# Crop-specific simulation parameters for yield forecasting across the European Community

Simulation Reports CABO-TT, no 32

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Study carried out on behalf of:
Agricultural Information Systems,
Institute for Remote Sensing Applications,
Joint Research Centre of the Commission of the
European Community

June 1993

Simulation Reports CABO-TT

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# Preface

This report is prepared by the DLO Centre for Agrobiological Research in the framework of the development, validation and testing of crop-specific agrometeorological models for yield forecasting purposes. It describes the parameterization and calibration of the crop simulation model WOFOST of the Crop Growth Monitoring System, which in turn will form part of an Agricultural Information System on the European Community. The description of the crop simulation model and its validation against official regional agricultural statistics are given in other reports.
The Crop Growth Monitoring System was developed by the DLO Winand Staring Centre on behalf of the Institute for Remote Sensing Applications of the Joint Research Centre (JRC-Ispra Site) of the Commission of the European Community under contract 3965-90-04 ED ISP-NL "Yield Forecasting Models, Part II" (SC Project 7185), and further elaborated in co-operation with the DLO Centre for Agrobiological Research under contract 4436-91-08 ED ISP NL "Crop-specific agrometeorological simulation models" (SC Project 7220).

This report is a contribution of the DLO Centre for Agrobiological Research (CABO-DLO, CABO Project 836) to the second contract. The overall objective of the second contract was to develop, validate and test new or existing crop-specific agrometeorological simulation models for routine quantitative forecasting of national and NUTS-1 yields every 10 days, and for areawise qualitative monitoring, every 10 days, of the conditions of the agricultural season over the whole of the EC. The model should work for each of the following annual crops : wheat, barley, oats, maize, rice, potato and sugar beet, tobacco, cotton, pulses, soybean, oil-seed rape, sunflower.

This report deals with the development of the crop simulation model, in particular with its parameterization and calibration for specific crops on the basis of detailed field experiments and regional crop calendars.
The sets of crop and crop type parameters represent the best estimate that could be made on the basis of the relatively limited amount of available data. There is clearly much room for refinements of the data sets, which can be done by analyzing much more trials and experiments, supported by an assessment of their relevance and representativeness for typical current agricultural systems, per crop and per region.

C.A. van Diepen
Project leader

# Acknowledgements

We gratefully acknowledge all people who provided experimental data to us:
D. Drew (Rothamstead, United Kingdom), V. Jordan (Long Ashton, Bristol, United Kingdom), D.K.L. McKerron (Scottish Crop Research Institute, Invergowrie, United Kingdom) G. Russell (University of Edinburgh, United Kingdom), B. Pedersen (Landbrugets Rådgivningscenter Århus, Denmark), D.K. Papakosta (Aristotle University Thessaloniki, Greece), V. Marletto (ERSA-SMR Bologna, Italy), V. Nuzzo (Agrobios Metapontum, Italy), A. Eaglesham (Agrobios Metapontum, Italy), F. d'Antuono (Instituto di Agrotecnica Viterbo, Italy), C. Zaragoza (SIA Zaragoza, Spain),
N. Stutterheim (INRA, France), M. Cabelguenne (INRA, Toulouse, France), A. Bouniols (INRA Toulouse, France), J.P. Palleau, (CETIOM, Dijon, France), E. Ebmeyer (Germany).
O. Dolstra (CPRO-DLO, the Netherlands), J. Wolf (TPE, WAU, The Netherlands) and various colleagues at CABO-DLO (Netherlands).
Furthermore we would like to thank W. Stol and J. Withagen of CABO-DLO and M.J.W. Jansen of GLW-DLO for their valuable contributions concerning modelling and statistical software, respectively.
Many thanks are also due to P. Vossen of JRC-Ispra for his kind support and counsel.

Wageningen, June 1993.

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# Summary


At the request of the Joint Research Centre of the European Community, the DLO Winand Staring Centre (SC-DLO) in co-operation with the DLO Centre for Agrobiological Research (CABO-DLO) in Wageningen the Netherlands, has executed the project: "Development, validation and testing of crop-specific agrometeorological simulation models". The objective of this project is to investigate the possibilities of agrometeorological simulation models for quantitative forecasting of national and regional yields of the main agricultural crops of the European Community.

This report describes the preparation of crop-specific data files of winter wheat, grain maize, spring barley, rice, sugar beet, potato, field bean, soybean, winter oilseed rape and sunflower. The crop-specific data files makes the yield simulation by the model specific for the chosen crop.

For all the crops an initial crop-specific data file was created or adapted (parameterization). The simulation results of the model with the initial crop-specific data file were adapted to field experiments and crop calendar data by altering some elements of the initial crop-specific data file (calibration). The simulation results with the calibrated file were used in de Koning *et al.* (1993) for validation with Eurostat yields.

Because abundant information was available of winter wheat, most attention was paid to this crop in the study. For this crop the mathematical calibration procedure was used to calibrate the initial crop-specific data file. The mathematical calibration did not improve the results of the crop growth model because the initial crop-specific data file was optimal calibrated already through the years. An optimal calibrated data file appeared not to be a guaranty for satisfying validation results. Some reasons were:

The WOFOST results were calculated for one point in the Netherlands and compared with Eurostat data of a whole country. The WOFOST model does not account for management, pests and diseases.

For the other crops the crop-specific data file was calibrated according to the manual calibration procedure.

For every crop the following data are given:

- Initial crop-specific data file (Appendix A1 to J1)
- Field experiments used for calibration and their sources (Appendix A2 to J2)
- Differences between initial crop-specific data file and calibrated data file (Appendix A3 to J3)
- Crop calendars and their sources (Appendix A4 to J4)
- Temperature sums between emergence and flowering and between flowering and harvest (except for rice, sugar beet and potato). For sugar beet and potato instead of flowering an alternative growth stage was chosen, secondary tap root growth for sugar beet and tuber initiation for potato (Appendix A4 to J4)

# 1 General introduction

The Directorate General for Agriculture of the EC requires timely forecasting of agricultural production to support the Common Agricultural Policy (CAP). Until now integration of Community statistics has been performed by the Statistical Office of the European Community (O.S.C.E. or Eurostat) in Luxembourg. Prediction of yields by Eurostat is based on statistical methods, using historical data and taking into account time trends and weather indicators. The Institute for Remote Sensing Applications (IRSA), of the Joint Research Centre (JRC) of the EC, located in Ispra, Italy, is in charge of a program to improve agricultural yield forecasts. This program is known as the Agriculture project or MARS project. Within the Agriculture Project of the EC, an Advanced System of Information on Agriculture is being developed. Three methods are investigated by JRC: conventional surveys, remote sensing, and agrometeorological modelling.
At the request of the JRC, the Winand Staring Centre (SC-DLO) in co-operation with the Centre for Agrobiological Research (CABO-DLO) in Wageningen the Netherlands, has executed the project: "Development, validation and test of crop-specific agrometeorological simulation models". The objective is in the contract described as "to develop, validate and test new or already existing agro-meteorological simulation models for 10-days routine quantitative forecasting of national and NUTS-1 yields and for 10-days areawise (regional), but qualitative monitoring of agricultural season conditions over the whole of the EC and for each of the following crops: wheat (spring and winter; hard and soft), barley (spring and winter), oats, maize (grain), rice, potato, sugar beet, pulses (human consumption), soybean, oilseed rape, sunflower, tobacco and cotton."
The project succeeds the project "Yield Forecasting Models, Part II", executed by the Winand Staring Centre in 1991.

In "Yield Forecasting Models Part II", The Winand Staring Centre has developed a Crop Growth Monitoring System (CGMS). This system includes a non crop-specific agrometeorological simulation model, linked with a weather system and a Geographical Information System (GIS). In the weather system, historic and current daily weather data are stored and interpolated to the grid points of a 50 x 50 kilometres mesh over the whole of the EC. The weather data are used in the crop growth model and the model results can be analysed and visualized with the GIS. In "Yield Forecasting Models, Part II", the crop growth simulation model was non crop-specific. In the current project, yields of all main agricultural crops of the EC were simulated individually. A yield forecasting model was defined, based on comparison between simulation results and historical records of statistical data.

The contribution of the Centre for Agrobiological Research (CABO-DLO) consisted of the adaptation of the crop growth model for crop-specific calculations and development of a yield forecasting algorithm. For each of the crops, standard values were gathered of parameters that represent specific crop characteristics. Insufficient data were available for oats, tobacco and cotton and these crops had therefore to be omitted. For the other crops, crop parameter values were adapted to regional conditions throughout Europe.
The effectiveness of using standard mathematical calibration procedures for optimizing parameter values was investigated. As result of this investigation for most crops a more simple approach for calibration was followed, namely the manual adaptation of crop parameters to

limited regional data using general modelling knowledge. Crop simulation outputs of the calibrated model were compared with results from independent field trials.
After CABO-DLO had calibrated and validated the model at point level, SC-DLO calculated grid yields with the model for historical weather records with the CGMS and aggregated these yields to yearly regional averages. These historical records of simulated regional yields were analysed by CABO-DLO and compared to historical official statistical yields by means of regression methods. This resulted in the formulation of a forecasting algorithm using crop model output of the current year for the forecasting of official yields in that year.
This procedure has resulted in the integration of the yield-forecasting model in the CGMS, allowing yearly forecasts of official yields and updating of the forecasting model to data of the most recent years.

In this report, the procedures used for updating crop parameters and calibration of the model will be presented.
In Chapter 2 a short overview is given of the methodology followed for the project at CABO-DLO. Detailed information about the methodology of the research for this project is discussed in de Koning *et al.* (1993). In Chapter 3 parameters, crop calendars, temperature sums and calibration of crop-specific parameters are described per crop. In Chapter 4 the study is discussed and some suggestions are made.

CABO-DLO has executed the project in the period from 1-1-1992 until 31-12-1992.

# 2 The crop growth model

## 2.1 Introduction

WOFOST (WOrld FOod STudies) was chosen as the crop growth model for the Crop Growth Monitoring System (CGMS). This model has been developed by the Centre for World Food studies in Wageningen, the Netherlands, in co-operation with the Agricultural University and the Centre for Agrobiological Research (van Diepen *et al.*, 1988, 1989).The model simulates phenological development and growth of a field crop from emergence to maturity as determined by the crop's response to environmental conditions.
Within the model two production levels are distinguished: potential and water-limited. The potential yield is determined by crop genetic properties, solar radiation, temperature regime and sowing date, and indicates the production ceiling for crops growing under optimum soil moisture conditions. The water-limited yield depends on natural water supply and includes effects of water-shortage. For both potential and water-limited production, nutrient availability, farm management and pest, weed and disease control are taken to be optimal (de Koning *et al.*, 1993).
The main model can be broadly divided into two sub-models: the crop growth sub-model and the soil water sub-model. These sub-models are connected by means of a relation, describing the effect of the soil water status on the transpiration and photosynthesis rate of the crop. The simulations are carried out in time steps of one day. For this document only the crop growth sub-model is considered.

## 2.2 The crop growth sub-model

Figure 1 illustrates the processes, described in the crop growth sub-model. The amount of intercepted light is determined by the level of incoming solar radiation and the leaf area of the crop. From the absorbed radiation and the photosynthetic characteristics of single leaves, the daily rate of potential gross photosynthesis is calculated. Part of the daily production of assimilates is used to provide energy for the maintenance of the life biomass (maintenance respiration). The remaining carbohydrates are partitioned among the major plant organs: roots, leaves, stems and storage organs and converted into structural plant material such as cellulose, proteins, lignin and lipids. In this conversion process some of the weight of carbohydrates is lost as growth respiration, in dependence of the composition of the various organs (Penning de Vries *et al.*, 1989). The leaf area index of the crop is calculated by multiplying the life leaf weight by the specific leaf area. During ageing of the crop, part of the life crop tissue dies due to senescence. Leaf mass is subdivided into age classes, and if the temperature sum of a class exceeds the crop-specific value during which leaves are functioning, they are assumed to die.
The crop growth curve and resulting yield are found by integrating the daily dry matter increase, partitioned to the plant organs, over the total crop growth period. Some simulated crop growth processes are influenced by temperature like the maximum rate of photosynthesis, and the maintenance respiration. Other processes are steered by the development stage: the partitioning of assimilates, the specific leaf area and the death rate of crop tissue. Phenological development of a crop can be characterized by the order and rate of appea-

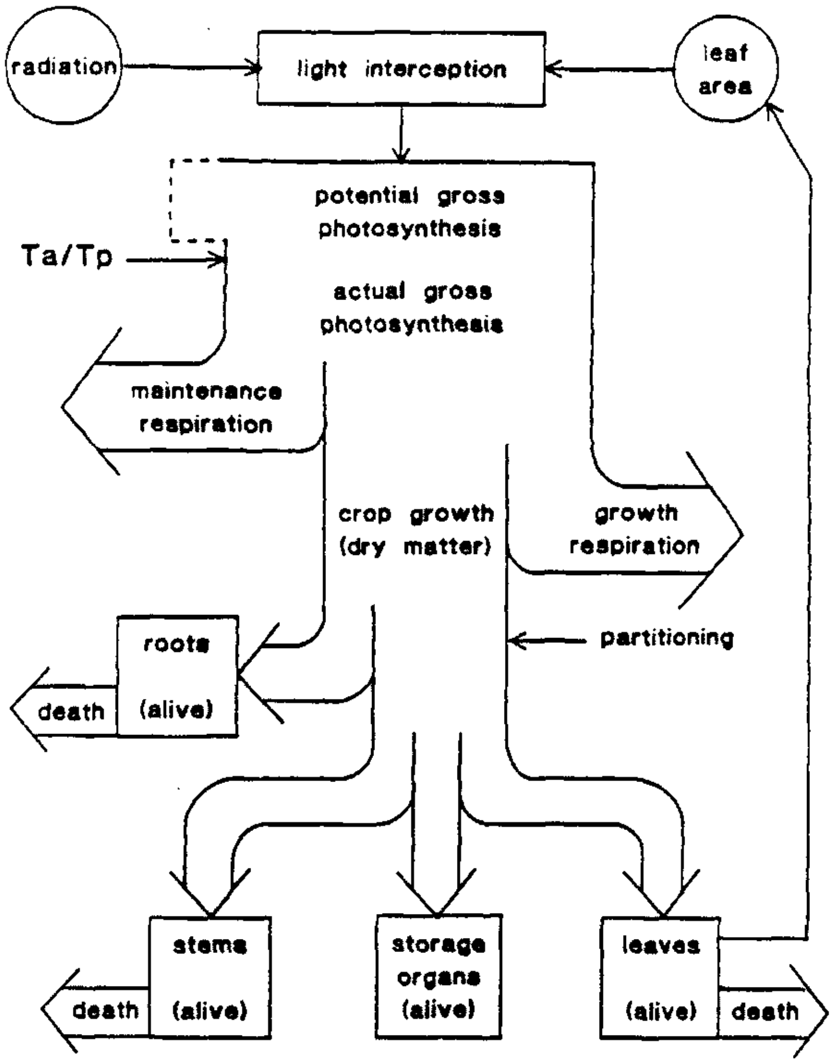


Figure 1 Crop growth processes (de Koning *et al.*, 1993). Ta/Tp is the actual transpiration (mm $d^{-1}$) divided by potential transpiration (mm $d^{-1}$), a measure for water deficiency of the plant by air.

rance of vegetative and reproductive plant organs. In the model the development rate is a function of ambient temperature, possibly modified by the effect of daylength (de Koning *et al.*, 1993).

## 2.3 Crop parameters

To be able to run the crop growth model a number of crop parameters is needed. They are listed in crop-specific data files as given in Appendix A1 to J1. This section explains their meaning.
After sowing the crop, the time needed until emergence has taken place is determined by a temperature sum (TSUMEM) of daily average temperatures above a threshold temperature (TBASEM) and with a maximum daily increase of the temperature sum of TEFFMX. In order to initiate crop growth, the dry weight (TDWI) and leaf area index (LAIEM) of the crop at emergence must be estimated. Growth after emergence depends on the photosynthesis rate, though the increase of leaf area during juvenile growth my be limited by the maximum relative daily increase of the leaf area index (LAI) in dependence of air temperature (RGRLAI). Phenological development is determined by temperature sums: TSUM1 from emergence to anthesis (development stage 1), TSUM2 from anthesis to maturity (development stage 2). The increases of temperature sum in dependence of the average air temperature is given by function DTSMTB. For some crops, phenological development is also influenced by daylength (IDSL), using an optimum (DLO) and critical (DLC) daylength. The assimilation parameters describe the response curve of single leaves to light: the maximum photosynthesis rate (AMAX) at light saturation and the light use efficiency (EFF) under light limiting conditions. AMAX depends on development stage (AMAXTB) and average temperature (TMPFTB). The gross photosynthesis of the canopy can also be limited due to low minimum temperatures (TMNFTB). Light distribution within the canopy is influenced by the leaf angle distribution of the crop, in the model accounted for by the extinction coefficient for diffuse visible light (KDIF). The relative rates of maintenance respiration (RML, RMO, RMR, RMS) and growth respiration (CVL, CVO, CVR, CVS) of each organ are determined by the composition of the crop tissue. Q10 indicates the relation between the maintenance respiration rate and temperature. The partitioning functions FRTB, FLTB, FSTB and FOTB distribute the daily dry matter growth between different plant organs as function of the development stage. Also depending on development stage is the specific leaf area (SLATB) which converts leaf weight into leaf area, while the life span (SPAN) of the leaves is used for the description of leaf death due to ageing. Leaf death due to drought stress is separately determined by the relative death rate PERDL. Initial rooting depth (RDI), root growth rate (RRI), maximum rooting depth (RDMCR), specific evapotranspiration (CFET) and drought sensitivity (DEPNR) of the crop are required to describe drought stress. RDRRTB and RDRSTB are the relative death rate of roots and stems, respectively, both depending on development stage.
The crop growth sub-model model is structured in a way that the growth of different annual crops can be simulated by only adapting the crop-specific parameters (de Koning *et al.*, 1993).

When the temperature sums for a crop are chosen too high, it is possible that the simulated crop does not reach the development stage at harvest (DVSEND). It is possible to stop the crop growth simulation model after a fixed number of days (FINTIM). Table 1 gives the number of days used as emergency break for the different crops.

Table 1 Forced end of crop growth simulation model calculation per crop.
J. day nr. = Julian day number.

| crop | FINTIM<br>J. day nr. |
|---|---|
| winter wheat | 300 |
| grain maize | 190 |
| barley | 200 |
| rice | 200 |
| sugar beet | 300 |
| potato | 200 |
| field bean | 200 |
| soybean | 200 |
| oilseed rape | 250 |
| sunflower | 225 |

## 2.4 Parameterization

Valuation of crop-specific parameters is called parameterization. It is the aim of the project to calculate the yield per crop in 50 x 50 km grids of the EC, each grid can be identified by a number. In every grid the environmental conditions are different. The growth and development rate of crops are adapted to these varying circumstances, and this is reflected in the values of the crop-specific parameters. For example, it is obvious that TSUM1 (section 2.3) in Germany is lower than the TSUM1 in Spain when crops are sown on the same date and have to flower on the same date. To be able to distinguish the different crop-specific data files per region for one crop, crop types were distinguished. Per crop type, one specific date file was composed and linked to regions and to grid cells.
In 1988, a collection of plant data values for use in crop growth simulation models has been documented by van Heemst. From these values the initial sets of crop-specific model parameters were selected for use by the WOFOST-model (van Diepen *et al.*, 1988). The WOFOST model of 1988 contained standard data sets for all the crops used in the present study. In a study by van Lanen *et al.* (1992) part of the original crop data files were adapted to European conditions with plant values for winter wheat, silage maize, potato and sugar beet from SUCROS87 (Spitters *et al.*, 1989) and for oilseed rape from various sources. The original and updated crop data files (van Diepen & de Koning, 1990) are the starting point for the present study. The initial crop-specific data files composed this way are given in Appendix A1 to J1. Detailed information about the literature used for parameterization is given per crop in Chapter 3.

## 2.5 Calibration

Calibration is the selection of the optimal value of parameters of the crop-specific data file with the aid of detailed field experiments and crop calendars. This can be done by a mathematical or manual calibration procedure. The advantage of a mathematical calibration procedure is the uniform treatment of the chosen parameters that have to be changed but detailed field experiment results are the basic condition for such an approach. This means

that the leaf area index (LAI, ha $ha^{-1}$), total above ground dry weight of dead and living plant organs (TAGP, ha $ha^{-1}$) and the dry weight of living storage organs (WSO, kg $ha^{-1}$) would have been measured during the growing season, for every crop and for different, well described, locations.
At the beginning of the project a questionnaire has been sent to a number of researchers within the EC, asking for such data. It turned out that within the time frame of this project for most crops, not enough data would become available for a thorough mathematical calibration. After all the mathematical calibration could only be used for winter wheat, while for the other crops a more conventional way of adjusting the model was inevitable, the manual calibration. This is described in section 2.5.3. Detailed information about the mathematical calibration is given in de Koning *et al.* (1993).
The sources of the field experiment data used for calibration are given per crop in Chapter 3. The data itself are listed in Appendix A2 - J2.

Field experiments may also provide sowing, anthesis and harvest data, which are useful for the creation of another calibration tool, the crop calendar. The crop calendar contains regional average sowing/planting dates, flowering/anthesis and harvest/maturity dates and is used to check simulated anthesis and harvest dates with. Due to lack of sufficient field experiment data for most of the crops this goal was not attained. As a consequence the crop calendars were derived from literature. The calendars and the literature sources they are based on are given in Appendix A4 to J4.

### 2.5.1 Temperature sums

It was not the intention to use the crop calendar for calibration only but for calculation of temperature sums as well. A temperature sum is the summation of the daily average temperature (°C) above a base temperature over a defined period.
When sowing, flowering and anthesis dates and weather data of a specific grid cell are known the temperature sum from emergence to anthesis (TSUM1) and from anthesis to harvest (TSUM2) can be calculated. Attention have to be paid to the fact that when the temperature sum from sowing to anthesis is calculated, the temperature sum from sowing to emergence (TSUMEM) has to be subtracted to get the TSUM1 as defined for the WOFOST model.
For calculation of the temperature sums the following method was used.
Some grid cells within a country were selected and sowing, flowering and harvest date of a specific crop was given. With the long year average temperatures of a nearby weather station the temperature sums between sowing and flowering and between flowering and harvest for this crop were calculated. To get TSUM1 and TSUM2 the temperature sum between sowing and emergence (TSUMEM) was subtracted from the calculated temperature sum between sowing and flowering. When this was done it appeared that some stations gave a TSUM1 that was too low, because in mountainous areas the weather stations tend to be build above the level where agriculture is possible. As a consequence the measured temperatures are lower than on crop level and the temperature sums drop. So the TSUM1 and TSUM2 values were obtained by calibration.
Later on during the study when the calibrated specific crop data files were ready, the yields were simulated with temperatures corrected for height and interpolated for every grid cell but the temperature sums were not recalculated.

In Chapter 3 per crop the sources for crop calendars and calibrated temperature sums are given. The crop calendars and calculated temperature sums are given in Appendix A4 to J4.

### 2.5.2 Start day of winter crops

It is possible to start a calculation run with the WOFOST model on a certain sowing or emergence day number. For winter crops like winter wheat and winter oilseed rape, the sowing date would be in the previous year. It is possible to calculate for this year but due to the fact that the model does not account for effects like vernalisation, the results may not be accurate. For winter crops the results improve when the simulation starts with an emergence at the 1st of January, with an estimated initial total crop dry weight (TDWI). As a consequence the calculation of the temperature sum between emergence and anthesis (TSUM1) starts on 1st of January for a winter crop.

### 2.5.3 Manual calibration

The manual calibration starts with a potential simulation run for a crop with the initial crop-specific data file, weather data of a nearby weather station and a suitable soil type. The sowing or planting date is chosen according to crop calendar dates.
The simulated flowering date was compared with the flowering date of an experiment or the crop calendar. If the flowering date did not correspond, the TSUM1 value of the initial crop-specific data file was changed. If the calculated date was later the value of TSUM1 became shorter, when the calculated date was too early the TSUM1 became higher. The same procedure was followed for the maturity/harvest date and TSUM2.
Next step was to compare the calculated yield and leaf area index with the measured yield and LAI. When, according to field experiments, too much leaf material was calculated with a too low dry matter production in the storage organ, the dry matter partitioning could be changed. With the adapted values of parameters the calibrated crop-specific data file was created. Per crop the changed parameter values are given in Appendix A3 to J3.
It appeared that TSUM1 and TSUM2 and the dry matter partitioning were the parameters that had to be adopted most often with calibration.

## 2.6 Aggregation and validation

With the calibrated crop-specific parameters, yields are calculated for every grid cell. For historic years before 1990, the yield is calculated using weather from weather stations in stead of interpolated weather on the grid cells because the interpolation algorithm of weather from weather stations on a *daily* basis to grid cells was not operational.
For the current year it was possible to simulate with interpolated weather and temperatures corrected for height.
In the aggregation procedure, the simulated yields of a crop in all grids were summarized for every NUTS 1 and 0 region. Only with winter wheat the aggregated yields were compared with experimental data from other fields than the field experiments used for calibration (validation). For the other crops such data were not available and for validation the aggregated yields were compared with Eurostat yield data. This is extensively described in de Koning *et al.* (1993) and this aspect will not be further treated in this report.

# 3 The crops

## 3.1 Winter wheat

### 3.1.1 Parameterization

For winter wheat values of the crop-specific parameters (section 2.4) are collected from van Diepen & de Koning (1990).
Calculation of temperature sum between emergence and anthesis (TSUM1) starts on 1st of January. This start point is chosen, due to the difficulty to simulate during the winter season. For example, there is no routine in the WOFOST model to calculate vernalisation.
The initial crop-specific data file for winter wheat is given in Appendix A1.

### 3.1.2 Field experiments

Field experiment data are from the United Kingdom (Rothamsted 1980 and 1981) , Belgium (Helecine 1985) and the Netherlands (Eest 1981, PAGV 1983, 1984, De Bouwing 1983, 1984). In Appendices A2a - h relevant data of these experiments are given.

### 3.1.3 Crop calendar and temperature sums

For winter wheat the crop calendar data are collected from Narciso *et al.* (1991), Falisse & Decelle (1990), Hough (1990).

For winter wheat the temperature sums were calculated. For every region a grid cell was chosen close to a weather station, situated on a representative altitude for wheat growing. The summation of the long year average temperature data of this station between 1st of January and flowering gave TSUM1 and between flowering and harvest gave TSUM2 for this grid. This leads to different values for the temperature sum in each grid cell. Each different temperature sums is interpreted as a distinct crop type. The crop calendar and calculated temperature sums are given in Appendix A4.
The calculated temperature sum of TSUM1 shows a range of 950 - 1500 °Cd. To restrict the number of crop types, TSUM1 is divided into 7 classes. Because of uncertainty of the harvest dates, especially in southern Europe, a common value for TSUM2 is chosen: 950 °Cd for some parts in the United Kingdom and Denmark, and 1000 °Cd for other countries. An overview of temperature sums for the European Community is given in table 1.1. The detailed distribution of crop types within the European Community is given in Appendix A3.
For some NUTS 1 regions no sowing, flowering or harvest data were available. In that case the TSUM1 and TSUM2 were estimated from surrounding regions.

### 3.1.4 Calibration

Winter wheat is the only crop with enough crop data (section 2.4) for mathematical calibration with the Price Algorithm (Stol *et al.*, 1992). A brief overview of the procedure follows here.

Of the 40 parameters of the crop-specific data file, five were chosen to be used in the calibration procedure. These five parameters are:

Table 1.1 Temperature sums for winter wheat from the 1st of January to flowering (TSUM1) and from flowering to harvest (TSUM2) per crop type of winter wheat based on the calculated temperature sums of Appendix A4 for countries and regions within countries of the European Community. The temperature sums are chosen with a temperature base of 0°C.

| crop type | country | NUTS code of regions | TSUM1 °Cd | TSUM2 °Cd |
|---|---|---|---|---|
| 0101 | United Kingdom | R71, R7A, R7B | 1000 | 950 |
| | Denmark | R9 | | |
| 0102 | United Kingdom | R7 without R71, R7A, R7B | 1050 | 1000 |
| | Ireland | R8 | | |
| | the Netherlands | R41, R42, R47 | | |
| | Germany | R11, R12, R13, R14 | | |
| 0103 | Germany | R15, R19 | 1125 | 1000 |
| | the Netherlands | R45 | | |
| | Belgium | R5 | | |
| | Luxembourg | R6 | | |
| 0104 | Germany | R16, R17, R18, R1A, R1B | 1200 | 1000 |
| | France | R23, R24 | | |
| 0105 | France | R2 without R23, R24 | 1250 | 1000 |
| | Italy | R3 without R37, R39, R3A, R3B | | |
| | Spain | RB1,RB2 | | |
| | Portugal | RC1 | | |
| 0106 | Italy | R37, R39, R3A, R3B | 1300 | 1000 |
| | Spain | RB3, RB4, RB5 | | |
| | Portugal | RC2 | | |
| | Greece | A1 | | |
| 0107 | Spain | RB6 | 1350 | 1000 |
| | Greece | RA2, RA3, RA4 | | |

1) One value (DVS1) of the partitioning function of dry matter to leaves and stems depending on development stage, (DVS), see Appendix A3 table A3b.
2) Specific leaf area as a function of development stage, (SLA)
3) Maximum relative increase in leaf area index, (RGRLAI)
4) Life span of leaves growing at 35 °C, (SPAN)
5) Maximum leaf $CO_2$-assimilation as a function of development stage, (AMAX)

The five parameters were chosen because of their importance for leaf development and final yield. On the first place partitioning of assimilates (DVS) within above ground dry matter determines the increase of leaf weight and this forces the leaf area index (LAI), because LAI is leaf weight multiplied by the specific leaf area (SLA). On the second place the life span of the leaves (SPAN) determines when the leaf life weight decreases due to death of leaf tissue. Leaf area directly determinates light interception and therefore assimilate production. The maximum photosynthesis rate at light saturation is determined by AMAX.

Within the calibration procedure simulation results, using different values of the 5 crop parameters, were compared with results of the 8 field experiments. Comparisons were made on the basis of the total above-ground dry weight of dead and living plant organs (TAGP, kg $ha^{-1}$), the dry weight of living storage organs (WSO, kg $ha^{-1}$) and the leaf area index (LAI, ha $ha^{-1}$). During the calibration procedure the values of the five parameters were allowed to vary between fixed boundaries according to their biologically plausible range. The values of the 5 crop parameters that caused the best fit of simulation results and field experiment values for TAGP, WSO and LAI were the results of the calibration procedure and used as the updated crop-specific parameters. The values of the five parameters before and after calibration are given in table 1.2.

Table 1.2 Five parameters used to calibrate the crop data file of the WOFOST growth model. Values before and after calibration and the biological plausible ranges are given.

| parameter | unit | standard value | range | value after calibration |
|---|---|---|---|---|
| AMAX | kg $ha^{-1}yr^{-1}$ | 40.00 | 35. - 45. | 35.83 |
| SLA | ha $kg^{-1}$ | 0.0020 | 0.001 - 0.003 | 0.00212 |
| RGRLAI | ha $ha^{-1}d^{-1}$ | 0.0070 | 0.006 - 0.015 | 0.00817 |
| SPAN | d | 35. | 31. - 39. | 31.3 |
| DVS1 | - | 0.7 | 0.51 - 0.94 | 0.646 |

The calibration of the partitioning of assimilates (DVS) needs further explanation. For the calibration only one value (DVS1, 0.70; see Appendix A3) in the total dry matter partitioning range from 0.00, 0.10 to 2.00 for winter wheat is used. This value could vary between 0.51 and 0.94. The other values of the dry matter partitioning remained unchanged.
The mathematical procedure is described in more detail by de Koning *et al.* (1993) and Stol *et al.* (1992). The best fitting values found for these five parameters were implemented in the crop-specific data file (Appendix A3).
The effect of the calibration procedure is shown (Figure 1.1 - 1.3) on dry matter grain production (kg $ha^{-1}$), total above-ground dry matter production (kg $ha^{-1}$) and leaf area index (ha $ha^{-1}$) in the following situations:

1) when calculated with the standard WOFOST crop-specific data file (suffix s)
2) when calculated with the WOFOST crop data file with the values after calibration of the five parameters of table 1.2 (suffix c).

*The simulation results are compared with the measured experimental field data (suffix m).*

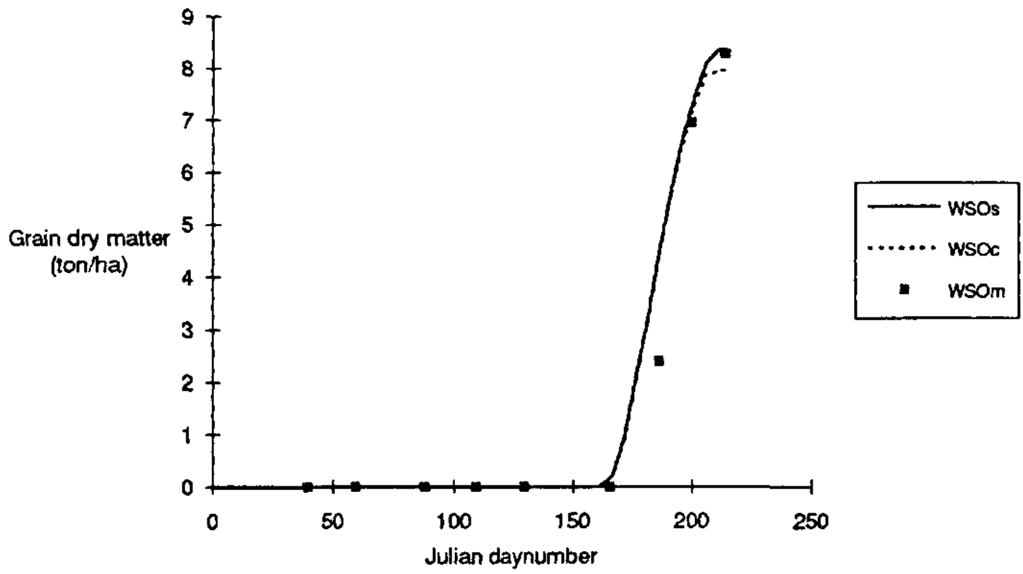


Figure 1.1 Measured dry matter grain yield (WSOm) of a PAGV field experiment of 1983 and simulated grain yield, using the initial crop-specific data file (WSOs) or the crop-specific data file after calibration (WSOc), in kg $ha^{-1}$.

