
| SLA | 0.0035 | 0.0035 | 0.0019 | 0.0019 | (Sivakumar et al., 1979; McCree, 1983) |

Leaf life span:

14 days at 28 °C = 400 d°C with Tbase = 0 °C , cv. RS610 (McCree, 1983), 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 $CH_2O$ $g^{-1}$ $d^{-1}$ (McCree, 1983)
leaves : 0.03 kg $CH_2O$ $kg^{-1}$ $d^{-1}$
stems : 0.015
roots : 0.010
panicles: 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) |
| panicles | 0.74 | (Penning de Vries et al., 1983) |

Dry matter distribution:

| DVS | 0 | 0.56 | 0.60 | 1.35 | 1.82 | 2.00 |
|---|---|---|---|---|---|---|
| leaves | 0.60 | 0.60 | 0.57 | 0 | 0 | 0 |
| stems | 0.40 | 0.40 | 0.43 | 0.39 | 0 | 0 |
| heads | 0 | 0 | 0 | 0.61 | 1.00 | 1.00 |

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

| DVS | 0 | 0.85 | 1.45 | 2.00 |
|---|---|---|---|---|
| fibrous roots | 0.20 | 0.20 | 0 | 0 |

(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:

Tbase = 5-17 °C, Tmax = 40-48 °C

Topt = 22-35 °C (Peacock & Heinrich, 1984)

Tbase = 10 °C, Topt = 23 °C, Tsum = 67 d°C, 10 sorghum hybrids (Kanemasu et al., 1975,

Tbase = 5 °C, Topt = 26 °C, Tsum = 97 d°C, 9 cv's (Stickler et al., 1962)

Tbase = 9 °C, Topt = 33 °C, Tmax = 40 °C (Cardwell, 1984)

Tbase = 10.6 °C, Tsum = 48 d°C (Angus et al., 1980/1981)

development:

most hybrids are day-neutral in their photoperiodic response.

Tbase1 = 10 °C, Topt1 = 30 °C

Tsum1 = 1200 d°C, cv. Pacific 303

Tsum1 = 1000 d°C, cv. Goldrush

Tsum1 = 730 d°C, cv. RS626 (Muldoon, 1985)

Tsum2 = 600 d°C, cv. RS626 (Neild, 1982), cv. Texas 610SR (Muchow et al., 1982) (Tbase2 and Topt2 estimated having the same value as Tbase1 and Topt1)

Initial weight:

16 kg $ha^{-1}$ shoot at 180000 plants $ha^{-1}$ (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 $ha^{-1}$ (Muchow et al., 1982).

Maximum rooting depth : 150 cm (Kaigama et al., 1977)

Table 6, Maize *Zea mays* L.

Leaf $CO_2$ assimilation:

net photosynthesis:

65 kg $CO_2$ $ha^{-1}$ $h^{-1}$ (El-Sharkawy et al., 1985)

effect of leaf age:

| rel. leaf age | 0 | 0.25 | 0.5 | 0.75 | 1.00 |
|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.0 | 1.0 | 0.90 | 0.70 | 0 |

(Van Laar & Penning de Vries, 1972)

effect of temperature:

| temperature | 0 | 6 | 30 | 42 | 51 |
|---|---|---|---|---|---|
| rel.max.$CO_2$ ass. | 0. | 0. | 1. | 1. | 0. |

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

| temperature | 12 | 18 | 24 | 30 | 36 | 42 |
|---|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.37 | 0.62 | 0.92 | 1.00 | 0.95 | 0.56 |

(Vong & Murata, 1977)

effect of air humidity:

| VPD | 10-15 | 35-45 | mbar |
|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 0.70 | (El-Sharkawy et al., 1985) |

Initial efficiency:

0.35 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ s (Van Laar & Penning de Vries, 1972)

Extinction coefficient:

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

Specific leaf area:

| DVS | 0 | 1. | 2. | |
|---|---|---|---|---|
| SLA | 0.0035 | 0.0016 | 0.0016 | (Sibma, 1987) |

Leaf life span:

Tbase= 9 °C (Brouwer et al., 1973)

Tsum= 870 d°C (Van Laar & Penning de Vries, 1972)

Maintenance respiration:

leaves : 0.03 kg $CH_2O$ $kg^{-1}$ $d^{-1}$
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:

| DVS | 0 | 0.48 | 0.9 | 1.25 | 1.37 | 2.00 |
|---|---|---|---|---|---|---|
| leaves | 0.62 | 0.62 | 0.28 | 0 | 0 | 0 |
| stems | 0.38 | 0.38 | 0.72 | 0.24 | 0 | 0 |
| cob | 0 | 0 | 0 | 0.76 | 1.00 | 1.00 |

(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.
Tbase1 = 7-8 °C (Warrington & Kanemasu, 1983;
Derieux & Bonhomme, 1982; Becker et al., 1953)
Topt1 = 28-32 °C (Warrington & Kanemasu, 1983, Derieux
& Bonhomme, 1982)
with Tbase1 and Tbase2 = 8 °C, and Topt1 and Topt2 = 30 °C:
Tsum1 = 745 d°C cv. Ohio 401
Tsum1 = 760 d°C cv. De Kalb XL-45
Tsum1 = 890 d°C cv. Pioneer 3306
Tsum2 = 770 d°C cv. Ohio 401
Tsum2 = 860 d°C cv. De Kalb XL-45
Tsum2 = 865 d°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 plants $ha^{-1}$ (ILACO, 1981)

Maximum rooting depth : 75 cm (Foth, 1962)

Table 7, Chick pea *Cicer arietinum* L.

Leaf $CO_2$ assimilation:

gross photosynthesis:

43 kg $CO_2$ $ha^{-1}$ $h^{-1}$, cv. Vilmorin
38 cv. Gibridnyj 27
37 cv. A64-7-A; C107
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:

| age | 7 | 14 | 21 | 28 days |
|---|---|---|---|---|
| rel.max.$CO_2$ ass. | 0.90 | 1.00 | 0.41 | 0.47 |

(Van der Maesen, 1972)

effect of temperature:

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

| temperature | 10 | 17 | 26 | 42 |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.90 | 1.00 | 1.00 | 0.65 |

(Singh et al., 1982)

effect of air humidity:

| VPD | 8 | 17 | 60 mbar |
|---|---|---|---|
| rel. $CO_2$ ass. | 0.96 | 1.00 | 0.78 |

(Singh et al., 1982)

Initial efficiency:

0.30 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ 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 $CH_2O$ $kg^{-1}$ $d^{-1}$

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:

| DVS | 0 | 1.13 | 1.20 | 1.27 | 1.72 | 1.84 | 1.97 | 2.00 |
|---|---|---|---|---|---|---|---|---|
| leaves | 0.60 | 0.60 | 0.60 | 0.55 | 0.12 | 0 | 0 | 0 |
| stems | 0.40 | 0.40 | 0.32 | 0.29 | 0.18 | 0.15 | 0 | 0 |
| pod wall | 0 | 0 | 0.08 | 0.16 | 0 | 0 | 0 | 0 |
| seeds | 0 | 0 | 0 | 0 | 0.70 | 0.85 | 1.00 | 1.00 |

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

| DVS | 0 | 0.45 | 0.95 | 1.25 | 1.55 | 2.00 |
|---|---|---|---|---|---|---|
| fibrous roots | 0.40 | 0.05 | 0.05 | 0.18 | 0 | 0 |

(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:

Tbase = 10 °C, Topt = 16 - 32 °C, Tmax = 45 °C

| temperature | 0 | 10 | 16 | 32 | 45 |
|---|---|---|---|---|---|
| devel. rate | 0 | 0 | 0.168 | 0.168 | 0 |

(Van der Maesen, 1972)

80 % germination Tbase= 0 °C; Topt = 33 °C; Tmax = 57 °C; Tsum = 50 d°C

(Covell et al., 1986)

development:

Chickpeas are long-day plants.

Tbase1 = 7 °C,

| daylength | 0 | 16 h | |
|---|---|---|---|
| Topt1 | 7 | 19.8 | (early varieties) |
| Topt1 | 7 | 14.4 | (late or mid-late varieties) |

Tsum1 = 340 d°C, Topt1 = 19.8 °C, early varieties

Tsum1 = 340 d°C, Topt1 = 14.4 °C, late varieties

Tbase2 = 7 °C, Topt2 = estimated at 28 °C

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

(Roberts et al., 1980; Siddique et al., 1984; Siddique & Sedgley, 1986)

Initial weight:

shoot weight 0.2 g per plant (Sheldrake & Saxena, 1979)

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

(Sheldrake & Saxena, 1979)

planting rate : 70000-400000 plants $ha^{-1}$ (Kay, 1979)

Maximum rooting depth : 120 cm (Sheldrake & Saxena, 1979)

Table 8, Mung bean *Vigna radiata* (L.) Wilczek

Leaf $CO_2$ assimilation:

gross photosynthesis:

37 kg $CO_2$ $ha^{-1}$ $h^{-1}$ (De-Sheng Tsai & Arteca, 1985)

net photosynthesis:

22 kg $CO_2$ $ha^{-1}$ $h^{-1}$ (Phogat et al., 1984)

13-31 depending on cultivar (Srinivasan et al., 1985)

effect of air humidity:

| VPD | 10-15 | 35-45 | mbar |
|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 0.66 | (El-Sharkawy et al., 1985) |

Specific leaf area:

| DVS | 0 | 1.00 | 2.00 | |
|---|---|---|---|---|
| SLA | 0.0026 | 0.0033 | 0.0016 | (Maniruzzaman, 1982) |

| days after planting | 18 | 33 | 45 | 55 | 66 | 77 |
|---|---|---|---|---|---|---|
| SLA | 0.0030 | 0.0021 | 0.0018 | 0.0014 | 0.0018 | 0.0015 |

(Leaf blades, Kuo et al., 1980)

Maintenance respiration:

leaves : 0.030 kg $CH_2O$ $kg^{-1}$ $d^{-1}$

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:

| DVS | 0 | 1.00 | 1.15 | 1.45 | 1.60 | 2.00 |
|---|---|---|---|---|---|---|
| leaves | 0.65 | 0.65 | 0.45 | 0.06 | 0.04 | 0 |
| stems | 0.35 | 0.35 | 0.48 | 0.39 | 0.16 | 0 |
| pods | 0 | 0 | 0.07 | 0.55 | 0.80 | 1.00 |

| DVS | 0 | 1.45 | 2.00 |
|---|---|---|---|
| fibrous roots | 0.45 | 0 | 0 |

(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 $CO_2$ assimilation:

net photosynthesis:

61-34 kg $CO_2$ $ha^{-1}$ $h^{-1}$, different cv.'s (Lush & Rawson, 1979)

26 (Phogat et al.,1984)

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. $CO_2$ ass. | 0 | 1.00 | 0.19 |

effect of temperature:

| temperature | 18 | 30 | 42 | |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 1.00 | 0.68 | (Littleton et al., 1981) |

effect of air humidity:

| VPD | 10-15 | 35-45 | mbar | |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 1. | 0.58 | | (El-Sharkawy et al., 1985) |

Initial efficiency:

0.37 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ s (Lush & Rawson, 1979)

0.32 (Littleton et al., 1981)

Specific leaf area:

| DVS | 0 | 2.00 | |
|---|---|---|---|
| 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)

Tbase = 20 °C, death rate = 0.0039 *(T-20) $d^{-1}$ cv. TVu 4552 (Littleton et al., 1979a)

Maintenance respiration:

leaves : 0.030 kg $CH_2O$ $kg^{-1}$ $d^{-1}$

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:

| DVS | 0 | 0.60 | 0.95 | 1.50 | 1.70 | 2.00 |
|---|---|---|---|---|---|---|
| leaves | 1.00 | 1.00 | 0.61 | 0 | 0 | 0 |
| stems | 0 | 0 | 0.39 | 0.28 | 0 | 0 |
| pods | 0 | 0 | 0 | 0.72 | 1.00 | 1.00 |

(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:

Tbase1 = 8 °C, Tsum1 = 660 d°C for photoperiod-insensitive genotypes;
Tsum1 = 710 d°C for photoperiod-sensitive genotypes, in a photo-thermal environment where flowering is determined by mean temperature. (Hadley et al., 1983)
Tsum2 = 370 d°C cv. K 2809 (Summerfield et al., 1977)
Tmax2 = about 28 °C (Hadley et al., 1983)
Tsum1 = 740 d°C
Tsum2 = 630 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 $CO_2$ assimilation:

gross photosynthesis:

40 kg $CO_2$ $ha^{-1}$ $h^{-1}$ cv. Prabhat (Grover et al., 1985)

net photosynthesis:

24 kg $CO_2$ $ha^{-1}$ $h^{-1}$ cv. LRG-30 (Rao, 1985)

effect of leaf age:

| days | 0 | 10 | 20 | 30 | 40 | 50 | 60 |
|---|---|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.15 | 0.79 | 1.00 | 0.91 | 0.70 | 0.46 | 0.31 |

(days = days after unfolding; Rawson & Constable, 1981)

Initial efficiency:

0.51 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ s (Rawson & Constable, 1981)

Extinction coefficient:

0.50 (Natarajan & Willey, 1985)

0.69 (PAR) (Sivakumar & Virmani, 1984)

Specific leaf area:

| DVS | 0 | 1.35 | 1.60 | 2.00 | |
|---|---|---|---|---|---|
| SLA | 0.0020 | 0.0034 | 0.0028 | 0.0028 | 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 $CH_2O$ $kg^{-1}$ $d^{-1}$

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:

| | | |
|---|---|---|
| leaves | 0.72 | |
| stems | 0.69 | |
| fibrous roots | 0.72 | (Penning de Vries & van Laar, 1982) |
| pods + seeds | 0.78 | (Penning de Vries et al., 1983) |