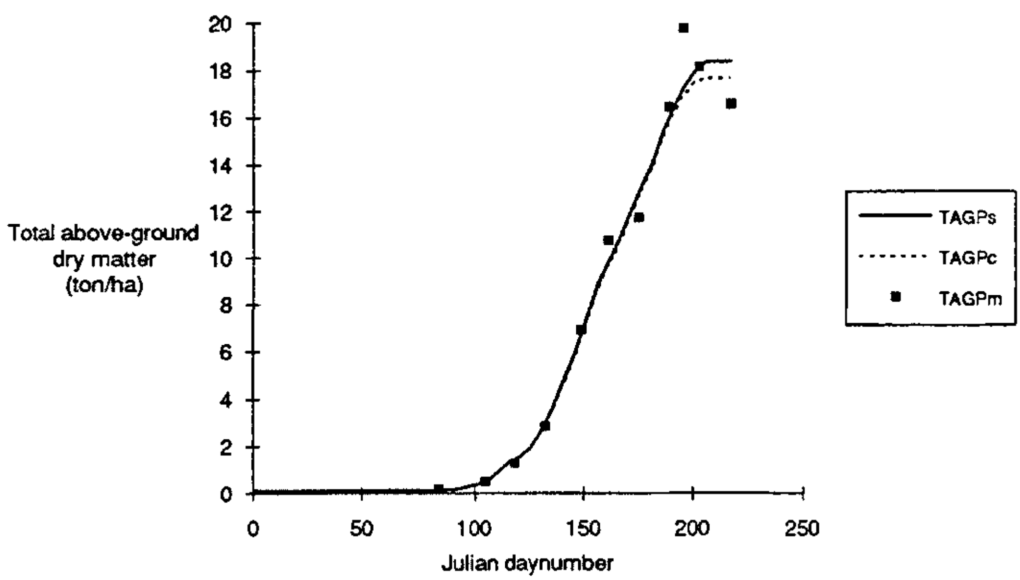


Figure 1.2 Measured total above-ground dry matter (TAGPm) of a Helecine field experiment of 1985 and simulated total above-ground dry matter, using the initial crop-specific data file (TAGPs) or the crop-specific data file after calibration (TAGPc), in kg $ha^{-1}$.

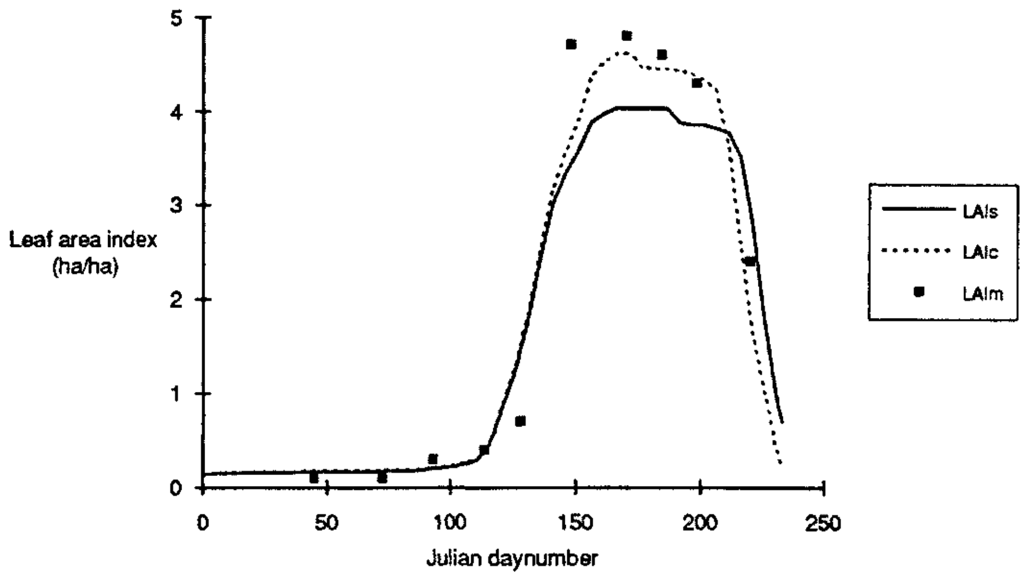


Figure 1.3 Measured leaf area index (LAlm) of a PAGV field experiment of 1984 and simulated leaf area index, using the initial crop-specific data file (LAls) or the crop data specific file after calibration (LAlc), in ha ha$^{-1}$.

Improvement of the results with the values of the calibration procedure was marginal (Figures 1.1 - 1.3). Indicating that the standard WOFOST crop parameter file is the result of developments in earlier research.
Some examples are given of the simulated values of WSO, TAGP and LAI, before and after calibration and values of LAI, WSO and TAGP of field experiments (Appendix A5).

## 3.1.5 Validation

After calibration the WOFOST-model was run with the calibrated crop-specific data file. The results were compared with independent series of field experiments to find out whether the yield over a series of years is simulated correctly by the model. For winter wheat data are used from former RIVRO now CPRO (Centre for Plant breeding and Reproduction Research). An example is shown (Figure 1.4) for simulated winter wheat yields on sandy soils (available water capacity (AWC) 0.10 cm$^3$ cm$^{-3}$), loam (AWC 0.14 cm$^3$ cm$^{-3}$) and loam/clay soils (AWC 0.21 cm$^3$ cm$^{-3}$). RIVRO winter wheat yields on sandy soils and clay soils and Eurostat yields for the Netherlands are also given. Yields are indicated in ton dry matter ha$^{-1}$year$^{-1}$. Numbers of Figure 1.4 are given in Appendix A6.
As can be seen, the loam/clay soil has the same yields as the potential yield, no water limitation occurred on these soils (Figure 1.4).

Both trial yields are lower than the water limited yields on the loam and sandy soil. Only in 1986 (a dry year) the model calculates a lower yield on sandy soils. This may be explained by the fact that during a dry year the pressure by diseases decreases, and that pests and diseases are not implemented in the model.

Winter wheat yields rise over the years due to improved management and variety. This causes a trend in the Eurostat data and field experiment data as well. Because the simulation model does not account for the trend, Eurostat and RIVRO data had to be corrected for a linear trend when compared with simulated data.

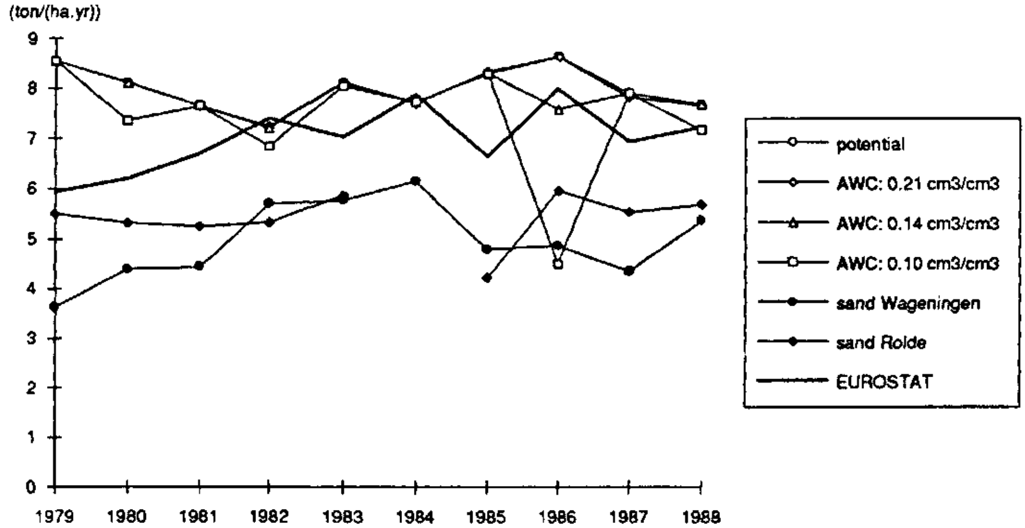


Figure 1.4 Dry matter yield from field experiments of RIVRO stations at sandy soils, Eurostat dry matter yield in The Netherlands, potential and water limited dry matter yield (ton/ha) simulated with the calibrated crop data file for a series of soils in the Netherlands (weather station Wageningen). Soils with 0.21 $cm^3\ cm^{-3}$, 0.14 $cm^3\ cm^{-3}$ and 0.10 $cm^3\ cm^{-3}$ available water capacity (AWC) are used in the simulation.

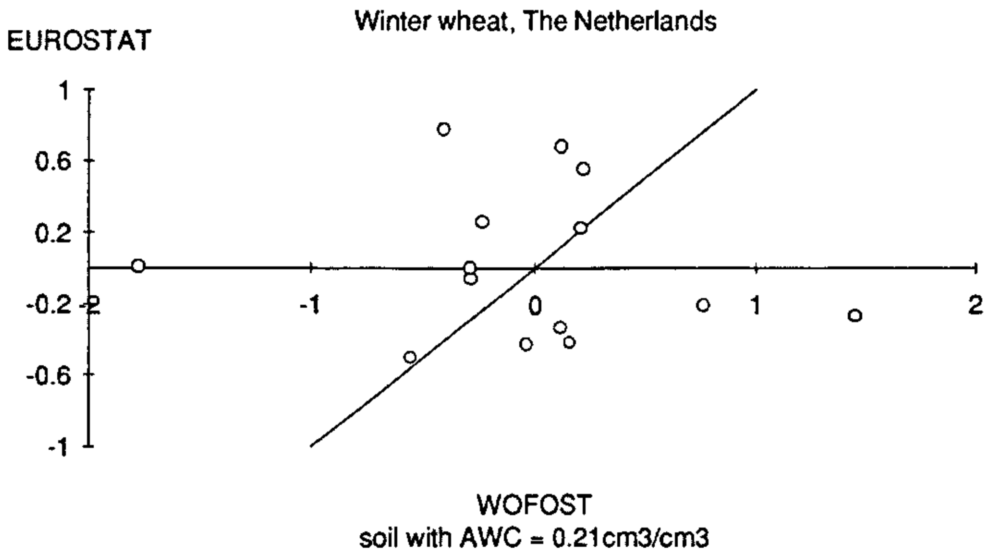


Figure 1.5 Comparison of normalized Eurostat yield data with normalized WOFOST (ton/ha) results for a series of years (1975 - 1989, every o is one year) of winter wheat on clay with an available water capacity of 0.21 $cm^3\ cm^{-3}$.

An example of such a comparison is given (Figure 1.5). Each dot indicates a year for which the corrected Eurostat yield is plotted against the WOFOST yield. From both measured and simulated yields, the average (measured and simulated) yield over the series of years has been subtracted respectively. This way a positive value means a better than average year, and a negative value a worse than average year. Good measured values should correspond

with good simulated values and vice versa.
Ideally there should be a linear relationship between the Eurostat data and the simulated data. Figure 1.5 indicates that there is no such a relation at all. Note also that the variation in simulated yields is larger than the variation in observed regional yields.
The relation between RIVRO and WOFOST data, and Eurostat and WOFOST data was not really satisfying. The variability in year to year yields was similar in both data sets, but directions of annual deviations from the average were not always consistent. Although the model and the crop, soil and weather data sets are not perfect, also the experimental and statistical data are somewhat inaccurate due to measuring estimation errors and inrepresentativeness. An other possible reason for the mismatching relation between RIVRO data and WOFOST results may be that these numbers were data for one point in the Netherlands, compared with Eurostat numbers which are an average over the whole country. As a consequence, differences between farming systems and soils are levelled out in the Eurostat data. For more information about corrections for average and trend see de Koning *et al.* (1993).

## 3.2 Grain maize

### 3.2.1 Parameterization

The basis crop data file for grain maize is the fodder maize crop-specific data file documented in Wolf & van Diepen (1991). This basis crop data file is given in Appendix B1.

### 3.2.2 Field experiments

For the calibration procedure of grain maize data were available on only two field experiments from Cabelguenne of the INRA in Toulouse (1980 and 1981). The field experiments are listed in Appendix B2.

### 3.2.3 Crop calendar and temperature sums

Grain maize crop calendar data of sowing, flowering and harvesting are collected from Eurostat data (1989), Narciso *et al.* (1992) and Bignon (1990). Based on these data a division of 5 crop types over the EC is made (table 2.1). This means that the EC is divided in large regions with the same temperature sum regime. The temperature sums coinside with values given by

Table 2.1 Temperature sums for grain maize from emergence to flowering (TSUM1) and from flowering to harvest (TSUM2) for regions within the European Community.

| crop type | country/region | TSUM1 °Cd | TSUM2 °Cd |
|---|---|---|---|
| 0201 | Germany<br>Luxembourg | 695 | 800 |
| 0202 | Southern Germany<br>Northern France | 695 | 860 |
| 0203 | Central France<br>Northern Italy | 775 | 880 |
| 0204 | Southern France<br>Italy<br>Spain<br>South Spain | 855 | 900 |
| 0205 | Greece<br>Southern Italy<br>Southern Spain | 935 | 920 |

Derieux & Bonhomme (1982). The crop calendar for maize is given in Appendix B4. In this Appendix regions received a value "-1" for TSUM1 and TSUM2 when no grain maize could be grown for climatological reasons.

### 3.2.4 Calibration

For grain maize the crop data file from Wolf and van Diepen (1991) was used. The values for assimilate partitioning were changed according to data from Wermke (1986).
Especially in the regions with higher temperatures the leaves died to soon with the data in the original crop data file. Based on data from van Heemst (1988) the leaf life span was increased. The values of these variables are used in the crop data file. The development of grain maize continues until maturity, while fodder maize normally does not reach that stage. Fodder maize is harvested before the grains are physiologically ripe. The crop data file for grain maize is given in Appendix B3. Because the calibration did not improve the results of fodder maize and the crop-specific data file for grain maize is very much the same, no calibration was considered necessary for grain maize.

## 3.3 Spring barley

### 3.3.1 Parameterization

As a basis the non-specific spring cereal crop-specific data file from the WOFOST documentation of van Diepen *et al.* (1988) was used (Appendix C1).

### 3.3.2 Field experiments

For calibration the variety experiments of the European Brewery Convention from 1983 to 1991 by Schildbach *et al.*, (1983, 1984, 1985, 1987), Schildbach & Larsen (1986), Curtis *et al.* (1988, 1989, 1990) and Sarx & Duijnhouwer (1991) (Appendix C2) are used. These field experiments match practical circumstances. This means that the experiments did not receive extra fertiliser, water or special protection against pests and diseases, therefor the yields may not be considered as potential yields.

### 3.3.3 Crop calendar and temperature sums

The crop calendar was derived from Russell (1990). Temperature sums of Appendix C4 were calculated per grid cell by the Staring Centre.

### 3.3.4 Calibration

The lower threshold temperature for emergence (°C, TBASEM) was derived from van Heemst (1988).
The dates of the crop calendar were used to calibrate the temperature sum from emergence to heading (°Cd, TSUM1) and the temperature sum used from heading to harvest (°Cd, TSUM2). Dates between sowing and emergence were used to calibrate the temperature sum from sowing to emergence (°Cd, TSUMEM).
The table of daily increase in temperature sum as function of the average temperature (°C; °Cd, DTSMTB), the initial total crop dry weight (kg $ha^{-1}$,TDW), the table of specific leaf area as a function of development stage, the extinction coefficient for diffuse visible light (-,KDIF), the table of maximum leaf $CO_2$ assimilation rate as a function of development stage (- ; kg $ha^{-1}$ $hr^{-1}$, AMAXTB), the reduction factor of AMAX (kg $ha^{-1}$ $hr^{-1}$, maximum leaf $CO_2$ assimilation rate) as function of average temperature (kg $ha^{-1}$ $hr^{-1}$, TMPFTB), efficiencies of conversion of biomass into leaves, storage organ, roots and stems (kg $kg^{-1}$,CVL, CVO, CVR, CVS), maintenance respiration rates of leaves, storage organ, roots and stems (kg $CH_2O$ $kg^{-1}$ $d^{-1}$, RML, RMO, RMR, RMS), the table with dry matter partitioning to roots, leaves, stems and storage organs (-; kg $kg^{-1}$, FRTB, FLTB, FSTB, FOTB) and initial rooting depth (cm, RDI) from van Diepen *et al.* (1988) are used.

# 3.4 Rice

## 3.4.1 Parameterization and calibration

The crop-specific date file of rice is based on MACROS from Penning de Vries *et al.* (1989) and slightly adapted data from the standard WOFOST parameter file (van Diepen *et al.*, 1988), it is given (Appendix D1).
For rice no individual experiments in Europe were available to calibrate the crop-specific parameters.
On basis of the crop calendar derived from Narciso *et al.* (1992) (Appendix D4) temperature sums for rice were calculated. Due to dependence of emergence of sown rice on water temperature rather than air temperature (which is used to calculate the temperature sums) for rice fixed emergence dates are used (Table 4.1).

Table 4.1 Julian day number for emergence of rice for regions within the European Community. J. day nr. = Julian day number

| crop type | country | NUTS code of regions | emergence J. day nr. |
|---|---|---|---|
| 0501 | Italy | 31 - 39, 3A, 3B | 126 |
| | Greece | RA | 135 |
| | France | R28 | 126 |
| | Spain | RB2,RB3, RB4, RB5,RB6 | 135 |

# 3.5 Sugar beet

## 3.5.1 Parameterization

The updated crop parameter set of WOFOST version 5.0 (van Diepen & de Koning, 1990) was used as initial data to run WOFOST. Most important variables are temperature sums and dry matter partitioning. Sugar beets do not reach the flowering stage. Therefore TSUM1 (temperature sum from emergence to flowering) has another meaning in the crop growth model. For sugar beets it will be defined as the temperature sum from emergence to growing point date (g.p.d.) (Spitters *et al.*, 1990). G.p.d. is defined as the date on which a beet contains 4 g. of sugar which coincides approximately with the start of full ground coverage (LAI of 3.5 - 4). This point also marks the start of secondary thickening of the tap root (Spitters *et al.*, 1990). Other authors place full ground coverage at an LAI of 2.5 - 3 (Milford et *al.*, 1985c,d).
The initial crop-specific data for sugar beet is given (Appendix E1).

## 3.5.2 Field experiments

For calibration field experiments of PAGV, 1983 and 1984 (van der Schans & Drenth, 1989), Brooms Barn, 1983 (Brown *et al.*, 1987) and Italian field experiments of 1985 - 1989 (L'Informatore Agrario), Zocca (1982) and Laureti *et al.* (1984) are used. The experiment results are listed (Appendices E2a - d).

## 3.5.3 Crop calendar and temperature sums

The crop calendar (Appendix E4) contains dates of sowing, fast tap root growth and harvest per grid cell and region. For sugar beet these dates are collected from Falisse (1992), Hough (1990) and Narciso *et al.* (1992).

## 3.5.4 Calibration

For the temperature sum from emergence to secondary tap root growth a base temperature of 3°C is used (van Heemst, 1988), and for the temperature sum from secondary tap root growth to harvest a base temperature of 0°C. After calibration 4 crop types of sugar were formed. The distribution of the types within the European Community are given (Table 5.1). The difference between the initial crop-specific data file and the calibrated crop-specific data file is given (Appendix E3).

Table 5.1 Distribution of sugar beet types within the European Community and sowing and harvest day per region and NUTS code.
J. day nr. = Julian day number.

| crop type | country/region | NUTS code of regions | sowing day J. day nr. | harvest day J. day nr. |
|---|---|---|---|---|
| 0601 | Germany | R1 | 90 | 300 |
| | N. France | R21 - R25 and R27 | 95 | 300 |
| | the Netherlands | R4 | 100 | 300 |
| | Belgium | R5 | 100 | 290 |
| | Luxembourg | R6 | 95 | 290 |
| | United Kingdom | R7 | 95 | 290 |
| | Ireland | R8 | 105 | 290 |
| | Denmark | R9 | 95 | 290 |
| 0602 | S. France | R26 and R28 | 95 | 300 |
| | Italy | R31 - R36 and R38 | 85 | 270 |
| | Spain | RB1, RB2, RB3, RB4 | 85 | 300 |
| | Portugal | RC | 85 | 300 |
| 0603 | Southern Italy | R37, R39, R3A, R3B | 85 | 260 |
| | Southern Spain | RB5, RB6 | 85 | 300 |
| 0604 | Greece | RA | 85 | 300 |

# 3.6 Potato

## 3.6.1 Parameterization

The initial values of the crop parameters for potato are taken from the crop data file of WOFOST version 5.0 (van Diepen & de Koning, 1990). This basic crop data file is given in Appendix F1.

## 3.6.2 Field experiments

Field experiments used for calibration are Varseveld 1968, 1969 by Gmelig Meyling & Bodlaender (1981), Varseveld 1971 - 1973 by Caesar *et al.*, (1981) and Heilbronn & MacKerron, (1984). The data are given in Appendices F2a - f.

## 3.6.3 Crop calendar and temperature sums

The crop calendar consists of three marking point, sowing/planting, anthesis and maturity date or day. Planting and harvest are clear points in the potato crop but flowering has no relation with the final tuber yield, if the plants flower at all. When the WOFOST model is used for potato, anthesis should be understood as the moment of tuber initiation. However the tuber initiation is difficult to spot and is never measured or mentioned in field experiments. As a consequence the temperature sums for potato are calibrated with the field experiments of section 3.6.2.

## 3.6.4 Calibration

The calibration procedure resulted in four crop types for potato differing in temperature sum and life span of the leaves (table 6.2). The distribution of the four potato types within the European Community is given (table 6.3).

Table 6.2 The four potato crop types with temperature sums and life span of leaves at 35 °C.

| crop type | TSUM1<br>°Cd | TSUM2<br>°Cd | SPAN<br>d |
|---|---|---|---|
| 0701 | 150 | 1550 | 37 |
| 0702 | 150 | 1675 | 37 |
| 0703 | 150 | 1800 | 40 |
| 0704 | 200 | 1800 | 40 |

Table 6.3 Regional distribution of potato types and planting day.
J. day nr. = Julian day number

| crop type | country/region | NUTS code of regions | planting day J. day nr. |
|---|---|---|---|
| 0701 | Germany | R1 | 105 |
| | N France | R21, R22, R23, R24, R25 | 105 |
| | the Netherlands | R4 | 105 |
| | Belgium | R5 | 105 |
| | Luxembourg | R6 | 105 |
| | United Kingdom | R7 | 115 |
| | Ireland | R8 | 105 |
| | Denmark | R9 | 105 |
| 0702 | S France | R26, R27, R28 | 105 |
| 0703 | N Italy | R31, R32, R33, R34, R35, R36 | 105 |
| 0704 | S Italy | R37, R38, R39, R3A, R3B | 105 |
| | Greece | RA | 65 |
| | Spain | RB | 115 |
| | Portugal | RC | 115 |

## 3.7 Field bean

Development stages of field beans principally differ from a cereal crop. The filling of the storage organ of a cereal starts after the flowering and this is the end of the vegetative development.
Field beans produce flowers over a longer period (one month, Sibma *et al.*, 1989). So it may occur that the first flower has a full grown pod and the latest flower just appears from the bud. Meanwhile the vegetative development continues, the plant grows and produces more leaves. Before the filling of the seeds reserves are already prepared. These features urged to use a different definition of the development stages (Table 7.1).

Table 7.1 Crop-specific development stages and according DVS code (Stokkers, 1990)

| Development stage | DVS code |
|---|---|
| emergence: | DVS = 0.01 |
| start flowering: | DVS = 0.60 |
| start pulse growth: | DVS = 0.80 |
| end flowering/start pulse filling: | DVS = 1.00 |
| harvest ripe: | DVS = 2.00 |

### 3.7.1 Parameterization and calibration

Like rice, field bean has no separate basis and calibrated crop-specific data file. The basis crop file was derived from data of Grashoff (1992). The crop-specific data file is given in Appendix G1.
For field beans one crop type is used, only the sowing date is adapted to regional differences within the European Community. The sowing dates per region are given in Appendix G3. The number of days between emergence and harvest (d, FINTIM) given in Appendix G3 may be considered as the ultimate harvest date but normally the crop should reach development stage 2 at which stage the simulation stops.

### 3.7.2 Field experiments

Outdoor pot experiment data from Kropff (1989) are used to calibrate original crop-specific data file. The experiment data are given in Appendix G2a.
Results of the calibrated WOFOST-model were compared with field experiments from Dantuma *et al.* (1983), Ebmeyer (1984) and Ebmeyer (1986), data of the experiments are given in Appendix G2b. But the fact that these experiments were not irrigated and no intermediate harvests were available, made them inconvenient to use as a test case for the WOFOST-model.
The results from WOFOST seemed reasonable using the initial crop-specific data file so the original WOFOST crop-specific data file is left unchanged.

### 3.7.3 Crop calendar and temperature sums

The crop calendar was derived from the field experiments of Dantuma *et al.* (1983), Ebmeyer (1984) and Ebmeyer (1986) and from Martínez (1988). For some places (*written in Italic*) the dates were estimated on basis of surrounding regions. The temperature sums were calculated by the Staring Centre.

# 3.8 Soybean

## 3.8.1 Parameterization

The initial crop-specific data file is based on the WOFOST soybean data file (van Diepen *et al.*, 1988). Temperature sum from emergence to anthesis (°Cd, TSUM1) was taken from van Heemst (1988).
The lower threshold for emergence (°C, TBASEM) and the temperature sum from sowing to emergence (°Cd, TSUMEM) was derived from Narciso (1992).
The reduction factor of AMAX (kg $ha^{-1}$ $hr^{-1}$, maximum leaf $CO_2$ assimilation rate) as function of average temperature (kg $ha^{-1}$ $hr^{-1}$, TMPFTB) was taken from Penning de Vries *et al.* (1989).
The initial crop-specific parameters are given in Appendix H1.

## 3.8.2 Field experiments

Two irrigated soybean field experiments from INRA in France were used to calibrate the crop file. They are given in Appendix H2a and b. WOFOST results were compared with data from Sivakumar *et al.* (1977) as well.

## 3.8.3 Crop calendar and temperature sums

Table 8.1 Sowing date and number of days between sowing day and harvest (cycle length) of 4 precocity classes of soybean in France for several regions. " * " means that irrigation is necessary (Arnaud & Prudon, 1986).

| Class | 00 (very early) | | 0 (early) | | I (mid late) | | II (late) | |
|---|---|---|---|---|---|---|---|---|
| Region | sowing date | length cycle | sowing date | length cycle | sowing date | length cycle | sowing date | length cycle |
| A | - | - | - | - | - | - | - | - |
| B | 118 | 150 | - | - | - | - | - | - |
| C | 123 | 130 | 118 | 150 | - | - | - | - |
| D | - | - | 115 | 130 | 110 | 150 | - | - |
| E | till 182 | 110* | - | - | 110 | 145 | 110 | 150 |
| F | till 187 | 100* | till 187 | 110* | till 187 | 110* | 125 | 150 |

Table 8.2 Connection of regions of table 8.1 to NUTS regions in France.

| region | NUTS region number |
|---|---|
| A | 21, 23, 221, 222, 223, 225, 24, 252, 263, S 272, N 281, NE 262 |
| B | 251, 224, 226, 243 |
| C | 253 |
| D | 261, S 262 |
| E | N 262, 281 |
| F | S coast of 281 and 282 |

The crop calendar is derived from data of Narciso (1992), L'Informatore Agrario (1989), Arnaud & Prudon (1986) and Ecochard (1986). The sowing dates and cycle length of very early, early, mid late and late soybean varieties in France and the NUTS regions are given (Table 8.1 and 8.2). The temperature sums from sowing to harvest are given per precocity class in France (Table 8.3).

Table 8.3 Temperature sums per precocity class from sowing to harvest of soybean in France with a temperature base of 6°C (Arnaud & Prudon, 1986).

| | class | 00 (very early) | 0 (early) | I (mid late) | II (late) |
|---|---|---|---|---|---|
| crop type | temperature sum °Cd | 1550-1700 °Cd | 1700-1800 °Cd | 1800-2000 °Cd | 2000-2200 °Cd |
| 0901 | 1300 | | | | |
| 0902 | 1400 | | | | |
| 0903 | 1300 | | | | |
| 0904 | | 1700 | 1700 | | |
| 0905 | | 1700 | 1700 | | |
| 0906 | | | | 1900 | |

In Appendix H3 the temperature sums from emergence to flowering (°Cd, TSUM1) and from flowering to harvest (°Cd, TSUM2) are given. The main soybean areas are in Southern France, Italy and Central en Southern Spain.

## 3.8.4 Calibration

The differences between the initial crop-specific data file and the calibrated file are given in Appendix H3. The following section explains where the new values originates from. The values for the maximum relative increase of the leaf area index (ha ha$^{-1}$ d$^{-1}$, RGRLAI), the extinction coefficient for diffuse visible light (-, KDIF), the maximum leaf $CO_2$ assimilation rate as function of the development stage (-; kg ha hr, AMAXTB), efficiencies of conversion of biomass into leaves, roots and stems (kg kg$^{-1}$, CVL, CVR, CVS) and the maintenance respiration rates of leaves, storage organ, roots and stems (kg $CH_2O$ kg$^{-1}$ d$^{-1}$, RML, RMO, RMR, RMS) are derived from van Heemst (1988). Efficiency of conversion of biomass into storage organ (kg kg$^{-1}$, CVO) is calculated with data from Penning de Vries (1989).
Dry matter partitioning is based on van Diepen *et al.* (1988) and Hanway (1976).

# 3.9 Winter oilseed rape

## 3.9.1 Parameterization

The crop data file of WOFOST version 5.0 for oilseed rape (van Diepen & de Koning, 1990) has served as starting point for the parameterization. Appendix I1 gives these initial crop-specific parameters of oilseed rape.

## 3.9.2 Field experiments

The oilseed rape crop-specific data file is calibrated with a rape seed field experiments from J.P. Palleau from 1984 to 1988. The data of Figure 9.1 are given in Table 9.1. Field data are given in Appendix I2.

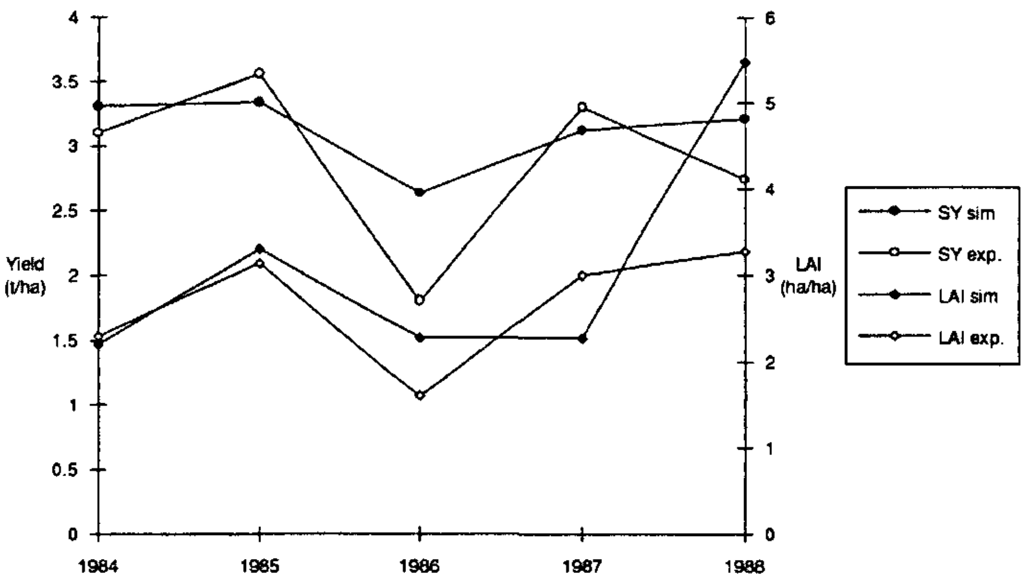


Figure 9.1 Simulated potential seed yield (SY sim) and field experiment data of oilseed rape dry matter seed yield (SY exp.) (t/ha) and leaf area index (LAI sim and LAI exp.) from 1984 to 1988 in Dijon (France).

Table 9.1 Measured and simulated dry matter seed yield and leaf area index at flowering of rape seed in Dijon 1984 - 1988.

| year | measured seed yield t/ha | simulated seed yield t/ha | measured LAI ha/ha | simulated LAI ha/ha |
|---|---|---|---|---|
| 1984 | 3.1 | 3.3 | 2.3 | 2.2 |
| 1985 | 3.6 | 3.3 | 3.1 | 3.3 |
| 1986 | 1.8 | 2.6 | 1.6 | 2.3 |
| 1987 | 3.3 | 3.1 | 3.0 | 2.3 |
| 1988 | 2.7 | 3.2 | 3.3 | 5.5 |

## 3.9.3 Crop calendar and temperature sums

A point of consideration is the dependence on daylength of oilseed rape. Not only the temperature provides the date of flowering but the daylength as well.
With the flowering and harvest dates of the crop calendar the parameters TSUM1 (number of °Cd from emergence to flowering), TSUM2 (number of °Cd from flowering to harvest), the SPAN (d, life span of leaves growing at 35 C°) and the DLO (hr, optimum daylength for development) of the crop-specific data file are calibrated. Values for these parameters changed per region so three crop types were defined, they are given in Appendix I3.
The crop calendar is derived from Falisse (1992), Hough (1990) and Narciso *et al.* (1992) and given in Appendix I4.

## 3.9.4 Calibration

In the calibrated crop-specific data file the parameter AMAXTB (-; kg ha hr, maximum leaf $CO_2$ assimilation rate as function of development stage) is based on van Heemst (1988) and the parameter RMO (kg $CH_2O$ $kg^{-1}$ $d^{-1}$, relative maintenance respiration rate of the storage organ) is based on Penning de Vries *et al.* (1989).

# 3.10 Sunflower

## 3.10.1 Parameterization

The initial crop-specific data file is the original sunflower file of WOFOST (van Diepen *et al.*, 1988).
Some parameters like maximum relative increase of the leaf area index (ha $ha^{-1}$ $d^{-1}$, RGRLAI) and leaf area index at emergence (ha $ha^{-1}$, LAIEM) are not given in the WOFOST file and derived from other sources. RGRLAI of grain maize is used and LAIEM is calculated from TDWI. TDWI (kg $ha^{-1}$, initial total crop dry weight), FRTB (-; kg $kg^{-1}$, fraction of total dry matter to roots as function of development stage), SLATB (-;ha $kg^{-1}$, specific leaf area as a function of development stage).
The lower threshold temperature for emergence (°C, TBASEM), the maximum effective temperature for emergence (°C, TEFFMX) and the temperature sum from sowing to emergence (°Cd, TSUMEM) are derived from van Heemst (1988).
The initial crop-specific data file is given in Appendix J1.

## 3.10.2 Field experiments

The data of the field experiments from INRA in France, that are used for calibration are given in Appendices J2a and b.

## 3.10.3 Crop calendar and temperature sums

The crop calendar is given in Appendix J4 and is derived from Narciso *et al.* (1992) and Eurostat (1989).

## 3.10.4 Calibration

With the flowering and harvest dates of the crop calendar the parameters TSUM1 (number of °Cd from emergence to flowering), TSUM2 (number of °Cd from flowering to harvest) and the SPAN (d, life span of leaves growing at 35 C°) of the crop-specific data file are calibrated. Because the values for these parameters didn't change per region only one sunflower crop type is defined. The difference per region originates from the sowing date. The sowing dates per region are given in Appendix I3.
The conversion efficiencies of assimilates into biomass and the maintenance respiration is based on the values of oilseed rape. The results with these parameters were better than with the original values. Oilseed rape was chosen because the oil content of the seeds is comparable.

# 4 Discussion and suggestions

The aim of this project was to investigate whether crop modelling is an appropriate method to calculate the crop yield as a function of weather, for the purpose of yield prediction. This is based on three assumptions:

- sufficient crop parameters could be obtained from literature. This proved to be correct for all crops, except tobacco, and cotton
- weather is the main cause of yield fluctuations for field crops. This is true for crops on fields in optimal conditions.
- good model

It is possible to get a acceptable fit for individual field experiments for a certain year. For a more accurate calculation more detailed knowledge of field experiments is necessary. It must be possible to get more information from experiment stations within the EG. After an inventarisation it may be necessary to do field experiments to fill in appearing gaps. For the modelling work there is a special need for:

- development of plant organs with time and temperature sums
- dry matter partitioning and absolute dry matter yields per plant organ against time, tem perature and development stage
- sowing, flowering or start of flowering, harvest dates at least (crop calendar)
- leaf area measurements

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# Appendix 1:
# Expressions

Parameter:
Variable (crop, soil) in the growth model WOFOST to which a single value is assigned, sometimes specific for a crop or soil type.
The parameters are given to the program in an input file.

Parameterization:
Valuation of parameters of the initial crop-specific data file. Values are found by use of literature, field experiments, expert knowledge and expertise. The result of parameterization is the initial crop-specific data file.

Calibration:
Adaptation of the initial crop-specific data file by altering parameters values, in such way that the simulation results of the model with the calibrated crop-specific data file fit to field experiments and crop calendar data by.
After calibration a new input file is composed with the calibrated values of the parameters (calibrated crop-specific data file).

Validation:
Comparison of the simulated yield with the real yields of field experiments or Eurostat yields. The yield is simulated with the calibrated crop-specific data file.

Aggregation:
Put together calculated yields for individual grids to larger geografic units (NUTS I or NUTS 0 level).

Temperature sum:
The summation of the daily average temperature (°C) above a base temperature over a defined period.

# Appendix 2:

## Calendar Julian day numbers

| Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 32 | 60 | 91 | 121 | 152 | 182 | 213 | 244 | 274 | 305 | 335 |
| 2 | 33 | 61 | 92 | 122 | 153 | 183 | 214 | 245 | 275 | 306 | 336 |
| 3 | 34 | 62 | 93 | 123 | 154 | 184 | 215 | 246 | 276 | 307 | 337 |
| 4 | 35 | 63 | 94 | 124 | 155 | 185 | 216 | 247 | 277 | 308 | 338 |
| 5 | 36 | 64 | 95 | 125 | 156 | 186 | 217 | 248 | 278 | 309 | 339 |
| 6 | 37 | 65 | 96 | 126 | 157 | 187 | 218 | 249 | 279 | 310 | 340 |
| 7 | 38 | 66 | 97 | 127 | 158 | 188 | 219 | 250 | 280 | 311 | 341 |
| 8 | 39 | 67 | 98 | 128 | 159 | 189 | 220 | 251 | 281 | 312 | 342 |
| 9 | 40 | 68 | 99 | 129 | 160 | 190 | 221 | 252 | 282 | 313 | 343 |
| 10 | 41 | 69 | 100 | 130 | 161 | 191 | 222 | 253 | 283 | 314 | 344 |
| 11 | 42 | 70 | 101 | 131 | 162 | 192 | 223 | 254 | 284 | 315 | 345 |
| 12 | 43 | 71 | 102 | 132 | 163 | 193 | 224 | 255 | 285 | 316 | 346 |
| 13 | 44 | 72 | 103 | 133 | 164 | 194 | 225 | 256 | 286 | 317 | 347 |
| 14 | 45 | 73 | 104 | 134 | 165 | 195 | 226 | 257 | 287 | 318 | 348 |
| 15 | 46 | 74 | 105 | 135 | 166 | 196 | 227 | 258 | 288 | 319 | 349 |
| 16 | 47 | 75 | 106 | 136 | 167 | 197 | 228 | 259 | 289 | 320 | 350 |
| 17 | 48 | 76 | 107 | 137 | 168 | 198 | 229 | 260 | 290 | 321 | 351 |
| 18 | 49 | 77 | 108 | 138 | 169 | 199 | 230 | 261 | 291 | 322 | 352 |
| 19 | 50 | 78 | 109 | 139 | 170 | 200 | 231 | 262 | 292 | 323 | 353 |
| 20 | 51 | 79 | 110 | 140 | 171 | 201 | 232 | 263 | 293 | 324 | 354 |
| 21 | 52 | 80 | 111 | 141 | 172 | 202 | 233 | 264 | 294 | 325 | 355 |
| 22 | 53 | 81 | 112 | 142 | 173 | 203 | 234 | 265 | 295 | 326 | 356 |
| 23 | 54 | 82 | 113 | 143 | 174 | 204 | 235 | 266 | 296 | 327 | 357 |
| 24 | 55 | 83 | 114 | 144 | 175 | 205 | 236 | 267 | 297 | 328 | 358 |
| 25 | 56 | 84 | 115 | 145 | 176 | 206 | 237 | 268 | 298 | 329 | 359 |
| 26 | 57 | 85 | 116 | 146 | 177 | 207 | 238 | 269 | 299 | 330 | 360 |
| 27 | 58 | 86 | 117 | 147 | 178 | 208 | 239 | 270 | 300 | 331 | 361 |
| 28 | 59 | 87 | 118 | 148 | 179 | 209 | 240 | 271 | 301 | 332 | 362 |
| 29 | | 88 | 119 | 149 | 180 | 210 | 241 | 272 | 302 | 333 | 363 |
| 30 | | 89 | 120 | 150 | 181 | 211 | 242 | 273 | 303 | 334 | 364 |
| 31 | | 90 | | 151 | | 212 | 243 | | 304 | | 365 |

# Appendix A:

## Winter wheat (*Triticum aestivum* L.)

# Appendix A1:
# Initial crop-specific data file of winter wheat

CROP DATA FILE for use with WOFOST Version 5.0, January 1990

```
crop identity
!CRPNAM    = SWW WHEAT, WINTER Su. (WWH.NEW),  winter wheat  (Triticum aestivum L.)
ICROP      =  1

** emergence
TBASEM     =  -10.0                  ! lower threshold temp. for emergence [C°]
TEFFMX     =  30.0                   ! max. eff. temp. for emergence [C°]
TSUMEM     =  0.                     ! temperature sum from sowing to emergence [C° d]

** phenology
IDSL       =  0                      ! indicates whether pre-anthesis development depends
                                     ! on temp. (=0), daylength (=1) , or both (=2)
DLO        =  -99.0                  ! optimum daylength for development [hr]
DLC        =  -99.0                  ! critical daylength (lower threshold) [hr]
TSUM1      =  1255.                  ! temperature sum from emergence to anthesis [C° d]
TSUM2      =   909.                  ! temperature sum from anthesis to maturity [C° d]
DTSMTB     =   0.00,      0.00,      ! daily increase in temp. sum
              30.00,     30.00,      ! as function of av. temp. [C°; C° d]
              45.00,     30.00
DVSEND     =   2.00                  ! development stage at harvest (= 2.0 at maturity [-])

** initial
TDW        =  210.00                 ! initial total crop dry weight [kg ha-1]
LAIEM      =  0.1370                 ! leaf area index at emergence [ha ha-1]
RGRLAI     =  0.0070                 ! maximum relative increase in LAI [ha ha-1 d-1]

** green area
SLATB      =  0.00,     0.0020,      ! specific leaf area
                        2.00,        0.0020,      ! as a function of DVS [-; ha kg-1]
SPA        =  0.000                  ! specific pod area [ha kg-1]
SSA        =  0.000                  ! specific stem area [ha kg-1]
SPAN       =  35.                    ! life span of leaves growing at 35 C° [d]
TBASE      =  0.0                    ! lower threshold temp. for ageing of leaves [C°]

** assimilation
KDIF       =  0.600                  ! extinction coefficient for diffuse visible light [-]
EFF        =  0.45                   ! light-use effic. single leaf [kg ha-1 hr-1 J-1 m2 s]
```

```
AMAXTB   =  0.00,    40.00,    ! maximum leaf CO2 assimilation rate
            1.00,    40.00,    ! as function of DVS [-; kg ha-1 hr-1]
            2.00,    20.00
TMPFTB   =  0.00,    0.01,     ! reduction factor of AMAX
            10.00,   0.60,     ! as function of av. temp. [C°; -]
            15.00,   1.00,
            25.00,   1.00,
            35.00,   0.00
TMNFTB   =  0.00,    0.00,     ! red. factor of gross assim. rate
            3.00,    1.00      ! as function of low min. temp. [C°; -]

** conversion of assimilates into biomass
CVL      =  0.685              ! efficiency of conversion into leaves [kg kg-1]
CVO      =  0.709              ! efficiency of conversion into storage org. [kg kg-1]
CVR      =  0.694              ! efficiency of conversion into roots [kg kg-1]
CVS      =  0.662              ! efficiency of conversion into stems [kg kg-1]

** maintenance respiration
Q10      =  2.0                ! rel. incr. in resp. rate per 10 C°temp. incr. [-]
RML      =  0.0300             ! rel. maint. resp. rate leaves [kg CH2O kg-1 d-1]
RMO      =  0.0100             ! rel. maint. resp. rate stor.org. [kg CH2O kg-1 d-1]
RMR      =  0.0150             ! rel. maint. resp. rate roots [kg CH2O kg-1 d-1]
RMS      =  0.0150             ! rel. maint. resp. rate stems [kg CH2O kg-1 d-1]
RFSETB   =  0.00,    1.00,     ! red. factor for senescence
            2.00,    1.00      ! as function of DVS [-; -]

** partitioning
FRTB     =  0.00,    0.50,     ! fraction of total dry matter to roots
            0.10,    0.50,     ! as a function of DVS [-; kg kg-1]
            0.20,    0.40,
            0.35,    0.22,
            0.40,    0.17,
            0.50,    0.13,
            0.70,    0.07,
            0.90,    0.03,
            1.20,    0.00,
            2.00,    0.00
FLTB     =  0.00,    0.65,
            0.10,    0.65,
            0.25,    0.70,
            0.50,    0.50,
            0.70,    0.15,
            0.95,    0.00,
            2.00,    0.00
```

```
FSTB      =  0.00,    0.35,
             0.10,    0.35,
             0.25,    0.30,
             0.50,    0.50,
             0.70,    0.85,
             0.95,    1.00,
             1.05,    0.00,
             2.00,    0.00
FOTB      =  0.00,    0.00,     ! fraction of above-gr. DM to stor. org.
             0.95,    0.00,     ! as a function of DVS [-; kg kg-1]
             1.05,    1.00,
             2.00,    1.00

** death rates
PERDL     =  0.030              ! max. rel. death rate of leaves due to water stress
RDRRTB    =  0.00,    0.000,    ! rel. death rate of stems
             1.50,    0.000,    ! as a function of DVS [-; kg kg-1 d-1]
             1.5001,  0.020,
             2.00,    0.020
RDRSTB    =  0.00,    0.000,    ! rel. death rate of roots
             1.50,    0.000,    ! as a function of DVS [-; kg kg-1 d-1]
             1.5001,  0.020,
             2.00,    0.020

** water use
CFET      =  1.00               ! correction factor transpiration rate [-]
DEPNR     =  4.5                ! crop group number for soil water depletion [-]
IAIRDU    =  0                  ! air ducts in roots present (=1) or not (=0)

** rooting
RDI       =  10.                ! initial rooting depth [cm]
RRI       =  1.2                ! maximum daily increase in rooting depth [cm d-1]
RDMCR     =  125.               ! maximum rooting depth [cm]

** nutrients
** maximum and minimum concentrations of N, P, and K in storage organsin vegetative organs
   [kg kg-1]
NMINSO    =  0.0110 ;  NMINVE  =  0.0030
NMAXSO    =  0.0310 ;  NMAXVE  =  0.0105
PMINSO    =  0.0016 ;  PMINVE  =  0.0004
PMAXSO    =  0.0060 ;  PMAXVE  =  0.0020
KMINSO    =  0.0030 ;  KMINVE  =  0.0070
KMAXSO    =  0.0080 ;  KMAXVE  =  0.0280
YZERO     =  200.               ! max. amount veg. organs at zero yield [kg ha-1]
NFIX      =  0.00               ! fraction of N-uptake from biol. fixation [kg kg-1]
```

# Appendix A2:

## Field experiment data of winter wheat

Appendix A2a. Winter wheat in Rothamsted, United Kingdom, 1980.

Early sown (20 September, 1979)
Weather station used for calibration: Brize Norton.
J. day nr. = Julian day number
-1 means no data available

Table A2a. Dry matter of storage organ, total dry matter accumulation and leaf area index of a winter wheat field experiment, Rothamsted, United Kingdom, 1980.

| J. day nr. | storage org. kg/ha | tot dry matter kg/ha | LAI ha/ha |
|---|---|---|---|
| 62 | -1 | 1500 | 1.9 |
| 104 | -1 | 3000 | 4.0 |
| 126 | -1 | 5000 | 6.5 |
| 162 | -1 | 11500 | 7.8 |
| 219 | -1 | 18800 | 1.0 |
| 230 | 8370 | 18000 | -1 |

Prew, R.D., Church, B.M., Dewar, A.M., Lacey, J., Magan, N., Penny, A., Plumb, R.T., Thorne, G.N., Todd, A.D., Williams, T.D., 1985.
Some factors limiting the growth and yield of winter wheat and their variation in two seasons.
Journal of Agricultural Science, Cambridge, 104, 135-162.

Appendix A2b. Winter wheat in Rothamsted, United Kingdom, 1981.

Early sown (15 September 1980)
Weather station used for calibration: Brize Norton.
J. day nr. = Julian day number
-1 means no data available

Table A2b. Dry matter of storage organ, total dry matter accumulation and leaf area index of a winter wheat field experiment, Rothamsted, United Kingdom, 1981.

| J. day nr. | storage org. kg/ha | tot dry matter kg/ha | LAI ha/ha |
|---|---|---|---|
| 75 | -1 | 1750 | 2.0 |
| 112 | -1 | 4500 | 5.0 |
| 126 | -1 | 4750 | 6.2 |
| 166 | -1 | 11750 | 8.5 |
| 219 | -1 | 18000 | 1.5 |
| 226 | 8230 | 20000 | -1 |

Prew, R.D., Church, B.M., Dewar, A.M., Lacey, J., Magan, N., Penny, A., Plumb, R.T., Thorne, G.N., Todd, A.D., Williams, T.D., 1985.
Some factors limiting the growth and yiled of winter wheat and their variation in two seasons.
Journal of Agricultural Science, Cambridge, 104, 135-162.

Appendix A2c. Field trial data of winter wheat, experiment station De Bouwing, Randwijk, the Netherlands, sown in 1982 and harvested in 1983.

Treatment N2
J. day nr. = Julian day number
LAI stem is dry matter stem * 0.0002 (pers.comm. H.van Keulen, mrt.1992)

Table A2c1. Intermediate harvest data of dry matter (DM) of green leaves, dead leaves, stem and sheat, chaff, grains and total dry matter during the growing season.

| date | J. day nr. | DM green leaf kg/ha | DM dead leaf kg/ha | DM stem + sheat kg/ha | DM chaff kg/ha | DM grains kg/ha | total dry matter kg/ha |
|---|---|---|---|---|---|---|---|
| 7/2/83 | 38 | 54.6 | | 9.7 | | | 64 |
| 28/2/83 | 59 | 56.5 | | 15.0 | | | 72 |
| 28/3/83 | 87 | 105.6 | | 26.1 | | | 132 |
| 18/4/83 | 108 | 369.1 | | 83.3 | | | 452 |
| 9/5/83 | 129 | 945.0 | 0.0 | 916.3 | | | 1861 |
| 24/5/83 | 144 | 1636.4 | 2.3 | 2395.0 | 0.0 | 0.0 | 4034 |
| 13/6/83 | 164 | 1826.8 | 155.5 | 5178.0 | 1314.7 | 0.0 | 8475 |
| 4/7/83 | 185 | 1513.7 | 637.4 | 7178.6 | 2173.8 | 2375.3 | 13879 |
| 18/7/83 | 199 | 343.3 | 1348.2 | 5498.1 | 2006.5 | 6798.7 | 15995 |
| 1/8/83 | 213 | 0.0 | 1730.9 | 5739.4 | 2112.7 | 8102.5 | 17686 |

Table A2c2. Intermediate harvest data of leaf area index (LAI) of green leaves, stem and sheats, and stem and leaves during the growing season.

| date | J. day nr. | LAI green leaf ha/ha | LAI stem + sheats ha/ha | LAI stem + leaf ha/ha |
|---|---|---|---|---|
| 7/2/83 | 38 | 0.12 | 0.002 | 0.12 |
| 28/2/83 | 59 | 0.12 | 0.003 | 0.12 |
| 28/3/83 | 87 | 0.25 | 0.005 | 0.26 |
| 18/4/83 | 108 | 0.81 | 0.017 | 0.83 |
| 9/5/83 | 129 | 2.20 | 0.183 | 2.38 |
| 24/5/83 | 144 | 3.83 | 0.479 | 4.31 |
| 13/6/83 | 164 | 4.22 | 1.036 | 5.26 |
| 4/7/83 | 185 | 3.26 | 1.436 | 4.70 |
| 18/7/83 | 199 | 0.48 | 1.100 | 1.58 |
| 1/8/83 | 213 | 0.00 | 1.148 | 1.15 |

Table A2c3. Intermediate harvest data of specific leaf area (SLA) of green leaves, stem and sheats, and stem and leaves during the growing season.

| date | J. day nr. | SLA gr. leaf ha/kg | SLA stem+ sheats ha/kg | SLA st + leaf ha/kg |
|---|---|---|---|---|
| 7/2/83 | 38 | 0.0022 | 0.0002 | |
| 28/2/83 | 59 | 0.0021 | 0.0002 | |
| 28/3/83 | 87 | 0.0024 | 0.0002 | |
| 18/4/83 | 108 | 0.0022 | 0.0002 | |
| 9/5/83 | 129 | 0.0023 | 0.0002 | |
| 24/5/83 | 144 | 0.0023 | 0.0002 | |
| 13/6/83 | 164 | 0.0023 | 0.0002 | 0.0040 |
| 4/7/83 | 185 | 0.0022 | 0.0002 | 0.0022 |
| 18/7/83 | 199 | 0.0014 | 0.0002 | 0.0008 |
| 1/8/83 | 213 | | 0.0002 | 0.0005 |

J.J.R. Groot, 1987.
Simulation of nitrogen balance in a system of winter wheat and soil
Simulation report CABO-TT, 13, 69p.

Appendix A2d. Field trial data of winter wheat, experiment station De Bouwing, Randwijk, the Netherlands, sown in 1983 and harvested in 1984.

Treatment N3
J. day nr. = Julian day number
LAI stem is dry matter stem * 0.0002 (pers.comm. H.van Keulen, mrt.1992)

Table A2d1. Intermediate harvest data of dry matter (DM) of green leaves, dead leaves, stem and sheat, chaff, grains and total dry matter during the growing season.

| date | J. day nr. | DM green leaf kg/ha | DM dead leaf kg/ha | DM stem + sheat kg/ha | DM chaff kg/ha | DM grains kg/ha | total dry matter kg/ha |
|---|---|---|---|---|---|---|---|
| 13/2/84 | 44.0 | 33.0 | | 0.0 | | | 33 |
| 12/3/84 | 71.0 | 43.7 | | 0.0 | | | 44 |
| 2/4/84 | 92.0 | 82.3 | | 3.6 | | | 86 |
| 24/4/84 | 114.0 | 367.0 | | 109.8 | | | 477 |
| 7/5/84 | 127.0 | 945.0 | 31.6 | 566.2 | | | 1543 |
| 28/5/84 | 148.0 | 1371.8 | 6.5 | 2249.3 | 0.0 | 0.0 | 3628 |
| 18/6/84 | 169.0 | 1677.1 | 29.1 | 4662.1 | 1074.3 | 0.0 | 7443 |
| 2/7/84 | 183.0 | 1636.5 | 219.0 | 6403.8 | 1595.6 | 437.2 | 10292 |
| 16/7/84 | 197.0 | 1274.5 | 404.4 | 6321.6 | 1863.2 | 2381.2 | 12245 |
| 6/8/84 | 218.0 | 741.1 | 693.4 | 5120.6 | 1869.8 | 6294.6 | 14720 |
| 21/8/84 | 233.0 | 0.0 | 1379.5 | 5643.5 | 1920.2 | 8168.2 | 17111 |

Table A2d2. Intermediate harvest data of leaf area index (LAI) of green leaves, stem and sheats, and stem and leaves during the growing season.

| date | Jul. days | LAI green leaf ha/ha | LAI stem + sheats ha/ha | LAI stem + leaf ha/ha |
|---|---|---|---|---|
| 13/2/84 | 44 | 0.06 | 0.000 | 0.06 |
| 12/3/84 | 71 | 0.08 | 0.000 | 0.08 |
| 2/4/84 | 92 | 0.14 | 0.001 | 0.14 |
| 24/4/84 | 114 | 0.80 | 0.022 | 0.82 |
| 7/5/84 | 127 | 2.19 | 0.113 | 2.30 |
| 28/5/84 | 148 | 3.54 | 0.450 | 3.99 |
| 18/6/84 | 169 | 3.96 | 0.932 | 4.89 |
| 2/7/84 | 183 | 3.24 | 1.281 | 4.52 |
| 16/7/84 | 197 | 2.96 | 1.264 | 4.22 |
| 6/8/84 | 218 | 1.72 | 1.024 | 2.74 |
| 21/8/84 | 233 | 0.00 | 1.129 | 1.13 |

Table A2d3. Intermediate harvest data of specific leaf area (SLA) of green leaves, stem and sheats, and stem and leaves during the growing season.

| date | J. day nr. | SLA gr. leaf ha/kg | SLA stem+ sheats ha/kg | SLA st + leaf ha/kg |
|---|---|---|---|---|
| 13/2/84 | 44 | 0.0018 | | |
| 12/3/84 | 71 | 0.0018 | | |
| 2/4/84 | 92 | 0.0017 | 0.0002 | |
| 24/4/84 | 114 | 0.0022 | 0.0002 | |
| 7/5/84 | 127 | 0.0023 | 0.0002 | |
| 28/5/84 | 148 | 0.0026 | 0.0002 | |
| 18/6/84 | 169 | 0.0024 | 0.0002 | 0.0046 |
| 2/7/84 | 183 | 0.0020 | 0.0002 | 0.0028 |
| 16/7/84 | 197 | 0.0023 | 0.0002 | 0.0023 |
| 6/8/84 | 218 | 0.0023 | 0.0002 | 0.0015 |
| 21/8/84 | 233 | | 0.0002 | 0.0006 |

J.J.R. Groot, 1987.
Simulation of nitrogen balance in a system of winter wheat and soil.
Simulation report CABO-TT, 13, 69 p.

Appendix A2e. Field trial data of winter wheat, experiment station of PAGV, Lelystad, the Netherlands, sown in 1982 and harvested in 1983.

Treatment N3
J. day nr. = Julian day number
LAI stem is dry matter stem * 0.0002 (pers.comm. H.van Keulen, mrt.1992)

Table A2e1. Intermediate harvest data of dry matter (DM) of green leaves, dead leaves, stem and sheat, chaff, grains and total dry matter during the growing season.

| date | J. day nr. | DM green leaf kg/ha | DM dead leaf kg/ha | DM stem + sheat kg/ha | DM chaff kg/ha | DM grains kg/ha | total dry matter kg/ha |
|---|---|---|---|---|---|---|---|
| 8/2/83 | 39 | 83.0 | | 18.0 | | | |
| 1/3/83 | 60 | 81.0 | | 18.0 | | | 99 |
| 29/3/83 | 88 | 212.0 | | 60.0 | | | 272 |
| 19/4/83 | 109 | 603.0 | | 138.0 | | | 741 |
| 10/5/83 | 130 | 1062.0 | 50.8 | 1377.7 | | | 2491 |
| 24/5/83 | 144 | 1959.2 | 73.8 | 2713.3 | | | 4746 |
| 14/6/83 | 165 | 2468.0 | 176.2 | 6622.5 | | | 9267 |
| 5/7/83 | 186 | 1721.4 | 559.9 | 8066.1 | 2434.6 | 2397.9 | 15180 |
| 19/7/83 | 200 | 735.3 | 1054.6 | 5967.8 | 2139.8 | 6944.4 | 16842 |
| 2/8/83 | 214 | 0.0 | 1592.5 | 5761.2 | 2142.9 | 8279.2 | 17776 |

Table A2e2. Intermediate harvest data of leaf area index (LAI) of green leaves, stem and sheats, and stem and leaves during the growing season.

| date | LAI J. day nr. | LAI green leaf ha/ha | LAI stem + sheats ha/ha | LAI stem + leaf ha/ha |
|---|---|---|---|---|
| 8/2/83 | 39 | 0.18 | 0.004 | 0.18 |
| 1/3/83 | 60 | 0.17 | 0.004 | 0.17 |
| 29/3/83 | 88 | 0.48 | 0.012 | 0.49 |
| 19/4/83 | 109 | 1.24 | 0.028 | 1.27 |
| 10/5/83 | 130 | 2.24 | 0.276 | 2.52 |
| 24/5/83 | 144 | 4.30 | 0.543 | 4.84 |
| 14/6/83 | 165 | 5.47 | 1.325 | 6.79 |
| 5/7/83 | 186 | 3.45 | 1.613 | 5.06 |
| 19/7/83 | 200 | 1.25 | 1.194 | 2.44 |
| 2/8/83 | 214 | 0.00 | 1.152 | 1.15 |

Table A2e3. Intermediate harvest data of specific leaf area (SLA) of green leaves, stem and sheats, and stem and leaves during the growing season.

| date | SLA J. day nr. | SLA gr. leaf ha/kg | SLA stem+ sheats ha/kg | SLA st + leaf ha/kg |
|---|---|---|---|---|
| 8/2/83 | 39 | 0.0022 | | |
| 1/3/83 | 60 | 0.0021 | | |
| 29/3/83 | 88 | 0.0023 | 0.0002 | |
| 19/4/83 | 109 | 0.0021 | 0.0002 | |
| 10/5/83 | 130 | 0.0021 | 0.0002 | |
| 24/5/83 | 144 | 0.0022 | 0.0002 | |
| 14/6/83 | 165 | 0.0022 | 0.0002 | |
| 5/7/83 | 186 | 0.0020 | 0.0002 | 0.0021 |
| 19/7/83 | 200 | 0.0017 | 0.0002 | 0.0011 |
| 2/8/83 | 214 | | 0.0002 | 0.0005 |

J.J.R. Groot, 1987.
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Simulation report CABO-TT,13, 69 p.

Appendix A2f. Field trial data of winter wheat, experiment station of PAGV, Lelystad, the Netherlands, sown in 1983 and harvested in 1984.

Treatment N2
J. day nr. = Julian day number
LAI stem is dry matter stem * 0.0002 (pers.comm. H.van Keulen, mrt.1992)

Table A2f1. Intermediate harvest data of dry matter (DM) of green leaves, dead leaves, stem and sheat, chaff, grains and total dry matter during the growing season.

| date | J. day nr. | DM green leaf kg/ha | DM dead leaf kg/ha | DM stem + sheat kg/ha | DM chaff kg/ha | DM grains kg/ha | total dry matter kg/ha |
|---|---|---|---|---|---|---|---|
| 14/2/84 | 45 | | | | | | 0 |
| 13/3/84 | 72 | | | | | | 0 |
| 3/4/84 | 93 | 126.0 | | 38.0 | | | 164 |
| 24/4/84 | 114 | 625.0 | | 226.0 | | | 851 |
| 8/5/84 | 128 | 1432.0 | | 1065.0 | | | 2497 |
| 28/5/84 | 148 | 1756.4 | 9.5 | 3092.8 | | | 4859 |
| 19/6/84 | 170 | 1701.1 | 140.9 | 6144.2 | 1156.3 | | 9143 |
| 3/7/84 | 184 | 1602.8 | 374.1 | 8220.0 | 1631.1 | 420.9 | 12249 |
| 17/7/84 | 198 | 1304.4 | 536.5 | 8093.5 | 1910.9 | 2628.2 | 14474 |
| 8/8/84 | 220 | 652.1 | 843.3 | 6820.2 | 2101.8 | 8140.5 | 18558 |
| 20/8/84 | 232 | 0.0 | 7288.0 | | 1842.4 | 8028.3 | 17159 |

Table A2f2. Intermediate harvest data of leaf area index (LAI) of green leaves, stem and sheats, and stem and leaves during the growing season.

| date | J. day nr. | LAI green leaf ha/ha | LAI stem + sheats ha/ha | LAI stem + leaf ha/ha |
|---|---|---|---|---|
| 14/2/84 | 45 | 0.10 | | |
| 13/3/84 | 72 | 0.14 | | |
| 3/4/84 | 93 | 0.25 | 0.008 | |
| 24/4/84 | 114 | 0.35 | 0.045 | |
| 8/5/84 | 128 | 0.48 | 0.213 | |
| 28/5/84 | 148 | 4.05 | 0.619 | 4.67 |
| 19/6/84 | 170 | 3.60 | 1.229 | 4.83 |
| 3/7/84 | 184 | 2.94 | 1.644 | 4.58 |
| 17/7/84 | 198 | 2.70 | 1.619 | 4.32 |
| 8/8/84 | 220 | 1.00 | 1.364 | 2.36 |
| 20/8/84 | 232 | 0.00 | 0.000 | 0.00 |

Table A2f3. Intermediate harvest data of specific leaf area (SLA) of green leaves, stem and sheats, and stem and leaves during the growing season.

| date | J. day nr. | SLA gr. leaf ha/kg | SLA stem+ sheats ha/kg | SLA st + leaf ha/kg |
|---|---|---|---|---|
| 14/2/84 | 45 | | | |
| 13/3/84 | 72 | | | |
| 3/4/84 | 93 | 0.0020 | 0.0002 | |
| 24/4/84 | 114 | 0.0006 | 0.0002 | |
| 8/5/84 | 128 | 0.0003 | 0.0002 | |
| 28/5/84 | 148 | 0.0023 | 0.0002 | |
| 19/6/84 | 170 | 0.0021 | 0.0002 | |
| 3/7/84 | 184 | 0.0018 | 0.0002 | 0.0028 |
| 17/7/84 | 198 | 0.0021 | 0.0002 | 0.0023 |
| 8/8/84 | 220 | 0.0015 | 0.0002 | 0.0011 |
| 20/8/84 | 232 | | | 0.0000 |

J.J.R. Groot, 1987.
Simulation of nitrogen balance in a system of winter wheat and soil.
Simulation report CABO-TT 13, 69 P.

Appendix A2g. Field trial data of winter wheat of experiment station of De Eest; CABO 432, the Netherlands, sown in 1979 and harvested in 1980.

variety Arminda
Field E= 80 kg N early en 80 kg N late
J. day nr. = Julian day number

Table A2g1. Intermediate harvest data of dry matter (DM) of green leaves, ear and total dry matter during the growing season.

| harvest nr. | date | DM J. day nr. | DM green leaf kg/ha | DM stem kg/ha | DM ear kg/ha | total dry matter kg/ha |
|---|---|---|---|---|---|---|
| 1 | 22/4/80 | 112 | | | | 836.6 |
| 2 | 6/5/80 | 126 | 913.1 | 472.2 | | 1385.3 |
| 3 | 19/5/80 | 139 | 1548.3 | 1619.7 | | 3168.0 |
| 4 | 3/6/80 | 154 | 1896.1 | 4148.5 | 734.1 | 6778.6 |
| 5 | 10/6/80 | 161 | 2001.0 | 5549.7 | 1572.7 | 9123.4 |
| 6 | 17/6/80 | 168 | 1991.7 | 6181.2 | 1853.9 | 10026.8 |
| 7 | 23/6/80 | 174 | 2043.3 | 7439.2 | 2740.9 | 12223.4 |
| 8 | 30/6/80 | 181 | 1701.3 | 7121.8 | 3542.6 | 12365.7 |
| 9 | 7/7/80 | 188 | 1460.7 | 6035.4 | 4341.1 | 11837.2 |
| 10 | 14/7/80 | 195 | 1652.4 | 6668.4 | 6595.6 | 14916.4 |
| 11 | 21/7/80 | 202 | 1375.5 | 5873.3 | 7928.2 | 15177.0 |
| 12 | 28/7/80 | 209 | 1500.9 | 5468.4 | 8216.2 | 15185.5 |
| 13 | 4/8/80 | 216 | 1337.5 | 6253.2 | 10165.4 | 17756.0 |
| 14 | 18/8/80 | 230 | | | 69270.0 | |

Table A2g2. Intermediate harvest data of leaf area index (LAI) of green leaves, stem and leaves, ears and total leaf area index during the growing season.

| harvest nr. | date | J. day nr. | LAI green leaf ha/ha | LAI stem ha/ha | LAI stem + leaf ha/ha | LAI ear ha/ha | total LAI ha/ha |
|---|---|---|---|---|---|---|---|
| 1 | 22/4/80 | 112 | 1.04 | 0.00 | 1.04 | | |
| 2 | 6/5/80 | 126 | 1.66 | 0.09 | 1.76 | | |
| 3 | 19/5/80 | 139 | 2.87 | 0.32 | 3.20 | | 3.47 |
| 4 | 3/6/80 | 154 | 3.87 | 0.83 | 4.70 | | |
| 5 | 10/6/80 | 161 | 4.43 | 1.11 | 5.54 | | |
| 6 | 17/6/80 | 168 | 3.99 | 1.24 | 5.23 | 0.59 | 7.38 |
| 7 | 23/6/80 | 174 | 3.86 | 1.49 | 5.35 | 0.65 | 7.43 |
| 8 | 30/6/80 | 181 | 3.34 | 1.42 | 4.76 | 0.89 | 7.46 |
| 9 | 7/7/80 | 188 | 2.59 | 1.21 | 3.80 | 0.63 | 5.60 |
| 10 | 14/7/80 | 195 | 2.62 | 1.33 | 3.95 | 0.76 | 6.14 |
| 11 | 21/7/80 | 202 | 2.29 | 1.17 | 3.47 | 0.85 | 6.06 |
| 12 | 28/7/80 | 209 | 1.41 | 1.09 | 2.51 | 0.71 | 4.55 |
| 13 | 4/8/80 | 216 | 1.03 | 1.25 | 2.28 | 0.76 | 4.91 |
| 14 | 18/8/80 | 230 | | | | | |

Table A2g3. Intermediate harvest data of specific leaf area (SLA) of green leaves, stem, ear and total specific leaf area during the growing season.

| harvest nr. | date | J. day nr. | SLA leaf ha/kg | SLA stem ha/kg | SLA ear ha/kg | total SLA ha/kg |
|---|---|---|---|---|---|---|
| 1 | 22/4/80 | 112 | | | | |
| 2 | 6/5/80 | 126 | 0.0018 | | | |
| 3 | 19/5/80 | 139 | 0.0019 | 0.0002 | | 0.0011 |
| 4 | 3/6/80 | 154 | 0.0020 | | | |
| 5 | 10/6/80 | 161 | 0.0022 | | | |
| 6 | 17/6/80 | 168 | 0.0020 | 0.0002 | 0.00032 | 0.00074 |
| 7 | 23/6/80 | 174 | 0.0019 | 0.0002 | 0.00024 | 0.00061 |
| 8 | 30/6/80 | 181 | 0.0020 | 0.0002 | 0.00025 | 0.00060 |
| 9 | 7/7/80 | 188 | 0.0018 | 0.0002 | 0.00014 | 0.00047 |
| 10 | 14/7/80 | 195 | 0.0016 | 0.0002 | 0.00011 | 0.00041 |
| 11 | 21/7/80 | 202 | 0.0017 | 0.0002 | 0.00011 | 0.00040 |
| 12 | 28/7/80 | 209 | 0.0009 | 0.0002 | 0.00009 | 0.00030 |
| 13 | 4/8/80 | 216 | 0.0008 | 0.0002 | 0.00007 | 0.00028 |
| 14 | 18/8/80 | 230 | | | | |

Appendix A2h. Field trial data of winter wheat of experiment station at Helecine, Belgium, sown in 1984 and harvested in 1985.