Dry matter distribution:

| DVS | 0 | 0.65 | 1.00 | 1.45 | 1.85 | 2.00 |
|---|---|---|---|---|---|---|
| leaves | 0.50 | 0.50 | 0.43 | 0.34 | 0 | 0 |
| stems | 0.50 | 0.50 | 0.57 | 0.50 | 0 | 0 |
| flowers | 0 | 0 | 0 | 0.16 | 0 | 0 |
| pod wall | 0 | 0 | 0 | 0 | 0.33 | 0.18 |
| seed | 0 | 0 | 0 | 0 | 0.67 | 0.82 |

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

| DVS | 0 | 1.35 | 1.75 | 2.00 | |
|---|---|---|---|---|---|
| fibrous roots | 0.30 | 0.30 | 0 | 0 | (Rao et al., 1984) |

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

Crop phenology:

emergence:

Tbase = 12.8 °C, Tsum = 58 d°C (Angus et al., 1980/1981)

development:

Tbase1 = 11 °C, Topt1 = 23 - 26 °C, Tmax1 = 45 °C

| | |
|---|---|
| Tsum1 = 600 d°C | cv. ICRISAT 7220 |
| Tsum1 = 685 | cv. ICRISAT 26 |
| Tsum1 = 725 | cv. ICRISAT 6973 |
| Tsum1 = 845 | cv. ICRISAT 7120 (McPherson et al., 1985) |
| Tsum1 = 780 | cv. Regur |
| Tsum1 = 1150 | cv. ICP7179 |
| Tsum2 = 585 | cv. Regur |
| Tsum2 = 565 | cv. ICP7179 (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 $CO_2$ assimilation:

gross photosynthesis:

32 kg $CO_2$ $ha^{-1}$ $h^{-1}$, 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:

| DVS | 0 | 0.45 | 0.75 | 1.3 | 1.57 | 2. |
|---|---|---|---|---|---|---|
| SLA | 0.0037 | 0.0037 | 0.0028 | 0.0039 | 0.0032 | 0.0032 |

(Maniruzzaman, 1982)

Maintenance respiration:

leaves : 0.030 kg $CH_2O$ $kg^{-1}$ $d^{-1}$

stems : 0.015

roots : 0.010 (Penning de Vries & Van Laar, 1982)

pods + seed : 0.013 (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) |
| pods + seed | 0.71 | (calculated from biomass composition (Geessink & Benedictus, 1973)) |

Dry matter distribution:

| DVS | 0 | 0.85 | 1.00 | 1.30 | 1.60 | 1.90 | 2.00 |
|---|---|---|---|---|---|---|---|
| leaves | 0.60 | 0.60 | 0.51 | 0.34 | 0.17 | 0 | 0 |
| stems | 0.40 | 0.40 | 0.49 | 0.56 | 0.30 | 0.27 | 0.20 |
| pods | 0 | 0 | 0 | 0.10 | 0.53 | 0.73 | 0.80 |

| DVS | 0 | 1.00 | 1.60 | 2.00 |
|---|---|---|---|---|
| fibrous roots | 0.35 | 0.04 | 0 | 0 |

seed 78 % of pods (Maniruzzaman, 1982)

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

Crop phenology:

emergence:

Tbase = 13 °C; Topt = 18-20 °C; Tmax = 25 °C; Tsum = 14 d°C
(Pilet & Went, 1956)
80% germination Tbase = 3 °C; Topt = 25 °C; Tmax = 33 °C; Tsum = 23 d°C
(Covell et al., 1986)
Tbase = 1.9 °C, Tsum = 89 d°C (Angus et al., 1980/1981)

development:

Tbase = 0 °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 $CO_2$ assimilation:

gross photosynthesis:

37 kg $CO_2$ $ha^{-1}$ $h^{-1}$ (Elmore et al., 1967)
29 (Woodward, 1976)
34 (Singh et al., 1974)

effect of leaf age:

| rel. leaf age | 0 | 0.13 | 1. | |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.17 | 1.00 | 0 | (Woodward, 1976) |

effect of temperature :

| temperature | 0 | 32 | 39 | 49 | | |
|---|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0 | 1.00 | 1.00 | 0 | | |

(Hofstra & Hesketh, 1969)

| temperature | 12 | 18 | 24 | 30 | 36 | 42 |
|---|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.77 | 0.91 | 1.00 | 0.94 | 0.84 | 0.63 |

(Vong & Murata, 1977)

| temperature | 10 | 32 | 37 | 40 | |
|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0 | 1.00 | 1.00 | 0.90 | (Harley et al., 1985) |

effect of air humidity:

no effect on $CO_2$ 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 $CO_2$ $h^{-1}$ 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:

| DVS | 0 | 0.45 | 0.90 | 2.00 | |
|---|---|---|---|---|---|
| SLA | 0.0020 | 0.0037 | 0.0037 | 0.0010 ha $kg^{-1}$ | (leaf blades ) |
| SLA | 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 $CH_2O$ $kg^{-1}$ $d^{-1}$

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:

| | |
|---|---|
| leaves | 0.72 |
| stems | 0.69 |
| fibrous roots | 0.72 (Penning de Vries & van Laar, 1982) |
| pod + seed | 0.68 (Penning de Vries et al., 1983) |

Dry matter distribution:

| DVS | 0 | 1.00 | 1.15 | 1.30 | 1.50 | 1.70 | 2.00 |
|---|---|---|---|---|---|---|---|
| leaves | 0.75 | 0.75 | 0.60 | 0.46 | 0.27 | 0 | 0 |
| stems | 0.25 | 0.25 | 0.27 | 0.27 | 0.28 | 0 | 0 |
| pod wall | 0 | 0 | 0.13 | 0.19 | 0.27 | 0 | 0 |
| seeds | 0 | 0 | 0 | 0.08 | 0.18 | 1.00 | 1.00 |

N.B. Fallen leaves included

(Hanway & Weber, 1971; Sivakumar et al., 1977)

| DVS | 0 | 0.75 | 1.50 | 2.00 |
|---|---|---|---|---|
| fibrous roots | 0.50 | 0.10 | 0 | 0 |

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

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

Crop phenology:

emergence:

Tbase = 4 °C, Topt = 18 °C, Tmax = 22 °C, Tsum = 140 d°C, soil temperatures (Muendel, 1986)

No change in rate of germination between 21 and 32 °C (Hodges & Doraiswamy, 1979)

80 % germination : Tbase = 5 °C; Topt = 35 °C; Tmax = 46 °C; Tsum = 38 d°C (Covell et al., 1986)

Tbase = 9 °C, Topt = 30 °C, Tmax = 41 °C (Cardwell, 1984)

Tbase = 9.9 °C, Tsum = 71 d°C (Angus et al., 1980/1981)

development:

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.

Tbase1 = 7 °C, Topt1 = 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 $CO_2$ assimilation:

gross photosynthesis:

field plants :

22-28 kg $CO_2$ $ha^{-1}$ $h^{-1}$ , cv. Florunner (Henning et al., 1979)

30 , cv. Florunner

27 , cv. Florigiant (Bhagsari & Brown, 1976a)

greenhouse plants:

28 kg $CO_2$ $ha^{-1}$ $h^{-1}$ , 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:

| relative leaf age | 0 | 0.2 | 1. |
|---|---|---|---|
| relative $CO_2$ ass. | 1. | 1. | 0 (Henning et al., 1979) |

| age (days) | 10 | 20 | 30 | 40 | 50 | 60 |
|---|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 0.99 | 0.88 | 0.77 | 0.65 | 0.56 |

(Trachtenberg & McCloud, 1976)

effect of temperature:

| temperature | 0 | 7 | 30 | 45 |
|---|---|---|---|---|
| relative $CO_2$ ass. | 0 | 0 | 1. | 0.78 |

(Paz & Pallas, 1986)

effect of air humidity:

| VPD | 10-15 | 35-45 | mbar |
|---|---|---|---|
| rel. $CO_2$ ass. | 1. | 0.57 | (El-Sharkawy et al., 1985) |

Initial efficiency:

0.42 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ 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:

Tbase = 10 °C, Tsum = 1000 d°C estimated (Leong & Ong, 1983)

Maintenance respiration:

leaves : 0.030 kg $CH_2O$ $kg^{-1}$ $d^{-1}$

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:

| DVS | 0 | 1.00 | 1.10 | 1.30 | 1.60 | 1.70 | 2.00 |
|---|---|---|---|---|---|---|---|
| leaves | 0.50 | 0.50 | 0.50 | 0.34 | 0.10 | 0.10 | 0.10 |
| stems | 0.50 | 0.50 | 0.40 | 0.56 | 0.32 | 0.15 | 0.15 |
| nuts | 0 | 0 | 0.03 | 0.03 | 0.51 | 0.68 | 0.68 |
| flowers | 0 | 0 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |

(Bouyer, 1949; McCloud, 1974; Ong, 1984)

| DVS | 0 | 0.20 | 1.50 | 2.00 | |
|---|---|---|---|---|---|
| fibrous roots | 0.20 | 0.08 | 0 | 0 | (Bouyer, 1949) |

seed 60-75 % of nuts

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

Crop phenology:

emergence:

Tbase = 10 °C, Topt = 30 °C, cv. Robut 33-1

Tsum = 120 d°C for 70 % emergence.

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

Tbase = 13 °C, Topt = 20 °C, Tmax = 38 °C (Cardwell, 1984)

Tbase = 13.3 °C, Tsum = 76 d°C (Angus et al., 1980/1981)

development:

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

Tbase1 = 10 °C, Topt1 = 30 °C

Tsum1 = 600 d°C, cv. Robut 33-1

Tsum2 = 750 d°C, 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 $CO_2$ assimilation:

net photosynthesis:

22 kg $CO_2$ $ha^{-1}$ $h^{-1}$ cv. TMV-1 (Rao, 1985)

29 cv. Glauca (Hall & Kaufmann, 1975)

effect of temperature:

| temperature | 20 | 30 | 34 | |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.79 | 1.00 | 1.00 | (Hall & Kaufmann, 1975) |

Specific leaf area:

| DVS | 0 | 2.00 | |
|---|---|---|---|
| SLA | 0.0030 | 0.0021 | (Lazim & El-Nadi, 1974) |

Maintenance respiration:

leaves : 0.030 kg $CH_2O$ $kg^{-1}$ $d^{-1}$

stems : 0.015

roots : 0.010 (Penning de Vries & Van Laar, 1982)

capsules : 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) |
| capsules | 0.62 | (calculated from biomass composition (Geessink & Benedictus, 1973)) |

Dry matter distribution:

| DVS | 0 | 0.90 | 1.00 | 1.30 | 1.70 | 1.90 | 2.00 |
|---|---|---|---|---|---|---|---|
| leaves | 0.80 | 0.80 | 0.70 | 0.40 | 0 | 0 | 0 |
| stems | 0.20 | 0.20 | 0.30 | 0.55 | 0.33 | 0 | 0 |
| capsules | 0 | 0 | 0 | 0.05 | 0.67 | 1.00 | 1.00 |

| DVS | 0 | 2.00 |
|---|---|---|
| fibrous roots | 0.25 | 0 |

(Narayanan & 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)

Tbase = 15.9 °C, Tsum = 21 d°C (Angus et al., 1980/1981)

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 $CO_2$ assimilation:

gross photosynthesis:

40 kg $CO_2$ $ha^{-1}$ $h^{-1}$ cv. Jet neuf (Duivenvoorde & Backx, 1984)

43 kg $CO_2$ $ha^{-1}$ $h^{-1}$

net photosynthesis:

15 kg $CO_2$ $ha^{-1}$ $h^{-1}$ cv. BSH-1

23 *B. juncea*: cv. Parkash (Dabas & Sheoran, 1984)

effect of leaf age:

| leaf age | 0 | 13 | 30 | days |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 1.00 | 0 | |

cv. Brutor (Rode et al., 1983)

effect of temperature:

| temperature | 18 | 24 | 29 | |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 0.98 | 0.90 | (Herath & Ormrod, 1973) |

Pod $CO_2$ assimilation:

gross photosynthesis:

40 kg $CO_2$ $ha^{-1}$ (pods) $h^{-1}$ cv. Jet neuf (Duivenvoorde & Backx, 1984)

net photosynthesis:

14 kg $CO_2$ $ha^{-1}$ (pods) $h^{-1}$ (Inanaga et al., 1979)

effect of pod age:

| DVS | 1.00 | 1.6 | 2.00 | |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 1.00 | 0 | (Inanaga et al., 1979) |

Initial efficiency:

0.5 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ s (Duivenvoorde & Backx, 1984)

Extinction coefficient:

0.54 (Chartier et al., 1983)

Specific leaf area:

| DVS | 0 | 2.00 |
|---|---|---|
| SLA | 0.0022 | 0.0019 |

cv. Zollerngold, cv. Cresus (Allen & Morgan, 1972), cv. Jet neuf (Duivenvoorde & Backx, 1984), cv. Zollerngold (Tayo & Morgan, 1975)

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 $CH_2O$ $kg^{-1}$ $d^{-1}$
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:

Tbase1 and Tbase2 = 4 °C, winter oilseed rape (Duivenvoorde & Backx, 1984)

Tbase1 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 & Kondra, 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 kg $CO_2$ $ha^{-1}$ $h^{-1}$ (Van Laar & Penning de Vries, 1972)

effect of temperature:

| temperature | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 0.92 | 0.82 | 0.68 | 0.50 |

(Hew et al., 1969)

| temperature | 10 | 20 | 30 | 40 |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.50 | 1.00 | 1.00 | 0.50 |

(Horie, 1977)

effect of leaf age:

| age | 0 | 10 | 20 | 30 | 40 | 45 days |
|---|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 0.96 | 0.77 | 0.54 | 0.19 | 0 |

(Elmore et al., 1967)

Initial efficiency:

0.27-.30 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ s

(Van Laar & Penning de Vries, 1972)

Extinction coefficient:

0.8 - 0.9 (Stern, 1962)

0.9 (Rawson et al., 1984)

Specific leaf area:

| DVS | 0 | 1.00 | |
|---|---|---|---|
| SLA | 0.0035 | 0.0025 | ha $kg^{-1}$ (Horie, 1977) |

Maintenance respiration:

leaves : 0.05 kg $CH_2O$ $kg^{-1}$ $d^{-1}$

stems : 0.0075

roots : 0.01

inflorescence : 0.023 (Horie, 1977)

Conversion factors:

| | |
|---|---|
| leaves | 0.59 |
| stems | 0.73 |
| fibrous roots | 0.71 |
| infloresence | 0.71 (Horie, 1977) |

Dry matter distribution:

| DVS | 0 | 0.85 | 0.91 | 1.22 | 1.35 | 1.72 | 2.00 |
|---|---|---|---|---|---|---|---|
| leaves | 0.50 | 0.50 | 0.41 | 0 | 0 | 0 | 0 |
| stems | 0.50 | 0.50 | 0.59 | 0.28 | 0 | 0 | 0 |
| capitulum | 0 | 0 | 0 | 0.34 | 0.46 | 0 | 0 |
| seed | 0 | 0 | 0 | 0.38 | 0.54 | 1.00 | 1.00 |

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

| DVS | 0 | 0.65 | 1.10 | 2.00 |
|---|---|---|---|---|
| fibrous roots | 0.50 | 0.50 | 0 | 0 |

(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:

Tbase1 = 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)

Tbase1 = 1 °C, Tsum1 = 1250 d°C cv. Stepniak (Doyle, 1975)

Tbase1 = 5 °C, Tsum1 = 1300 d°C cv. Mammoth Russian (Horie, 1977)

Planting 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 $CO_2$ assimilation:

gross photosynthesis:

30 kg $CO_2$ $ha^{-1}$ $h^{-1}$, no significant clonal differences (Veltkamp, 1985)

net photosynthesis :

35-41 kg $CO_2$ $ha^{-1}$ $h^{-1}$ (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)

| temperature | 15 | 23 | 35 | 45 | |
|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.69 | 1.00 | 1.00 | 0.31 | (El-Sharkawy et al., 1984a) |

effect of air humidity:

| VPD | 0 | 16 | 53 | mbar | |
|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 1.00 | 0 | | (El-Sharkawy et al., 1984b) |

Initial efficiency:

0.39 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ 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 mg $CO_2$ $g^{-1}$ $h^{-1}$ = 0.030 kg $CH_2O$ $kg^{-1}$ $d^{-1}$

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:

Tbase = 13 °C, Tmax = 36-40 °C, Tsum = 220 d°C

Topt = 30 °C cv. Maus 10

= 28.5 °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 Tbase = 10 °C
assumed time till tuber initiation 30 days: Tsum1 = 420 d°C
rest of the year, 314 days: Tsum2 = 4400 d°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 $CO_2$ assimilation:

net photosynthesis:

31 kg $CO_2$ $ha^{-1}$ $h^{-1}$ (average for 36 genotypes, Bhagsari,1981; Bhagsari & Harmon, 1982)

effect of leaf age:

| leaf age | 0 | 90 | days |
|---|---|---|---|
| rel. $CO_2$ ass. | 0.97 | 0.29 | (Fujise & Tsuno, 1962) |

effect of temperature :

| temperature | 28 | 32 | 36 | |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 1.00 | 0.81 | (Tsuno & Fujise, 1965) |

| temperature | 5 | 15 | 25 | 35 | |
|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.29 | 0.45 | 0.93 | 1.00 | cv. Tai-lung 57 |
| rel. $CO_2$ ass. | 0.42 | 0.65 | 0.95 | 1.00 | cv. Red-tuber-tail |

(Wu et al., 1974)

Extinction coefficient:

0.45 (Fujise & Tsuno, 1962)

Specific leaf area:

| days after planting | 0 | 57 | 150 | |
|---|---|---|---|---|
| SLA | 0.0017 | 0.0031 | 0.0020 | (leaf blade) |

(Tsuno & Fujise, 1965)

| SLA | 0.0012 | 0.0021 | 0.0014 | (leaf blade + petiole) |
|---|---|---|---|---|

leaf blade = 0.68 * (leaf blade + petiole) (Bourke, 1985)

Leaf life span:

60-80 days (Tsuno & Fujise, 1965);

45 days at 25 °C (Bhattacharya et al., 1985)

Maintenance respiration:

| | |
|---|---|
| leaves : | 0.028 kg $CH_2O$ $kg^{-1}$ $d^{-1}$ |
| stems : | 0.020 |
| fibrous roots : | 0.025 |
| tubers : | 0.005 (Tsuno & Fujise, 1965) |

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:

| DVS | 0 | 1.00 | 1.55 | 1.65 | 2.00 |
|---|---|---|---|---|---|
| leaves | 0.60 | 0.60 | 0 | 0 | 0 |
| stems | 0.40 | 0.40 | 0.15 | 0 | 0 |
| tubers | 0 | 0 | 0.85 | 1.00 | 1.00 |

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

| DVS | 0 | 1.50 | 2.00 |
|---|---|---|---|
| fibrous roots | 0.35 | 0 | 0 |

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

moisture content 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 $CO_2$ assimilation:

net photosynthesis:

| | |
|---|---|
| 15 kg $CO_2$ $ha^{-1}$ $h^{-1}$ | cv. W729R (Ku et al., 1977) |
| 26-28 | cv. Russet Burbank |
| 35 | cv. Lemhi |
| 29-50 | cv. A66107-51 |
| 28-40 | cv. A6948-4 (Dwelle et al., 1983) |
| 15 | cv. Bintje (Teubner, 1985) |
| 22 | cv. Procura (unpublished data, CABO-867, 1986) |
| 9 | cv. Lenino |
| 7 | cv. Sowa |
| 8 | cv. Nysa (Markowski et al., 1979) |

effect of leaf age:

| days after full expansion | 0 | 25 | |
|---|---|---|---|
| relative $CO_2$ assimilation | 1.00 | 0 | (Frier, 1977) |

effect of temperature:

| temperature | 0 | 7 | 19 | 29 | 37 |
|---|---|---|---|---|---|
| rel. $CO_2$ ass. | 0 | 0 | 1.00 | 1.00 | 0 |

(Dwelle et al., 1981; Ku et al., 1977)

Initial efficiency:

0.38 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ s (Teubner, 1985)

Extinction coefficient:

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

Specific leaf area:

| DVS | 0 | 1.30 | 2.00 | |
|---|---|---|---|---|
| SLA | 0.0032 | 0.0032 | 0.0015 | (Gmelig Meyling, 1981) |

Leaf life span:

Tbase = 0 °C, cv. Sebago : Tsum = 325 d°C ; cv. Monano : Tsum = 410 d°C (Ingram, 1980)

Maintenance respiration:

leaves : 0.03 kg $CH_2O$ $kg^{-1}$ $d^{-1}$

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:

cv. Dore:

| | | | | | |
|---|---|---|---|---|---|
| DVS | 0 | 1.00 | 1.57 | 1.68 | 2.00 |
| leaves | 0.80 | 0.79 | 0 | 0 | 0 |
| stems | 0.20 | 0.17 | 0.16 | 0 | 0 |
| tubers | 0 | 0.04 | 0.84 | 1.00 | 1.00 |

cv. Favorita:

| | | | | | |
|---|---|---|---|---|---|
| DVS | 0 | 1.00 | 1.52 | 1.62 | 2.00 |
| leaves | 0.80 | 0.77 | 0 | 0 | 0 |
| stems | 0.20 | 0.15 | 0.15 | 0 | 0 |
| tubers | 0 | 0.08 | 0.85 | 1.00 | 1.00 |

cv. Marijke:

| | | | | | |
|---|---|---|---|---|---|
| DVS | 0 | 1.00 | 1.39 | 1.51 | 2.00 |
| leaves | 0.80 | 0.80 | 0 | 0 | 0 |
| stems | 0.20 | 0.20 | 0.24 | 0 | 0 |
| tubers | 0 | 0 | 0.76 | 1.00 | 1.00 |

cv. Irene (on sandy soil):

| | | | | | | |
|---|---|---|---|---|---|---|
| DVS | 0 | 0.53 | 1.00 | 1.33 | 1.56 | 2.00 |
| leaves | 0.80 | 0.80 | 0.58 | 0 | 0 | 0 |
| stems | 0.20 | 0.20 | 0.42 | 0.42 | 0 | 0 |
| tubers | 0 | 0 | 0 | 0.58 | 1.00 | 1.00 |

cv. Mara:

| | | | | | | |
|---|---|---|---|---|---|---|
| DVS | 0 | 0.81 | 1.00 | 1.34 | 1.44 | 2.00 |
| leaves | 0.80 | 0.80 | 0.76 | 0 | 0 | 0 |
| stems | 0.20 | 0.20 | 0.24 | 0.23 | 0 | 0 |
| tubers | 0 | 0 | 0 | 0.77 | 1.00 | 1.00 |

cv. Multa:

| | | | | | | |
|---|---|---|---|---|---|---|
| DVS | 0 | 0.81 | 1.00 | 1.33 | 1.44 | 2.00 |
| leaves | 0.80 | 0.80 | 0.76 | 0 | 0 | 0 |
| stems | 0.20 | 0.20 | 0.24 | 0.23 | 0 | 0 |
| tubers | 0 | 0 | 0 | 0.77 | 1.00 | 1.00 |

(Van Heemst, 1986)

| | | | | |
|---|---|---|---|---|
| DVS | 0 | 1.00 | 1.33 | 2.00 |
| fibrous roots | 0.30 | 0.10 | 0 | 0 |

(unpublished data)

moisture content tubers : 76 % (Penning de Vries et al., 1983)

Crop phenology:

emergence:

Tbase = 2 °C, Topt = 25 °C, Tmax = 33 °C, Tsum = 385 d°C

cv. Maris Piper (MacKerron, 1984), cv. Desiree (Midmore, 1984), cv. Sebago (Sale, 1973; Sale, 1979), cv.'s Ostara, Jaerla, Semenic, Super, Desiree, Magura, Colina, Eba, Procura (Berindei et al., 1984)

development:

Tbase1 = 7 °C (Gutierrez et al., 1985; Van Heemst, 1986)

Topt1 = 18 °C,

Tmax1 = 29 °C

Tsum1 = 0 d°C, cv.'s Dore, Favorita

Tsum1 = 30 d°C, cv. Marijke

Tsum1 = 170 d°C, cv. Irene on sandy soil

Tsum1 = 80 d°C, cv.'s Mara, Multa (Van Heemst, 1986)

N.B. Development stage 1.00 is tuber initiation.

Tsum2 = 500 d°C, cv. Dore

Tsum2 = 530 d°C, cv. Favorita

Tsum2 = 690 d°C, cv. Marijke

Tsum2 = 625 d°C, cv. Irene on sandy soil

Tsum2 = 800 d°C, cv. Mara

Tsum2 = 810 d°C, 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 *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 cv. Sharpe's Klein E monobeet (Milford & Pearman, 1975)

17 (Lawlor & Milford, 1973)

50 cv. Dobrovicka A (Hodanova, 1979)

17 cv. MS NB1 x NB4 (Nevins & Loomis, 1970)

30 cv. Hillashogn (Hofstra & Hesketh, 1969)

dark respiration:

3 kg $CO_2$ $ha^{-1}$ $h^{-1}$ (Cary, 1977)

effect of leaf age:

| age | 20 | 55 days |
|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 0 |

(Hodanova, 1979; age estimated from leaf position)

effect of temperature:

| temperature | 20 | 28 | 41 | 45 |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 0.80 | 1.00 | 1.00 | 0 |

cv. Hillashogn (Hofstra & Hesketh, 1969)

Initial efficiency:

0.31 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ s cv. F58-554H (Taylor & Terry, 1984)

Extinction coefficient:

0.65 (PAR) (Clark & Loomis, 1978)

Specific leaf area:

| age (days) | 0 | 25 | 85 | 150 | |
|---|---|---|---|---|---|
| SLA | 0.0030 | 0.0012 | 0.0007 | 0.0007 | (Leaf blades + petioles) |

(Houba, 1973; Loach, 1970; Milford & Lenton, 1976; Snyder & Carlson, 1978)

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:

| leaf number | 1 | 25 | 65 | |
|---|---|---|---|---|
| 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 $CH_2O$ $kg^{-1}$ $d^{-1}$ | |
| 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:

| | | |
|---|---|---|
| leaves | 0.72 | |
| fibrous roots | 0.72 | (Penning de Vries & van Laar, 1982) |
| storage roots | 0.82 | (Penning de Vries et al., 1983) |

Dry matter distribution:

| DVS | 0 | 1(20 d) | 1.88(135 d) | 2.(150 d) |
|---|---|---|---|---|
| leaves | 0.95 | 0.95 | 0 | 0 |
| storage roots | 0.05 | 0.05 | 1.00 | 1.00 |

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

| DVS | 0 | 1(20 d) | 1.46(d) | 2.(150 d) |
|---|---|---|---|---|
| fibrous roots | 0.15 | 0.11 | 0 | 0 |

(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:

Tbase = 2 °C (Dubetz et al., 1962); Topt = 23 °C, Tsum = 189 d°C (Radke & Bauer, 1969)
Tbase = 3 °C, Tsum = 80 d°C for 50 % emergence (Gummerson & Jaggard, 1985)
Tmax = 30 °C (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)

| plant age | 50 | 300 days | |
|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 0.60 | (Varlet-Grancher et al., 1981) |

| plant age | 3 | 8 | 15 | 21 month |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 0.60 | 0.43 | 0.43 |

(measured at blade 4, average of twelve varieties, Hartt & Burr, 1967)

| plant age | 3 | 5 | 15 | 21 month |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 1.00 | 0.69 | 0.69 |

(measured at leaves of one month old, Kortschak & Forbes, 1969)

effect of temperature:

| temperature | 9 | 40 | |
|---|---|---|---|
| rel. $CO_2$ ass. | 0.76 | 1.00 | (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:

| DVS | 0.21 | 0.29 | 0.64 | 1.00 |
|---|---|---|---|---|
| SLA | 0.00089 | 0.00116 | 0.00079 | 0.00104 |

(Rege & Sannabhadti, 1943)

| age (months) | 0 | 9 | 17.5 |
|---|---|---|---|
| SLA | 0.00120 | 0.00084 | 0.00084 (Glover, 1974) |

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 $CH_2O$ $kg^{-1}$ $d^{-1}$

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:

| days after emergence | 0 | 12 | 56 | 84 | 174 | 365 |
|---|---|---|---|---|---|---|
| leaves | 1.00 | 1.00 | 0.79 | 0.66 | 0.24 | 0.24 |
| stems | 0 | 0 | 0.21 | 0.34 | 0.76 | 0.76 |

(Ayres, 1936)

| fibrous roots | 0.67 | 0.67 | 0.67 | 0.16 | 0.16 | 0.16 |
|---|---|---|---|---|---|---|

(Borden, 1944)

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 *Gossypium hirsutum* L.