Treatment 6
Cultivar Corin
J. day nr. = Julian day number
B.D.B. = Bodemkundige dienst van België
L.B.W.B. = Laboratorium voor Bodem- en Waterbeheersing
L.B.B. = Laboratorium voor Bodemvruchtbaarheid en Bodembiologie
sowing date 10-11-84
harvest date 12-08-85 harvest: 7743 kg/ha dm; 9218 kg/ha with 16% moisture (L.B.W.B.)
No base fertilization harvest: 7203.67 kg/ha (B.D.B.)

Nitrogen fertilazation

N fertilization and partitioning. N was given as NH4NO3 (26%) (Source B.D.B.)

| date | 19/3/83 | 18/4/83 | 5/6/83 | totaal |
|---|---|---|---|---|
| kg/ha | 60 | 70 | 45 | 175 |

7/6/85 start flowering
13/6/85 flowering
19/6/85 end flowering

Table A2h1. Dry matter production of stems, green and dead leaves, ears and total above-ground plant parts during the growing season (Source L.B.B.).

| date | J. day nr. | tot. dm kg/ha | dm stem kg/ha | dm leaf kg/ha | dm dead kg/ha | dm ear kg/ha | dm stem+leaf kg/ha |
|---|---|---|---|---|---|---|---|
| 25/3/85 | 84 | 165.7 | 57.8 | 107.8 | 0.0 | 0.0 | 165.7 |
| 15/4/85 | 105 | 496.3 | 169.1 | 327.3 | 0.0 | 0.0 | 496.3 |
| 29/4/85 | 119 | 1302.3 | 464.0 | 838.4 | 56.1 | 0.0 | 1302.3 |
| 13/5/85 | 133 | 2834.0 | 1247.0 | 1587.0 | 139.4 | 0.0 | 2834.0 |
| 29/5/85 | 149 | 6893.0 | 4258.5 | 2634.5 | 200.7 | 0.0 | 6893.0 |
| 10/6/85 | 161 | 10723.0 | 6541.2 | 2573.3 | 0.0 | 1574.4 | 9114.6 |
| 24/6/85 | 175 | 11718.7 | 7109.5 | 2306.3 | 823.8 | 2302.9 | 9415.8 |
| 8/7/85 | 189 | 16417.7 | 8596.4 | 2488.5 | 1462.7 | 5132.8 | 11084.9 |
| 22/7/85 | 203 | 18132.0 | 7071.5 | 1875.9 | 1869.2 | 9303.2 | 8947.4 |
| 5/8/85 | 217 | 16539.3 | 5903.5 | 1488.5 | 7392.0 | 9147.3 | 7392.0 |

Table A2h2. Intermediate harvest data of leaf area index of green leaves, stems and stems and leaves during the growing season.

| date | J. day nr. | LAI leaf ha/ha | LAI stem ha/ha | LAI stem + leaf ha/ha |
|---|---|---|---|---|
| 25/3/85 | 84 | 0.18 | 0.01 | 0.19 |
| 15/4/85 | 105 | 0.93 | 0.03 | 0.96 |
| 29/4/85 | 119 | 2.17 | 0.09 | 2.27 |
| 13/5/85 | 133 | 5.12 | 0.25 | 5.37 |
| 29/5/85 | 149 | 6.00 | 0.85 | 6.85 |
| 10/6/85 | 161 | 5.30 | 1.31 | 6.60 |
| 24/6/85 | 175 | 4.14 | 1.42 | 5.57 |
| 8/7/85 | 189 | 3.05 | 1.72 | 4.77 |
| 22/7/85 | 203 | 0.75 | 1.41 | 2.17 |
| 5/8/85 | 217 | | 1.18 | 1.18 |

Table A2h3. Intermediate harvest data of specific leaf area of green leaves and stem and leaves during the growing season.

| date | J. day nr. | SLA leaf | SLA leaf + stem |
|---|---|---|---|
| 25/3/85 | 84 | 0.00167 | 0.00116 |
| 15/4/85 | 105 | 0.00283 | 0.00194 |
| 29/4/85 | 119 | 0.00259 | 0.00174 |
| 13/5/85 | 133 | 0.00323 | 0.00189 |
| 29/5/85 | 149 | 0.00228 | 0.00099 |
| 10/6/85 | 161 | 0.00206 | 0.00072 |
| 24/6/85 | 175 | 0.00180 | 0.00059 |
| 8/7/85 | 189 | 0.00123 | 0.00043 |
| 22/7/85 | 203 | 0.00040 | 0.00024 |
| 5/8/85 | 217 | 0.00000 | 0.00016 |

K.Vlassak, J. Feyen, 1985.
Proefveld te Helecine, meetgegevens - groeiseizoen 1985, K.U. Leuven, Europese Zaadmaatschappij N.V. (S.E.S.), Bodemkundige Dienst van België, Koninklijk Belgisch Instituut tot Verbetering van de Biet (K.B.I.V.B.), Firma CHAPEX, 128 p.

# Appendix A3:
# Region specific data of winter wheat

Table A3a Occurrence of flowering and maturity day based on literature (Appendix A4) and temperature sums derived from calculated temperature sums (Appendix A4) of winter wheat crop types grown in regions of the European Community. The start date for calculations with the WOFOST program of winter wheat is 1st of January (see section 2.6).
TSUM1 = temperature sum from the 1st of January to flowering
TSUM2 = temperature sum from flowering to harvest
J. day nr. = Julian day number.

| crop type | country | NUTS codes of region | flowering J. day nr. | maturity J. day nr. | TSUM1 °Cd | TSUM2 °Cd |
|---|---|---|---|---|---|---|
| 0101 | United Kingdom | R71, R7A, R7B | 160 | 227 | 1000 | 950 |
| | Denmark | R9 | 160 | 227 | | |
| 0102 | N. Germany | R11, R12, R13, R14 | 166 | 213 | 1050 | 1000 |
| | The Netherlands | R41, R42, R47 | 161 | 220 | | |
| | United Kingdom | R7 without R71, R7A, R7B | 160 | 227 | | |
| | Ireland | R8 | 176 | 238 | | |
| 0103 | C. Germany | R15, R19 | 166 | 213 | 1125 | 1000 |
| | the Netherlands | R45 | 161 | 220 | | |
| | Belgium | R5 | 161 | 237 | | |
| | Luxembourg | R6 | 176 | 222 | | |
| 0104 | S. Germany | R16, R17, R18, R1A, R1B | 166 | 213 | 1200 | 1000 |
| | France | R23, R24 | 155 | 225 | | |
| 0105 | France | R2 without R23, R24 | 144 | 217 | 1250 | 1000 |
| | Italy | R3 without R37, R39, R3A, | 135 | 193 | | |
| | Spain | R3B | 130 | 196 | | |
| | Portugal | RB1, RB2 | 140 | 207 | | |
| | | RC1 | | | | |
| 0106 | Italy | R37, R39, R3A, R3B | 125 | 181 | 1300 | 1000 |
| | Spain | RB3, RB4, RB5 | 135 | 212 | | |
| | Portugal | RC2 | 140 | 207 | | |
| | Greece | A1 | 135 | 196 | | |
| 0107 | Spain | RB6 | 120 | 176 | 1350 | 1000 |
| | Greece | RA2, RA3, RA4 | 146 | 207 | | |

Table A3b Calibrated parameters of the partitioning section of the initial crop-specific data file (Appendix A1) of winter wheat. The bold printed number of the DVS column is the so called DVS1 parameter that is used in the mathematical calibration procedure of section 2.5.

| DVS | FLTB | FSTB | FOTB |
|---|---|---|---|
| 0.50 | 0.50 | 0.50 | 0.00 |
| **0.646** | 0.30 | 0.70 | |
| 0.95 | 0.00 | 1.00 | 0.00 |

# Appendix A4:

## Crop calendar of winter wheat

Table A4. Flowering and maturity day (Julian day number) and calculated temperature sums of winter wheat for regions within the European Community. Each NUTS region contains several grid cells. The temperture sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calculated temperature sum from 1st of January to flowering
TSUM2 = calculated temperature sum from flowering to maturity
Base temperature TSUM1 and TSUM2, 0°C.
J. day nr. = Julian day number

| NUTS code | grid cell | flowering J. day nr. | maturity J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|
| R15 | 3531 | 166 | 213 | 1204 | 843 | Germany | N.R. West-Falen | 2 |
| R21 | 2924 | 140 | 196 | 1000 | 946 | France | Ile de France | 2 |
| R22 | 3125 | 156 | 209 | 1243 | 955 | | Bassin Parisien | 2 |
| R22 | 2624 | 156 | 209 | 1168 | 953 | | Bassin Parisien | 2 |
| R23 | 3325 | 166 | 232 | 1290 | 1171 | | Nord-Pas de Calais | 2 |
| R241 | 2930 | 154 | 219 | 931 | 1127 | | Lorraine | 2 |
| R242 | 2831 | 144 | 217 | 934 | 1337 | | Alsace | 2 |
| R31 | 2132 | 135 | 196 | 1249 | 1189 | Italy | Nord Ovest | 1 |
| R32 | 2235 | 135 | 196 | 1114 | 1314 | | Lombardia | 1 |
| R33 | 2339 | 135 | 196 | 1136 | 1315 | | Nord Est | 1 |
| R34 | 2037 | 135 | 196 | 1113 | 1327 | | Emilia-romagna | 1 |
| R35 | 1637 | 135 | 191 | 1401 | 1068 | | Centro W | 1 |
| R35 | 1741 | 135 | 191 | 1347 | 1138 | | Centro O | 1 |
| R36 | 1439 | 135 | 191 | 1449 | 1113 | | Lazio | 1 |
| R381 | 1542 | 135 | 191 | 1549 | 1203 | | Abruzzi | 1 |
| R37 | 1242 | 125 | 181 | 1710 | 1198 | | Campania | 1 |
| R382 | 1443 | 125 | 181 | 1473 | 1139 | | Molise | 1 |
| R39 | 1345 | 125 | 181 | 1445 | 1174 | | Sud | 1 |
| R3A | 540 | 125 | 181 | 1676 | 1084 | | Sicilia | 1 |
| R3B | 1234 | 125 | 181 | 1219 | 978 | | Sardinia | 1 |
| R42 | 3730 | 161 | 213 | 1114 | 894 | Nederland | Oost | 2 |
| R47 | 3728 | 161 | 237 | 1048 | 1258 | | West | 2 |
| R6 | 3129 | 176 | 222 | 1281 | 826 | Luxembourg | | 2 |
| R7 | 3721 | 176 | 238 | 1185 | 981 | UK | | 3 |
| R74 | 3822 | 160 | 227 | 952 | 1036 | UK | East Anglia | 2 |
| R8 | 4211 | 176 | 238 | 1204 | 877 | Ireland | | 3 |
| RA121 | 1458 | 135 | 196 | 1352 | 1377 | Greece | Imathia | 1 |
| RA122 | 1357 | 135 | 196 | 1268 | 1347 | | Thessaloniki | 1 |
| RA123 | 1356 | 135 | 196 | 1274 | 1361 | | Kilkis | 1 |
| RA14 | 1056 | 135 | 196 | 1444 | 1351 | | Thessalia | 1 |
| RA124 | 1156 | 135 | 196 | 1303 | 1351 | | Pella | 1 |
| RA125 | 1356 | 135 | 196 | 1274 | 1361 | | Pieria | 1 |
| RA126 | 1456 | 135 | 196 | 1284 | 1346 | | Serres | 1 |
| RA127 | 1255 | 135 | 196 | 969 | 1158 | | Chalkidiki | 1 |
| RA128 | 1255 | 135 | 196 | 969 | 1158 | | Kentriki Makedonia | 1 |
| RA129 | 1156 | 135 | 196 | 1303 | 1351 | | Kentriki Makedonia | 1 |
| RA21 | 959 | 146 | 207 | 1604 | 1429 | | Ipeiros | 1 |
| RA23 | 656 | 146 | 207 | 1801 | 1366 | | Dytiki Ellanda | 1 |
| RB1 | 1905 | 130 | 196 | 1410 | 1148 | Spain | Noroeste | 1 |
| RB2 | 1517 | 130 | 196 | 1275 | 1353 | | Noreste | 1 |
| RB3 | 1212 | 140 | 207 | 1469 | 1538 | | Madrid | 1 |
| RB42 | 1013 | 140 | 207 | 1499 | 1543 | | Castilla-La Mancha | 1 |
| RB431 | 1007 | 140 | 207 | 1697 | 1500 | | Badajoz | 1 |
| RB41 | 1610 | 130 | 217 | 997 | 1609 | | Extremadura | 1 |
| RB432 | 1209 | 130 | 217 | 1715 | 2095 | | Caceres | 1 |
| RB51 | 1422 | 140 | 196 | 1507 | 1142 | | N.Este | 1 |
| RB52 | 917 | 140 | 196 | 1845 | 1239 | | S.Este | 1 |
| RB5 | 923 | 140 | 196 | 1534 | 1173 | | S.Este | 1 |

Table A4. Flowering and maturity day (Julian day number) and calculated temperature sums of winter wheat for regions within the European Community. Each NUTS region contains several grid cells. The temperture sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calculated temperature sum from 1st of January to flowering
TSUM2 = calculated temperature sum from flowering to maturity
Base temperature TSUM1 and TSUM2, 0°C.
J. day nr. = Julian day number

| NUTS code | grid cell | flowering J. day nr. | maturity J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|
| RB611 | 413 | 130 | 186 | 1876 | 1218 | Spain | Almeria | 1 |
| RB614 | 610 | 130 | 186 | 1367 | 1151 | | Granada | 1 |
| RB616 | 710 | 130 | 186 | 1692 | 1206 | | Jaen | 1 |
| RB617 | 609 | 130 | 186 | 1568 | 1152 | | Malaga | 1 |
| RB62 | 515 | 130 | 186 | 1873 | 1322 | | Murcia | 1 |
| RB612 | 407 | 110 | 166 | 1539 | 967 | | Cadiz | 1 |
| RB613 | 608 | 110 | 166 | 1234 | 988 | | Cordoba | 1 |
| RB615 | 705 | 110 | 166 | 1494 | 1066 | | Huelva | 1 |
| RB618 | 607 | 110 | 166 | 1374 | 1059 | | Sevilla | 1 |

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2 Falisse, A. & Y. Decelle, 1990, Froment, Avoine; Etude effectuée par la Faculté des Sciences Agronomiques de Gembloux (Belgique).

3 Hough, M.N., 1990, Agrometeorological aspects of crops in the United Kingdom and Ireland. A review for Sugar Beet, Oilseed Rape, Peas, Wheat, Barley, Oats, Potatoes, Apples and Pears; Joint Research Centre, Commission of the European Community.

## Appendix A5:

**Measured and simulated dry matter grain yield, total above-ground dry matter and leaf area index of winter wheat.**

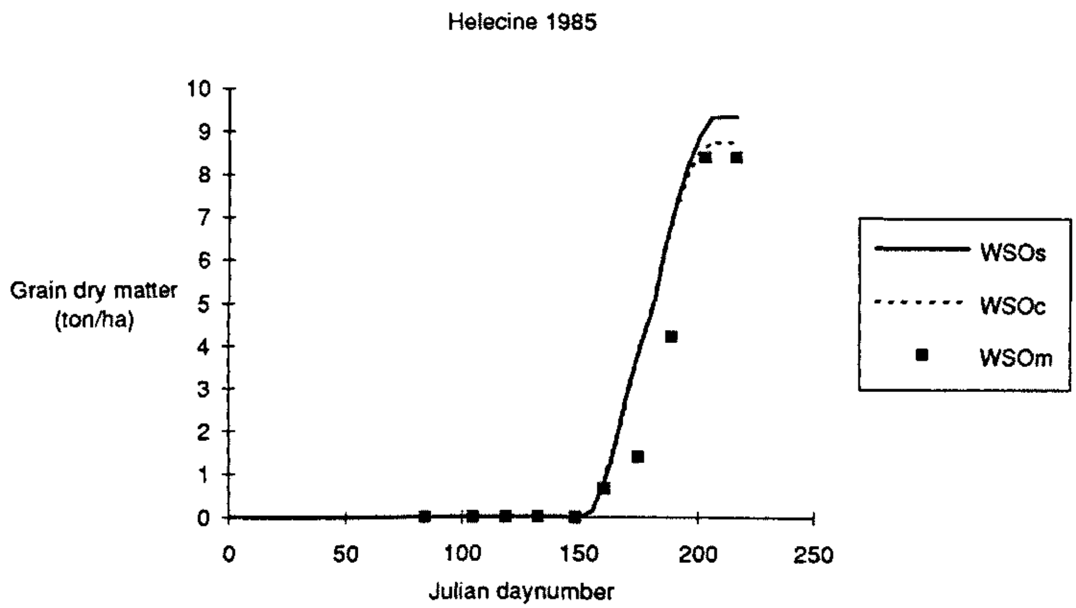


Figure A5a Measured dry matter grain yield (WSOm) of a Belgium field experiment in Helecine 1985 and simulated grain yield, using the initial crop-specific data file (WSOs) or the crop-specific data file after calibration (WSOc), in kg $ha^{-1}$.

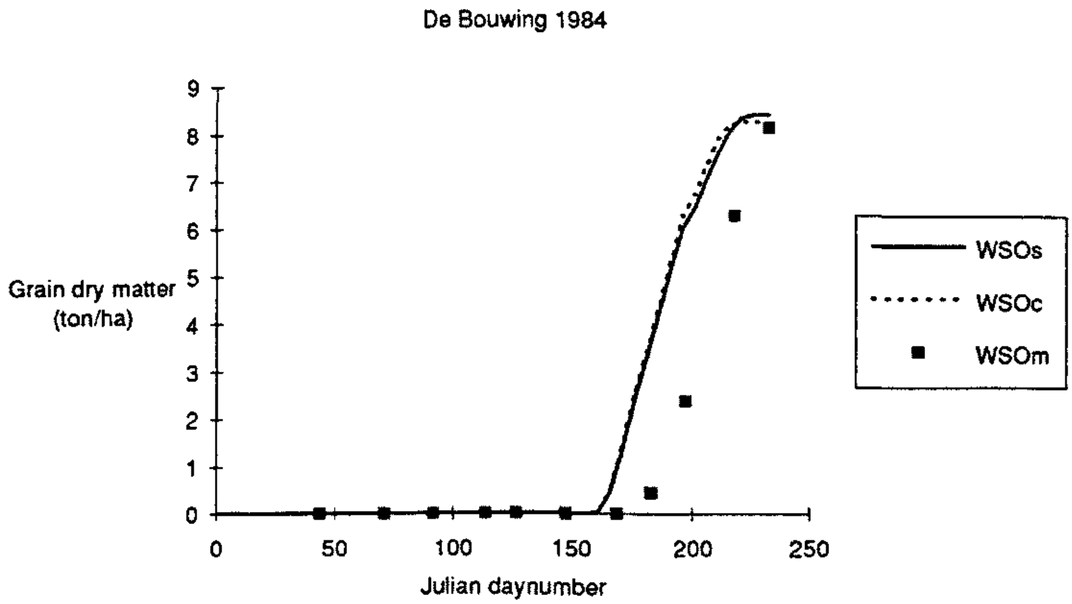


Figure A5b Measured dry matter grain yield (WSOm) of a CABO field experiment in Randwijk (1984) and simulated grain yield, using the initial crop-specific data file (WSOs) or the crop-specific data file after calibration (WSOc), in kg $ha^{-1}$.

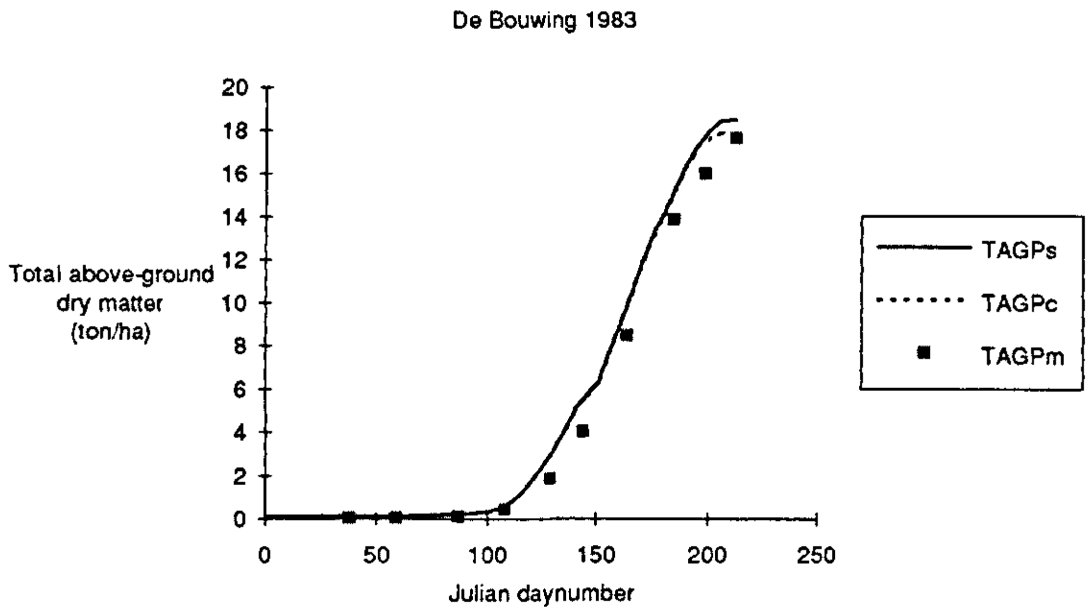


Figure A5c Measured total dry matter (TAGPm) of a CABO field experiment in Randwijk (1983) and simulated total dry matter, using the initial crop-specific data file (TAGPs) or the crop-specific data file after calibration (TAGPc), in kg $ha^{-1}$.

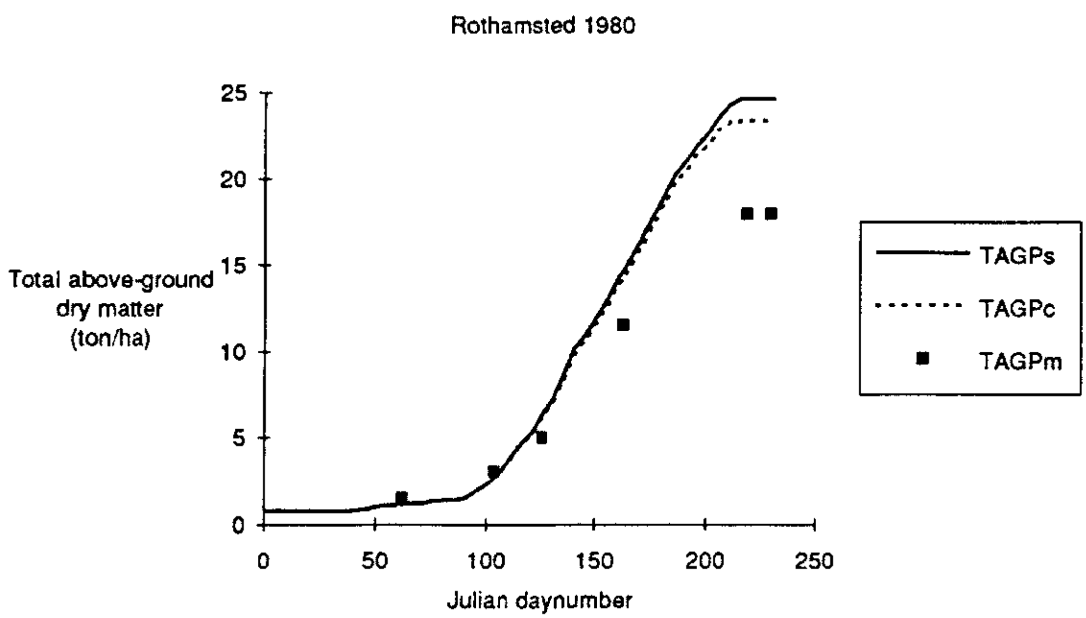


Figure A5c Measured total dry matter (TAGPm) of a field experiment in Rothamsted 1980 and simulated total dry matter, using the initial crop-specific data file (TAGPs) or the crop-specific data file after calibration (TAGPc), in kg $ha^{-1}$.

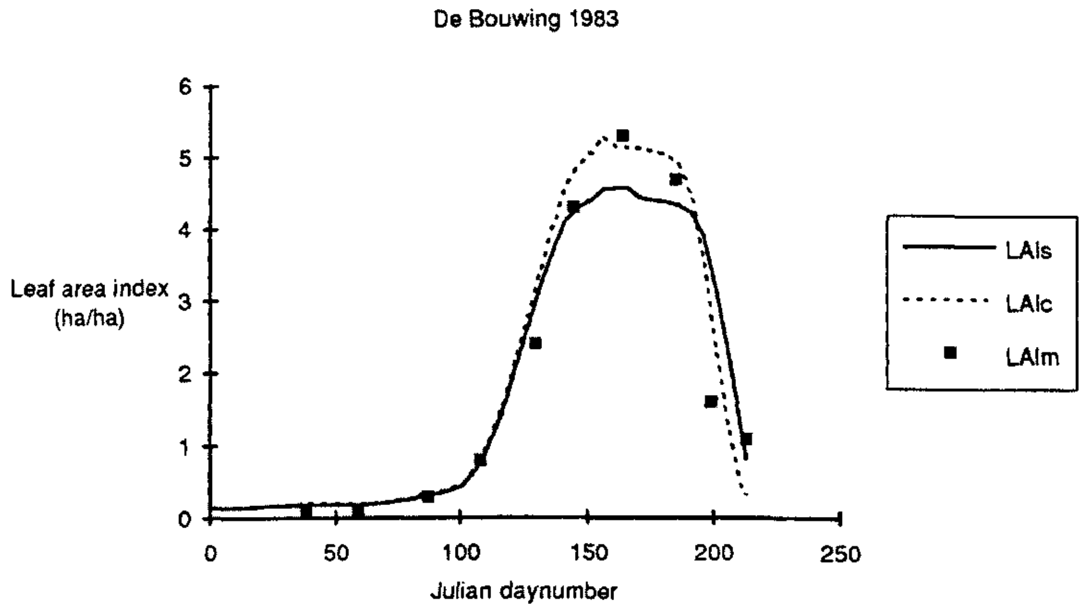


Figure A5e Measured leaf area index (LAIm) of a CABO field experiment in Randwijk (1983) and simulated leaf area index, using the initial crop-specific data file (LAIs) or the crop-specific data file after calibration (LAIc), in ha $ha^{-1}$.

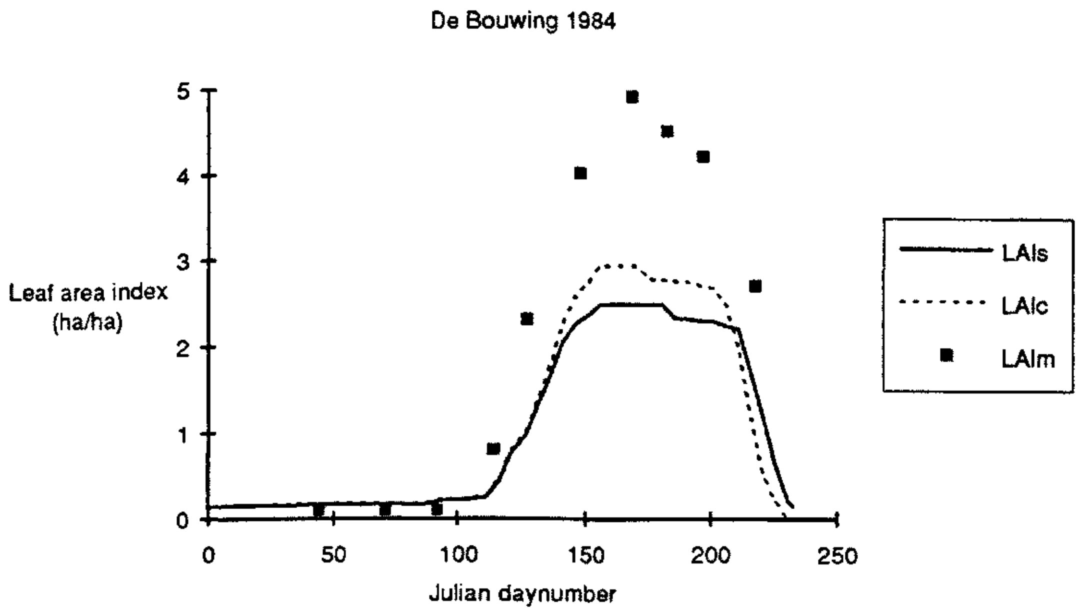


Figure A5e Measured leaf area index (LAIm) of a CABO field experiment in Randwijk (1984) and simulated leaf area index, using the initial crop-specific data file (LAIs) or the crop-specific data file after calibration (LAIc), in ha $ha^{-1}$.

# Appendix A6:

## Simulated grain yield, field experiment and Eurostat data of winter wheat in the Netherlands (1979 to 1988)

Appendix A6. Potential production results of crop growth simulation model WOFOST of winter wheat and field experiment and Eurostat data of the Netherlands for 10 years.