Leaf $CO_2$ assimilation:

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) |

Initial efficiency:

0.41 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ s

cv. Stoneville 213 (Mutsaers, 1982) cv. Deltapine 16 (Constable & Rawson, 1980)

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 $CH_2O$ $kg^{-1}$ $d^{-1}$
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:

| DVS | 0 | 0.90 | 1.03 | 1.70 | 1.77 | 2.00 |
|---|---|---|---|---|---|---|
| leaves | 0.60 | 0.60 | 0.50 | 0 | 0 | 0 |
| stems | 0.40 | 0.40 | 0.50 | 0.10 | 0 | 0 |
| bolls | 0 | 0 | 0 | 0.90 | 1.00 | 1.00 |

(Merani & Aharonov, 1964; Halevy, 1976; Hearn, 1969b; Wells & Meredith,1984)

| DVS | 0 | 1.6 | |
|---|---|---|---|
| fibrous roots | 0.33 | 0 | (Halevy, 1976) |

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.

| age | 0 | 30 | 125 | days |
|---|---|---|---|---|
| SLA | 0.0029 | 0.0033 | 0.0033 | *C. capsularis* |
| SLA | 0.0028 | 0.0031 | 0.0031 | *C. olitorius* |

(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 $CH_2O$ $kg^{-1}$ $d^{-1}$
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:

| | | | | | | |
|---|---|---|---|---|---|---|
| DVS | 0 | 0.18 | 0.40 | 1.00 | 2.00 | |
| leaves | 0.83 | 0.83 | 0.40 | 0.71 | 0 | |
| stems | 0.17 | 0.17 | 0.60 | 0.29 | 0 | |
| fruit | 0 | 0 | 0 | 0 | 1.00 | *C. capsularis* |
| | | | | | | |
| DVS | 0 | 0.16 | 0.37 | 1.00 | 2.00 | |
| leaves | 0.81 | 0.81 | 0.35 | 0.67 | 0 | |
| stems | 0.19 | 0.19 | 0.65 | 0.33 | 0 | |
| fruit | 0 | 0 | 0 | 0 | 1.00 | *C. olitorius* |

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

| | | | | |
|---|---|---|---|---|
| DVS | 0 | 0.50 | 1.30 | 2.00 |
| fibrous roots | 0.10 | 0.30 | 0 | 0 |

(Sen & Banerjee, 1960; Ghosel & 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 $CO_2$ assimilation:

gross photosynthesis:

25 kg $CO_2$ $ha^{-1}$ $h^{-1}$ cv. Havanna seed 211 (Turner & Incoll, 1971)

net photosynthesis:

| | |
|---|---|
| 18-25 kg $CO_2$ $ha^{-1}$ $h^{-1}$ | (Hackett, 1973) |
| 17-21 | (Hesketh & Moss, 1963) |
| 34 | (Rawson & Woodward, 1976) |
| 25 | (Rawson & Hackett, 1974) |
| 15-20 | (Peterson & Zelitch, 1985) |

effect of leaf age:

| age | 0 | 14 | 56 (days) |
|---|---|---|---|
| rel CO2 ass. | 0 | 1.00 | 0 |

cv. Mammoth (Rawson & Hackett, 1974)

| age | 0 | 13 | 52 days |
|---|---|---|---|
| rel. CO2 ass. | 0.72 | 1.00 | 0.16 |

cv.'s Consolotion 402, Bright Yellow (Wada et al., 1967)

effect of temperature:

| temperature | 35 | 20 | 10 | |
|---|---|---|---|---|
| rel. $CO_2$ ass. | 1.00 | 0.86 | 0.81 | young leaves |
| | 1.00 | 1.00 | 0.90 | old leaves cv. Brigth Yellow |
| | 1.00 | 0.66 | 0.52 | young leaves |
| | 1.00 | 0.91 | 0.79 | old leaves cv. Burley 21 |

(Haraguchi & Shimizu, 1970)

| temperature | 36 | 45 | 51 | |
|---|---|---|---|---|
| rel. $CO_2$ ass | 1.00 | 1.00 | 0 | (Zioni & Itai, 1972) |

Initial efficiency:

0.83 kg $CO_2$ $J^{-1}$ $ha^{-1}$ $h^{-1}$ $m^2$ s (Vaclavik, 1973)

Specific leaf area:

| DVS | 0 | 0.30 | 1.00 | 2.00 |
|---|---|---|---|---|
| SLA | 0.0010 | 0.0031 | 0.0031 | 0.0023 |

(Raper et al., 1977; Tejwani et al., 1957)

Leaf life span:

56 days at 24 °C (Rawson & Hackett, 1974)

37-45 days at 25 °C cv. Mammoth 17L (Rawson & Woodward, 1976) resp. at high and low light.

Maintenance respiration:

leaves : 0.030 kg $CH_2O$ $kg^{-1}$ $d^{-1}$

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:

N.B. DVS=0 at transplanting !!

| DVS | 0 | 0.3 | 0.45 | 1. | 2. |
|---|---|---|---|---|---|
| leaves | 0.70 | 0.85 | 0.85 | 0.40 | 0.40 |
| stems | 0.30 | 0.15 | 0.15 | 0.60 | 0.32 |
| pods | 0 | 0 | 0 | 0 | 0.28 |

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)

| DVS | 0 | 0.25 | 1.5 | 2. |
|---|---|---|---|---|
| fibrous roots | 0.20 | 0.25 | 0.15 | 0.25 |

(Bertinuson et al., 1970; Morgan & Street, 1935; Raper et al., 1977)

Crop phenology:

development:

Tbase1 = 0 °C, Topt1 = 22-26 °C, Tmax1 = 39 °C

Tsum1 = 785 d°C (transplanting - flowering)

cv. NC2326 (Haroon et al., 1972), cv.'s Burley 21, Ky 151, Hicks (Kasperbauer, 1970)

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)

References:

Aase, J.K., 1978. Relationship between leaf area and dry matter in winter wheat. Agronomy Journal 70, 563-565

Agata, W., 1982. The characteristics of dry matter and yield production in sweet potato under field conditions. In: R.L. Villareal 100 & T.D. Griggs (Eds.) Sweet Potato. Proceedings of the First International Symposium. Asian Vegetable Research and Development Center. Shanhua, Tainan, Taiwan, China. 119-127

Akati, S., 1980. Studies on the differences in photosynthesis and photorespiration among crops. Bulletin of the National Institute of Agricultural Sciences, Series D, 31, 1-57

Alim, A., 1978. A Handbook of Bangladesh jute. EFFAT Begum, Dacca. 218 pp.

Allen, E.J. & D.G. Morgan, 1972. A quantitative analysis of the effects of nitrogen on the growth, development and yield of oilseed rape. Journal of Agricultural Science, Cambridge 78, 315-324

Allen, E.J. & D.G. Morgan, 1975. A quantitative comparison of the growth, development and yield of different varieties of oilseed rape. Journal of Agricultural Science, Cambridge 85, 159-174

Allen, E.J. & R.K. Scott, 1980. An analysis of growth of the potato crop. Journal of Agricultural Science, Cambridge 94, 583-606

Andrews, A.K. & L.V. Svec, 1975. Photosynthetic activity of soybean pods at different growth stages compared to leaves. Canadian Journal of Plant Science 55, 501-505

Angus, J.F., R.B. Cunningham, M.W. Moncur & D.H. Mackenzie, 1980/1981. Phasic development in field crops. 1. Thermal response in the seedling phase. Field Crops Research 3, 365-378

Arrevets, J., 1972. Exigences minerales du sorgho. Etude d'une variete Voltaique a grande tige. Agronomie Tropicale 16-1, 32-46

Aslam, M., S.B. Lowe & L.A. Hunt, 1977. Effect of leaf age on photosynthesis and transpiration of cassava (*Manihot esculenta*). Canadian Journal of Botany 55, 2288-2295.

Ayres, A., 1936. Effect of age upon the absorption of mineral nutrients by sugar cane under field conditions. Journal of the American Society of Agronomy 28, 871-886

Azim-Ali, S.N., P.J. Gregory & J.L. Monteith, 1984. Effects of planting density on water use and productivity of pearl millet (*Pennisetum typhoides*) grown on stored water. 1. Growth of roots and shoots. Experimental Agriculture 20, 203-214.

Baker, D.N. & R.E. Meyer, 1966. Influence of stand geometry on light interception and net photosynthesis in cotton. Crop Science 6, 15-19

Bauer, A., A.B. Frank & A.L. Black, 1984. Estimation of spring wheat leaf growth rates and anthesis from air temperature. Agronomy Journal 76, 829-835

Becker, W.R., F.J. Dijkhuis en Chr. Kan, 1953. De bepaling van de specifieke warmtesombehoefte van mais. Verslag van het Centraal Instituut voor Landbouwkundig Onderzoek over 1953. 118-123

Begg, J.E., 1965. The growth and development of a crop of bulrush millet (*Pennisetum typhoides* S.& H.). Journal of Agricultural Science, Cambridge 65, 341-349.

Begg, J.E., J.F. Bierhuizen, E.R. Lemon, D.K. Misra, R.O. Slatyer & W.R. Stern, 1964. Diurnal energy and water exchanges in bulrush millet in an area of high solar radiation. Agricultural Meteorology 1, 294-312.

Berindei, M., D. Năstase, A. Chiriac & A. Canarache, 1984. Producţii de cartof de 100 tone/ha. Lucrari Ştiintifice (Anale) I.C.P.C. Braşov 14, 107-118

Bernelot Moens, H.L. & J.E. Wolfert, 1975. Winterkoolzaad. Statistische gegevens, teelt, verwerking, gebruik. Publicatie nr.16. Proefstation voor de Akkerbouw, Lelystad. 65 pp.

Bertinuson, T.A., E. Larssen, B. Teveris, M.G. Comfort & M. Petersen, 1970. Nutrient uptake and dry matter accumulation of Connecticut shadegrown wrapper tobacco for three consecutive years. Tobacco Science 155, 49-51

Bhagsari, A.S., 1981. Relation of photosynthetic rates to yield in sweet potato genotypes. HortScience 16, 779-780

Bhagsari, A.S. & R.H. Brown, 1976a. Photosynthesis in peanut (*Arachis*) genotypes. Peanut Science 3, 1-5

Bhagsari, S.S. & R.H. Brown, 1976b. Relationship of net photosynthesis to carbon dioxide concentration and leaf characteristics in selected peanut (*Arachis*) genotypes. Peanut Science 3, 10-14

Bhagsari, A.S., R.H. Brown & J.S. Schepers, 1976. Effect of moisture stress on photosynthesis and some related physiological characteristics in peanut. Crop Science 16, 712-715

Bhagsari, A.S. & S.A. Harmon, 1982. Photosynthesis and photosynthate partitioning in sweet potato genotypes. Journal of the American Society for Horticultural Science 107, 506-510

Bhattacharya, N.C., P.K. Biswas, S. Bhattacharya, N. Sionit & B.R. Strain, 1985. Growth and yield response of sweet potato to atmospheric $CO_2$ enrichment. Crop Science 25, 975-981

Biscoe, P.V., R.K. Scott & J.L. Monteith, 1975. Barley and its environment. 3. Carbon budget of the stand. Journal of Applied Ecology 12, 269-291

Blum, A., 1985. Photosynthesis and transpiration in leaves and ears of wheat and barley varieties. Journal of Experimental Botany 36, 432-440

Boonstra, A.E.H.R., 1940. Rasverschillen bij bieten. 4. De invloed van de vochtigheid van den bodem op den groei bij 2 Kuhn stammen. Mededelingen van het Instituut voor Suikerbietenteelt 10, 1-81

Borden, R.J., 1944. The early development and rate of nutrient uptake by sugar cane. The Hawaiian Planters' Record 48, 43-57

Bourke, R.M., 1985. Influence of nitrogen and potassium fertilizer on growth of sweet potato (*Ipomoea batatas*) in Papua New Guinea. Field Crops Research 12, 363-375

Bouyer, S., 1949. Croissance et nutrition minérale de l'arachide. L'Agronomie Tropicale 4, 229-265

Brouwer, R., A. Kleinendorst & J.Th. Locher, 1973. Growth responses of maize to temperature. Proceedings Uppsala symposium, 1970. Plant response to climatic factors. UNESCO 1973, 169-174

Brown, D.M., 1960. Soybean ecology. 1. Development-temperature relationships from controlled environment studies. Agronomy Journal 52, 493-496

Brown, K.F. & P.V. Biscoe, 1985. Fibrous root growth and water use of sugar beet. Journal of Agricultural Science, Cambridge 105, 679-691

Carberry, P.S. & L.C. Campbell, 1985. The growth and development of pearl millet as affected by photoperiod. Field Crops Research 11, 207-217

Carberry, P.S., L.C. Campbell & F.R. Bidinger, 1985. The growth and development of pearl millet as affected by plant population. Field Crops Research 11, 193-205

Garcia-Huidobro, J., J.L. Monteith & G.R. Squire, 1985. Time, temperature and germination of Pearl millet (*Pennisetum typhoides* S. & H.). 3. Inhibition of germination by short exposure to high temperature. Journal of Experimental Botany 36, 338-343

Cardwell, V.B., 1984. Seed germination and crop production. In: M.B. Tesar (Ed.) Physiological basis of crop growth and development. American Society of Agronomy, Crop Science Society of America, Madison, Wisconsin. 53-92

Cary, J.W., 1977. Photosynthesis of sugarbeets under N and P stress : field measurements and carbon balance. Agronomy Journal 69, 739-744

Chamberlin, R.L. & G.L. Wilson, 1982. Development of yield in two grain-sorghum hybrids. 1. Dry weight and carbon-14 studies. Australian Journal of Agricultural Research 33, 1009-1018

Chartier, M., B. Fabre, G. Gosse & J.C. Rode, 1983. Bilan radiatif d'un couvert de colza. Proceedings of the 6th International rapeseed conference, Paris. 154-165

Chaudhary, T.N. & B.P. Ghildyal, 1969. Germination response of rice seeds to constant and alternating temperatures. Agronomy Journal 61, 328-330

Chauhan, Y.S. & S.C. Bhargava, 1984. Physiological analysis of growth and yield variation of rapeseed and mustard. Journal of Agricultural Science, Cambridge 103, 249-252

Chowdhury, S.I., A.F.M. Maniruzzaman, A.S. Miah & A. Salam, 1982. Physiology of grain development and yield in mungbean. In: A.K. Kaul(Ed.) Proceedings of the National Workshop on Pulses, August 1981, 179-193

Clark, E.A. & R.S. Loomis, 1978. Dynamics of leaf growth and development in sugarbeets. Journal of the American Society of Sugar Beet Technologists 20, 97-113

Clarke, J.M. & G.M. Simpson, 1978. Growth analysis of *Brassica napus* cv. Tower. Canadian Journal of Plant Science 58, 587-595

Clements, H.F. & S. Nakata, 1967. Minimum temperatures for sugar cane germination. In: J. Bague (Ed.) Proceedings of the International Society of Sugar Cane Technologists. Twelfth Congress. Elsevier Publishing Compagny. Amsterdam-London-New York. 554-560

Connor, D.J. & J.H. Cock, 1981. Response of cassava to water shortage. 2. Canopy dynamics. Field Crops Research 4, 285-296

Connor, D.J., J.H. Cock & G.E. Parra, 1981. Response of cassava to water shortage. 1. Growth and yield. Field Crops Research 4, 181-200

Constable, G.A. & H.M. Rawson, 1980. Effect of leaf position, expansion and age on photosynthesis, transpiration and water use efficiency of cotton. Australian Journal of Plant Physiology 7, 89-100

Courpront, C. & J. Tauzin, 1975. Cinétique d'absorption des éléments nutritifs par une culture de soja dans les sols sableux irrigués des landes de Gascogne. Comptes Rendus des Seances de l'Academie d'Agriculture de France 61, 963-980

Covell, S., R.H. Ellis, E.H. Roberts & R.J. Summerfield, 1986. The influence of temperature on seed germination rate in grain legumes. 1. A comparison of chickpea, lentil, soyabean and cowpea at constant temperatures. Journal of Experimental Botany 37, 705-715

Dabas, S. & I.S. Sheoran, 1984. Photosynthesis, respiration and stomatal conductance in two species of *Brassica* under water stress. Indian Journal of Plant Physiology 28, 177-183

Dantuma, G., 1973. Rates of photosynthesis in leaves of wheat and barley varieties. Netherlands Journal of Agricultural Science 21, 188-198

Davidson, H.R. & C.A. Campbell, 1983. The effect of temperature, moisture and nitrogen on the rate of development of spring wheat as measured by degree days. Canadian Journal of Plant Science 63, 833-846

Derieux, M. & R. Bonhomme, 1982. Heat unit requirements for maize hybrids in Europe. Results of the European FAO sub-network. 1. Sowing-silking period. Maydica 27, 59-77

De-Sheng Tsai & R.N. Arteca, 1985. Effects of root applications of gibberellic acid on photosynthesis and growth in C3 and C4 plants. Photosynthesis Research 6, 147-157

Diez, R., G.A. Orioli & I. Mogilner, 1962. La absorcion neta de algunos elementos minerales en caña de azucar durante el transcurso de su periodo vegetativo. Bonplandia 1, 143-157

Doorenbos, J., A.H. Kassam, C.L.M. Bentvelsen, V. Branscheid, J.M.G.A. Plusje, M. Smit, G.O. Uittenbogaard & H.K. van der Wal, 1979. Yield response to Water. FAO Irrigation and Drainage Paper 33. FAO, Rome. 193 pp.

Downton, J. & R.O. Slatyer, 1972. Temperature dependence of photosynthesis in cotton. Plant Physiology 50, 518-522

Doyle, A.D., 1975. Influence of temperature and daylength on phenology of sunflowers in the field. Australian Journal of Experimental Agriculture and Animal Husbandry 15, 88-92

Dubetz, S., G.C. Russell & D.T. Anderson, 1962. Effect of soil temperature on seedling emergence. Canadian Journal of Plant Science 42, 481-487

Duivenvoorde J. & M. Backx, 1984. Simulatie van het productiepatroon van koolzaad aan de hand van een veldproef bij de Rijksdienst IJselmeerpolders te Lelystad. M.Sc. thesis, Dept. of Theoretical Production Ecology, Agricultural University, Wageningen. 116 pp.

Duke, J.A., 1981. Handbook of legumes of world economic importance. Plenum Press. New York and London. 345 pp.

Dwelle, R.B., G.E. Kleinkopf & J.J. Pavek, 1981. Stomatal conductance and gross photosynthesis of potato (*Solanum tuberosum* L.) as influenced by irradiance, temperature, and stage. Potato Research 24, 49-59

Dwelle, R.B., P.J. Hurley & J.J. Pavek, 1983. Photosynthesis and stomatal conductance of potato clones (*Solanum tuberosum* L.). Plant Physiology 72, 172-176

Elmore, C.D., J.D. Hesketh & H. Muramoto, 1967. A survey of rates of leaf growth, leaf aging and leaf photosynthesic rates among and within species. Journal of the Arizona Academy of Science 4, 215-219

El-Sharkawy, M.A., J.H. Cock & A.A. Held, 1984a. Photosynthetic responses of cassava cultivars (*Manihot esculenta* Crantz) from different habitats to temperature. Photosynthesis Research 5, 243-250

El-Sharkawy, M.A., J.H. Cock & A.A. Held, 1984b. Water use efficiency of cassava. 2. Differing sensitivity of stomata to air humidity in cassava and other warm-climate species. Crop Science 24, 503-507

El-Sharkawy, M.A., J.H. Cock & A. del Pilar Hernandez, 1985. Stomatal response to air humidity and its relation to stomatal density in a wide range of warm climate species. Photosynthesis Research 7, 137-149

El-Sharkawy, M.A. & J.D. Hesketh, 1964. Effects of temperature and water deficit on leaf photosynthetic rates of different species. Crop Science 4, 514-518

Erdman, J.W., 1972. Een vergelijkend groei-analytisch onderzoek van de rijstcultivars IR 8 en Acorni. CELOS Rapporten, no. 78, 5-30

Evans, J.R., 1983. Nitrogen and photosynthesis in the flag leaf of wheat (*Triticum aestivum* L.) Plant Physiology 72, 297-302

Fabro, L.E., O.K. Bautista & M.M. Malixi, 1976. Dry matter accumulation and nutrient uptake of 'BNAS 51' sweet potato at different stages of growth. Philippine Agriculturist 60, 205-213

Fengshan, H., Z. Ming & Z. Shongshan, 1984. Study on the causes for photosynthetic decrease of wheat at the middle day (I). Acta Agronomica Sinica 10, 137-143

Fick, G.W., W.A. Williams & R.S. Loomis, 1971. Recovery from partial defoliation and root pruning in sugar beet. Crop Science 11, 718-721

Flynt, R.W., C.D. Raper & E.K. York, 1978. Comparative pre-floral growth of flue-cured tobacco in field and controlled environments. Agronomy Journal 70, 555-559

Foth, H.D., 1962. Root and top growth of corn. Agronomy Journal 54, 49-52

Frank, R. & M. Marek, 1983. The response of the net photosynthetic rate to irradiance in barley leaves as influenced by nitrogen supply. Photosynthetica 17, 572-577

Friedrich, J.W. & R.C. Huffaker, 1980. Photosynthesis, leaf resistances, and Ribulose-1,5-biphosphate carboxylase degradation in senescing barley leaves. Plant Physiology 65, 1103-1107

Frier, V., 1977. The relationship between photosynthesis and tuber growth in *Solanum tuberosum* L. Journal of Experimental Botany 28, 999-1007

Fujise, K. & Y. Tsuno, 1962. Studies on the dry matter production of sweet potato. 1. Photosynthesis in the sweet potato with special references to measuring of intact leaves under natural conditions. Proceedings Crop Science Society Japan 13, 145-149

Gallagher, J.N. & P.V. Biscoe, 1978. Radiation absorption, growth and yield of cereals. Journal of Agricultural Science, Cambridge 91, 47-60

Geessink, E.F. & N. Benedictus, 1973. Veevoedertabel 1973. Centraal Veevoederbureau in Nederland.

Ghosel, S.K. & Chattopadhyay, 1977. Effect of chronic moisture stress on *capsularis* and *olitorius* jute. 1. Growth and yield. Indian Agriculturist 21, 281-288

Gimenez, C. & E. Fereres, 1986. Genetic variability in sunflower cultivars under drought. II. Growth and water relations. Australian Journal of Agricultural Research 37, 583-597

Glover, J., 1973. The dark respiration of sugar-cane and the loss of photosynthate during growth of a crop. Annals of Botany 37, 845-852

Glover, J., 1974. The rate of apparent photosynthesis of whole sugarcane plants. Annals of Botany 38, 909-1020

Gmelig Meyling, H.D., 1981. Opbrengst en rasvroegheid bij aardappelen. CABO-verslag nr. 36, CABO, Wageningen. 47pp.

Godin, V.J. & P.C. Spensley, 1971. Oils and oilseeds. TPI Crop and Product Digests no. 1. London, 170 + XXI pp.

Gregory, P.J., M. McGowan, P.V. Biscoe & B. Hunter, 1978a. Water relations of winter wheat. 1. Growth of the root system. Journal of Agricultural Science, Cambridge 91, 91-102

Gregory, P.J., M. McGowan & P.V. Biscoe, 1978b. Water relations of winter wheat. 2. Soil water relations. Journal of Agricultural Science, Cambridge 91, 103-116

Gregory, P.J. & G. R. Squire, 1979. Irrigation effects on roots and shoots of pearl millet (*Pennisetum typhoides*). Experimental Agriculture 15, 161-168

Grobbelaar, W.P., 1963. Responses of young maize plants to root temperatures. Mededelingen van de Landbouwhogeschool te Wageningen 63 (5), 1-71

Grover, A., K.R. Koundal & S.K. Sinha, 1985. Senescence of attached leaves : regulation by developing pods. Physiologia Plantarum 63, 87-92

Gummerson, B. & K. Jaggard, 1985. Soil temperature measurements and sowing date decisions. British Sugar Beet Review 53, 63-65

Gutierrez, J.R., A. Bravo, N. Jaeger & E.R. Hajek, 1985. Fenologia de la papa (*Solanum tuberosum*) y su relacion con la temperatura en Lipingüe (Decima region, Chile). Ciencia e Investigacion Agraria 12, 137-142

Hackett, C., 1973. An exploration of the carbon economy of the tobacco plant. Australian Journal of Biological Science 26, 1057-1071

Hadley, P., E.H. Roberts, R.J. Summerfield & F.R. Minchin, 1983. A quantitative model of development in cowpea (*Vigna unguiculata* (L.) Walp.) in relation to photoperiod and temperature, and implications for screening germplasm. Annals of Botany 51, 531-543

Halevy, J., 1976. Growth rate and nutrient uptake of two cotton cultivars grown under irrigation. Agronomy Journal 68, 701-705

Hall, A.E. & M.R. Kaufmann, 1975. Stomatal response to environment with *Sesamum indicum* L. Plant Physiology 55, 455-459

Hall, C.J.J. van & C. van de Koppel, 1948. De landbouw in de Indische archipel. Deel 2a, Voedingsgewassen en geneesmiddelen. Uitgeverij W. van Hoeve, 's-Gravenhage. 905 pp.