Table A6. Simulated potential dry matter grain yield of winter wheat on soils with different available water capacity (AWC) with weather data from Wageningen. Yield data of winter wheat on experiment stations at Randwijk, Wageningen and Rolde and Yield data of Eurostat for the Netherlands from 1979 to 1988.

| year | potential yield t/ha | potential yield on soils with different AWC AWC 21 cm3/cm3 t/ha | AWC 16 cm3/cm3 t/ha | AWC 14 cm3/cm3 t/ha | AWC 10 cm3/cm3 t/ha | yield on experiment stations clay Randwijk t/ha | sand Wageningen t/ha | sand Rolde t/ha | dm 14% Eurostat t/ha |
|---|---|---|---|---|---|---|---|---|---|
| 1979 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 | 6.7 | 3.6 | 5.5 | 5.9 |
| 1980 | 8.1 | 8.1 | 8.1 | 8.1 | 7.4 | 7.0 | 4.4 | 5.3 | 6.2 |
| 1981 | 7.6 | 7.6 | 7.6 | 7.6 | 7.6 | 7.0 | 4.4 | 5.3 | 6.7 |
| 1982 | 7.2 | 7.2 | 7.2 | 7.2 | 6.8 | | 5.7 | 5.3 | 7.4 |
| 1983 | 8.1 | 8.1 | 8.1 | 8.1 | 8.0 | 7.8 | 5.8 | 5.9 | 7.0 |
| 1984 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 10.2 | 6.1 | | 7.9 |
| 1985 | 8.3 | 8.3 | 8.3 | 8.3 | 8.3 | 6.7 | 4.8 | 4.2 | 6.6 |
| 1986 | 8.6 | 8.6 | 8.5 | 7.6 | 4.5 | 9.2 | 4.9 | 6.0 | 8.0 |
| 1987 | 7.9 | 7.8 | 7.9 | 7.9 | 7.9 | 7.2 | 4.4 | 5.5 | 6.9 |
| 1988 | 7.7 | 7.7 | 7.7 | 7.7 | 7.2 | 7.7 | 5.4 | 5.7 | 7.2 |

# Appendix B:

## Grain maize (*Zea mays* L.)

# Appendix B1:
# Initial crop-specific data file of grain maize

CROP DATA FILE for use with WOFOST Version 5.0, January 1990

```
crop identity
!CRPNAM    = MASMAIZE North EC (MAS.SAV), grain maize  (Zea mays L.)
ICROP      =  2

** emergence
TBASEM     =   4.0                  ! lower threshold temp. for emergence [C°]
TEFFMX     =  30.0                  ! max. eff. temp. for emergence [C°]
TSUMEM     =  110.                  ! temperature sum from sowing to emergence [C° d]

** phenology
IDSL       =  0                     ! indicates whether pre-anthesis development depends
                                    ! on temp. (=0), daylength (=1) , or both (=2)
DLO        =  -99.0                 ! optimum daylength for development [hr]
DLC        =  -99.0                 ! critical daylength (lower threshold) [hr]
TSUM1      =  693.                  ! temperature sum from emergence to anthesis [C° d]
TSUM2      =  786.                  ! temperature sum from anthesis to maturity [C° d]
DTSMTB     =   0.00,     0.00,      ! daily increase in temp. sum
               6.00,     0.00,      ! as function of av. temp. [C°; C° d]
              30.00,    24.00,
              35.00,    24.00
DVSEND     =  2.5                   ! development stage at harvest (= 2.0 at maturity [-])

** initial
TDW        =  5.00                  ! initial total crop dry weight [kg ha-1]
LAIEM      =  0.0074                ! leaf area index at emergence [ha ha-1]
RGRLAI     =  0.0294                ! maximum relative increase in LAI [ha ha-1 d-1]

** green area
SLATB      =  0.00,     0.0035,     ! specific leaf area
              0.78,     0.0016,     ! as a function of DVS [-; ha kg-1]
              2.00,     0.0016,
SPA        =  0.000                 ! specific pod area [ha kg-1]
SSA        =  0.000                 ! specific stem area [ha kg-1]
SPAN       =  31.                   ! life span of leaves growing at 35 C° [d]
TBASE      =  10.0                  ! lower threshold temp. for ageing of leaves [C°]

** assimilation
KDIF       =  0.650                 ! extinction coefficient for diffuse visible light [-]
EFF        =  0.45                  ! light-use effic. single leaf [kg ha-1 hr-1 J-1 m2 s]
```

```
AMAXTB   =  0.00,    70.00,    ! maximum leaf CO2 assimilation rate
            1.25,    70.00,    ! as function of DVS [-; kg ha-1 hr-1]
            1.50,    63.00,
            1.75,    49.00,
            2.00,    21.00
TMPFTB   =  0.00,    0.01,     ! reduction factor of AMAX
            9.00,    0.05,     ! as function of av. temp. [C°; -]
           16.00,    0.80,
           18.00,    0.94,
           20.00,    1.00,
           30.00,    1.00,
           36.00,    0.95,
           42.00,    0.56,
TMNFTB   =  5.00,    0.00,     ! red. factor of gross assim. rate
            8.00,    1.00      ! as function of low min. temp. [C°; -]

** conversion of assimilates into biomass
CVL      =  0.680              ! efficiency of conversion into leaves [kg kg-1]
CVO      =  0.671              ! efficiency of conversion into storage org. [kg kg-1]
CVR      =  0.690              ! efficiency of conversion into roots [kg kg-1]
CVS      =  0.658              ! efficiency of conversion into stems [kg kg-1]

** maintenance respiration
Q10      =  2.0                ! rel. incr. in resp. rate per 10 C°temp. incr. [-]
RML      =  0.0300             ! rel. maint. resp. rate leaves [kg CH2O kg-1 d-1]
RMO      =  0.0100             ! rel. maint. resp. rate stor.org. [kg CH2O kg-1 d-1]
RMR      =  0.0150             ! rel. maint. resp. rate roots [kg CH2O kg-1 d-1]
RMS      =  0.0150             ! rel. maint. resp. rate stems [kg CH2O kg-1 d-1]
RFSETB   =  0.00,    1.00,     ! red. factor for senescence
            1.50,    1.00,     ! as function of DVS [-; -]
            1.75,    0.75,
            2.00,    0.25

** partitioning
FRTB     =  0.00,    0.40,     ! fraction of total dry matter to roots
            0.10,    0.37,     ! as a function of DVS [-; kg kg-1]
            0.20,    0.34,
            0.30,    0.31,
            0.40,    0.27,
            0.50,    0.23,
            0.60,    0.19,
            0.70,    0.15,
            0.80,    0.10,
            0.90,    0.06,
            1.00,    0.00,
            2.00,    0.00
```

```
FLTB     =  0.00,    0.70,    ! fraction of above-gr. DM to leaves
            0.33,    0.70,    ! as a function of DVS [-; kg kg-1]
            0.88,    0.15,
            0.95,    0.00,
            2.00,    0.00
FSTB     =  0.00,    0.30,    ! fraction of above-gr. DM to stems
            0.33,    0.30,    ! as a function of DVS [-; kg kg-1]
            0.88,    0.85,
            0.95,    1.00,
            1.05,    0.00,
            2.00,    0.00
FOTB     =  0.95,    0.00,    ! fraction of above-gr. DM to stor. org.
            1.05,    0.00,    ! as a function of DVS [-; kg kg-1]
            1.20,    1.00,
            2.00,    1.00

** death rates
PERDL    =  0.030             ! max. rel. death rate of leaves due to water stress
RDRRTB   =  0.00,    0.000,   ! rel. death rate of stems
            1.50,    0.000,   ! as a function of DVS [-; kg kg-1 d-1]
            1.5001,  0.020,
            2.00,    0.020
RDRSTB   =  0.00,    0.000,   ! rel. death rate of roots
            1.50,    0.000,   ! as a function of DVS [-; kg kg-1 d-1]
            1.5001,  0.020,
            2.00,    0.020

** water use
CFET     =  1.00              ! correction factor transpiration rate [-]
DEPNR    =  4.5               ! crop group number for soil water depletion [-]
IAIRDU   =  0                 ! air ducts in roots present (=1) or not (=0)

** rooting
RDI      =  10.               ! initial rooting depth [cm]
RRI      =   1.5              ! maximum daily increase in rooting depth [cm d-1]
RDMCR    =  100.              ! maximum rooting depth [cm]

** nutrients
** maximum and minimum concentrations of N, P, and K in storage organsin vegetative organs
   [kg kg-1]
NMINSO   =  0.0095 ;  NMINVE  =  0.0040
NMAXSO   =  0.0220 ;  NMAXVE  =  0.0125
PMINSO   =  0.0017 ;  PMINVE  =  0.0004
PMAXSO   =  0.0075 ;  PMAXVE  =  0.0030
KMINSO   =  0.0020 ;  KMINVE  =  0.0050
KMAXSO   =  0.0060 ;  KMAXVE  =  0.0200
YZERO    =  400.              ! max. amount veg. organs at zero yield [kg ha-1]
NFIX     =  0.00              ! fraction of N-uptake from biol. fixation [kg kg-1]
```

# Appendix B2:

## Field experiment data of grain maize

Appendix B2a. Intermediate harvest results of a grain maize field experiment of INRA at Toulouse, France (1985).

Toulouse Auzeville INRA France
Plot I9
Mais Irrigated (high level)
Weather station: Toulouse
*J. day nr. = Julian day number*
LAI = Leaf area index (ha/ha)
SLA = specific leaf area (ha/kg)

| | |
|---|---|
| max rooth depth | 1.7 m |
| max LAI | 8 m2/m2 |
| LAI at maturity | 6.4 m2/m2 |
| Sowing date | 18/4/85 |

| | |
|---|---|
| Temperature sum from sowing to emergence | 80°Cd |
| Temperature sum from sowing to flowering | 950 °Cd |
| Temperature sum from sowing to maturity | 1950 °Cd |

Table B2a. Total dry matter, grain yield, leaf area index and specific leaf area of the grain maize field experiment in Toulouse during the growing season of 1985.

| date | J. day nr. | total dry matter kg/ha | grains kg/ha | LAI m2/m2 | SLA ha/kg |
|---|---|---|---|---|---|
| 18/4/85 | 108 | 0 | | 0.00 | 0.00000 |
| 10/6/85 | 161 | 1080 | | 1.82 | 0.00038 |
| 24/6/85 | 175 | 4820 | | 6.46 | 0.00063 |
| 15/7/85 | 196 | 10301 | | 8.14 | 0.00042 |
| 14/8/85 | 226 | 19440 | | 7.90 | 0.00034 |
| 23/8/85 | 266 | 23230 | | 6.19 | 0.00026 |
| 3/10/85 | | 23420 | 11270 | | |

Source: Cabelguenne, INRA, Toulouse.

Appendix B2b. Intermediate harvest results of a grain maize field experiment of INRA at Toulouse, France (1986).

Toulouse Auzeville INRA France
Plot CO4
Mais Irrigated (high level)
J. day nr. = Julian day number
LAI = Leaf area index (ha/ha)
SLA = specific leaf area (ha/kg)

| | | |
|---|---|---|
| max rooth depth | 1.6 m | |
| max LAI | 5.82 m2/m2 | |
| LAI at maturity | 5.23 m2/m2 | |
| Sowing date | 5/5/86 | daynumber 125 |

| | |
|---|---|
| Temperature sum from sowing to emergence | 80°Cd |
| Temperature sum from sowing to flowering | 950 °Cd |
| Temperature sum from sowing to maturity | 1950 °Cd |

Table B2b. Total dry matter, grain yield, leaf area index and specific leaf area of the grain maize field experiment in Toulouse during the growing season of 1986.

| date | J. day nr. | total dry matter kg/ha | grains kg/ha | LAI m2/m2 | SLA ha/kg |
|---|---|---|---|---|---|
| 5/5/86 | 125 | 0 | | 0.00 | |
| 27/5/86 | 147 | 83 | | 0.14 | 0.00169 |
| 12/6/86 | 163 | 422 | | 0.61 | 0.00145 |
| 30/6/86 | 181 | 2992 | | 4.10 | 0.00137 |
| 21/7/86 | 202 | 7259 | | 5.00 | 0.00069 |
| 12/8/86 | 224 | 14389 | | 5.14 | 0.00036 |
| 27/8/86 | 239 | 20350 | | 5.82 | 0.00029 |
| 8/9/86 | 251 | 25201 | | 5.23 | 0.00021 |
| 7/10/86 | 280 | 21350 | 11540 | | |

Source: Cabelguenne, INRA, Toulouse.

# Appendix B3:
# Region specific data of grain maize

Table B3a Occurrence of sowing, flowering and maturity day and calibrated temperature sums of grain maize crop types, grown in regions within countries of the European Community.
TSUM1 = temperature sum from emergence to flowering
TSUM2 = temperature sum from flowering to harvest
J. day nr. = Julian day number.

| crop type | country | NUTS codes of region | sowing J. day nr. | flowering J. day nr. | maturity J. day nr. | TSUM1 °Cd | TSUM2 °Cd |
|---|---|---|---|---|---|---|---|
| 0201 | Germany | R13, R15, R16, R17 | 121 | 207 | 293 | 695 | 800 |
| | Luxembourg | R6 | | | | | |
| 0202 | S. Germany | R18, R19, R1A | 121 | 207 | 293 | 695 | 860 |
| | N. France | R21, R22, R23 | 115 | 207 | 293 | | |
| 0203 | C. France | R24, R25, R27 | 115 | 207 | 293 | 775 | 880 |
| | N. Italy | R31, R32, R33 | 105 | 207 | 293 | | |
| 0204 | S. France | R26, R28 | 115 | 207 | 293 | 855 | 900 |
| | Italy | R34,R35,R36,R37,R38 | 107 | 191 | 293 | | |
| | Spain | RB1, Rb2, RB3, RB4 | 115 | 207 | 293 | | |
| | Portugal | RC | 115 | 207 | 293 | | |
| 0205 | Greece | RA | 110 | 161 | 293 | 935 | 920 |
| | S. Italy | R39,R3A,R3B | 125 | 196 | 293 | | |
| | S. Spain | RB5,RB6 | 69 | 166 | 258 | | |

**No grain maize assumed in:**
Berlin (R1B)
The Netherlands (R4)
Belgium (R5)
United Kingdom (R7)
Ireland (R8)
Denmark (R9)

Table B3b Calibrated parameters of the initial crop-specific data file (Appendix B1) of grain maize.

```
DVSEND    =  2.00                 ! development stage at harvest (= 2.0 at maturity [-])

** initial
TDW       =  50.00                ! initial total crop dry weight [kg ha-1]
LAIEM     =  0.04836              ! leaf area index at emergence [ha ha-1]

** green area
SLATB     =  0.00,     0.0026,    ! specific leaf area
             0.78,     0.0012,    ! as a function of DVS [-; ha kg-1]
             2.00,     0.0012,

SPAN      =  33.                  ! life span of leaves growing at 35 C° [d]

** assimilation
KDIF      =  0.600                ! extinction coefficient for diffuse visible light [-]

** partitioning
FLTB      =  0.00      0.62
             0.33      0.62
             0.88      0.15
             0.95      0.15
             1.10      0.10
             1.20      0.00
             2.00      0.00
FSTB      =  0.00      0.38
             0.33      0.38
             0.88      0.85
             0.95      0.85
             1.10      0.40
             1.20      0.00
             2.00      0.00
FOTB      =  0.95      0.00
             1.10      0.50
             1.20      1.00
             2.00      1.00

** rooting
RRI       =  2.2                  ! maximum daily increase in rooting depth [cm d-1]
```

# Appendix B4:

## Crop calendar of grain maize

Table B4. Sowing, female flowering and maturity day (Julian day number) and calculated temperature sums of grain maize for *regions within the European Community. Each NUTS region contains several grid cells. The temperture sums* are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calculated temperature sum from emergence to female flowering, base temperature of 6°C.
TSUM2 = calculated temperature sum from female flowering to harvest, base temperature of 6°C.
Temperature sum from sowing to emergence is 110°Cd, with a base temperature of 4°C.
J. day nr. = Julian day number

| NUTS code | grid cell | sowing J. day nr. | female flowering J. day nr. | harvest day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|---|
| R11 | -1 | -1 | -1 | -1 | -1 | -1 | Germany | Schleswig-Holstein | 2 |
| R12 | -1 | -1 | -1 | -1 | -1 | -1 | | Hamburg | 2 |
| R13 | 3834 | 121 | 207 | 293 | 648 | 745 | | Niedersachsen | 2 |
| R14 | -1 | -1 | -1 | -1 | -1 | -1 | | Bremen | 2 |
| R15 | 3531 | 123 | 207 | 293 | 717 | 838 | | Nordrhein-Westfalen | 2 |
| R16 | -1 | -1 | -1 | -1 | -1 | -1 | | Hessen | 2 |
| R17 | 3132 | 121 | 207 | 293 | 805 | 888 | | Rheinland-Pfalz | 2 |
| R18 | 2934 | 127 | 207 | 293 | 694 | 813 | | Baden-Württemberg | 2 |
| R19 | 3037 | 121 | 207 | 293 | 658 | 745 | | Bayern | 2 |
| R1A | -1 | -1 | -1 | -1 | -1 | -1 | | Saarland | 2 |
| R1B | -1 | -1 | -1 | -1 | -1 | -1 | | Berlin | 2 |
| R21 | -1 | -1 | -1 | -1 | -1 | -1 | France | Île de France | 2 |
| R221 | 3127 | 115 | 207 | 293 | 777 | 877 | | Champagne-Ardenne | 2 |
| R222 | 3125 | 115 | 207 | 293 | 790 | 905 | | Picardie | |
| R224 | 2722 | 115 | 207 | 293 | 803 | 935 | | Centre | |
| R23 | -1 | -1 | -1 | -1 | -1 | -1 | | Nord - Pas-de-Calais | 2 |
| R24 | -1 | -1 | -1 | -1 | -1 | -1 | | Est | 2 |
| R251 | 2618 | 115 | 207 | 293 | 809 | 1017 | | Pays de la Loire | 2 |
| R253 | 2319 | 115 | 207 | 293 | 981 | 1119 | | Poitou-Charentes | |
| R261 | 2119 | 115 | 207 | 293 | 893 | 1105 | | Aquitaine | 2 |
| R262 | 1922 | 115 | 207 | 293 | 879 | 1105 | | Midi-Pyrénées | 2 |
| R263 | -1 | -1 | -1 | -1 | -1 | -1 | | Limousin | 2 |
| R271 | 2127 | 115 | 207 | 293 | 1056 | 1249 | | Rhône-Alpes | 2 |
| R272 | 2424 | 115 | 207 | 293 | 782 | 880 | | Auvergne | |
| R28 | -1 | -1 | -1 | -1 | -1 | -1 | | Mediterranée | 2 |
| R311 | 2133 | 105 | 207 | 293 | 266 | 1814 | Italy | Piemonte | 3 |
| R312 | 2232 | 105 | 207 | 293 | 242 | 1501 | | Valle d'Aosta | |
| R313 | 1933 | 105 | 207 | 293 | 240 | 1734 | | Liguria | |
| R32 | 2235 | 105 | 207 | 293 | 619 | 1713 | | Lombardia | 3 |
| R331 | 2236 | 105 | 207 | 293 | 284 | 1683 | | Trentino-Alto Adige | 3 |
| R332 | 2238 | 105 | 207 | 293 | 806 | 1748 | | Veneto | |
| R333 | 2339 | 105 | 207 | 293 | 832 | 1761 | | Friuli-Venezia Giulia | |
| R34 | 2037 | 107 | 191 | 293 | 838 | 1800 | | Emilia-Romagna | 3 |
| R351 | 1837 | 107 | 191 | 293 | 95 | 1800 | | Toscana | 3 |
| R352 | 1639 | 107 | 191 | 293 | 580 | 1865 | | Umbria | |
| R353 | 1840 | 107 | 191 | 293 | 395 | 1857 | | Marche | |
| R36 | 1439 | 107 | 191 | 293 | 106 | 1884 | | Lazio | 3 |
| R37 | 1242 | 107 | 191 | 293 | 508 | 2276 | | Campania | 3 |
| R381 | 1542 | 107 | 191 | 293 | 132 | 2041 | | Abruzzi | 3 |
| R382 | 1444 | 107 | 191 | 293 | 143 | 2157 | | Molise | |
| R391 | 1345 | 125 | 196 | 293 | -77 | 2167 | | Puglia | 3 |
| R392 | 1146 | 125 | 196 | 293 | 654 | 2078 | | Basilicata | |
| R393 | 847 | 125 | 196 | 293 | 498 | 2227 | | Calabria | |
| R3A | 540 | 125 | 196 | 293 | 55 | 2265 | | Sicilia | 3 |
| R3B | 1234 | 125 | 196 | 293 | 87 | 1745 | | Sardegna | 3 |
| R4 | -1 | -1 | -1 | -1 | -1 | -1 | the Netherlands | | |
| R5 | -1 | -1 | -1 | -1 | -1 | -1 | Belgium | | |
| R6 | -1 | -1 | -1 | -1 | -1 | -1 | Luxembourg | | 1 |
| R7 | -1 | -1 | -1 | -1 | -1 | -1 | United Kingdom | | 1 |
| R7A | -1 | -1 | -1 | -1 | -1 | -1 | | Scotland | 1 |
| R7B | -1 | -1 | -1 | -1 | -1 | -1 | | Northern Ireland | 1 |
| R8 | -1 | -1 | -1 | -1 | -1 | -1 | Ireland | | 1 |
| R9 | -1 | -1 | -1 | -1 | -1 | -1 | Denmark | | 1 |
| RA | 1156 | 110 | 191 | 293 | 1016 | 1622 | Greece | | 2 |

Table B4. Sowing, female flowering and maturity day (Julian day number) and calculated temperature sums of grain maize for regions within the European Community. Each NUTS region contains several grid cells. The temperture sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calculated temperature sum from emergence to female flowering, base temperature of 6°C.
TSUM2 = calculated temperature sum from female flowering to harvest, base temperature of 6°C.
Temperature sum from sowing to emergence is 110°Cd, with a base temperature of 4°C.
J. day nr. = Julian day number

| NUTS code | grid cell | sowing J. day nr. | female flowering J. day nr. | harvest day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|---|
| RB11 | 1905 | 115 | 217 | 293 | 887 | 963 | Spain | Galicia | 2 |
| RB12 | 1912 | 115 | 217 | 293 | 793 | 917 | | Asturias | 2 |
| RB13 | 1913 | 115 | 207 | 293 | 884 | 1002 | | Cantabria | 2 |
| RB22 | 1616 | 115 | 207 | 293 | 1106 | 1302 | | Navarra | 2 |
| RB24 | 1418 | 115 | 207 | 293 | 1041 | 1237 | | Aragon | |
| RB3 | 1211 | 115 | 207 | 293 | 1346 | 1577 | | Madrid | 2 |
| RB421 | 1013 | 115 | 207 | 293 | 1255 | 1447 | | Albacete | 2 |
| RB422 | 1009 | 115 | 207 | 293 | 1166 | 1698 | | Ciudad Real | |
| RB425 | 1209 | 115 | 207 | 293 | 1340 | 1841 | | Toledo | |
| RB431 | 905 | 115 | 207 | 293 | 1008 | 1696 | | Badajoz | |
| RB432 | 1206 | 115 | 207 | 293 | 1220 | 1729 | | Cáceres | |
| RB5 | -1 | -1 | -1 | -1 | -1 | -1 | | Este | 2 |
| RB61 | 608 | 67 | 166 | 256 | 832 | 1697 | | Andalucia | 2 |
| RB7 | -1 | -1 | -1 | -1 | -1 | -1 | | Canarias | 2 |
| RC1 | 1605 | 115 | 207 | 293 | 720 | 1066 | Portugal | Continente | 2 |
| RC12 | 1204 | 115 | 207 | 293 | 908 | 1351 | | Centro | |

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EUROSTAT Agriculture Statistical Yearbook, 5A, Luxembourg.

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Agrometeorological aspects of crops in Italy, Spain and Greece.
A summary review for common wheat, durum wheat, barley, maize, rice, sugar beet, sunflower, soya bean, rape, potato, cotton, olive and grape crops.
Joint Research Centre, Commision of the European Communities, Luxembourg, Aquater, 438 p.

3 Bignon, J., 1990.
Agrometeorologie et physiologie du mais grain dans la Communaute Europeenne.
Joint Research Centre, Commision of the European Communities, Luxembourg, 195 p.

-1 means: no data available or no grain maize grown

# Appendix C:

## Spring barley (*Hordeum vulgare* L.)

# Appendix C1:
# Initial crop-specific data file of spring barley

```
CROP DATA FILE for use with WOFOST Version 5.0, January 1990

crop identity
!CRPNAM    = Barley  (Hordeum vulgare L.)
ICROP      = 3

** emergence
TBASEM     = -10.0                    ! lower threshold temp. for emergence [C°]
TEFFMX     =  30.0                    ! max. eff. temp. for emergence [C°]
TSUMEM     =   0.                     ! temperature sum from sowing to emergence [C° d]

** phenology
IDSL       = 0                        ! indicates whether pre-anthesis development depends
                                      ! on temp. (=0), daylength (=1) , or both (=2)
DLO        = -99.0                    ! optimum daylength for development [hr]
DLC        = -99.0                    ! critical daylength (lower threshold) [hr]
TSUM1      = 800.                     ! temperature sum from emergence to anthesis [C° d]
TSUM2      = 750.                     ! temperature sum from anthesis to maturity [C° d]
DTSMTB     =  0.00,      0.00,        ! daily increase in temp. sum
             30.00,     30.00,        ! as function of av. temp. [C°; C° d]
             45.00,     30.00
DVSEND     = 2.00                     ! development stage at harvest (= 2.0 at maturity [-])

** initial
TDWI       = 420.00                   ! initial total crop dry weight [kg ha-1]
LAIEM      =  0.274                   ! leaf area index at emergence [ha ha-1]
RGRLAI     =  0.0070                  ! maximum relative increase in LAI [ha ha-1 d-1]

** green area
SLATB      = 0.00,      0.0020,       ! specific leaf area
             2.00,      0.0020        ! as a function of DVS [-; ha kg-1]
SPA        = 0.000                    ! specific pod area [ha kg-1]
SSA        = 0.000                    ! specific stem area [ha kg-1]
SPAN       = 35.                      ! life span of leaves growing at 35 C° [d]
TBASE      = 0.0                      ! lower threshold temp. for ageing of leaves [C°]

** assimilation
KDIF       = 0.600                    ! extinction coefficient for diffuse visible light [-]
EFF        = 0.45                     ! light-use effic. single leaf [kg ha-1 hr-1 J-1 m2 s]
```

```
AMAXTB   =  0.00,   40.00,   ! maximum leaf CO2 assimilation rate
            1.00,   40.00,   ! as function of DVS [-; kg ha-1 hr-1]
            2.00,   20.00
TMPFTB   =  0.00,   0.01,    ! reduction factor of AMAX
           10.00,   0.60,    ! as function of av. temp. [C°; -]
           15.00,   1.00,
           25.00,   1.00
           35.00,   0.00
TMNFTB   =  0.00,   0.00,    ! red. factor of gross assim. rate
            3.00,   1.00     ! as function of low min. temp. [C°; -]

** conversion of assimilates into biomass
CVL      =  0.685            ! efficiency of conversion into leaves [kg kg-1]
CVO      =  0.709            ! efficiency of conversion into storage org. [kg kg-1]
CVR      =  0.694            ! efficiency of conversion into roots [kg kg-1]
CVS      =  0.662            ! efficiency of conversion into stems [kg kg-1]

** maintenance respiration
Q10      =  2.0              ! rel. incr. in resp. rate per 10 C°temp. incr. [-]
RML      =  0.0300           ! rel. maint. resp. rate leaves [kg CH2O kg-1 d-1]
RMO      =  0.0100           ! rel. maint. resp. rate stor.org. [kg CH2O kg-1 d-1]
RMR      =  0.0150           ! rel. maint. resp. rate roots [kg CH2O kg-1 d-1]
RMS      =  0.0150           ! rel. maint. resp. rate stems [kg CH2O kg-1 d-1]
RFSETB   =  0.00,   1.00,    ! red. factor for senescence
            2.00,   1.00     ! as function of DVS [-; -]

** partitioning
FRTB     =  0.00,   0.50,    ! fraction of total dry matter to roots
            0.10,   0.50,    ! as a function of DVS [-; kg kg-1]
            0.20,   0.40,
            0.35,   0.22,
            0.40,   0.17,
            0.50,   0.13,
            0.70,   0.07,
            0.90,   0.03,
            1.20,   0.00,
            2.00,   0.00
FLTB     =  0.00,   0.65,    ! fraction of above-gr. DM to leaves
            0.10,   0.65,    ! as a function of DVS [-; kg kg-1]
            0.25,   0.70,
            0.50,   0.50,
            0.70,   0.15,
            0.95,   0.00,
            2.00,   0.00
```

```
FSTB     =  0.00,    0.35,    ! fraction of above-gr. DM to stems
            0.10,    0.35,    ! as a function of DVS [-; kg kg-1]
            0.25,    0.30,
            0.50,    0.50,
            0.70,    0.85,
            0.95,    1.00,
            1.05,    0.00,
            2.00,    0.00
FOTB     =  0.00,    0.00,    ! fraction of above-gr. DM to stor. org.
            0.95,    0.00,    ! as a function of DVS [-; kg kg-1]
            1.05,    1.00,
            2.00,    1.00

** death rates
PERDL    =  0.030             ! max. rel. death rate of leaves due to water stress
RDRRTB   =  0.00,    0.000,   ! rel. death rate of stems
            1.50,    0.000,   ! as a function of DVS [-; kg kg-1 d-1]
            1.5001,  0.020,
            2.00,    0.020
RDRSTB   =  0.00,    0.000,   ! rel. death rate of roots
            1.50,    0.000,   ! as a function of DVS [-; kg kg-1 d-1]
            1.5001,  0.020,
            2.00,    0.020

** water use
CFET     =  1.00              ! correction factor transpiration rate [-]
DEPNR    =  4.5               ! crop group number for soil water depletion [-]
IAIRDU   =  0                 ! air ducts in roots present (=1) or not (=0)

** rooting
RDI      =  60.               ! initial rooting depth [cm]
RRI      =  1.2               ! maximum daily increase in rooting depth [cm d-1]
RDMCR    =  125.              ! maximum rooting depth [cm]

** nutrients
** maximum and minimum concentrations of N, P, and K in storage organsin vegetative organs
   [kg kg-1]
NMINSO   =  0.0110 ;  NMINVE  =  0.0030
NMAXSO   =  0.0310.;  NMAXVE  =  0.0105
PMINSO   =  0.0016 ;  PMINVE  =  0.0004
PMAXSO   =  0.0060 ;  PMAXVE  =  0.0020
KMINSO   =  0.0030 ;  KMINVE  =  0.0070
KMAXSO   =  0.0080 ;  KMAXVE  =  0.0280
YZERO    =  200.              ! max. amount veg. organs at zero yield [kg ha-1]
NFIX     =  0.00              ! fraction of N-uptake from biol. fixation [kg kg-1]
```

# Appendix C2:

## Field experiment data of spring barley

Appendix C2. Field experiments of the European Brewery Convention of spring barley throughout Europe.

Table C2. Sowing and harvest dates and day numbers and dry matter yields (real and relative) for spring barley varieties and the weather stations used for calibration in countries within the European Community. For every country the field experiment station is given and its location.

WST. means weather station used for calibration
(at the end of the appendix a list with names is given)
J. day nr. = Julian day number

Germany EBH (Ober-Flörsheim) N 49°.45', E 8°.05' (WST. 10763)

| standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100* | FINTIM |
|---|---|---|---|---|---|---|---|---|---|
| Aramir | 25/3/82 | 84 | 30/7/82 | 211 | 4.444 | 1 | 92 | 4.830 | |
| Aramir | 15/3/83 | 74 | 28/7/83 | 209 | 5.074 | 2 | 94 | 5.398 | |
| Gimpel | 15/3/84 | 75 | 9/8/84 | 222 | 5.568 | 3 | 93 | 5.987 | |
| Aramir | 3/4/85 | 93 | 9/8/85 | 221 | 5.855 | 4 | 94 | 6.229 | |
| Gimpel | 8/4/86 | 98 | 1/8/86 | 213 | 4.759 | 5 | 87 | 5.470 | |
| Gimpel | 1/4/87 | 91 | 13/8/87 | 225 | 5.578 | 6 | 101 | 5.523 | |
| Alexis | 5/4/88 | 96 | 8/8/88 | 221 | 6.313 | 7 | 108 | 5.845 | 125 |
| Alexis | 14/3/89 | 73 | 27/7/89 | 208 | 4.899 | 8 | 104 | 4.711 | |
| Alexis | 13/3/90 | 72 | 31/7/90 | 212 | 5.800 | 9 | | | |
| average | | 84 | | 216 | | | | | |

Hungen, N 50°.25', E 8°.55'

| standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100* | FINTIM |
|---|---|---|---|---|---|---|---|---|---|
| Aramir | 29/3/82 | 88 | 2/8/82 | 214 | 5.695 | 1 | 99 | 5.753 | |
| Aramir | 22/4/83 | 112 | 10/8/83 | 222 | 3.922 | 2 | 103 | 3.808 | |
| Gimpel | 20/3/84 | 80 | 20/8/84 | 233 | 5.892 | 3 | 103 | 5.720 | |
| Aramir | 4/4/85 | 94 | 22/8/85 | 234 | 5.475 | 4 | 97 | 5.644 | |
| Gimpel | 16/4/86 | 106 | 5/8/86 | 217 | 6.076 | 5 | 96 | 6.329 | |
| Gimpel | 9/4/87 | 99 | 31/8/87 | 243 | 5.460 | 6 | 97 | 5.629 | |
| Alexis | 15/4/88 | 106 | 8/8/88 | 221 | 5.086 | 7 | 88 | 5.779 | |
| Alexis | 29/3/89 | 88 | 10/8/89 | 222 | 4.271 | 8 | 96 | 4.449 | |
| Alexis | 26/3/90 | 85 | 7/8/90 | 219 | 4.000 | 9 | | | |
| average | | 95 | | 225 | | | | | |

Rethmar, N52°.20', E 10°.05'

| standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100* | FINTIM |
|---|---|---|---|---|---|---|---|---|---|
| Aramir | 2/4/82 | 92 | 30/7/82 | 211 | 6.929 | 1 | 98 | 7.070 | |
| Aramir | 25/4/83 | 115 | 5/8/83 | 217 | 3.869 | 2 | 98 | 3.948 | |
| Gimpel | 28/3/84 | 88 | 23/8/84 | 236 | 6.138 | 3 | 102 | 6.018 | |
| Aramir | 19/4/85 | 109 | 14/8/85 | 226 | 5.513 | 4 | 97 | 5.683 | |
| Gimpel | 29/4/86 | 119 | 14/8/86 | 226 | 6.977 | 5 | 101 | 6.908 | |
| Gimpel | 6/4/87 | 96 | 25/8/87 | 237 | 6.574 | 6 | 100 | 6.574 | |
| Alexis | 11/4/88 | 102 | 9/8/88 | 222 | 5.397 | 7 | 94 | 5.741 | |
| Alexis | 28/3/89 | 87 | 27/7/89 | 208 | 5.950 | 8 | 106 | 5.613 | |
| Alexis | 19/3/90 | 78 | 2/8/90 | 214 | 5.800 | 9 | | | |
| average | | 98 | | 222 | | | | | |

Roggenstein, N48°.10', E 11°.16' (WST. 10866)

| standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100* | FINTIM |
|---|---|---|---|---|---|---|---|---|---|
| Aramir | 18/3/83 | 77 | 27/7/83 | 208 | 6.592 | 2 | 97 | 6.796 | |
| Gimpel | 21/3/84 | 81 | 17/8/84 | 230 | 6.758 | 3 | 95 | 7.114 | |
| Gimpel | 3/4/86 | 93 | 4/8/86 | 216 | 6.008 | 5 | 101 | 5.949 | |
| Gimpel | - | - | - | - | 5.005 | 6 | 105 | 4.767 | |
| Alexis | 5/4/88 | 96 | 6/8/88 | 219 | 7.905 | 7 | 105 | 7.529 | 123 |
| Alexis | 6/3/90 | 65 | 30/7/90 | 211 | 6.000 | 9 | | | |
| average | | 82 | | 217 | | | | | |

| Country | Site | standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100= | FINTIM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Germany | Weihenstephan, N 48°.23', E 11°.45' (WST. 10866) | | | | | | | | | | |
| | | Aramir | 25/3/82 | 84 | 28/7/82 | 209 | 6.375 | 1 | 91 | 7.006 | |
| | | Aramir | 20/3/83 | 79 | 20/7/83 | 201 | 5.239 | 2 | 98 | 5.346 | |
| | | Aramir | 1/4/85 | 91 | 14/8/85 | 226 | 6.292 | 4 | 96 | 6.554 | |
| | | Alexis | 7/4/88 | 98 | 11/8/88 | 224 | 5.222 | 7 | 99 | 5.275 | |
| | | Alexis | 13/3/89 | 72 | 28/7/89 | 209 | 5.275 | 8 | 105 | 5.024 | |
| | | Alexis | 8/3/90 | 67 | 30/7/90 | 211 | 5.400 | 9 | | | |
| | | avearge | | 82 | | 213 | | | | | |
| France | Arras, N 50°.17', E 2°.46' (WST. 7055) | | | | | | | | | | |
| | | Triumph | 5/4/88 | 96 | 17/8/88 | 230 | 7.158 | 7 | 96 | 7.456 | |
| | | Prisma | 27/3/89 | 86 | 7/8/89 | 219 | 7.641 | 8 | 102 | 7.491 | 133 |
| | | Prisma | 7/2/90 | 38 | 25/7/90 | 206 | 7.800 | 9 | | | |
| | | average | | 73 | | 218 | | | | | |
| | Augy | | | | | | | | | | |
| | | Prisma | 17/2/90 | 48 | 3/8/90 | 215 | 5.300 | 9 | | | |
| | Chatillon, N 47°.51', E 4°.34' | | | | | | | | | | |
| | | Triumph | 11/3/87 | 70 | 15/8/87 | 227 | 5.170 | 6 | 98 | 5.275 | |
| | | Prisma | 18/3/89 | 77 | 1/7/89 | 182 | 5.704 | 8 | 102 | 5.592 | |
| | | Prisma | 8/3/90 | 67 | 5/8/90 | 217 | 5.200 | 9 | | | |
| | | average | | 71 | | 209 | | | | | |
| | Compiegne, N 49°.24', E 2°.49' | | | | | | | | | | |
| | | Triumph | 11/3/88 | 71 | 20/8/88 | 233 | 6.269 | 7 | 93 | 6.741 | |
| | | Prisma | 2/4/89 | 92 | 2/8/89 | 214 | 5.383 | 8 | 94 | 5.727 | |
| | | average | | 82 | | 224 | | | | | |
| | Issoudun, N 46°.57', E 2°.00' (WST. 7255) | | | | | | | | | | |
| | | Aramir | 3/3/82 | 62 | 16/7/82 | 197 | 4.353 | 1 | 90 | 4.837 | |
| | | Aramir | 8/3/83 | 67 | 22/7/83 | 203 | 4.470 | 2 | 93 | 4.806 | |
| | | Triumph | 28/2/84 | 59 | 27/7/84 | 209 | 6.532 | 3 | 101 | 6.467 | 151 |
| | | Triumph | 10/3/87 | 69 | 5/8/87 | 217 | 4.555 | 6 | 89 | 5.118 | |
| | | Triumph | 22/2/88 | 53 | 25/7/88 | 207 | 5.377 | 7 | 85 | 6.326 | |
| | | Prisma | 17/2/89 | 48 | 17/7/89 | 198 | 4.828 | 8 | 93 | 5.191 | |
| | | Prisma | 21/2/90 | 52 | 16/7/90 | 197 | 3.800 | 9 | | | |
| | | average | | 59 | | 204 | | | | | |
| | Maule (Yvelines), N48°55', E 1°.51' | | | | | | | | | | |
| | | Aramir | 18/3/82 | 77 | 7/8/82 | 219 | 4.639 | 1 | 89 | 5.212 | |
| | | Aramir | 15/3/83 | 74 | 3/8/83 | 215 | 4.723 | 2 | 96 | 4.920 | |
| | | Triumph | 10/3/84 | 70 | 13/8/84 | 226 | 6.121 | 3 | 100 | 6.121 | |
| | | Triumph | 14/3/85 | 73 | 5/8/85 | 217 | 3.648 | 4 | 98 | 3.722 | |
| | | Triumph | 4/4/86 | 94 | 7/8/86 | 219 | 5.542 | 5 | 106 | 5.228 | |
| | | Triumph | 13/3/87 | 72 | 6/8/87 | 218 | 4.696 | 6 | 90 | 5.218 | |
| | | Triumph | 3/3/88 | 63 | 6/8/88 | 219 | 5.516 | 7 | 95 | 5.806 | |
| | | Prisma | 14/3/89 | 73 | 25/7/89 | 206 | 3.235 | 8 | 88 | 3.676 | |
| | | Prisma | 7/3/90 | 66 | 27/7/90 | 208 | 4.600 | 9 | | | |
| | | average | | 74 | | 216 | | | | | |

| | | standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100= | FINTIM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| France | Pithiviers, N 48°.10', E 2°.15' | | | | | | | | | | |
| | | Aramir | 2/3/82 | 61 | 17/7/82 | 198 | 5.457 | 1 | 93 | 5.868 | |
| | | Aramir | 9/3/83 | 68 | 4/8/83 | 216 | 4.598 | 2 | 96 | 4.790 | |
| | | Triumph | 1/3/84 | 61 | 16/8/84 | 229 | 6.026 | 3 | 109 | 5.528 | |
| | | Triumph | 7/3/85 | 66 | 12/8/85 | 224 | 5.104 | 4 | 95 | 5.373 | |
| | | Triumph | 17/3/86 | 76 | 31/7/86 | 212 | 5.758 | 5 | 106 | 5.432 | |
| | | Triumph | 9/3/87 | 68 | 6/8/87 | 218 | 4.813 | 6 | 89 | 5.408 | |
| | | Triumph | 23/2/88 | 54 | 26/7/88 | 208 | 5.550 | 7 | 85 | 6.529 | |
| | | Prisma | 16/2/89 | 47 | 18/7/89 | 199 | 5.481 | 8 | 85 | 6.448 | |
| | | Prisma | 22/2/90 | 53 | 13/7/90 | 194 | 3.300 | 9 | | | |
| | | average | | 62 | | 211 | | | | | |
| France | Recy, N 48°.59', E 4°.18' | | | | | | | | | | |
| | | Triumph | 3/3/87 | 62 | 6/8/87 | 218 | 6.185 | 6 | 99 | 6.247 | |
| | | Triumph | 3/3/88 | 63 | 2/8/88 | 215 | 7.167 | 7 | 91 | 7.876 | |
| | | Prisma | 7/3/89 | 66 | 27/7/89 | 208 | 5.032 | 8 | 88 | 5.718 | |
| | | Prisma | 27/2/90 | 58 | 2/8/90 | 214 | 6.000 | 9 | | | |
| | | average | | 62 | | 214 | | | | | |
| Italy | | | | | | | | | | | |
| | Chianciano, N 43°.08', E 11°.09' | | | | | | | | | | |
| | | | 23/12/87 | 357 | 8/7/88 | 190 | 3.907 | 7 | 100 | 3.907 | |
| | Fabro, N 42°.40, E 12°.00' | | | | | | | | | | |
| | | Alexis | 15/12/88 | 350 | 20/7/89 | 201 | 3.641 | 8 | 105 | 3.468 | |
| | | Alexis | 20/12/89 | 354 | 5/7/90 | 186 | 5.800 | 9 | | | |
| | | average | | 352 | | 194 | | | | | |
| | La Foc. | | | | | | | | | | |
| | | Aramir | 6/12/85 | 340 | 3/7/86 | 184 | 4.263 | 5 | 93 | 4.584 | |
| | | Gimpel | 12/12/86 | 346 | 13/7/87 | 194 | 6.834 | 6 | 88 | 7.766 | |
| | | average | | 343 | | 189 | | | | | |
| | Manzia | | | | | | | | | | |
| | | Aramir | 5/12/85 | 339 | 2/7/86 | 183 | 4.170 | 5 | 96 | 4.344 | |
| | Padova, N 45°.05', E 11°.08' (WST. 16090) | | | | | | | | | | |
| | | Alexis | 6/11/87 | 310 | 28/6/88 | 180 | 5.451 | 7 | 89 | 6.125 | 236 |
| | Perugi | | | | | | | | | | |
| | | Alexis | 15/2/89 | 46 | 20/7/89 | 201 | - | 8 | - | 5.573 | |
| | Pomezia, N 41°41', E 12°.39' | | | | | | | | | | |
| | | Aramir | 20/12/81 | 354 | 14/6/82 | 165 | 4.992 | 1 | 98 | 5.094 | |
| | | Aramir | 25/11/82 | 329 | 22/6/83 | 173 | 4.179 | 2 | 89 | 4.695 | |
| | | Aramir | 7/12/83 | 341 | 29/6/84 | 181 | 4.974 | 3 | 91 | 5.466 | |
| | | average | | 341 | | 173 | | | | | |

Denmark — Hyldagergaard, N 55°.33', E 12°.10' (WST. 6180)

| standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100= | FINTIM |
|---|---|---|---|---|---|---|---|---|---|
| Aramir | 1/4/82 | 91 | 18/8/82 | 230 | 5.389 | 1 | 95 | 5.673 | |
| Aramir | 19/4/83 | 109 | 12/8/83 | 224 | 5.072 | 2 | 103 | 4.924 | |
| Triumph | 2/4/84 | 93 | 16/8/84 | 229 | 7.358 | 3 | 109 | 6.750 | |
| Triumph | 22/4/85 | 112 | 27/8/85 | 239 | 7.018 | 4 | 101 | 6.949 | 127 |
| Triumph | 11/4/86 | 101 | 18/8/86 | 230 | 6.683 | 5 | 98 | 6.819 | |
| Triumph | 24/4/87 | 114 | 16/9/87 | 259 | 5.289 | 6 | 94 | 5.627 | |
| Triumph | 15/4/88 | 106 | 14/8/88 | 227 | 5.085 | 7 | 95 | 5.353 | |
| Prisma | 30/3/89 | 89 | 9/8/89 | 221 | 6.911 | 8 | 97 | 7.125 | |
| Prisma | 28/3/90 | 87 | 8/8/90 | 220 | 6.400 | 9 | | | |
| average | | 100 | | 231 | | | | | |

Denmark — Tystofte, N 55°.15', E 11°.20' (WST. 6180)

| standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100= | FINTIM |
|---|---|---|---|---|---|---|---|---|---|
| Aramir | 2/4/82 | 92 | 4/8/82 | 216 | 5.027 | 1 | 95 | 5.292 | |
| Aramir | 20/4/83 | 110 | 17/8/83 | 229 | 4.163 | 2 | 97 | 4.292 | |
| Triumph | 17/4/84 | 108 | 15/8/84 | 228 | 3.372 | 3 | 91 | 3.705 | |
| Triumph | 19/4/85 | 109 | 9/9/85 | 252 | 6.501 | 4 | 107 | 6.076 | |
| Triumph | 22/4/86 | 112 | 21/8/86 | 233 | 5.904 | 5 | 100 | 5.904 | |
| Triumph | 5/5/87 | 125 | 4/9/87 | 247 | 5.383 | 6 | 92 | 5.851 | |
| Triumph | 13/4/88 | 104 | 15/8/88 | 228 | 5.260 | 7 | 94 | 5.596 | |
| Prisma | 30/3/89 | 89 | 10/8/89 | 222 | 7.545 | 8 | 104 | 7.255 | |
| Prisma | 26/3/90 | 85 | 7/8/90 | 219 | 7.200 | 9 | | | |
| average | | 104 | | 230 | | | | | |

Greece — Thessaloniki, N 40°.38', E 22°.50' (WST. 16622)

| standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100= | FINTIM |
|---|---|---|---|---|---|---|---|---|---|
| Aramir | 16/12/81 | 350 | 17/6/82 | 168 | 4.787 | 1 | 83 | 5.768 | 183 |
| Aramir | 9/12/82 | 343 | 20/6/83 | 171 | 3.258 | 2 | 98 | 3.324 | |
| average | | 347 | | 170 | | | | | |

Ag Mam

| standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100= | FINTIM |
|---|---|---|---|---|---|---|---|---|---|
| Aramir | 9/12/81 | 343 | 22/6/82 | 173 | 3.320 | 1 | 78 | 4.256 | |
| Aramir | 15/12/82 | 349 | 10/6/83 | 161 | 2.352 | 2 | 105 | 2.240 | |
| average | | 346 | | 167 | | | | | |

Spain — Albacete, N 39°.01', W 2°.09'

| standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100= | FINTIM |
|---|---|---|---|---|---|---|---|---|---|
| Alexis | 30/1/89 | 30 | 8/7/89 | 189 | 8.977 | 8 | 106 | 8.469 | |
| Alexis | 7/2/90 | 38 | 13/6/90 | 164 | 3.200 | 9 | | | |
| average | | 34 | | 177 | | | | | |

Burgos

| standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100= | FINTIM |
|---|---|---|---|---|---|---|---|---|---|
| Alexis | 16/2/89 | 47 | 17/7/89 | 198 | 3.523 | 8 | 101 | 3.488 | |

Granada, N 37°.12', W 3°.36'

| standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100= | FINTIM |
|---|---|---|---|---|---|---|---|---|---|
| Gimpel | 18/12/86 | 352 | 14/7/87 | 195 | 4.012 | 6 | 84 | 4.776 | |
| Alexis | 10/12/88 | 345 | 1/7/89 | 182 | 2.654 | 8 | 104 | 2.552 | |
| Alexis | 28/12/89 | 362 | 1/7/90 | 182 | 5.800 | 9 | | | |
| average | | 353 | | 186 | | | | | |

Bell Loch (Lerida), N 41°.37', E 0°.47'

| standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100= | FINTIM |
|---|---|---|---|---|---|---|---|---|---|
| Gimpel | 5/12/86 | 339 | 29/6/87 | 180 | 2.638 | 6 | 70 | 3.769 | |
| Alexis | 29/11/88 | 334 | 10/7/89 | 191 | 3.491 | 8 | 103 | 3.389 | |
| average | | 337 | | 186 | | | | | |

| | | standard variety | sowing date | J. day nr. | harvest date | J. day nr. | d.m. yield (t/ha) | reference | rel. | t/ha 100= | FINTIM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Spain | Navarra | | | | | | | | | | |
| | | Gimpel | 6/3/87 | 65 | 31/7/87 | 212 | 5.813 | 6 | 112 | 5.190 | |
| | Pamplona, N 42°.45', W 1°.40' | | | | | | | | | | |
| | | Aramir | 18/3/86 | 77 | 28/7/86 | 209 | 4.063 | 5 | 107 | 3.797 | |
| Spain | Sevilla, N 37°.25', W 6°.00' (WST. 8391) | | | | | | | | | | |
| | | Aramir | 2/12/81 | 336 | 2/6/82 | 153 | 7.256 | 1 | 98 | 7.404 | |
| | | Aramir | 25/11/82 | 329 | 28/5/83 | 148 | 6.820 | 2 | 95 | 7.179 | |
| | | Aramir | 5/12/83 | 339 | 8/6/84 | 160 | 8.614 | 3 | 100 | 8.614 | |
| | | Gimpel | 29/11/84 | 334 | 10/6/85 | 161 | 7.242 | 4 | 100 | 7.242 | 187 |
| | | Aramir | 20/11/85 | 324 | 10/6/86 | 161 | 7.080 | 5 | 96 | 7.375 | |
| | | average | | 332 | | 157 | | | | | |
| Portugal | Beja, N 38°.02', W 7°.652' | | | | | | | | | | |
| | | Aramir | 15/1/82 | 15 | 15/7/82 | 196 | 5.725 | 1 | 99 | 5.783 | |
| | | Aramir | 12/12/83 | 346 | 26/6/84 | 178 | 7.861 | 3 | 101 | 7.783 | |
| | | Gimpel | 8/1/85 | 8 | 25/7/85 | 206 | 3.931 | 4 | 89 | 4.417 | |
| | | Aramir | 6/12/85 | 340 | 23/7/86 | 204 | 3.640 | 5 | 86 | 4.232 | |
| | | Gimpel | 2/12/86 | 336 | 22/7/87 | 203 | 4.363 | 6 | 82 | 5.321 | |
| | | Alexis | 23/12/87 | 357 | 20/7/88 | 202 | - | 7 | - | 2.936 | |
| | | Alexis | 7/12/88 | 342 | 16/6/89 | 167 | 5.642 | 8 | 101 | 5.586 | |
| | | Alexis | 22/1/90 | 22 | 22/6/90 | 173 | 4.000 | 9 | | | |
| | | average | | | | 191 | | | | | |
| | Elvas, N 38°.53', W 7°.09' | | | | | | | | | | |
| | | Aramir | 23/11/81 | 327 | 9/6/82 | 160 | 4.931 | 1 | 99 | 4.981 | |
| | | Aramir | 22/11/82 | 326 | 27/6/83 | 178 | 4.223 | 2 | 103 | 4.100 | |
| | | Aramir | 2/12/83 | 336 | 27/6/84 | 179 | 7.204 | 3 | 95 | 7.583 | |
| | | Gimpel | 22/11/84 | 327 | 2/7/85 | 183 | 3.897 | 4 | 113 | 3.449 | |
| | | Aramir | 13/11/85 | 317 | 12/6/86 | 163 | 5.053 | 5 | 97 | 5.209 | |
| | | Gimpel | 19/11/86 | 323 | 9/6/87 | 160 | 4.619 | 6 | 94 | 4.914 | |
| | | Alexis | 20/11/87 | 324 | 11/7/88 | 193 | - | 7 | - | 4.398 | |
| | | Alexis | 22/11/88 | 327 | 7/6/89 | 158 | 4.324 | 8 | 105 | 4.118 | |
| | | Alexis | 11/1/90 | 11 | 15/6/90 | 160 | 3.700 | 9 | | | |
| | | average | | | | 171 | | | | | |
| | Vila Franca de Xira, N 39°.57', W 8°.57' | | | | | | | | | | |
| | | Aramir | 7/12/82 | 341 | 26/6/83 | 177 | 1.507 | 2 | 79 | 1.907 | |

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3 Schildbach R., J. Larsen, J. Hiddema & I.D.C. Duijnhouwer, 1985
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9 Sarx, H.G. & I.D.C. Duijnhouwer, 1991
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Weather station number

| | | |
|---|---|---|
| 3 649 | Brize Norton | United Kingdom |
| 3 683 | Stansted A. | United Kingdom |
| 3 969 | Dublin | Ireland |
| 6 180 | Kobenhavn/Kastrup | Denmark |
| 6 260 | De Bilt | the Netherlands |
| 6 370 | Eindhoven | the Netherlands |
| 6 447 | Uccle | Belgium |
| 7 055 | Beauvais | France |
| 7 255 | Bourges | France |
| 8 391 | Sevilla/San Pablo | Spain |
| 10 763 | Nurnberg | Germany |
| 10 866 | Munchen-Riem | Germany |
| 16 090 | Verona/Villafranc | Italy |
| 16 622 | Thessaloniki/Mikr | Greece |

# Appendix C3:

# Region specific data of spring barley

Table C3a Occurrence of sowing, flowering and maturity day of spring barley grown in regions within countries of the European Community.
J. day nr. = Julian day number.

| crop type | country | NUTS codes per region | sowing J. day nr. | flowering J. day nr. | maturity J. day nr. |
|---|---|---|---|---|---|
| 0301 | Germany | R18, R19 | 85 | 160 | 200 |
| | Germany | R11 without R18 and R19 | 80 | 160 | 215 |
| | Denmark | R9 | 80 | 171 | 222 |
| | the Netherlands | R4 | 75 | 166 | 227 |
| | Belgium | R5 | 75 | 160 | 227 |
| | Luxembourg | R6 | 75 | 130 | 196 |
| | United Kingdom | R7 | 75 | 160 | 253 |
| | Ireland | R8 | 75 | 161 | 253 |
| | France N, C | R21, R22, R23, R24, R25 | 75 | 145 | 210 |
| | Spain N | RB1, RB2, RB3, RB4 | 60 | 135 | 193 |
| | France S | R26, R27, R28 | 50 | 130 | 186 |
| | Italy N | R31, R32, R33, R34, R35, R36 | 50 | 130 | 186 |
| | Italy S | R37, R39, R3A, R3B | 45 | 140 | 201 |
| | Portugal | RC | 45 | - | - |
| | Spain S | RB5,RB6 | 40 | 135 | 191 |
| | Greece | RA | 40 | 140 | 201 |

Table C3b Calibrated parameters of the initial crop-specific data file (Appendix C1) of barley.

| | | | | |
|---|---|---|---|---|
| ** emergence | | | | |
| TBASEM | = | 3.0 | | ! lower threshold temp. for emergence [C°] |
| TSUMEM | = | 110. | | ! temperature sum from sowing to emergence [C° d] |
| ** phenology | | | | |
| TSUM1 | = | 800. | | ! temperature sum from emergence to anthesis [C° d] |
| TSUM2 | = | 750. | | ! temperature sum from anthesis to maturity [C° d] |
| DTSMTB | = | 0.00, | 0.00, | ! daily increase in temp. sum |
| | | 35.00, | 35.00, | ! as function of av. temp. [C°; C° d] |
| | | 45.00, | 35.00 | |
| ** initial | | | | |
| TDW | = | 50.00 | | ! initial total crop dry weight [kg $ha^{-1}$] |
| ** green area | | | | |
| SLATB | = | 0.00, | 0.0020, | ! specific leaf area |
| | | 0.29, | 0.0055, | ! as a function of DVS [-; ha $kg^{-1}$] |
| | | 0.91, | 0.0029, | |
| | | 1.46, | 0.0022, | |
| | | 2.00, | 0.0022 | |
| SPAN | = | 20. | | ! life span of leaves growing at 35 C° [d] |
| ** assimilation | | | | |
| KDIF | = | 0.440 | | ! extinction coefficient for diffuse visible light [-] |
| EFF | = | 0.34 | | ! light-use effic. single leaf [kg $ha^{-1}$ $hr^{-1}$ $J^{-1}$ $m^2$ s] |
| AMAXTB | = | 0.00, | 36.00, | ! maximum leaf CO2 assimilation rate |
| | | 1.21, | 36.00, | ! as function of DVS [-; kg $ha^{-1}$ $hr^{-1}$] |
| | | 2.00, | 12.00 | |
| TMPFTB | = | 0.00, | 0.00, | ! reduction factor of AMAX |
| | | 10.00, | 1.00, | ! as function of av. temp. [C°; -] |
| | | 30.00, | 1.00, | |
| | | 35.00, | 1.00 | |
| ** conversion of assimilates into biomass | | | | |
| CVL | = | 0.720 | | ! efficiency of conversion into leaves [kg $kg^{-1}$] |
| CVO | = | 0.740 | | ! efficiency of conversion into storage org. [kg $kg^{-1}$] |
| CVR | = | 0.720 | | ! efficiency of conversion into roots [kg $kg^{-1}$] |
| CVS | = | 0.690 | | ! efficiency of conversion into stems [kg $kg^{-1}$] |
| ** maintenance respiration | | | | |
| RML | = | 0.030 | | ! rel. maint. resp. rate leaves [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RMO | = | 0.007 | | ! rel. maint. resp. rate stor.org. [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RMR | = | 0.010 | | ! rel. maint. resp. rate roots [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RMS | = | 0.015 | | ! rel. maint. resp. rate stems [kg CH2O $kg^{-1}$ $d^{-1}$] |

```
** partitioning
FRTB      = 0.00,    0.70,    ! fraction of total dry matter to roots
            0.33,    0.50,    ! as a function of DVS [-; kg kg-1]
            1.00,    0.00,
            2.00,    0.00
FLTB      = 0.00,    1.00,    ! fraction of above-gr. dry matter to leaves
            0.33,    1.00,    ! as a function of DVS [-; kg kg-1]
            0.80,    0.30,
            1.00,    0.00,
            2.00,    0.00
FSTB      = 0.00,    0.00,    ! fraction of above-gr. dry matter to stems
            0.33,    0.00,    ! as a function of DVS [-; kg kg-1]
            0.80,    0.70,
            1.00,    0.50,
            1.01,    0.00,
            2.00,    0.00
FOTB      = 0.00,    0.00,    ! fraction of above-gr. dry matter to stor. org.
            0.80,    0.00,    ! as a function of DVS [-; kg kg-1]
            1.00,    0.50,
            1.01,    1.00,
            2.00,    1.00

** rooting
RDI       = 10.               ! initial rooting depth [cm]
```

# Appendix C4:

## Crop calendar of spring barley

Table C4. Sowing, flowering and maturity day (Julian day number) and calculated temperature sums of barley for regions within the European Community. Each NUTS region contains several grid cells. The temperture sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calculated temperature sum from emergence to flowering, base temperature of 0°C.
TSUM2 = calculated temperature sum from flowering to harvest, base temperature of 0°C.
J. day nr. = Julian day number

| NUTS code | grid cell | sowing J. day nr. | flowering J. day nr. | harvest J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|---|
| R11 | 4135 | 90 | 171 | 222 | 906 | 886 | Germany | Schleswig-Holstein | 1 |
| R12 | 4035 | 90 | 171 | 222 | 906 | 883 | | Hamburg | 1 |
| R13 | 3834 | 95 | 156 | 212 | 648 | 936 | | Niedersachen | 1 |
| R14 | 3933 | 95 | 156 | 212 | 663 | 939 | | Bremen | 1 |
| R15 | 3531 | 95 | 156 | 212 | 711 | 983 | | Nordrhein-Westfalen | 1 |
| R16 | 3333 | 79 | 156 | 227 | 837 | 1296 | | Hessen | 1 |
| R17 | 3231 | 79 | 156 | 227 | 750 | 1190 | | Rheinland-Pfalz | 1 |
| R18 | 2934 | 79 | 156 | 227 | 802 | 1271 | | Baden-Württemberg | 1 |
| R19 | 3037 | 85 | 161 | 196 | 791 | 592 | | Bayern | 1 |
| R1A | 3030 | 64 | 130 | 196 | 509 | 1028 | | Saarland | 1 |
| R1B | 3839 | 95 | 156 | 212 | 730 | 1041 | | Berlin (West) | 1 |
| R21 | 2924 | 64 | 130 | 196 | 606 | 1082 | France | Île de France | 1 |
| R22 | 3125 | 85 | 166 | 227 | 1004 | 1134 | | Picardie | 1 |
| R221 | 3127 | 64 | 130 | 196 | 581 | 1076 | | Champagne-Ardenne | 1 |
| R223 | 3222 | 51 | 156 | 222 | 948 | 1095 | | Haute-Normandie | 1 |
| R224 | 2722 | 64 | 130 | 196 | 622 | 1091 | | Centre | 1 |
| R225 | 3019 | 51 | 156 | 222 | 1006 | 1151 | | Basse-Normandie | 1 |
| R226 | 2527 | 64 | 130 | 196 | 620 | 1149 | | Bourgogne | 1 |
| R23 | 3325 | 85 | 166 | 227 | 943 | 1082 | | Nord, Pas de Calais | 1 |
| R24 | 2629 | 64 | 130 | 196 | 610 | 1135 | | Est | 1 |
| R251 | 2618 | 51 | 156 | 222 | 1163 | 1262 | | Pays de la Loire | 1 |
| R252 | 3015 | 51 | 156 | 222 | 984 | 1082 | | Bretagne | 1 |
| R28 | 1827 | 36 | 130 | 186 | 1034 | 1115 | | Mediterranée | 1 |
| R31 | 2132 | 36 | 130 | 186 | 958 | 1043 | Italy | Nord Ovest | 1 |
| R32 | 2235 | 36 | 130 | 186 | 942 | 1158 | | Lombardia | 1 |
| R33 | 2339 | 36 | 130 | 186 | 944 | 1161 | | Nord Est | 1 |
| R34 | 2037 | 36 | 130 | 186 | 944 | 1168 | | Emilia-Romagna | 1 |
| R35 | 1637 | 31 | 130 | 181 | 1070 | 929 | | Centro W | 1 |
| R35 | 1741 | 31 | 130 | 181 | 1052 | 992 | | Centro E | 1 |
| R36 | 1430 | 31 | 130 | 181 | -1 | -1 | | Lazio | 1 |
| R37 | 1242 | 31 | 130 | 181 | 1425 | 1107 | | Campania | 1 |
| R38 | 1542 | 31 | 130 | 181 | 1194 | 1051 | | Abruzzi-Molise | 1 |
| R39 | 1345 | 59 | 140 | 201 | 1146 | 1407 | | Sud | 1 |
| R3A | 540 | 59 | 140 | 201 | 1255 | 1416 | | Sicilia | 1 |
| R3B | 1234 | 31 | 130 | 181 | 1043 | 908 | | Sardegna | 1 |
| R4 | 3830 | 85 | 166 | 227 | 888 | 1036 | the Nederlands | | 1 |
| R501 | 3528 | 85 | 166 | 227 | 962 | 1093 | Belgium | Antwerpen | 1 |
| R502 | 3427 | 85 | 166 | 227 | 1043 | 1158 | | Brabant | 1 |
| R503 | 3326 | 85 | 166 | 227 | 969 | 1106 | | Hainaut | 1 |
| R504 | 3329 | 79 | 156 | 227 | 794 | 1234 | | Liege | 1 |
| R505 | 3429 | 85 | 166 | 227 | 968 | 1105 | | Limburg | 1 |
| R506 | 3228 | 79 | 156 | 227 | 765 | 1208 | | Luxembourg | 1 |
| R507 | 3327 | 79 | 156 | 227 | 747 | 1172 | | Namur | 1 |
| R508 | 3426 | 85 | 166 | 227 | 937 | 1073 | | Oost-Vlaanderen | 1 |
| R509 | 3525 | 85 | 166 | 227 | 881 | 1024 | | West-Vlaanderen | 1 |
| R6 | 3129 | 64 | 130 | 196 | 510 | 1023 | Luxembourg | | 1 |
| R71 | 4419 | 51 | 161 | 217 | 532 | 686 | UK | North | 1 |
| R711 | 4320 | 90 | 201 | 263 | 1209 | 900 | | Cleveland, Durham | 1 |
| R712 | 4318 | 51 | 161 | 253 | 681 | 1226 | | Cumbria | 1 |
| R713 | 4520 | 90 | 201 | 263 | 1264 | 940 | | Northumberland, Tyne and Wear | 1 |
| R72 | 4220 | 51 | 161 | 217 | 852 | 849 | | Yorkshire and Humberside | 1 |
| R73 | 3920 | 51 | 161 | 217 | 838 | 855 | | East Midlands | 1 |
| R74 | 3822 | 79 | 151 | 222 | 604 | 1067 | | East Anglia | 1 |
| R75 | 3620 | 79 | 151 | 222 | 615 | 1070 | | South East | 1 |
| R761 | 3718 | 51 | 161 | 217 | 857 | 855 | | Avon, Gloucestershire, Wiltshire | 1 |
| R762 | 3515 | 51 | 156 | 222 | 752 | 915 | | Cornwall, Devon | 1 |

Table C4. Sowing, flowering and maturity day (Julian day number) and calculated temperature sums of barley for regions within the European Community. Each NUTS region contains several grid cells. The temperture sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calculated temperature sum from emergence to flowering, base temperature of 0°C.
TSUM2 = calculated temperature sum from flowering to harvest, base temperature of 0°C.
J. day nr. = Julian day number

| NUTS code | grid cell | sowing J. day nr. | flowering J. day nr. | harvest day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|---|
| R763 | 3617 | 51 | 156 | 222 | 872 | 1013 | UK | Dorset, Somerset | 1 |
| R77 | 3918 | 51 | 161 | 217 | 771 | 820 | | West Midlands | 1 |
| R78 | 4118 | 51 | 161 | 253 | 843 | 1356 | | North West | 1 |
| R791 | 3815 | 51 | 161 | 253 | 957 | 1436 | | Clwyd, Dyfed, Gwynedd,Powys | 1 |
| R792 | 3716 | 51 | 156 | 222 | 868 | 1007 | | Gwent, Glamorgan | 1 |
| R7A1 | 4718 | 90 | 201 | 263 | 1185 | 889 | | Borders c. Fife Lothanian Tayside | 1 |
| R7A2 | 4516 | 51 | 161 | 253 | 738 | 1210 | | Dumfries & Galloway, Strathclyde | 1 |
| R7A4 | 4916 | 90 | 201 | 263 | 900 | 693 | | Grampian | 1 |
| R7B | 4514 | 51 | 161 | 253 | 890 | 1324 | Northern Ireland | | 1 |
| R8 | 4211 | 51 | 161 | 253 | 835 | 1264 | Ireland | | 1 |
| R9 | 4534 | 90 | 171 | 222 | 777 | 800 | Denmark | | 1 |
| RA | 1156 | 59 | 140 | 201 | 1025 | 1384 | Greece | | 1 |
| RB41 | 1610 | 31 | 135 | 196 | 933 | 1089 | Spain | Castilla-Leon | 1 |
| RB2 | 1517 | 31 | 135 | 196 | 1171 | 1272 | | Noroeste | 1 |
| RB5 | 1421 | 59 | 135 | 191 | 771 | 995 | | Este | 1 |

Reference

1 Russell, G., 1990
Barley knowledge base, Joint Research Centre, 135 p.

-1 means: no data available or no barley grown

# Appendix D:

## Rice (*Oryza sativa* L.)

# Appendix D1:
# Initial crop-specific data of rice

CROP DATA FILE for use with WOFOST Version 5.4, June 1992

```
crop identity
!CRPNAM    = Rice  (Oryza sativa L.)

** emergence
TBASEM     =   8.0                   ! lower threshold temp. for emergence [C°]
TEFFMX     =  22.0                   ! max. eff. temp. for emergence [C°]
TSUMEM     = 100.                    ! temperature sum from sowing to emergence [C° d]

** phenology
IDSL       = 0                       ! indicates whether pre-anthesis development depends
                                     ! on temp. (=0), daylength (=1) , or both (=2)
DLO        = -99.0                   ! optimum daylength for development [hr]
DLC        = -99.0                   ! critical daylength (lower threshold) [hr]
TSUM1      = 875.                    ! temperature sum from emergence to anthesis [C° d]
TSUM2      = 625.                    ! temperature sum from anthesis to maturity [C° d]
DTSMTB     =  0.00,     0.00,        ! daily increase in temp. sum
             10.00,     0.00,        ! as function of av. temp. [C°; C° d]
             25.00,    15.00
DVSEND     = 2.00                    ! development stage at harvest (= 2.0 at maturity [-])

** initial
TDW        = 55.00                   ! initial total crop dry weight [kg ha-1]
LAIEM      =  0.08                   ! leaf area index at emergence [ha ha-1]
RGRLAI     =  0.0070                 ! maximum relative increase in LAI [ha ha-1 d-1]

** green area
SLATB      = 0.00,    0.0022,        ! specific leaf area
             0.60,    0.0022,        ! as a function of DVS [-; ha kg-1]
             1.00,    0.0022,
             2.00,    0.0022
SPA        =  0.000                  ! specific pod area [ha kg-1]
SSA        =  0.000                  ! specific stem area [ha kg-1]
SPAN       = 50.                     ! life span of leaves growing at 35 C° [d]
TBASE      =  0.0                    ! lower threshold temp. for ageing of leaves [C°]

** assimilation
KDIF       = 0.60                    ! extinction coefficient for diffuse visible light [-]
EFF        = 0.45                    ! light-use effic. single leaf [kg ha-1 hr-1 J-1 m2 s]
```

```
AMAXTB   =  0.00,    40.00,   ! maximum leaf CO2 assimilation rate
            1.00,    40.00,   ! as function of DVS [-; kg ha-1 hr-1]
            1.30,    40.00,
            2.00,    40.00
TMPFTB   =  0.00,    0.01,    ! reduction factor of AMAX
           10.00,    0.00,    ! as function of av. temp. [C°; -]
           25.00,    1.00,
           35.00,    1.00,
           42.00,    0.00
TMNFTB   =  0.00,    0.00,    ! red. factor of gross assim. rate
            3.00,    1.00     ! as function of low min. temp. [C°; -]

** conversion of assimilates into biomass
CVL      =  0.754             ! efficiency of conversion into leaves [kg kg-1]
CVO      =  0.684             ! efficiency of conversion into storage org. [kg kg-1]
CVR      =  0.754             ! efficiency of conversion into roots [kg kg-1]
CVS      =  0.754             ! efficiency of conversion into stems [kg kg-1]

** maintenance respiration
Q10      =  2.0               ! rel. incr. in resp. rate per 10 C°temp. incr. [-]
RML      =  0.0300            ! rel. maint. resp. rate leaves [kg CH2O kg-1 d-1]
RMO      =  0.0150            ! rel. maint. resp. rate stor.org. [kg CH2O kg-1 d-1]
RMR      =  0.0150            ! rel. maint. resp. rate roots [kg CH2O kg-1 d-1]
RMS      =  0.0200            ! rel. maint. resp. rate stems [kg CH2O kg-1 d-1]
RFSETB   =  0.00,    1.00,    ! red. factor for senescence
            2.00,    1.00     ! as function of DVS [-; -]
** partitioning
FRTB     =  0.00,    0.20,    ! fraction of total dry matter to roots
            0.50,    0.20,    ! as a function of DVS [-; kg kg-1]
            0.80,    0.15,
            1.00,    0.15,
            1.10,    0.00,
            2.00,    0.00
FLTB     =  0.00,    0.40,    ! fraction of above-gr. DM to leaves
            0.50,    0.35,    ! as a function of DVS [-; kg kg-1]
            0.85,    0.18,
            0.90,    0.15,
            1.00,    0.00,
            1.10,    0.00,
            2.00,    0.00
FSTB     =  0.00,    0.60,    ! fraction of above-gr. DM to stems
            0.50,    0.65,    ! as a function of DVS [-; kg kg-1]
            0.85,    0.82,
            0.90,    0.55,
            1.00,    0.25,
            1.10,    0.15,
            1.20,    0.00,
            2.00,    0.00
```

```
FOTB      = 0.85,    0.00,     ! fraction of above-gr. DM to stor. org.
            0.90,    0.30,     ! as a function of DVS [-; kg kg-1]
            1.00,    0.75,
            1.10,    0.85,
            1.20,    1.00,
            2.00,    1.00

** death rates
PERDL     = 0.030              ! max. rel. death rate of leaves due to water stress
RDRRTB    = 0.00,    0.000,    ! rel. death rate of stems
            1.50,    0.000,    ! as a function of DVS [-; kg kg-1 d-1]
            1.5001,  0.020,
            2.00,    0.020
RDRSTB    = 0.00,    0.000,    ! rel. death rate of roots
            1.50,    0.000,    ! as a function of DVS [-; kg kg-1 d-1]
            1.5001,  0.020,
            2.00,    0.020

** water use
CFET      = 1.00               ! correction factor transpiration rate [-]
DEPNR     = 3.5                ! crop group number for soil water depletion [-]
IAIRDU    = 1                  ! air ducts in roots present (=1) or not (=0)

** rooting
RDI       = 10.                ! initial rooting depth [cm]
RRI       =  1.2               ! maximum daily increase in rooting depth [cm d-1]
RDMCR     = 80.                ! maximum rooting depth [cm]

** nutrients
** maximum and minimum concentrations of N, P, and K in storage organsin vegetative organs
   [kg kg-1]
NMINSO    = 0.0090 ; NMINVE  =  0.0032
NMAXSO    = 0.0270 ; NMAXVE  =  0.0110
PMINSO    = 0.0011 ; PMINVE  =  0.0003
PMAXSO    = 0.0040 ; PMAXVE  =  0.0016
KMINSO    = 0.0025 ; KMINVE  =  0.0070
KMAXSO    = 0.0075 ; KMAXVE  =  0.0280
YZERO     = 200.               ! max. amount veg. organs at zero yield [kg ha-1]
NFIX      = 0.00               ! fraction of N-uptake from biol. fixation [kg kg-1]
```