Hansen, G.K., 1971. Photosynthesis, transpiration and diffusion resistance in relation to water potential in leaves during water stress. Acta Agricultura Scandinavica 21, 163-171

Hanway, J.J. & C.R. Weber, 1971. Dry matter accumulation in soybean (*Glycine max* (L) Merrill) plants as influenced by N, P, and K fertilization. Agronomy Journal 63, 263-266

Haraguchi, N. & S. Shimizu, 1970. Photosynthetic activities in tobacco plants. 2. Relationship between photosynthetic activity and chlorophyll content. Botanical Magazine Tokyo 83, 411-418

Harley, P.C., J.A. Weber & D.M. Gates, 1985. Interactive effects of light, leaf temperature, $CO_2$ and $O_2$ on photosynthesis in soybean. Planta 165, 249-263

Haroon, M., R.C. Long & J.A. Weybrew, 1972. Effect of day/night temperature on factors associated with growth of *Nicotiana tabacum* L. in controlled environments. Agronomy Journal 64, 509-515

Hartt, C.E. & G.O. Burr, 1967. Factors affecting photosynthesis in sugar cane. In: J. Bague (Ed.) Proceedings of the International Society of Sugar Cane Technologists. Twelfth Congress. Elsevier Publishing Company. Amsterdam-London-New York. 554-560

Hearn, A.B., 1969a. Growth and performance of cotton in a desert environment. 1. Morphological development of the crop. Journal of Agricultural Science, Cambridge 73, 65-74

Hearn, A.B., 1969b. The growth and performance of cotton in a desert environment. 2. Dry matter production. Journal of Agricultural Science, Cambridge 73, 75-86

Heemst, H.D.J. van, 1986. The distribution of dry matter during growth of a potato crop. Potato Research 29, 55-66

Henning, R.J., R.H. Brown & D.A.A. Ashley, 1979. Effect of leaf position and plant age on photosynthesis and translocation in peanut. 1. Apparent photosynthesis and 14C translocation. Peanut Science 6, 46-50

Herath, H.M.W. & D.P. Ormrod, 1973. Temperature and sulphur nutrition effects on the $CO_2$-assimilation rates of barley, peas and rape. Plant and Soil 38, 525-530

Hesketh, J.D. & D.N. Moss, 1963. Variation in the response of photosynthesis to light. Crop Science 3, 107-110

Hew, C-S., G. Krotkov & D.T. Canvin, 1969. Effects of temperature on photosynthesis and $CO_2$ evolution in light and darkness by green leaves. Plant Physiology 44, 671-677

Hocking, P.J. & B.T. Steer, 1983. Distribution of nitrogen during growth of sunflower (*Helianthus annuus* L.). Annals of Botany 51, 787-799

Hodanova, D., 1979. Sugar beet canopy photosynthesis as limited by leaf age and irradiance. Estimation by models. Photosynthetica 13, 376-385

Hodanova, D., 1981. Photosynthetic capacity, irradiance and sequential senescence of sugar beet leaves. Biologia Plantarum (Praha) 23, 58-67

Hodges, T. & P.C. Doraiswamy, 1979. Crop phenology literature review for corn, soybean, wheat, barley, sorghum, rice, cotton and sunflower. Lockheed Electronics Company, Inc. Houston, Texas. 90 pp.

Hodges, T., E.T. Kanemasu & I.D. Teare, 1979. Modeling dry matter accumulation and yield of grain sorghum. Canadian Journal of Plant Science 59, 803-818

Hofstra, G. & J.D. Hesketh, 1969. Effects of temperature on the gas exchange of leaves in the light and dark. Planta 85, 228-237

Horie, T., 1977. Simulation of sunflower growth. 1. Formulation and parametrization of dry matter production, leaf photosynthesis, respiration and partitioning of photosynthates. Bulletin of the National Institute of Agricultural Sciences, ser. A, 24, 45-70

Houba, V.J.G., 1973. Effect of nitrogen dressings on growth and development of sugar-beet. Agricultural Research Reports 791, Pudoc, Wageningen. 65 pp.

Howeler, R.H. & L.F. Cadavid, 1983. Accumulation and distribution of dry matter and nutrients during a 12-month growth cycle of cassava. Field Crops Research 7, 123-139.

ILACO (Ed.), 1981. Agricultural compendium for rural development in the tropics and subtropics. Elsevier Scientific Publishing Company. Amsterdam-Oxford-New York. 739 pp.

Inanaga, S., A. Kumura & Y. Murata, 1979. Photosynthesis and yield of rapeseed. Japan Agricultural Research Quarterly 13, 169-173

Ingram, K.T., 1980. Mathematical modeling of the growth and development of potatoes (*Solanum tuberosum* L.). Ph.D.Thesis University of Florida. 156 pp.

Irvine, J.E., 1967. Photosynthesis in sugarcane varieties under field conditions. Crop Science 7, 297-300

Jansen, D.M. & P. Gosseye,1986. Simulation of millet (*Pennisetum americanum*) as influenced by waterstress. Simulation Reports CABO-TT 10, 108 pp.

Jin-qiang, C. & L. Ming-qi, 1983. The effects of nitrogen nutrition on photosynthesis and photorespiration of jute leaves, with special reference to the relation between photorespiration and nitrate reduction. Acta Phytophysiologia Sinica 9, 251-258

Johansen, C., M. Waseque & S. Begum, 1985a. Effect and interaction of photoperiod, temperature, water stress and nitrogen on flowering and growth in jute. Field Crops Research 12, 397-406

Johansen, C., M. Waseque, M. Mainuddin Ahmed & S. Begum, 1985b. Plant growth curves and fibre quality changes of jute (*Corchorus* spp.) grown in Bangladesh. Field Crops Research 12, 387-395

Jonker, J.J., 1958. Bewortelingsonderzoek en ondergrondbewerking in de Noordoostpolder. W.E.J. Tjeenk Willink N.V., Zwolle. 164 pp.

Kaigama, B.K., I.D. Teare, L.R. Stone & W.L. Powers, 1977. Root and top growth of irrigated and nonirrigated grain sorghum. Crop Science 17, 555-559

Kamal, M.S., 1959. A physiological study of shading and density effects on the growth and the efficiency of solar energy conversion in some field crops. Mededelingen van de Landbouwhogeschool te Wageningen, 59 (5), Wageningen. 101 pp.

Kanemasu, E.T., D.L. Bark & E.C. Choy, 1975. Effect of soil temperature on sorghum emergence. Plant and Soil 43, 411-417

Kasperbauer, M.J., 1970. Photo- and thermo-control of flowering in tobacco (*Nicotiana tabacum* L.). Agronomy Journal 62, 825-827

Kay, D.E., 1979. Food legumes. TPI Crop and Product Digest No. 3. Tropical Products Institute, London. 435 pp.

Kay, D.E., 1973. Root crops. TPI Crop and Product Digest No. 2. Tropical Products Institute, London. 270 pp.

Keating B.A. & J.P. Evenson, 1979. Effect of soil temperature on sprouting and sprout elongation of stem cuttings of cassava (*Manihot esculenta* Crantz). Field Crops Research 2, 241-251.

Keulen, H. van & J. Wolf, Eds. 1986. Modelling agricultural production: weather, soils and crops. Simulation Monographs, Pudoc, Wageningen. 479 pp.

King, J.R. & Z.P. Kondra, 1986. Photoperiodic response of spring oilseed rape (*Brassica napus* L. and *B. campestris* L.). Field Crops Research 13, 367-373

Kortschak, H.P. & A. Forbes, 1969. The effects of shade and age on the photosynthesis rate of sugarcane. Progress in Photosynthesis Research 1, 383-387

Kramer, C., 1954. De warmtesom in de kiemingsperiode van zomergerst. K.N.M.I. Wetenschappelijk Rapport W.R. 54-001(3-132). De Bilt. 25 pp.

Krieg, D.R. & R.B. Hutmacher, 1986. Photosynthetic rate control in sorghum: stomatal and nonstomatal factors. Crop Science 26, 112-117

Ku, S-B., G.E. Edwards & C.B. Tanner, 1977. Effects of light, carbon dioxide, and temperature on photosynthesis, oxygen inhibition of photosynthesis, and transpiration in *Solanum tuberosum*. Plant Physiology 59, 868-872

Kumbhar, D.D. & K.R. Sonar, 1980. Dry matter production and nutrient uptake pattern of two rice varieties grown under upland conditions. Journal of the Indian Society of Soil Science 28, 178-183

Kumura, A., 1969. Studies on dry matter production of soybean plant. 6. Changes in spectral composition of solar radiation penetrating through leaf canopy and photosynthatic rate of single leaf as affected by light quality. Proceedings of the Crop Science Society of Japan 38, 408-418

Kuo, C.G., F.H. Hsu, J.S. Tsay & H.G. Park, 1980. Variation in specific leaf weight and RuDPCase activity in mungbean. Canadian Journal of Plant Science 60, 1059-1062

Laar, H.H. van & F.W.T. Penning de Vries, 1972. $CO_2$-assimilation light response curves of leaves; some experimental data. Verslagen nr.62, Instituut voor Biologisch en Scheikundig Onderzoek van Landbouw-gewassen. 53 pp.

Lawlor, D.W. & G.F.J. Milford, 1973. The effect of sodium on growth of water-stressed sugar beet. Annals of Botany 37, 597-604

Lawrence, D.K. & J. Ridley, 1984. Effects of Paclobutrazole, a new growth retardant, on photosynthetic parameters in sugar beet. In: C. Sybesma (Ed.) Advances in photosynthesis research. Proceedings of the 6th International Congress on Photosynthesis, Brussels, Belgium, August 1-6, 1983, Volume 6. Martinus Nijhoff/Dr. W. Junk Publishers. The Hague/Boston/Lancester. 41-44

Lazim, M.H. & A.H. El-Nadi, 1974. Growth and yield of irrigated sesame. 1. Effects of population and variety on vegetative growth. Experimental Agriculture 10, 65-69

Leong, S.K. & C.K. Ong, 1983. The influence of temperature and soil water deficit on the development and morphology of groundnut (*Arachis hypogaea* L.). Journal of Experimental Botany 148, 1551-1561

Littleton, E.J., M.D. Dennett, J. Elston & J.L. Monteith, 1979a. The growth and development of cowpeas (*Vigna unguiculata*) under tropical field conditions. 1. Leaf area. Journal of Agricultural Science, Cambridge 93, 291-307

Littleton, E.J., M.D. Dennett, J.L. Monteith & J. Elston, 1979b. The growth and development of cowpeas (*Vigna unguiculata*) under tropical field conditions. 2. Accumulation and partition of dry weight. Journal of Agricultural Science, Cambridge 93, 309-320

Littleton, E.J., M.D. Denneth, J. Elston & J.L Monteith, 1981. The growth and development of cowpeas (*Vigna unguiculata*) under tropical field conditions. 3. Photosynthesis of leaves and pods. Journal of Agricultural Science, Cambridge 97, 539-550

Loach, K., 1970. Analysis of differences in yield between six sugar-beet varieties. Annals of Applied Biology 66, 217-223

Lugg, D.G. & T.R. Sinclair, 1979. A survey of soybean cultivars for variability in specific leaf weight. Crop Science 19, 887-892

Luo, C-C., 1979. Specific leaf weight (SLW) as related to the yield and its components in rice. Botanical Bulletin of Academia Sinica 20, 145-157

Lush, W.M. & H.M. Rawson, 1979. Effects of domestication and region of origin on leaf gas exchange in cowpea (*Vigna unguiculata* (L.) Walp.) Photosynthetica 13, 419-427

MacKerron, D.K.L., 1984. Potato sprout emergence in soil as a function of temperature and time from planting. Abstracts EAPR Triennial Conference Interlaken, 364-365

Maesen, L.J.G. van der, 1972. *Cicer* L., a monograph of the genus, with special reference to the chickpea (*Cicer arietinum* L.), its ecology and cultivation. Mededelingen Landbouwhogeschool Wageningen 72-10. 342 pp.

Maniruzzaman, A.F.M., 1982. Agronomy Division, BARI, Tajdebpur, Bangladesh. Pers. comm.

Markowski, A., J. Koscielniak & W. Budzioch, 1979. Net photosynthesis rate and different leaf traits as related to the position of leaves on plant, growth phase and growing conditions in three varieties of potato. Bulletin de l'Academie Polonaise des Sciences. Serie des sciences biologiques 27, 423-431

Marshall, B., 1978. Leaf and ear photosynthesis of winter wheat crops. Thesis, University of Nottingham, 160 pp.

Marshall, B. & P.V. Biscoe, 1980. A model for C3 leaves describing the dependence of net photosynthesis on irradiance. Journal of Experimental Botany 31, 41-48

Martin, J.H. & W.H. Leonard, 1967. Principles of field crop production. The Mcmillan Company, New York. 1044 pp.

Mauney, J.R.,1966. Floral initiation of upland cotton *Gossypium hirsutum* L. in response to temperatures. Journal of Experimental Botany 17, 452-459

McCloud, D.E., 1974. Growth analysis of high yielding peanuts. Proceedings Soil and Crop Science Society of Florida 33, 24-26

McCree, K.J.,1983. Carbon balance as a function of plant size in sorghum plants. Crop Science 23, 1173-1177

McPherson, H.G. & R.O. Slatyer, 1973. Mechanisms regulating photosynthesis in *Pennisetum typhoides*. Australian Journal of Biological Sciences 26, 329-339.