# Appendix D3:

## Region specific data of rice

Table D3a Occurrence of planting, flowering and maturity/harvest day of rice grown in regions within countries of the European Community.
J. day nr. = Julian day number.

| crop type | country | NUTS codes of region | planting J. day nr. | flowering J. day nr. | maturity J. day nr. |
|---|---|---|---|---|---|
| 0501 | France | R28 | 126 | 238 | 288 |
| | Italy | R3, R3A, R3B | 126 | 238 | 288 |
| | Greece | RA | 135 | 258 | 258 |
| | Spain | RB2 | 135 | 217 | 288 |
| | Spain | RB2 - RB6 | 135 | 238 | 288 |

## Appendix D4:

## Crop calendar of rice

Table D4. Planting, flowering and maturity day (Julian day number) of rice for regions within the European Community.
No temperature sums are calculated for rice.
J. day nr. = Julian day number

| NUTS code | planting J. day nr. | flowering J. day nr. | maturity day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|
| R11 | -1 | -1 | -1 | -1 | -1 | Germany | Schleswig-Holstein | 1 |
| R12 | -1 | -1 | -1 | -1 | -1 | | Hamburg | 1 |
| R13 | -1 | -1 | -1 | -1 | -1 | | Niedersachsen | 1 |
| R14 | -1 | -1 | -1 | -1 | -1 | | Bremen | 1 |
| R15 | -1 | -1 | -1 | -1 | -1 | | Nordrhein-Westfalen | 1 |
| R16 | -1 | -1 | -1 | -1 | -1 | | Hessen | 1 |
| R17 | -1 | -1 | -1 | -1 | -1 | | Rheinland-Pfalz | 1 |
| R18 | -1 | -1 | -1 | -1 | -1 | | Baden-Württemberg | 1 |
| R19 | -1 | -1 | -1 | -1 | -1 | | Bayern | 1 |
| R1A | -1 | -1 | -1 | -1 | -1 | | Saarland | 1 |
| R21 | -1 | -1 | -1 | -1 | -1 | France | Île de France | 1 |
| R22 | -1 | -1 | -1 | -1 | -1 | | Bassin Parisien | 1 |
| R23 | -1 | -1 | -1 | -1 | -1 | | Nord - Pas-de-Calais | 1 |
| R24 | -1 | -1 | -1 | -1 | -1 | | Est | 1 |
| R25 | -1 | -1 | -1 | -1 | -1 | | Ouest | 1 |
| R26 | -1 | -1 | -1 | -1 | -1 | | Sud-Ouest | 1 |
| R27 | -1 | -1 | -1 | -1 | -1 | | Centre-Est | 1 |
| R28 | 126 | 238 | 288 | -1 | -1 | | Mediterranée | 2 |
| R31 | 126 | 238 | 288 | -1 | -1 | Italy | Nord Ovest | 1 |
| R32 | 126 | 238 | 288 | -1 | -1 | | Lombardia | 1 |
| R33 | 126 | 238 | 288 | -1 | -1 | | Nord Est | 1 |
| R34 | 126 | 238 | 288 | -1 | -1 | | Emilia-Romagna | 1 |
| R35 | 126 | 238 | 288 | -1 | -1 | | Centro | 1 |
| R36 | 126 | 238 | 288 | -1 | -1 | | Lazio | 1 |
| R37 | 126 | 238 | 288 | -1 | -1 | | Campania | 1 |
| R38 | 126 | 238 | 288 | -1 | -1 | | Abruzzi-Molise | 1 |
| R39 | 126 | 238 | 288 | -1 | -1 | | Sud | 1 |
| R3A | 126 | 238 | 288 | -1 | -1 | | Sicilia | 1 |
| R3B | 126 | 238 | 288 | -1 | -1 | | Sardegna | 1 |
| R41 | -1 | -1 | -1 | -1 | -1 | the Netherlands | Noord-Nederland | 1 |
| R42 | -1 | -1 | -1 | -1 | -1 | | Oost-Nederland | 1 |
| R45 | -1 | -1 | -1 | -1 | -1 | | Zuid-Nederland | 1 |
| R47 | -1 | -1 | -1 | -1 | -1 | | West-Nederland | 1 |
| R51 | -1 | -1 | -1 | -1 | -1 | Belgium | Vlaams Gewest | 1 |
| R52 | -1 | -1 | -1 | -1 | -1 | | Region Wallone | 1 |
| R53 | -1 | -1 | -1 | -1 | -1 | | Brussel | 1 |
| R6 | -1 | -1 | -1 | -1 | -1 | Luxembourg | | 1 |
| R71 | -1 | -1 | -1 | -1 | -1 | United Kingdom | North | 1 |
| R72 | -1 | -1 | -1 | -1 | -1 | | Yorkshire and Humberside | 1 |
| R73 | -1 | -1 | -1 | -1 | -1 | | East Midlands | 1 |
| R74 | -1 | -1 | -1 | -1 | -1 | | East Anglia | 1 |
| R75 | -1 | -1 | -1 | -1 | -1 | | South East | 1 |
| R76 | -1 | -1 | -1 | -1 | -1 | | South West | 1 |
| R77 | -1 | -1 | -1 | -1 | -1 | | West Midlands | 1 |
| R78 | -1 | -1 | -1 | -1 | -1 | | North West | 1 |
| R79 | -1 | -1 | -1 | -1 | -1 | | Wales | 1 |
| R7A | -1 | -1 | -1 | -1 | -1 | | Scotland | 1 |
| R7B | -1 | -1 | -1 | -1 | -1 | | Northern Ireland | 1 |
| R8 | -1 | -1 | -1 | -1 | -1 | Ireland | | 1 |
| R9 | -1 | -1 | -1 | -1 | -1 | Denmark | | 1 |
| RA1 | 135 | 217 | 258 | -1 | -1 | Greece | Voreia Ellada | 1 |
| RA2 | 135 | 217 | 258 | -1 | -1 | | Kentriki Ellada | 1 |
| RA3 | 135 | 217 | 258 | -1 | -1 | | Attiki | 1 |
| RA4 | 135 | 217 | 258 | -1 | -1 | | Nisia | 1 |

Table D4. Planting, flowering and maturity day (Julian day number) of rice for regions within the European Community.
No temperature sums are calculated for rice.
J. day nr. = Julian day number

| NUTS code | planting J. day nr. | flowering J. day nr. | maturity day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|
| RB1 | 135 | 217 | 258 | -1 | -1 | Spain | Noroeste | 1 |
| RB2 | 135 | 217 | 288 | -1 | -1 | | Noreste | 1 |
| RB3 | 135 | 238 | 288 | -1 | -1 | | Madrid | 1 |
| RB4 | 135 | 238 | 288 | -1 | -1 | | Centro | 1 |
| RB5 | 135 | 238 | 288 | -1 | -1 | | Este | 1 |
| RB6 | 135 | 238 | 288 | -1 | -1 | | Sur | 1 |
| RC1 | -1 | -1 | -1 | -1 | -1 | Portugal | Continente | 1 |

References

1 Narciso, G., P. Ragi, A. Venturi, 1992.
Agrometeorological aspects of crops in Italy, Spain and Greece.
A summary review for common wheat, durum wheat, barley, maize, rice, sugar beet, sunflower, soya bean, rape, potato, cotton, olive and grape crops.
Joint Research Centre, Commision of the European Communities, Luxembourg, Aquater, 438 p.

2 Eurostat, 1989.
EUROSTAT Agriculture Statistical Yearbook, 5A, Luxembourg.

-1 means: no data available or no rice grown

# Appendix E:

## Sugar beet (*Beta vulgaris* L.)

# Appendix E1:
## Initial crop-specific data file of sugar beet

CROP DATA FILE for use with WOFOST Version 5.0, January 1990

crop identity
!CRPNAM = SUGARBEET (SSU.SAV), sugar beet (*Beta vulgaris* L.)
ICROP = 5

| | | | | |
|---|---|---|---|---|
| ** emergence | | | | |
| TBASEM | = | 3.0 | | ! lower threshold temp. for emergence [C°] |
| TEFFMX | = | 20.0 | | ! max. eff. temp. for emergence [C°] |
| TSUMEM | = | 90. | | ! temperature sum from sowing to emergence [C° d] |
| ** phenology | | | | |
| IDSL | = | 0 | | ! indicates whether pre-anthesis development depends |
| | | | | ! on temp. (=0), daylength (=1) , or both (=2) |
| DLO | = | -99.0 | | ! optimum daylength for development [hr] |
| DLC | = | -99.0 | | ! critical daylength (lower threshold) [hr] |
| TSUM1 | = | 365. | | ! temperature sum from emergence to anthesis [C° d] |
| TSUM2 | = | 1622. | | ! temperature sum from anthesis to maturity [C° d] |
| DTSMTB | = | 0.00, | 0.00, | ! daily increase in temp. sum |
| | | 3.00, | 0.00, | ! as function of av. temp. [C°; C° d] |
| | | 21.00, | 18.00 | |
| | | 35.00, | 18.00 | |
| DVSEND | = | 3.00 | | ! development stage at harvest (= 2.0 at maturity [-]) |
| ** initial | | | | |
| TDWI | = | 0.51 | | ! initial total crop dry weight [kg $ha^{-1}$] |
| LAIEM | = | 0.0007 | | ! leaf area index at emergence [ha $ha^{-1}$] |
| RGRLAI | = | 0.0160 | | ! maximum relative increase in LAI [ha $ha^{-1}$ $d^{-1}$] |
| ** green area | | | | |
| SLATB | = | 0.00, | 0.0020, | ! specific leaf area |
| | | 2.00, | 0.0020, | ! as a function of DVS [-; ha $kg^{-1}$] |
| SPA | = | 0.000 | | ! specific pod area [ha $kg^{-1}$] |
| SSA | = | 0.000 | | ! specific stem area [ha $kg^{-1}$] |
| SPAN | = | 35. | | ! life span of leaves growing at 35 C° [d] |
| TBASE | = | 3.0 | | ! lower threshold temp. for ageing of leaves [C°] |
| ** assimilation | | | | |
| KDIF | = | 0.690 | | ! extinction coefficient for diffuse visible light [-] |
| EFF | = | 0.45 | | ! light-use effic. single leaf [kg $ha^{-1}$ $hr^{-1}$ $J^{-1}$ $m^2$ s] |

```
AMAXTB   =  0.00,   22.50,   ! maximum leaf CO2 assimilation rate
            1.00,   45.00,   ! as function of DVS [-; kg ha-1 hr-1]
            1.13,   45.00
            1.80,   36.00
            2.00,   36.00

TMPFTB   =   0.00,  0.01,    ! reduction factor of AMAX
             3.00,  0.60,    ! as function of av. temp. [C°; -]
            10.00,  0.80,
            15.00,  1.00,
            20.00,  1.00
            30.00,  0.95
            35.00,  0.83
            40.00,  0.60

TMNFTB   =  0.00,   0.00,    ! red. factor of gross assim. rate
            3.00,   1.00     ! as function of low min. temp. [C°; -]

** conversion of assimilates into biomass
CVL      =  0.720            ! efficiency of conversion into leaves [kg kg-1]
CVO      =  0.820            ! efficiency of conversion into storage org. [kg kg-1]
CVR      =  0.720            ! efficiency of conversion into roots [kg kg-1]
CVS      =  0.690            ! efficiency of conversion into stems [kg kg-1]

** maintenance respiration
Q10      =  2.0              ! rel. incr. in resp. rate per 10 C°temp. incr. [-]
RML      =  0.0300           ! rel. maint. resp. rate leaves [kg CH2O kg-1 d-1]
RMO      =  0.0030           ! rel. maint. resp. rate stor.org. [kg CH2O kg-1 d-1]
RMR      =  0.0150           ! rel. maint. resp. rate roots [kg CH2O kg-1 d-1]
RMS      =  0.0150           ! rel. maint. resp. rate stems [kg CH2O kg-1 d-1]
RFSETB   =  0.00,   1.00,    ! red. factor for senescence
            2.00,   1.00     ! as function of DVS [-; -]

** partitioning
FRTB     =  0.00,   0.20,    ! fraction of total dry matter to roots
            0.91,   0.29,    ! as a function of DVS [-; kg kg-1]
            1.00,   0.30,
            1.05,   0.17,
            1.15,   0.15,
            1.24,   0.11,
            1.29,   0.09,
            1.30,   0.09,
            1.57,   0.08,
            1.92,   0.01
            2.00,   0.02
```

```
FLTB     =  0.00,    0.85,    ! fraction of above-gr. DM to leaves
            0.91,    0.85,    ! as a function of DVS [-; kg kg-1]
            1.00,    0.80,
            1.05,    0.55,
            1.15,    0.34,
            1.24,    0.10,
            1.29,    0.06,
            1.30,    0.06,
            1.57,    0.05,
            2.00,    0.05
FSTB     =  0.00,    0.15,    ! fraction of above-gr. DM to stems
            0.91,    0.15,    ! as a function of DVS [-; kg kg-1]
            1.00,    0.20,
            1.05,    0.25,
            1.15,    0.37,
            1.24,    0.45,
            1.29,    0.35,
            1.30,    0.20
            1.57,    0.10,
            1.92,    0.05,
            2.00,    0.05
FOTB     =  0.00,    0.00,    ! fraction of above-gr. DM to stor. org.
            1.00,    0.00,    ! as a function of DVS [-; kg kg-1]
            1.05,    0.20,
            1.15,    0.29,
            1.24,    0.45,
            1.29,    0.59,
            1.30,    0.74
            1.57,    0.85,
            1.92,    0.90,
            2.00,    0.90

** death rates
PERDL    =  0.030             ! max. rel. death rate of leaves due to water stress
RDRRTB   =  0.00,    0.000,   ! rel. death rate of stems
            1.50,    0.000,   ! as a function of DVS [-; kg kg-1 d-1]
            1.5001,  0.020,
            2.00,    0.020
RDRSTB   =  0.00,    0.000,   ! rel. death rate of roots
            1.50,    0.000,   ! as a function of DVS [-; kg kg-1 d-1]
            1.5001,  0.020,
            2.00,    0.020

** water use
CFET     =  1.00              ! correction factor transpiration rate [-]
DEPNR    =  2.0               ! crop group number for soil water depletion [-]
IAIRDU   =  0                 ! air ducts in roots present (=1) or not (=0)
```

```
** rooting
RDI       =  10.              ! initial rooting depth [cm]
RRI       =   1.2             ! maximum daily increase in rooting depth [cm d-1]
RDMCR     = 120.              ! maximum rooting depth [cm]

** nutrients
** maximum and minimum concentrations of N, P, and K in storage organsin vegetative organs
   [kg kg-1]
NMINSO    = 0.0060 ;  NMINVE  =  0.0180
NMAXSO    = 0.0130 ;  NMAXVE  =  0.0280
PMINSO    = 0.0008 ;  PMINVE  =  0.0015
PMAXSO    = 0.0018 ;  PMAXVE  =  0.0032
KMINSO    = 0.0060 ;  KMINVE  =  0.0180
KMAXSO    = 0.0130 ;  KMAXVE  =  0.0360
YZERO     = 0.                ! max. amount veg. organs at zero yield [kg ha-1]
NFIX      = 0.00              ! fraction of N-uptake from biol. fixation [kg kg-1]
```

# Appendix E2:

## Field experiment data of sugar beet

Appendix E2a. Field experiment data of optimal irrigated or not irrigated sugar beet of the PAGV at Lelystad, the Netherlands, 1983.

Table E2a. Total dry matter, dry matter beet yield, sugar percentage of fresh and dry matter of irrigated and not irrigated fields of PAGV experimental station at Lelystad, the Netherlands, during the growing season of 1983, measured from figures (de Jonge, 1989).
J. day nr. = Julian day number

| | | optimal irrigation | | | | no irrigation | | | |
|---|---|---|---|---|---|---|---|---|---|
| date | J. day nr. | total dm yield t/ha | dm yield beet t/ha | sugar % fresh | sugar % dry | total dm yield t/ha | dm yield beet t/ha | sugar % fresh | sugar % dry |
| 5/5/83 | 125 | 0.00 | 0.00 | | | 0.00 | 0.00 | | |
| 7/6/83 | 158 | 0.00 | 0.00 | | | 0.00 | 0.00 | | |
| 14/6/83 | 165 | 0.00 | 0.00 | | | 0.00 | 0.00 | | |
| 22/6/83 | 173 | 0.06 | 0.06 | | | 0.00 | 0.00 | | |
| 28/6/83 | 179 | 0.27 | 0.27 | | | 0.07 | 0.07 | | |
| 5/7/83 | 186 | 1.24 | 1.24 | | | 0.26 | 0.26 | | |
| 13/7/83 | 194 | 3.85 | 3.35 | | | 1.24 | 1.24 | | |
| 27/7/83 | 208 | 6.87 | 4.21 | 8.58 | 67.24 | 3.26 | 2.32 | 14.55 | 69.15 |
| 10/8/83 | 222 | 10.07 | 4.33 | 11.92 | 74.04 | 5.87 | 3.10 | 18.48 | 72.73 |
| 24/8/83 | 236 | 12.68 | 3.85 | 11.92 | 73.32 | 8.15 | 2.64 | 14.31 | 72.73 |
| 14/9/83 | 257 | 16.92 | 6.46 | 14.31 | 76.42 | 12.46 | 4.04 | 13.11 | 71.54 |
| 28/9/83 | 271 | 18.64 | 8.06 | 15.62 | 77.26 | 14.32 | 5.71 | 13.23 | 70.46 |
| 12/10/83 | 286 | 18.43 | 8.89 | 16.10 | 78.69 | 14.61 | 6.36 | 13.71 | 74.52 |
| 29/10/83 | 302 | 17.63 | 9.19 | 16.10 | 77.85 | 14.71 | 7.11 | 14.31 | 69.75 |

Jonge, P. de, 1989.
Jaarboek 1987/'88, Proefstation voor de akkerbouw en de groenteteelt in de vollegrond regionale onderzoekcentra, Lelystad, 43, 339 p.

Appendix E2b. Field experiment data of optimal irrigated or not irrigated sugar beet of the PAGV at Lelystad, the Netherlands, 1984.

Table E2b. Total dry matter, dry matter beet yield, sugar percentage of fresh and dry matter of irrigated and not irrigated fields of PAGV experimental station at Lelystad, the Netherlands, during the growing season of 1984, measured from figures (de Jonge, 1989).
J. day nr. = Julian day number

| | | optimal irrigation | | | | no irrigation | | | |
|---|---|---|---|---|---|---|---|---|---|
| date | J. day nr. | total dm yield t/ha | dm yield beet t/ha | sugar % fresh | sugar % dry | total dm yield t/ha | dm yield beet t/ha | sugar % fresh | sugar % dry beet |
| 11/7/84 | 192 | 3.27 | 1.13 | 6.46 | 59.15 | 3.12 | 1.15 | 8.08 | 62.87 |
| 25/7/84 | 206 | 7.59 | 2.42 | 9.86 | 65.94 | 7.23 | 2.69 | 10.02 | 69.49 |
| 8/8/84 | 220 | 10.50 | 4.85 | 10.18 | 69.66 | 10.00 | 5.19 | 14.87 | 70.95 |
| 22/8/84 | 234 | 13.73 | 8.44 | 12.61 | 68.69 | 10.85 | 6.46 | 19.23 | 70.46 |
| 5/9/84 | 248 | 18.58 | 10.30 | 11.80 | 70.30 | 11.69 | 6.23 | 19.39 | 69.49 |
| 19/9/84 | 262 | 20.11 | 10.82 | 12.93 | 70.95 | 11.35 | 7.27 | 12.93 | 67.56 |
| 3/10/84 | 276 | 21.00 | 12.08 | 14.55 | 71.27 | 11.19 | 6.92 | 11.47 | 66.26 |
| 17/10/84 | 290 | 20.11 | 12.12 | 14.71 | 74.18 | 10.81 | 6.73 | 11.64 | 64.97 |
| 31/10/84 | 304 | 19.75 | 12.16 | 15.19 | 74.51 | 12.31 | 7.50 | 12.93 | 67.88 |

Jonge, P. de, 1989.
Jaarboek 1987/'88, Proefstation voor de akkerbouw en de groenteteelt in de vollegrond regionale onderzoekcentra, Lelystad, 43, 339 p.

Appendix E2c. Field experiment data of sugar beet of Broom's Barn Experimental Station, Suffolk, United Kingdom, 1983.

Table E2c. Potential, irrigated and water limited total dry matter production of sugar beet at Suffolk and the development stage and temperature sum from sowing, during the growing season of 1983.
DVS = development stage
TSUM = temperture sum (°Cd)
J. day number = Julian day number
dm = dry matter

| J. day nr. | irrigated total dm t/ha | potential total dm simulated t/ha | water limited total dm t/ha | DVS | TSUM °Cd |
|---|---|---|---|---|---|
| 123 | 0.00 | 0.0 | 0.00 | 0 | 0 |
| 171 | 0.30 | | 0.30 | | |
| 173 | 0.39 | 0.4 | 0.39 | 0.73 | 448 |
| 178 | 0.60 | | 0.60 | | |
| 183 | 1.39 | 1.4 | 1.39 | 0.92 | 562 |
| 185 | 1.70 | | 1.70 | | |
| 192 | 3.06 | | 3.06 | | |
| 193 | 3.38 | 3.8 | 3.30 | 1.06 | 717 |
| 199 | 5.28 | | 4.72 | | |
| 203 | 6.71 | 6.4 | 5.83 | 1.15 | 878 |
| 206 | 7.78 | | 6.67 | | |
| 213 | 9.17 | 8.5 | 8.60 | 1.25 | 1043 |
| 220 | 11.11 | | 8.30 | | |
| 223 | 11.90 | 10.9 | 8.94 | 1.33 | 1171 |
| 233 | 14.55 | 13.1 | 11.07 | 1.42 | 1332 |
| 241 | 16.67 | | 12.78 | | |
| 243 | 16.84 | 15.1 | 13.26 | 1.51 | 1476 |
| 253 | 17.70 | 16.6 | 15.64 | 1.58 | 1602 |
| 262 | 18.47 | | 17.78 | | |
| 263 | 18.49 | 17.9 | 17.82 | 1.64 | 1700 |
| 273 | 18.69 | 19.1 | 18.21 | 1.71 | 1810 |
| 283 | 18.89 | 20.0 | 18.61 | 1.77 | 1920 |
| 293 | 19.81 | 20.9 | 17.95 | 1.82 | 2000 |
| 303 | 20.74 | 21.7 | 17.29 | 1.85 | 2045 |
| 304 | 20.83 | 21.8 | 17.22 | 1.85 | 2045 |

Brown K.F., A.B. Messem, R.J. Dunham & P.V. Biscoe, 1987.
Effect of drought on growth and water use of sugar beet.
Journal of Agricultural Science, Cambridge, 109, 421 - 435.

Appendix E2d. Field experiment data from several years and experiment stations of Italy.

Table E2d. Fresh root yield and calculated dry matter (DM) root yield and sugar yield, sowing dates and an early and late harvest date and day numbers for several years and places in Italy (L'Informatore Agrario (1985-1989), Zocca (1982) and Laureti et al. (1984)).
dn = Julian day number

| place | experimental year | sowing date | dn | first harvest date | dn 1 | second harvest date | dn 2 | fresh root yield (t/ha) | DM 20% root yield (t/ha) | sugar yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| Albinia (Grosseto) | 1983 | 22-Feb | 52 | 3-Aug | 215 | | | 75.72 | 15.14 | 10.23 |
| | | | | | | 13-Sep | 256 | 113.88 | 22.78 | 11.74 |
| | 1984 | 8-Mar | 67 | 1-Aug | 213 | | | 70.69 | 14.14 | 12.38 |
| | | | | | | 3-Sep | 246 | 93.53 | 18.71 | 15.32 |
| | 1985 | 29-Mar | 88 | 12-Aug | 224 | | | 66.94 | 13.39 | 9.03 |
| | | | | | | 5-Sep | 248 | 71.63 | 14.33 | 10.49 |
| | 1986 | 25-Mar | 84 | 5-Aug | 217 | | | 66.64 | 13.33 | 10.96 |
| | | | | | | 1-Sep | 244 | 71.89 | 14.38 | 13.44 |
| | 1987 | 7-Mar | 66 | 10-Aug | 222 | | | 82.08 | 16.42 | 11.99 |
| | | | | | | 11-Sep | 254 | 87.24 | 17.45 | 13.83 |
| Argelato (Bologna) | 1983 | 8-Mar | 67 | 23-Aug | 235 | | | 74.56 | 14.91 | 13.13 |
| | 1984 | 14-Mar | 73 | 10-Sep | 253 | | | 82.38 | 16.48 | 12.10 |
| | 1985 | 30-Mar | 89 | 2-Sep | 245 | | | 60.94 | 12.19 | 11.95 |
| | 1986 | 20-Mar | 79 | 8-Sep | 251 | | | 85.92 | 17.18 | 13.65 |
| | 1987 | 5-Mar | 64 | 7-Sep | 250 | | | 76.05 | 15.21 | 12.08 |
| | 1988 | 11-Mar | 70 | 12-Sep | 255 | | | 75.05 | 15.01 | 12.24 |
| Palata Pepoli (Bologna) | 1988 | 15-Mar | 74 | 18-Aug | 230 | | | 80.42 | 16.08 | 13.79 |
| | | | | | | 12-Sep | 255 | 91.38 | 18.28 | 14.28 |
| Avezzano (L'Aquila) | 1983 | 28-Apr | 118 | 8-Nov | 312 | | | 95.84 | 19.17 | 13.75 |
| Bagnolo Mella (Brescia) | 1987 | 10-Mar | 69 | 29-Sep | 272 | | | 86.02 | 17.20 | 13.27 |
| Borgo Faiti (Latina) | 1983 | 8-Mar | 67 | 12-Sep | 255 | | | 109.40 | 21.88 | 14.62 |
| Carpinello (Forlì) | 1983 | 11-Mar | 70 | 17-Aug | 229 | | | 62.05 | 12.41 | 9.87 |
| | | | | | | 5-Sep | 248 | 76.12 | 15.22 | 10.73 |
| | 1984 | 10-Mar | 69 | 17-Aug | 229 | | | 65.73 | 13.15 | 10.46 |
| | | | | | | 26-Sep | 269 | 84.73 | 16.95 | 13.18 |
| | 1985 | 25-Mar | 84 | 19-Aug | 231 | | | 39.71 | 7.94 | 7.49 |
| | | | | | | 16-Sep | 259 | 48.92 | 9.78 | 7.97 |
| | 1986 | 21-Mar | 80 | 19-Aug | 231 | | | 65.33 | 13.07 | 11.16 |
| | | | | | | 16-Sep | 259 | 77.99 | 15.60 | 13.50 |
| | 1987 | 6-Mar | 65 | 18-Aug | 230 | | | 59.72 | 11.94 | 9.35 |
| | | | | | | 17-Sep | 260 | 64.68 | 12.94 | 9.69 |
| | 1988 | 9-Mar | 68 | 17-Aug | 229 | | | 55.27 | 11.05 | 10.50 |
| | | | | | | 13-Sep | 256 | 62.02 | 12.40 | 11.66 |
| Cento (Ferrara) | 1983 | 10-Mar | 69 | 16-Aug | 228 | | | 88.66 | 17.73 | 13.22 |
| | | | | | | 8-Sep | 251 | 104.08 | 20.82 | 14.63 |
| | 1984 | 14-Mar | 73 | 20-Aug | 232 | | | 78.30 | 15.66 | 9.06 |
| | | | | | | 19-Sep | 262 | 93.75 | 18.75 | 11.70 |
| | 1985 | 30-Mar | 89 | 20-Aug | 232 | | | 78.27 | 15.65 | 13.35 |
| | | | | | | 11-Sep | 254 | 96.07 | 19.21 | 15.66 |
| | 1986 | 28-Mar | 87 | 18-Aug | 230 | | | 56.76 | 11.35 | 7.59 |
| | | | | | | 15-Sep | 258 | 68.49 | 13.70 | 9.25 |
| Collecorvino (Pescara) | 1987 | 24-Mar | 83 | 30-Sep | 273 | | | 90.72 | 18.14 | 13.32 |
| Godo (Ravenna) | 1983 | 8-Mar | 67 | 22-Aug | 234 | | | 70.45 | 14.09 | 12.15 |
| | | | | | | 12-Sep | 255 | 84.69 | 16.94 | 12.93 |
| | 1984 | 13-Mar | 72 | 21-Aug | 233 | | | 78.33 | 15.67 | 11.97 |
| | | | | | | 18-Sep | 261 | 95.76 | 19.15 | 15.11 |
| | 1985 | 26-Mar | 85 | 20-Aug | 232 | | | 54.03 | 10.81 | 10.79 |
| | | | | | | 11-Sep | 254 | 57.87 | 11.57 | 11.89 |
| | 1986 | 24-Mar | 83 | 18-Aug | 230 | | | 76.59 | 15.32 | 11.56 |
| | | | | | | 11-Sep | 254 | 86.70 | 17.34 | 13.72 |
| | 1987 | 5-Mar | 64 | 19-Aug | 231 | | | 59.03 | 11.81 | 10.25 |
| | | | | | | 16-Sep | 259 | 66.43 | 13.29 | 11.56 |
| | 1988 | 10-Mar | 69 | 22-Aug | 234 | | | 79.73 | 15.95 | 12.47 |
| | | | | | | 13-Sep | 256 | 90.33 | 18.07 | 13.89 |

| place | experimental year | sowing date | dn | first harvest date | dn 1 | second harvest date | dn 2 | root yield (t/ha) | DM 20% root yield (t/ha) | sugar yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|---|
| Manfredonia (Foggia) | 1985 | 27-Mar | 86 | 10-Sep | 253 | | | 65.48 | 13.10 | 11.13 |
| | 1986 | 3-Apr | 93 | 5-Sep | 248 | | | 43.02 | 8.60 | 6.26 |
| Osimo (Ancona) | 1983 | 3-Mar | 62 | 22-Aug | 234 | | | 32.60 | 6.52 | 5.20 |
| | | | | | | 16-Sep | 259 | 42.80 | 8.56 | 5.41 |
| Porto Tolle (Rovigo) | 1983 | 10-Mar | 69 | 22-Aug | 234 | | | 49.23 | 9.85 | 8.66 |
| | | | | | | 15-Sep | 258 | 58.95 | 11.79 | 8.70 |
| | 1985 | 5-Apr | 95 | 22-Aug | 234 | | | 57.52 | 11.50 | 9.56 |
| | | | | | | 17-Sep | 260 | 65.47 | 13.09 | 11.34 |
| | 1986 | 27-Mar | 86 | 20-Aug | 232 | | | 61.43 | 12.29 | 10.21 |
| | | | | | | 22-Sep | 265 | 70.20 | 14.04 | 12.73 |
| | 1987 | 12-Mar | 71 | 24-Aug | 236 | | | 64.53 | 12.91 | 12.31 |
| | | | | | | 22-Sep | 265 | 75.47 | 15.09 | 13.95 |
| | 1988 | 10-Mar | 69 | 25-Aug | 237 | | | 75.80 | 15.16 | 12.15 |
| | | | | | | 29-Sep | 272 | 89.68 | 17.94 | 12.07 |
| Recanati (Macerata) | 1983 | 10-Mar | 69 | 20-Sep | 263 | | | 81.42 | 16.28 | 12.48 |
| | 1984 | 15-Mar | 74 | 18-Sep | 261 | | | 49.45 | 9.89 | 9.26 |
| | 1985 | 27-Mar | 86 | 25-Sep | 268 | | | 31.24 | 6.25 | 6.63 |
| | 1986 | 20-Mar | 79 | 23-Sep | 266 | | | 71.90 | 14.38 | 13.42 |
| | 1987 | 11-Mar | 70 | 21-Sep | 264 | | | 70.83 | 14.17 | 14.75 |
| | 1988 | 14-Mar | 73 | 27-Sep | 270 | | | 105.00 | 21.00 | 167.40 |
| Rovigo (Veneto) | 1983 | 5-Mar | 64 | 17-Aug | 229 | | | 79.80 | 15.96 | 11.16 |
| | | | | | | 15-Sep | 258 | 92.40 | 18.48 | 12.26 |
| | 1984 | 15-Mar | 74 | 23-Aug | 235 | | | 88.87 | 17.77 | 12.43 |
| | | | | | | 1-Oct | 274 | 118.24 | 23.65 | 16.17 |
| Tre Ponti (Pesaro) | 1983 | 10-Mar | 69 | 1-Sep | 244 | | | 65.25 | 13.05 | 11.52 |
| | 1984 | 16-Mar | 75 | 19-Sep | 262 | | | 50.68 | 10.14 | 9.11 |
| | 1985 | 3-Apr | 93 | 10-Sep | 253 | | | 33.61 | 6.72 | 6.72 |
| | 1986 | 24-Mar | 83 | 22-Sep | 265 | | | 80.10 | 16.02 | 11.05 |
| | 1987 | 11-Mar | 70 | 3-Sep | 246 | | | 32.60 | 6.52 | 6.45 |
| | 1988 | 7-Mar | 66 | 19-Sep | 262 | | | 41.43 | 8.29 | 6.30 |
| Zapponeta (Fogia) | 1987 | 16-Mar | 75 | 31-Aug | 243 | | | 60.27 | 12.05 | 10.36 |