McPherson, H.G., I.J. Warrington & H.L. Turnbull, 1985. The effects of temperature and daylength on the rate of development of pigeonpea. Annals of Botany 56, 597-611

Mederski, H.J., M.E. Miller & C.R. Weaver, 1973. Accumulated heat units for classifying corn hybrid maturity. Agronomy Journal 65, 743-747

Merani, A. & B. Aharonov, 1964. Rate of nitrogen absorption and dry matter production by upland cotton grown under irrigation. Israel Journal of Agricultural Research 14, 3-9

Midmore, D.J., 1984. Potato (*Solanum* spp.) in the hot tropics. 1. Soil temperature effects on emergence, plant development and yield. Field Crops Research 8, 255-271

Milford, G.F.J., 1973. The growth and development of the storage root of sugar beet. Annals of Applied Biology 75, 427-438

Milford, G.F.J. & J.R. Lenton, 1976. Effect of photoperiod on growth of sugar beet. Annals of Botany 40, 1309-1315

Milford, G.F.J. & I. Pearman, 1975. The relationship between photosynthesis and the concentration of carbohydrates in the leaves of sugar beet. Photosynthetica 9, 78-83

Monsi, M., H. Iwaki, S. Kuraishi, T. Saeki & N. Nomoto, 1962. Physiological and ecological analyses of shade tolerance of plants. 2. Growth of dark-treated green-gram under varying light intensities. Botanical Magazine Tokyo 75, 185-194

Morgan, M.F. & O.E. Street, 1935. Rates of growth and nitrogen assimilation of Havanna seed tobacco. Journal of Agricultural Research 51, 163-172

Morita, H. & T. Murakami, 1981. A planning of cropping season of rice in cool region. 1. Relation between accumulated aero-heat unit and heading date of rice. Japanese Journal of Crop Science 50, 338-343

Moula, S.P. & P. Krishnamoorthy, 1972. Uptake of nutrients by green gram (*Phaseolus radiatus*, L.). Andhra Agricultural Journal 19, 127-133

Muchov, R.C., 1985. Phenology, seed yield and water use of grain legumes grown under different soil water regimes in a semi-arid tropical environment. Field Crops Research 11, 81-97

Muchow, R.C. & D.B. Coates, 1986. An analysis of the environmental limitation to yield of irrigated grain sorghum during the dry season in tropical Australia using a radiation interception model. Australian Journal of Agricultural Research 37, 135-148

Muchow, R.C., D.B. Coates, G.L. Wilson & M.A. Foale, 1982. Growth and productivity of irrigated *Sorghum bicolor* L. in Northern Australia. 1. Plant density and arrangement effects on light interception and distribution, and grain yield, in the hybrid Texas 610SR in low and medium latitudes. Australian Journal of Agricultural Research 33, 773-784

Muendel, H.-H., 1986. Emergence and vigor of soybean in relation to initial seed moisture and soil temperature. Agronomy Journal 78, 765-769

Muldoon, D.K., 1985. Growth, mineral composition and grain yield of irrigated and rainfed millets and sorghum. Journal of Agricultural Science 105, 31-38

Mutsaers, H.J.W., 1976. Growth and assimilate conversion of cotton bolls (*Gossypium hirsutum* L.). 2. Influence of temperature on boll maturation period and assimilate conversion. Annals of Botany 40, 317-324

Mutsaers, H.J.W., 1982. Photosynthesis of cotton canopies (*Gossypium hirsutum* L.) Field Crops Research 5, 95-111

Nagarajah, S., 1975. The relation between photosynthesis and stomatal resistance of each leaf surface in cotton leaves. Physiologia Plantarum 34, 62-66

Narayanan, A. & K.B. Reddy, 1982. Growth, development and yield of sesame (*Sesamum indicum* L.) cultivars. Field Crops Research 5, 217-224

Natarajan, M. & R.W. Willey, 1985. Effect of row arrangement on light interception and yield in sorghum-pigeonpea intercropping. Journal of Agricultural Science 104, 263-270

Neild, R.E., 1982. Temperature and rainfall influences on the phenology and yield of grain sorghum and maize: a comparison. Agricultural Meteorology 27, 79-88

Nevins, D.J. & R.S. Loomis, 1970. Nitrogen nutrition and photosynthesis in sugar beet (*Beta vulgaris* L.) Crop Science 10, 21-25

Ohki, K., 1986. Photosynthesis, chlorophyll, and transpiration responses in aluminium stressed wheat and sorghum. Crop Science 26, 572-575

Ohno, Y., 1976. Varietal differences of photosynthetic efficiency and dry matter production in Indica rice. Technical Bulletin Tropical Agriculture Research Center 9, 72 pp.

Ojehomon, O.O., 1970. A comparison of the vegetative growth, development and seed yield of three varieties of cowpea, *Vigna unguiculata* (L.) Walp. Journal of Agricultural Science, Cambridge 74, 363-374

Olugbemi, L.B., J. Bingham & R.B. Austin, 1976. Ear and flag leaf photosynthesis of awned and awnless *Triticum* species. Annals of Applied Biology 84, 231-240

Ong, C.K., 1983. Response to temperature in a stand of pearl millet (*Pennisetum typhoides* S. & H.). 1. Vegetative development. Journal of Experimental Botany 34, 322-336

Ong, C.K., 1984. The influence of temperature and water deficits on the partitioning of dry matter in groundnut (*Arachis hypogaea* L.). Journal of Experimental Botany 35, 746-755

Ong, C.K. & J.L. Monteith, 1985. Response of pearl millet to light and temperature. Field Crops Research 11, 141-160.

Osman, A.M., 1971. Dry-matter production of a wheat crop in relation to light interception and photosynthetic capacity of leaves. Annals of Botany 35, 1017-1035

Palit, P. & A.C. Bhattacharyya, 1982. Source-sink control of jute productivity. Indian Journal of Plant Physiology 25, 187-200

Palit, P. & A.C. Bhattacharyya, 1984a. Measurement of leaf area per plant of white jute (*Corchorus capsularis* L.) and tossa jute (*Corchorus olotorius* L.) using the average specific leaf weight value. Tropical Agriculture, Trinidad 61, 59-62

Palit, P. & A.C. Bhattacharyya, 1984b. Characterization of the type of photosynthetic carbon dioxide fixation in jute (*Corchorus olitorius* L.). Journal of Experimental Botany 35, 169-173

Pallas, J.E. & Y.B. Samish, 1974. Photosynthetic response of peanut. Crop Science 14, 478-482

Patarroyo Murcia, F., 1980. Analisis de crecimiento del ajonjoli (*Sesamum indicum* L.) bajo dos diferentes condiciones de suministro de agua. M.Sc. Thesis Universidad Nacional de Colombia, Bogota, Colombia.

Paz, N. & J.E. Pallas, 1986. Photosynthetic capacity of isolated leaf cells from *Arachis hypogaea* L. Photosynthetica 20, 61-66

Peacock, J.M. & G.M. Heinrich, 1984. Light and temperature responses in sorghum. In: Proceedings of the international Symposium on Agrometeorology of Sorghum and Millet in the Semi-Arid Tropics. ICRISAT, India, 143-158

Penning de Vries, F.W.T. & H.H. van Laar (Eds), 1982. Simulation of plant growth and crop production. Simulation Monographs, Pudoc, Wageningen. 307 pp.

Penning de Vries, F.W.T., H.H. van Laar & M.C.M Chardon, 1983. Bioenergetics of growth of seeds, fruits, and storage organs. In : Potential productivity of field crops under different environments, IRRI, Los Banos, Philippines, 37-60.

Peterson, R.B. & I. Zelitch, 1985. Recognition of superior photosynthetic efficiency in the field using the $CO_2$-depletion technique. Plant Physiology 78, 424-426

Phogat, B.S., D.P. Singh & P. Singh, 1984. Responses of cowpea (*Vigna unguiculata* (L.) Walp.) and mungbean (*Vigna radiata* (L.) Wilczek) to irrigation. 2. Effects on $CO_2$ exchange, radiation characteristics and growth. Irrigation Science 5, 61-72

Pilet, P.E. & F.W. Went, 1956. Control of growth of *Lens culinaris* by temperature and light. American Journal of Botany 43, 190-198

Qwebedeaux, B. & R. Chollet, 1975. Growth and development of soybean (*Glycine max* (L.) Merr.) pods. Plant Physiology 55, 745-748

Radke, J.K. & R.E. Bauer, 1969. Growth of sugar beets as affected by root temperatures. Part 1: Greenhous studies. Agronomy Journal 61, 860-863

Raghavendra, A., 1980. Variation with age in the photosynthetic carbon fixation pattern by leaves of *Amaranthus paniculatus* and *Oryza sativa* : change in the primary carboxylation but no shift from C4 or C3 pathway. Physiologia Plantarum 49, 405-409

Ramanujam T. & P. Indira, 1983. Canopy structure on growth and development of cassava (*Manihot esculenta* Crantz). Turrialba 33, 321-326.

Rao, A.N. & V.S. Rama Das, 1981. Leaf photosynthetic characters and crop growth rate in six cultivars of groundnut (*Arachis hypogaea* L.). Photosynthetica 15, 97-103

Rao, A.S., Y.P. Luthra, I.S. Sheoran & R. Singh, 1984. Partitioning of carbon and nitrogen during growth and development of pigeonpea (*Cajanus cajan* L.). Journal of Experimental Botany 35, 774-784

Rao, G.G., 1985. Studies on some aspects of photosynthesis in pigeon pea and gingelley under NaCl salinity. Journal of Nucear Agricultural Biology 14, 99-101

Raper, C.D., J.F. Thomas & E.K. York, 1977. Temperatures in early post-transplant growth: an evaluation of accumulated heat units for predicting development of tobacco. Tobacco Science 46, 139-143

Rawson, H.M., J.E. Begg & R.G. Woodward, 1977. The effect of atmospheric humidity on photosynthesis, transpiration and water use efficiency of leaves of several plant species. Planta 134, 5-10

Rawson, H.M. & G.A. Constable, 1981. Gas exchange of pigeonpea: a comparison with other crops and a model of carbon production and its distribution within the plant. Proceedings of the International Workshop on Pigeonpeas, Vol 1, Patancheru, Hyderabad, India, ICRISAT, 175-189

Rawson, H.M., R.L. Dunstone, M.J. Long & J.E. Begg, 1984. Canopy development, light interception and seed production in sunflower as influenced by temperature and radiation. Australian Journal of Plant Physiology 11, 255-265

Rawson, H.M. & C. Hackett, 1974. An exploration of the carbon economy of the tobacco plant. 3. Gas exchange of leaves in relation to position on the stem, ontogeny and nitrogen content. Australian Journal of Plant Physiology 1, 551-560

Rawson, H.M. & R.G. Woodward, 1976. Photosynthesis and transpiration in dicotyledonous plants. 1. Expanding leaves of tobacco and sunflower. Australian Journal of Plant Physiology 3, 247-256

Reddy, M.S. & R.W. Willey, 1981. Growth and resource use studies in an intercrop of pearl millet/groundnut. Field Crops Research 4, 13-24

Reddy, V.C., C.V.S. Bhaskar, A.S. Raghavendra & V.S.R. Das, 1984. Photosynthesis of wheat cultivars in relation to photosynthetic unit and stomatal conductance. Photosynthetica 18, 226-230

Rege, R.D. & S.K. Sannabhadti, 1943. Problems of sugarcane physiology in the Deccan canal tract. 4. Mineral nutrition : (A) Phosphates. The Indian Journal of Agricultural Science 13, 87-111

Rivera, E., S. Silva & J. Vicente-Chandler, 1983. Distribution of pigeon peas, cassava, coffee and grass roots in an ultisol. Journal of Agriculture of the University of Puerto Rico 67, 278-285

Roberts, E.H., R.J. Summerfield, F.R. Minchin & P. Hadley, 1980. Phenology of chickpeas (*Cicer arietinum* L.) in contrasting aerial environments. Experimental Agriculture 16, 343-360

Rode, J.C., G. Gosse et M. Chartier, 1983. Vers une modelisation de la production du graines du colza de printemps. Informations Techniques CETIOM 82, 10-20

Rood, S.B., D.J. Major, J.M. Carefoot & J.B. Bole, 1984a. Seasonal distribution of nitrogen in oilseed rape. Field Crops Research 8, 333-340

Rood, S.B., D.J. Major & W.A. Charnetski, 1984b. Seasonal changes in $14CO_2$ assimilation and 14C translocation in oilseed rape. Field Crops Research 8, 341-348

Rossem, C. van, 1917. De hoeveelheid der voedingsstoffen, die door rijst in verschillende levensstadia worden opgenomen. Mededelingen van het Agricultuur-chemisch Laboratorium 17, 18-30

Roy, R.N. & B.C. Wright, 1973. Sorghum growth and nutrient uptake in relation to soil fertility. 1. Dry matter accumulation patterns, yield, and N content of grain. Agronomy Journal 65, 5-10

Russelle, M.P. & F.E. Bolton, 1980. Soil temperature effects on winter wheat and winter barley emergence in the field. Agronomy Journal 72, 823-827

Saha, S.N. & S.C. Bhargava, 1980. Physiological analysis of the growth, development and yield of oil-seed sesame. Journal of Agricultural Science, Cambridge 95, 733-736

Saint-Clair, P.M., 1972. Responses of *Lens esculenta* Moench to controlled environmental factors. Mededelingen Landbouwhogeschool Wageningen 72-12, 84 pp.

Sale, P.J.M., 1973. Productivity of vegetable crops in a region of high solar input. 1. Growth and development of the potato (*Solanum tuberosum* L.). Australian Journal of Agricultural Research 24, 733-749

Sale, P.J.M., 1974. Productivity of vegetable crops in a region of high solar input. 3. Carbon balance of potato crops. Australian Journal of Plant Physiology 1, 283-296

Sale, P.J.M., 1979. Growth of potatoes (*Solanum tuberosum* L.) to the small tuber stage as related to soil temperature. Australian Journal of Agricultural Research 30, 667-675

Sarig, S., Y. Kapulnik, I. Nur & Y. Okon, 1984. Response of non-irrigated *Sorghum bicolor* to *Azospirillum* inoculation. Experimental Agriculture 20, 59-66

Sarma, M.S., 1969. Jute. Field Crop Abstracts 22, 323-336

Sato, K., 1972. Growth responses of rice plant to environmental conditions. 1. The effects of air-temperatures on the growth at vegetative stage. Proceedings of the Crop Science Society of Japan 41, 388-393

Sato, K. & J.M. Kim, 1980. Relationships between environmental conditions and production- and consumption activities of individual leaves in the population of rice plant in a paddy field. 1. Changes in photosynthesis and dark respiration of individual leaves under field conditions. Japanese Journal of Crop Science 49, 243-255

Saxena, N.P. & A.R. Sheldrake, 1980. Physiology of growth, development, and yield of chickpeas in India. In : J.M. Green, Y.L.Nene & J.B. Smithson (Eds.) Proceedings of an International Workshop on chickpea improvement, 1979, Hyderabad, India. ICRISAT, Hyderabad, 89-96

Saxena, N.P., M. Natarajan & M.S. Reddy, 1983. Chickpea, pigeon pea, and groundnut. In: W.H. Smith & S.J. Banta (Eds.) Potential productivity of field crops under different environments. Los Banos, Philippines, IRRI, 281-305

Sen, P.K. & K.L. Banerjee, 1960. Physiological studies in jute: 1. effect of nitrogen, phosphorus and potassium on growth of jute (*Corchorus olitorius* L. var. C.G.). Indian Agriculturist 4, 121-128

Shanthakumari, P., V. Balasubramanian & S.K. Sinha, 1975. Distribution of photosynthates in chickpeas (*Cicer arietinum* L.) Indian Journal of Experimental Biology 13, 208-209

Sheldrake, A.R. & A. Narayanan, 1979. Growth, development and nutrient uptake in pigeonpeas (*Cajanus cajan*). Journal of Agricultural Science, Cambridge 92, 513-526

Sheldrake, A.R. & N.P. Saxena, 1979. Growth and development of chickpeas under progressive moisture stress. In: H. Mussell & R.C. Staples (Eds.) Stress physiology in crop plants. John Wiley & Sons, New York, 465-483

Shieh, Y-J., 1977. Effect of planting density on community photosynthesis and on yielding components of rice plants. Botanical Bulletin of Academia Sinica 18, 153-168

Sibma, 1., 1987. Ontwikkeling en groei van mais. Gewassenreeks, deel I, Pudoc, Wageningen. 57 pp.

Siddique, K.H.M. & R.H. Sedgley, 1986. Chickpea (*Cicer arietinum* L.), a potential grain legume for South-Western Australia: seasonal growth and yield. Australian Journal of Agricultural Research 37, 245-261

Siddique, K.H.M., R.H. Sedgley & C. Marshall, 1984. Effect of plant density on growth and harvest index of branches in chickpea (*Cicer arietinum* L.). Field Crops Research 9, 193-203

Singh, D.P., H.M. Rawson & N.C. Turner, 1982. Effect of radiation, temperature and humidity on photosynthesis, transpiration and water use efficiency of chickpea (*Cicer arietinum* L.). Indian Journal of Plant Physiology 25, 32-39

Singh, M., W.L. Ogren & J.M. Widholm, 1974. Photosynthetic characteristics of several C3 and C4 plant species grown under different light intensities. Crop Science 14, 563-566

Singh, V. & C. Singh, 1976. Note on influence of temperature on field emergence of sunflower seed. Pantnagar Journal of Research 1, 75-76

Sivakumar, M.V.K., N. Seetharama, Sardar Singh & F.R. Bidinger, 1979. Water relations, growth, and dry matter accumulation of sorghum under post-rainy season conditions. Agronomy Journal 71, 843-847

Sivakumar, M.V.K., H.M. Taylor & R.H. Shaw, 1977. Top and root relations of field-grown soybeans. Agronomy Journal 69, 470-473

Sivakumar, M.V.K. & S.M. Virmani, 1984. Crop production in relation to interception of photosynthetically active radiation. Agricultural and Forest Meteorology 31, 131-141

Slobbe, W.G. van, 1973. Een vergelijkend groei-analytisch onderzoek van de rijstcultivar Acorni bij verschillende plantdichtheden. CELOS rapporten no. 86, 27 pp.

Snyder, F.W. & G.E. Carlson, 1978. Photosynthate partitioning in sugarbeet. Crop Science 18, 657-661

Spaeth, S.C. & T.R. Sinclair, 1983a. Carbon exchange rate of intact individual soya bean pods. 1. Response to step changes in light and temperature. Annals of Botany 51, 331-338

Spaeth, S.C. & T.R. Sinclair, 1983b. Carbon exchange rate of intact individual soya bean pods. 2. Ontogeny of temperature sensitivity. Annals of Botany 51, 339-346

Spiertz, J.H.J., 1978. Grain production and assimilate utilization of wheat in relation to cultivar characteristics, climate factors and nitrogen supply. Pudoc, Wageningen. 249 pp.

Squire, G.R., B. Marshall, A.C. Terry & J.L Monteith, 1984. Response to temperature in a stand of pearl millet. 6. Light interception and dry matter production. Journal of Experimental Botany 35, 599-610

Srinivasan, P.S., R. Chandrababu, N. Natarajaratnam & S.R. Sree Rabgaswamy, 1985. Leaf photosynthesis and yield potential in green gram (*Vigna radiata* (L.) Wilczek) cultivars. Tropical Agriculture (Trinidad) 62, 222-224

Stern, W.R., 1962. Light measurements in pastures. Herbage Abstracts 32, 91-96

Stickler, F.C., A.W. Pauli & A.J. Casady, 1962. Comparative responses of Kaoliang and other grain sorghum types to temperature. Crop Science 2, 136-139

Summerfield, R.J., P.J. Dart, P.A. Huxley, A.R.J. Eaglesham, F.R. Minchin & J.M. Day, 1977. Nitrogen nutrition of cowpea (*Vigna unguiculata*). 1. Effects of applied nitrogen and symbiotic nitrogen fixation on growth and seed yield. Experimental Agriculture 13, 129-142

Summerfield, R.J., F.R. Minchin, K.A. Stewart & B.J. Ndunguru, 1978. Growth, reproductive development and yield of effectively nodulated cowpea plants in contrasting aerial environments. Annals of Applied Biology 90, 277-291

Summerfield, R.J., E.H. Roberts, W. Erskine & R.H. Ellis, 1985. Effects of temperature and photoperiod on flowering in lentils (*Lens culinaris* Medic.). Annals of Botany 56, 659-671

Szlovak, S., 1975. A study of flooding effect on maize transpiration at two nutrient levels. Acta Botanica Academiae Scientiarum Hungaricae 21, 167-174

Takeda, G., 1979. Ecological analysis of photosynthesis of barley and wheat. Japan Agricultural Research Quarterly 13, 180-185

Taniyama, T., Y. Tsuno, A.T. Lubis, H. Suprapto & L. Zen, 1983. Survey of rice plants in the Province of Lampung, Indonesia. 1. On the growth of rice plants in dry season. Japanese Journal of Tropical Agriculture 27, 265-275

Taylor, H.M., W.K. Mason, A.T.P. Bennie & H.R. Rowse, 1982. Responses of soybeans to two row spacings and two soil water levels. 1. An analysis of biomass accumulation, canopy development, solar radiation interception and components of seed yield. Field Crops Research 5, 1-14

Taylor, S.E. & N. Terry, 1984. Limiting factors in photosynthesis. 5. Photochemical energy supply colimits photosynthesis at low values of intercellular $CO_2$ concentration. Plant Physiology 75, 82-86

Tayo, T.O., 1982. Growth, development and yield of pigeon pea (*Cajanus cajan* (L.) Millsp.) in the lowland tropics. 1. Effect of plant population density. Journal of Agricultural Science, Cambridge 98, 65-69

Tayo, T.O. & D.G. Morgan, 1975. Quantitative analysis of the growth, development and distribution of flowers and pods in oil seed rape (*Brassica napus* L.). Journal of Agricultural Science, Cambridge 85, 103-110

Tejwani, K.G., C.K. Ramakrishna Kurup & K.V. Venkatraman, 1957. Growth studies on and nutrient uptake by cigar tobacco-1. The Indian Journal of Agricultural Science 26, 317-327

Tejwani, K.G., K.V. Venkatraman & C.K. Ramakrishna Kurup 1959. Growth studies on and nutrient uptake by cigar tobacco. 2. The absorption of nutrients by cigar tobacco at different stages of growth. The Indian Journal of Agricultural Science 29, 72-86

Teubner, F., 1985. Messung der Photosynthese und Transpiration an Weizen, Kartoffel und Sonnenblume. Diplomarbeit, Bayreuth, 116 pp.

Thorne, G.N., I. Pearman, W. Day & A.D. Todd, 1988. Estimation of radiation interception by winter wheat from measurements of leaf area. Journal of agricultural Science, Cambridge 110, 101-108

Trachtenberg, C.H. & D.E. McCloud, 1976. Net photosynthesis of peanut leaves at varying light intensities and leaf ages. Soil and Crop Science Society of Florida Proceedings 35, 54-55

Tsuno, Y. & K. Fujise, 1965. Studies on the dry matter production of sweet potato. Bulletin of the National Institute of Agricultural Sciences, Series D No. 13, 1-132

Tsuno, Y., T. Taniyama & H. Suprapto, 1983. The photosynthesis and estimation of productivity of cassava. Japanese Journal of Crop Science 52, 84-492

Turner, N.C. & L.D. Incoll, 1971. The vertical distribution of photosynthesis in crops of tobacco and sorghum. Journal of Applied Ecology 8, 581-591

Vaclavik, J., 1973. Effect of different leaf age on the relationship between the $CO_2$ uptake and water vapour efflux in tobacco plants. Biologia Plantarum (Praha) 15, 233-236

Varlet-Grancher, C. & R. Bonhomme, 1979. Application aux couverts végétaux des lois de rayonnement en milieu diffusant. 2. Interception de l'énergie solaire par une culture. Annales Agronomiques 30, 1-26

Varlet-Grancher, C., R. Bonhomme, M. Chartier & P. Artis, 1981. Évolution de la réponse photosynthétique des feuilles et efficience théorique de la photosynthèse brute d'une culture de canne à sucre (*Sacharum officinarum* L.) Agronomie 1, 473-481

Veltkamp, H.J., 1985. Physiological causes of yield variation in cassava (*Manihot esculenta* Crantz). Ph.D.Thesis, Agricultural University Wageningen Papers 85-6. Agricultural University Wageningen. 103 pp.

Vertregt, N. & F.W.T. Penning de Vries, 1987. A rapid method for determining the efficiency of biosynthesis of plant biomass. Journal of Theoretical Biology 128, 109-119

Vong, N.Q. & Y. Murata, 1977. Studies on the physiological characteristcs of C3 and C4 crop species. 1. The effects of air temperature on the apparent photosynthesis, dark respiration and nutrient absorption of some crops. Japanese Journal of Crop Science 46, 45-52

Wada, Y., S. Watanabe & S. Kuroda, 1967. Changes in the photosynthetic activities and chlorophyll contents of growing tobacco leaves. Botanical Magazine Tokyo 80, 123-129

Waldron, J.C., K.T. Glasziou & T.A. Bull, 1967. The physiology of sugar-cane. 9. Factors affecting photosynthesis and sugar storage. Australian Journal of Biological Sciences 20, 1043-1052

Warncke, D.D. & S.A. Barber, 1974. Root development and nutrient uptake by corn grown in solution culture. Agronomy Journal 66, 514-516

Warrag, M.O.A. & A.E. Hall, 1984. Reproductive responses of cowpea (*Vigna unguiculata* (1.) Walp.) to heat stress. 1. Responses to soil and day air temperatures. Field Crops Research 8, 3-16

Warrington, I.J. & E.T. Kanemasu, 1983. Corn growth response to temperature and photoperiod 1. Seedling emergence, tassel initiation, and anthesis. Agronomy Journal 75, 749-754

Weiss, E.A., 1971. Castor, Sesame and Safflower. Leonard Hill, London. 901 pp.

Wells, R. & W.R. Meredith, 1984. Comparative growth of obsolete and modern cotton cultivars. 1. Vegetative dry matter partitioning. Crop Science 24, 858-862

Williams, R.F., 1960. The physiology of growth of the wheat plant. 1. Seedling growth and the pattern of growth at the shoot apex. Australian Journal of Biological Sciences 13, 401-428

Williams, R.F., 1966. The physiology of growth in the wheat plant. 3. Growth of the primary shoot and inflorescence. Australian Journal of Biological Science 19, 949-966

Winzeler, H., 1980. Der Einfluss der Sorte und der Temperatur auf morphologische und physiologische Ertragskomponenten von *Triticum aestivum* L. Diss. ETH Nr.6567. aku-Fotodruck Zurich. 127 pp.

Wit, C.T. de, et al., 1978. Simulation of assimilation, respiration and transpiration of crops. Simulation Monographs, Pudoc, Wageningen. 140 pp.

Woodward, R.G., 1976. Photosynthesis and expansion of leaves of soybean grown in two environments. Photosynthetica 10, 274-279

Wu, H. B.-F., T.-T. Yu & T.-D. Liou, 1974. Physiological and biochemical comparisons of sweet potato varieties sensitive (Tai-lung 57) and insensitive (Red-tuber-tail) to chilling temperatures. In: R.L. Bieleski, A.R. Ferguson & M.M. Cresswell (Eds.) Mechanisms of regulation of plant growth. Bulletin 12, The Royal Society of New Zealand, Wellington. 483-486

Zioni, A.B. & C. Itai, 1972. Short- and long-term effects of high temperatures (47-49 C) on tobacco leaves. 1. Photosynthesis. Physiologia Plantarum 27, 216-219