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# Appendix E3:
# Region specific data of sugar beet

Table E3a1 Calibrated temperature sums and life span of leaves of sugar beet crop types.
TSUM1 = temperature sum from emergence to secundary tap root growth
TSUM2 = temperature sum from secundary tap root growth to harvest.
SPAN = life span of leaves growing at 35°C

| crop type | TSUM1 °Cd | TSUM2 °Cd | SPAN d |
|---|---|---|---|
| 0601 | 650 | 1400 | 35 |
| 0602 | 700 | 1400 | 35 |
| 0603 | 800 | 1400 | 37 |
| 0604 | 850 | 1400 | 36 |

Table E3a2 Occurrence of sowing and harvest day of sugar beet crop types in regions within countries of the European Community.
J. day nr. = Julian day number.

| crop type | country | NUTS codes per region | sowing J. day nr. | harvest J. day nr. |
|---|---|---|---|---|
| 0601 | Germany | R1 | 90 | 300 |
| | N. France | R21 - R25 and R27 | 95 | 300 |
| | the Netherlands | R4 | 100 | 300 |
| | Belgium | R5 | 100 | 290 |
| | Luxembourg | R6 | 95 | 290 |
| | United Kingdom | R7 | 95 | 290 |
| | Ireland | R8 | 105 | 290 |
| | Denmark | R9 | 95 | 290 |
| 0602 | S. France | R26 and R28 | 95 | 300 |
| | Italy | R31 - R36 and R38 | 85 | 270 |
| | Spain | RB1, RB2, RB3, RB4 | 85 | 300 |
| | Portugal | RC | 85 | 300 |
| 0603 | Southern Italy | R37, R39, R3A, R3B | 85 | 260 |
| | Southern Spain | RB5, RB6 | 85 | 300 |
| 0604 | Greece | RA | 85 | 300 |

Table E3b Calibrated parameters of the initial crop-specific data file (Appendix E1) of sugar beet.

```
** green area
SPAN    =  35

** partitioning

FRTB    =  0.00    0.20     ! fraction of total dry matter to roots
           0.91    0.29     ! as a function of DVS [-; kg kg-1]
           1.00    0.30
           1.15    0.15
           1.29    0.09
           1.30    0.09
           1.57    0.08
           1.92    0.01
           2.00    0.02
FLTB    =  0.00    0.85     ! fraction of above-gr. dry matter to leaves
           0.91             ! as a function of DVS [-; kg kg-1]
           1.00    0.50
           1.15
           1.29
           1.30    0.05
           1.57
           1.92
           2.00    0.05
FSTB    =  0.00    0.15     ! fraction of above-gr. dry matter to stems
           0.91             ! as a function of DVS [-; kg kg-1]
           1.00    0.50
           1.15
           1.29
           1.30    0.10
           1.57    0.10
           1.92    0.05
           2.00    0.05
FOTB    =  0.00    0.00     ! fraction of above-gr. dry matter to stor. org.
           0.91             ! as a function of DVS [-; kg kg-1]
           1.00
           1.15
           1.29    0.00
           1.30    0.85
           1.57    0.85
           1.92    0.90
           2.00    0.90
```

## Appendix E4:

### Crop calendar of sugar beet

Table E4. Sowing, secundary tap root growth and harvest day (Julian day number) and calculated temperature sums of sugar beet for regions within the European Community. Each NUTS region contains several grid cells. The temperature sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calculated temperature sum from emergence to secundary tap root growth, base temperature of 3°C.
TSUM2 = calculated temperature sum from secundary tap root growth to harvest, base temperature of 0°C.
Temperature sum from sowing to emergence is 90°Cd, base temperature of 3°C.
J. day nr. = Julian day number

| NUTS code | grid cell | sowing J. day nr. | secundary tap root growth J. day nr. | harvest J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|---|
| R11 | 4135 | 90 | 176 | 298 | 590 | 1813 | Germany | Schleswig-Holstein | |
| R12 | 4035 | 90 | 176 | 298 | 613 | 1813 | | Hamburg | |
| R13 | 3834 | 90 | 176 | 298 | 645 | 1844 | | Niedersachsen | |
| R14 | 3933 | 90 | 176 | 298 | 650 | 1846 | | Bremen | |
| R15 | 3531 | 90 | 176 | 298 | 699 | 1925 | | Nordrhein-Westfalen | 2 |
| R16 | 3333 | 90 | 176 | 298 | 716 | 1915 | | Hessen | |
| R17 | 3231 | 90 | 176 | 298 | 676 | 1880 | | Rheinland-Pfalz | |
| R18 | 2934 | 90 | 176 | 298 | 704 | 1913 | | Baden-Württemberg | |
| R19 | 3037 | 90 | 176 | 298 | 648 | 1825 | | Bayern | |
| R1A | 3131 | 90 | 176 | 298 | 683 | 1885 | | Saarland | |
| R21 | 2924 | 95 | 161 | 289 | 545 | 2219 | France | Île de France | |
| R22 | 3125 | 95 | 161 | 289 | 496 | 2106 | | Bassin Parisien | 2 |
| R23 | 3325 | 90 | 161 | 304 | 483 | 2194 | | Nord - Pas-de-Calais | 2 |
| R24 | 2830 | 93 | 161 | 293 | 490 | 2130 | | Est | 2 |
| R25 | | -1 | -1 | -1 | -1 | -1 | | Ouest | |
| R26 | | -1 | -1 | -1 | -1 | -1 | | Sud-Ouest | |
| R27 | | -1 | -1 | -1 | -1 | -1 | | Centre-Est | |
| R28 | | -1 | -1 | -1 | -1 | -1 | | Mediterranée | |
| R31 | 2132 | 85 | 166 | 258 | 863 | 2004 | Italy | Nord Ovest | 3 |
| R32 | 2235 | 85 | 166 | 258 | 905 | 2060 | | Lombardia | 3 |
| R33 | 2339 | 85 | 166 | 258 | 941 | 2079 | | Nord Est | 3 |
| R34 | 2037 | 85 | 166 | 258 | 941 | 2156 | | Emilia Romgna/Po | 3 |
| R351 | 1836 | 85 | 166 | 248 | 883 | 1834 | | Toscana | 3 |
| R352 | 2033 | 85 | 166 | 248 | 879 | 1837 | | Umbria | 3 |
| R353 | 1741 | 64 | 156 | 238 | 839 | 1847 | | Marche | 3 |
| R36 | 1439 | 85 | 166 | 248 | 926 | 1896 | | Lazio | 3 |
| R37 | 1242 | 64 | 146 | 248 | 816 | 2365 | | Campania | 3 |
| R381 | 1542 | 64 | 156 | 238 | 805 | 1813 | | Abruzzi | 3 |
| R382 | 1443 | 64 | 146 | 248 | 611 | 2161 | | Molise | 3 |
| R39 | 1345 | 64 | 146 | 248 | 759 | 2417 | | Sud | 3 |
| R3A | | -1 | -1 | -1 | -1 | -1 | | Sicilia | 3 |
| R3B | | -1 | -1 | -1 | -1 | -1 | | Sardegna | 3 |
| R41 | 3930 | 100 | 175 | 300 | 535 | 1772 | the Netherlands | Noord-Nederland* | |
| R42 | 3730 | 100 | 175 | 300 | 611 | 1898 | | Oost-Nederland* | |
| R45 | 3628 | 100 | 175 | 300 | 608 | 1897 | | Zuid-Nederland* | |
| R47 | 3626 | 100 | 175 | 300 | 573 | 1909 | | West-Nederland* | |
| R5 | 3427 | 100 | 174 | 283 | 695 | 1886 | Belgium | | 2 |
| R6 | 3129 | 97 | 177 | 285 | 661 | 1747 | Luxembourg* | | |
| R71 | | -1 | -1 | -1 | -1 | -1 | United Kingdom | North | 1 |
| R72 | 4220 | 95 | 175 | 288 | 486 | 1602 | | Yorkshire and Humberside | 1 |
| R73 | 4020 | 95 | 175 | 288 | 495 | 1590 | | East Midlands | 1 |
| R74 | 3822 | 95 | 175 | 288 | 520 | 1683 | | East Anglia | 1 |
| R75 | | -1 | -1 | -1 | -1 | -1 | | South East | 1 |
| R76 | 3515 | 95 | 175 | 288 | 421 | 1496 | | South West | 1 |
| R77 | 3818 | 95 | 175 | 288 | 493 | 1598 | | West Midlands | 1 |
| R78 | 4118 | 95 | 175 | 288 | 505 | 1597 | | North West | 1 |
| R79 | 3816 | 95 | 175 | 288 | 316 | 1335 | | Wales | 1 |
| R7A | | -1 | -1 | -1 | -1 | -1 | | Scotland | 1 |
| R7B | | -1 | -1 | -1 | -1 | -1 | | Northern Ireland | 1 |
| R8 | 4414 | 105 | 175 | 288 | 472 | 1551 | Ireland | | 1 |
| R9 | | -1 | -1 | -1 | -1 | -1 | Denmark | | |

Table E4. Sowing, secundary tap root growth and harvest day (Julian day number) and calculated temperature sums of sugar beet for regions within the European Community. Each NUTS region contains several grid cells. The temperature sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calculated temperature sum from emergence to secundary tap root growth, base temperature of 3°C.
TSUM2 = calculated temperature sum from secundary tap root growth to harvest, base temperature of 0°C.
Temperature sum from sowing to emergence is 90°Cd, base temperature of 3°C.
J. day nr. = Julian day number

| NUTS code | grid cell | sowing J. day nr. | secundary tap root growth J. day nr. | harvest J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|---|
| RA11 | 1562 | 85 | 176 | 299 | 1219 | 2734 | Greece | Anatoliki Makedonia, Thraki | 3 |
| RA12 | 1457 | 85 | 176 | 299 | 1109 | 2596 | | Kentriki Makedonia | 3 |
| RA13 | 1255 | 85 | 176 | 299 | 884 | 2328 | | Dytiki Makedonia | 3 |
| RA14 | 1156 | 85 | 176 | 299 | 1149 | 2688 | | Thessalia | 3 |
| RA15 | 1458 | 85 | 176 | 299 | 1177 | 2688 | | Anatoliki Makedonia | 3 |
| RA18 | 1562 | 85 | 176 | 299 | 1219 | 2734 | | Thraki | 3 |
| RA2 | | -1 | -1 | -1 | -1 | -1 | | Kentriki Ellada | 3 |
| RA213 | 1153 | -1 | 176 | 299 | 1160 | 2439 | | Ioannina | 3 |
| RA3 | | -1 | -1 | -1 | -1 | -1 | | Attiki | 3 |
| RA4 | | -1 | -1 | -1 | -1 | -1 | | Nisia | 3 |
| RB1 | | -1 | -1 | -1 | -1 | -1 | Spain | Noroeste | 3 |
| RB2 | 1517 | 95 | 166 | 349 | 829 | 3361 | | Noreste | 3 |
| RB3 | | -1 | -1 | -1 | -1 | -1 | | Madrid | 3 |
| RB4 | | 85 | 156 | 339 | -1 | -1 | | Centro | 3 |
| RB41 | 1610 | 85 | 156 | 339 | 510 | 2994 | | Castilla-Leon | 3 |
| RB42 | 1013 | 85 | 156 | 339 | 641 | 3405 | | Castilla-La Mancha | 3 |
| RB43 | 1107 | 85 | 156 | 339 | 750 | 3583 | | Extremadura | 3 |
| RB5 | | -1 | -1 | -1 | -1 | -1 | | Este | 3 |
| RB6 | | -1 | -1 | -1 | -1 | -1 | | Sur | 3 |
| RC1 | | -1 | -1 | -1 | -1 | -1 | Portugal | Continente | |

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* means: values estimated
-1 means: no data available or no sugar beet grown.

# Appendix F:

## Potato (*Solanum tuberosum* L.)

# Appendix F1:
# Initial crop-specific data file of potato

CROP DATA FILE for use with WOFOST Version 5.0, January 1990

crop identity

| | | | | |
|---|---|---|---|---|
| !CRPNAM | = | Potato (*Solanum tuberosum* L.) | | |
| ICROP | = | 7 | | |

** emergence

| | | | | |
|---|---|---|---|---|
| TBASEM | = | 3.0 | | ! lower threshold temp. for emergence [C°] |
| TEFFMX | = | 18.0 | | ! max. eff. temp. for emergence [C°] |
| TSUMEM | = | 170. | | ! temperature sum from sowing to emergence [C° d] |

** phenology

| | | | | |
|---|---|---|---|---|
| IDSL | = | 0 | | ! indicates whether pre-anthesis development depends |
| | | | | ! on temp. (=0), daylength (=1) , or both (=2) |
| DLO | = | -99.0 | | ! optimum daylength for development [hr] |
| DLC | = | -99.0 | | ! critical daylength (lower threshold) [hr] |
| TSUM1 | = | 152. | | ! temperature sum from emergence to anthesis [C° d] |
| TSUM2 | = | 1209. | | ! temperature sum from anthesis to maturity [C° d] |
| DTSMTB | = | 0.00, | 0.00, | ! daily increase in temp. sum |
| | | 2.00, | 0.00, | ! as function of av. temp. [C°; C° d] |
| | | 13.00, | 11.00 | |
| | | 18.00, | 11.00 | |
| | | 29.00, | 11.00 | |
| DVSEND | = | 2.00 | | ! development stage at harvest (= 2.0 at maturity [-]) |

** initial

| | | | | |
|---|---|---|---|---|
| TDWI | = | 33.0 | | ! initial total crop dry weight [kg $ha^{-1}$] |
| LAIEM | = | 0.0589 | | ! leaf area index at emergence [ha $ha^{-1}$] |
| RGRLAI | = | 0.0120 | | ! maximum relative increase in LAI [ha $ha^{-1}$ $d^{-1}$] |

** green area

| | | | | |
|---|---|---|---|---|
| SLATB | = | 0.00, | 0.0030, | ! specific leaf area |
| | | 1.10, | 0.0030, | ! as a function of DVS [-; ha $kg^{-1}$] |
| | | 2.00, | 0.0015 | |
| SPA | = | 0.000 | | ! specific pod area [ha $kg^{-1}$] |
| SSA | = | 0.000 | | ! specific stem area [ha $kg^{-1}$] |
| SPAN | = | 35. | | ! life span of leaves growing at 35 C° [d] |
| TBASE | = | 2.0 | | ! lower threshold temp. for ageing of leaves [C°] |

** assimilation

| | | | | |
|---|---|---|---|---|
| KDIF | = | 1.000 | | ! extinction coefficient for diffuse visible light [-] |
| EFF | = | 0.45 | | ! light-use effic. single leaf [kg $ha^{-1}$ $hr^{-1}$ $J^{-1}$ $m^2$ s] |

| | | | | |
|---|---|---|---|---|
| AMAXTB | = | 0.00, | 30.00, | ! maximum leaf CO2 assimilation rate |
| | | 1.57, | 30.00, | ! as function of DVS [-; kg $ha^{-1}$ $hr^{-1}$] |
| | | 2.00, | 0.00 | |
| TMPFTB | = | 0.00, | 0.01, | ! reduction factor of AMAX |
| | | 3.00, | 0.01, | ! as function of av. temp. [C°; -] |
| | | 10.00, | 0.75, | |
| | | 15.00, | 1.00, | |
| | | 20.00, | 1.00 | |
| | | 26.00, | 0.75 | |
| | | 33.00, | 0.01 | |
| TMNFTB | = | 0.00, | 0.00, | ! red. factor of gross assim. rate |
| | | 3.00, | 1.00 | ! as function of low min. temp. [C°; -] |

** conversion of assimilates into biomass

| | | | |
|---|---|---|---|
| CVL | = | 0.720 | ! efficiency of conversion into leaves [kg $kg^{-1}$] |
| CVO | = | 0.850 | ! efficiency of conversion into storage org. [kg $kg^{-1}$] |
| CVR | = | 0.720 | ! efficiency of conversion into roots [kg $kg^{-1}$] |
| CVS | = | 0.690 | ! efficiency of conversion into stems [kg $kg^{-1}$] |

** maintenance respiration

| | | | | |
|---|---|---|---|---|
| Q10 | = | 2.0 | | ! rel. incr. in resp. rate per 10 C°temp. incr. [-] |
| RML | = | 0.0300 | | ! rel. maint. resp. rate leaves [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RMO | = | 0.0045 | | ! rel. maint. resp. rate stor.org. [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RMR | = | 0.0100 | | ! rel. maint. resp. rate roots [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RMS | = | 0.0150 | | ! rel. maint. resp. rate stems [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RFSETB | = | 0.00, | 1.00, | ! red. factor for senescence |
| | | 2.00, | 1.00 | ! as function of DVS [-; -] |

** partitioning

| | | | | |
|---|---|---|---|---|
| FRTB | = | 0.00, | 0.20, | ! fraction of total dry matter to roots |
| | | 1.00, | 0.20, | ! as a function of DVS [-; kg $kg^{-1}$] |
| | | 1.36, | 0.00, | |
| | | 2.00, | 0.00 | |
| FLTB | = | 0.00, | 0.75, | ! fraction of above-gr. DM to leaves |
| | | 1.00, | 0.75, | ! as a function of DVS [-; kg kg-1] |
| | | 1.27, | 0.00, | |
| | | 2.00, | 0.00 | |
| FSTB | = | 0.00, | 0.25, | ! fraction of above-gr. DM to stems |
| | | 1.27, | 0.25, | ! as a function of DVS [-; kg kg-1] |
| | | 1.36, | 0.00 | |
| | | 2.00, | 0.00 | |
| FOTB | = | 0.00, | 0.00, | ! fraction of above-gr. DM to stor. org. |
| | | 1.00, | 0.00, | ! as a function of DVS [-; kg $kg^{-1}$] |
| | | 1.27, | 0.75, | |
| | | 1.36, | 1.00 | |
| | | 2.00, | 1.00 | |

```
** death rates
PERDL    = 0.030              ! max. rel. death rate of leaves due to water stress
RDRRTB   = 0.00,     0.000,   ! rel. death rate of stems
           1.50,     0.000,   ! as a function of DVS [-; kg kg-1 d-1]
           1.5001,   0.020,
           2.00,     0.020
RDRSTB   = 0.00,     0.000,   ! rel. death rate of roots
           1.50,     0.000,   ! as a function of DVS [-; kg kg-1 d-1]
           1.5001,   0.020,
           2.00,     0.020

** water use
CFET     = 1.00               ! correction factor transpiration rate [-]
DEPNR    = 3.0                ! crop group number for soil water depletion [-]
IAIRDU   = 0                  ! air ducts in roots present (=1) or not (=0)

** rooting
RDI      = 10.                ! initial rooting depth [cm]
RRI      =  1.2               ! maximum daily increase in rooting depth [cm d-1]
RDMCR    = 50.                ! maximum rooting depth [cm]

** nutrients
** maximum and minimum concentrations of N, P, and K in storage organsin vegetative organs
   [kg kg-1]
NMINSO   = 0.0085 ; NMINVE = 0.0150
NMAXSO   = 0.0220 ; NMAXVE = 0.0400
PMINSO   = 0.0011 ; PMINVE = 0.0014
PMAXSO   = 0.0055 ; PMAXVE = 0.0100
KMINSO   = 0.0110 ; KMINVE = 0.0130
KMAXSO   = 0.0280 ; KMAXVE = 0.0380
YZERO    = 0.                 ! max. amount veg. organs at zero yield [kg ha-1]
NFIX     = 0.00               ! fraction of N-uptake from biol. fixation [kg kg-1]
```

# Appendix F2:

## Field experiment data of potato

Appendix F2a. Field experiment data of 6 potato varieties at Varseveld, the Netherlands, 1968, (Gmelig Meyling & Bodlaender, 1981)

| Varieties | | | | |
|---|---|---|---|---|
| | 1=Prudal | mid early; industrial | 4=Noorderling | midlate-late; ware |
| | 2=Mentor | mid-late; industrial | 5=Alpha | late; ware |
| | 3=Irene | midlate-late; ware | 6=Pimpernel | midlate-late; ware |

J. day nr. = Julian day number

NPL 60.000
Field example 10 pl
plant date 16 April (106)
emergence 15 May (135)

| harvest nr. | harvest date | J. day nr. |
|---|---|---|
| 1 | 27-May | 148 |
| 2 | 10-Jun | 162 |
| 3 | 24-Jun | 176 |
| 4 | 8-Jul | 190 |
| 5 | 22-Jul | 204 |
| 6 | 5-Aug | 218 |
| 7 | 19-Aug | 232 |
| 8 | 2-Sep | 246 |
| 9 | 16-Sep | 260 |
| 10 | 30-Sep | 274 |

Table F2a. Measured dry matter production of leaves (WLVms), stems (WSTms), storage organ (WSOms) and total underground organs (und) and calculated leaf area index (LAIca) of 6 potato varieties during the growing season of 1968 at Varseveld.

| variety | | harvest nr. | J. day nr. | WLVms t/ha | WSTms t/ha | und t/ha | WSOms t/ha | LAIca ha/ha |
|---|---|---|---|---|---|---|---|---|
| | | | 106 | 0.00 | 0.00 | | 0.00 | |
| | | | 135 | 0.00 | 0.00 | | 0.00 | |
| Prudal | | 1 | 148 | 0.16 | 0.04 | 0.05 | 0.00 | 0.49 |
| | 1 | 2 | 162 | 1.22 | 0.39 | 0.27 | 0.48 | 3.66 |
| | 1 | 3 | 176 | 1.78 | 0.88 | 0.30 | 2.66 | 5.35 |
| | 1 | 4 | 190 | 1.78 | 1.45 | 0.35 | 4.95 | 5.34 |
| | 1 | 5 | 204 | 1.65 | 1.53 | 0.40 | 9.58 | 4.94 |
| | 1 | 6 | 218 | 1.07 | 1.22 | 0.30 | 11.38 | 3.21 |
| | 1 | 7 | 232 | 0.70 | 1.15 | 0.33 | 13.58 | 2.10 |
| | 1 | 8 | 246 | 0.33 | 0.99 | 0.25 | 13.48 | 1.00 |
| | 1 | 9 | 260 | 0.00 | 0.81 | 0.14 | 15.46 | 0.00 |
| | 1 | 10 | 274 | 0.00 | 0.66 | 0.15 | 12.94 | 0.00 |

| variety | | harvest nr. | J. day nr. | WLVms t/ha | WSTms t/ha | und t/ha | WSOms t/ha | LAIca ha/ha |
|---|---|---|---|---|---|---|---|---|
| | | | 106 | 0.00 | 0.00 | | 0.00 | 0.0 |
| | | | 135 | 0.00 | 0.00 | | 0.00 | 0.0 |
| Mentor | | 1 | 148 | 0.27 | 0.09 | 0.07 | 0.00 | 0.80 |
| | 2 | 2 | 162 | 1.33 | 0.60 | 0.28 | 0.40 | 4.00 |
| | 2 | 3 | 176 | 2.00 | 1.47 | 0.34 | 2.31 | 6.01 |
| | 2 | 4 | 190 | 1.95 | 2.13 | 0.40 | 5.12 | 5.85 |
| | 2 | 5 | 204 | 1.96 | 2.38 | 0.44 | 9.02 | 5.89 |
| | 2 | 6 | 218 | 1.45 | 2.34 | 0.38 | 10.01 | 4.34 |
| | 2 | 7 | 232 | 1.13 | 2.00 | 0.36 | 15.19 | 3.40 |
| | 2 | 8 | 246 | 0.69 | 1.85 | 0.32 | 16.91 | 2.06 |
| | 2 | 9 | 260 | 0.20 | 1.61 | 0.27 | 18.04 | 0.60 |
| | 2 | 10 | 274 | 0.00 | 1.64 | 0.16 | 14.93 | 0.00 |

| variety | | harvest nr. | J. day nr. | WLVms t/ha | WSTms t/ha | und t/ha | WSOms t/ha | LAIca ha/ha |
|---|---|---|---|---|---|---|---|---|
| | | | 106 | 0.00 | | | 0.00 | 0.0 |
| | | | 135 | 0.00 | | | 0.00 | |
| Irene | | 1 | 148 | 0.25 | 0.06 | 0.05 | 0.00 | 0.74 |
| | 3 | 2 | 162 | 1.35 | 0.60 | 0.19 | 0.00 | 4.05 |
| | 3 | 3 | 176 | 1.90 | 1.83 | 0.36 | 0.21 | 5.71 |
| | 3 | 4 | 190 | 2.00 | 2.82 | 0.44 | 1.26 | 5.99 |
| | 3 | 5 | 204 | 1.79 | 3.35 | 0.54 | 3.89 | 5.36 |
| | 3 | 6 | 218 | 1.31 | 3.88 | 0.42 | 6.06 | 3.93 |
| | 3 | 7 | 232 | 1.09 | 3.34 | 0.47 | 14.22 | 3.27 |
| | 3 | 8 | 246 | 0.70 | 3.11 | 0.37 | 11.89 | 2.11 |
| | 3 | 9 | 260 | 0.12 | 2.57 | 0.34 | 9.93 | 0.35 |
| | 3 | 10 | 274 | 0.00 | 2.15 | 0.20 | 12.57 | 0.00 |

| variety | | harvest nr. | J. day nr. | WLVms t/ha | WSTms t/ha | und t/ha | WSOms t/ha | LAIca ha/ha |
|---|---|---|---|---|---|---|---|---|
| | | | 106 | 0.00 | 0.00 | | 0.00 | 0.0 |
| | | | 135 | | | | 0.00 | |
| Noorderling | | 1 | 148 | 0.24 | 0.08 | 0.07 | 0.00 | 0.73 |
| | 4 | 2 | 162 | 1.03 | 0.53 | 0.20 | 0.13 | 3.10 |
| | 4 | 3 | 176 | 1.72 | 1.71 | 0.31 | 1.52 | 5.15 |
| | 4 | 4 | 190 | 1.67 | 2.33 | 0.41 | 3.06 | 5.01 |
| | 4 | 5 | 204 | 1.39 | 2.46 | 0.46 | 6.79 | 4.16 |
| | 4 | 6 | 218 | 1.36 | 2.81 | 0.38 | 7.78 | 4.07 |
| | 4 | 7 | 232 | 0.55 | 1.68 | 0.35 | 10.80 | 1.64 |
| | 4 | 8 | 246 | 0.46 | 1.92 | 0.26 | 12.90 | 1.39 |
| | 4 | 9 | 260 | 0.21 | 2.03 | 0.24 | 14.23 | 0.63 |
| | 4 | 10 | 274 | 0.00 | 1.55 | 0.21 | 13.25 | 0.00 |

| variety | | harvest nr. | J. day nr. | WLVms t/ha | WSTms t/ha | und t/ha | WSOms t/ha | LAIca ha/ha |
|---|---|---|---|---|---|---|---|---|
| Alpha | | | 106 | 0.00 | 0.00 | | 0.00 | 0.0 |
| | | | 135 | | | | 0.00 | |
| | 5 | 1 | 148 | 0.21 | 0.05 | 0.06 | 0.00 | 0.62 |
| | 5 | 2 | 162 | 1.29 | 0.48 | 0.16 | 0.10 | 3.87 |
| | 5 | 3 | 176 | 2.03 | 1.40 | 0.26 | 1.42 | 6.10 |
| | 5 | 4 | 190 | 2.00 | 2.41 | 0.29 | 3.27 | 6.00 |
| | 5 | 5 | 204 | 2.09 | 3.01 | 0.43 | 5.04 | 6.28 |
| | 5 | 6 | 218 | 2.08 | 3.54 | 0.46 | 10.38 | 6.23 |
| | 5 | 7 | 232 | 1.29 | 3.54 | 0.40 | 11.08 | 3.87 |
| | 5 | 8 | 246 | 1.01 | 2.97 | 0.42 | 14.04 | 3.03 |
| | 5 | 9 | 260 | 0.35 | 2.14 | 0.29 | 15.16 | 1.06 |
| | 5 | 10 | 274 | 0.00 | 2.48 | 0.27 | 14.00 | 0.00 |

| variety | | harvest nr. | J. day nr. | WLVms t/ha | WSTms t/ha | und t/ha | WSOms t/ha | LAIca ha/ha |
|---|---|---|---|---|---|---|---|---|
| Pimpernel | | | 106 | 0.00 | 0.00 | | 0.00 | 0.00 |
| | | | 135 | | | | 0.00 | |
| | 6 | 1 | 148 | 0.18 | 0.04 | 0.08 | 0.00 | 0.55 |
| | 6 | 2 | 162 | 1.02 | 0.38 | 0.26 | 0.00 | 3.05 |
| | 6 | 3 | 176 | 2.15 | 1.78 | 0.61 | 0.41 | 6.44 |
| | 6 | 4 | 190 | 2.42 | 2.86 | 0.70 | 1.46 | 7.27 |
| | 6 | 5 | 204 | 2.27 | 3.88 | 0.76 | 2.12 | 6.80 |
| | 6 | 6 | 218 | 1.88 | 3.65 | 0.97 | 7.07 | 5.63 |
| | 6 | 7 | 232 | 1.71 | 4.19 | 0.78 | 11.22 | 5.14 |
| | 6 | 8 | 246 | 1.35 | 4.04 | 0.70 | 10.87 | 4.06 |
| | 6 | 9 | 260 | 0.95 | 3.79 | 0.55 | 15.34 | 2.85 |
| | 6 | 10 | 274 | 0.00 | 2.91 | 0.48 | 15.61 | 0.00 |

Gmelig Meyling, H.D. & K.B.A. Bodlaender, 1981.
Varietal differences in growth, development and tuber production of potatoes.
Netherlands journal of Agricultural Science, 29, 113 - 127.

Appendix F2b. Field experiment data of 6 potato varieties at Varseveld, the Netherlands, 1969, (Gmelig Meyling & Bodlaender, 1981)

| Varieties | | | | |
|---|---|---|---|---|
| | 1=Prudal | mid early; industrial | 4=Bintje | mid early; ware |
| | 2=Mentor | mid-late; industrial | 5=Alpha | late; ware |
| | 3=Irene | midlate-late; ware | 6=Pimpernel | midlate-late; ware |

J. day nr. = Julian day number

NPL 60.000 (pl/ha)
Field example 10 pl
plant date -
emergence 12 May

| harvest nr. | harvest date | J. day nr. |
|---|---|---|
| 1 | 2-Jun | 153 |
| 2 | 16-Jun | 167 |
| 3 | 30-Jun | 181 |
| 4 | 14-Jul | 195 |
| 5 | 28-Jul | 209 |
| 6 | 11-Aug | 223 |
| 7 | 25-Aug | 237 |
| 8 | 8-Sep | 251 |
| 9 | 22-Sep | 265 |
| 10 | 6-Oct | 279 |

Table F2b. Measured dry matter production of leaves (WLVms), stems (WSTms), storage organ (WSOms) and total underground organs (und) and calculated leaf area index (LAIca) of 6 potato varieties during the growing season of 1969 at Varseveld.

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 153 | 1 | 0.08 | 0.03 | 0.02 | 0.01 | 2.54 |
| 2 | 167 | 1 | 0.14 | 0.06 | 0.03 | 0.20 | 4.11 |
| 3 | 181 | 1 | 0.14 | 0.07 | 0.04 | 0.54 | 4.30 |
| 4 | 195 | 1 | 0.16 | 0.09 | 0.05 | 0.84 | 4.66 |
| 5 | 209 | 1 | 0.10 | 0.06 | 0.04 | 1.08 | 3.12 |
| 6 | 223 | 1 | 0.05 | 0.06 | 0.02 | 1.03 | 1.65 |
| 7 | 237 | 1 | 0.01 | 0.05 | 0.01 | 1.06 | 0.34 |
| 8 | 251 | 1 | 0.01 | 0.03 | 0.02 | 1.02 | 0.17 |
| 9 | 265 | 1 | 0.00 | 0.03 | 0.01 | 1.11 | 0.00 |
| 10 | 279 | 1 | 0.00 | 0.03 | 0.01 | 1.06 | 0.00 |

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 153 | 2 | 0.09 | 0.04 | 0.02 | 0.00 | 2.60 |
| 2 | 167 | 2 | 0.15 | 0.10 | 0.05 | 0.12 | 4.43 |
| 3 | 181 | 2 | 0.18 | 0.14 | 0.05 | 0.43 | 5.26 |
| 4 | 195 | 2 | 0.15 | 0.14 | 0.06 | 0.74 | 4.63 |
| 5 | 209 | 2 | 0.12 | 0.15 | 0.06 | 1.01 | 3.71 |
| 6 | 223 | 2 | 0.06 | 0.12 | 0.03 | 1.03 | 1.94 |
| 7 | 237 | 2 | 0.05 | 0.12 | 0.03 | 1.21 | 1.42 |
| 8 | 251 | 2 | 0.03 | 0.11 | 0.02 | 1.24 | 0.95 |
| 9 | 265 | 2 | 0.02 | 0.08 | 0.01 | 1.24 | 0.69 |
| 10 | 279 | 2 | 0.00 | 0.07 | 0.00 | 1.32 | 0.00 |

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 153 | 3 | 0.08 | 0.02 | 0.01 | 0.00 | 2.25 |
| 2 | 167 | 3 | 0.15 | 0.08 | 0.05 | 0.07 | 4.42 |
| 3 | 181 | 3 | 0.18 | 0.13 | 0.06 | 0.29 | 5.40 |
| 4 | 195 | 3 | 0.17 | 0.18 | 0.08 | 0.51 | 5.23 |
| 5 | 209 | 3 | 0.14 | 0.20 | 0.06 | 0.86 | 4.33 |
| 6 | 223 | 3 | 0.09 | 0.16 | 0.05 | 1.04 | 2.82 |
| 7 | 237 | 3 | 0.06 | 0.16 | 0.04 | 1.18 | 1.66 |
| 8 | 251 | 3 | 0.02 | 0.15 | 0.04 | 1.21 | 0.68 |
| 9 | 265 | 3 | 0.03 | 0.12 | 0.02 | 1.23 | 1.02 |
| 10 | 279 | 3 | 0.01 | 0.10 | 0.01 | 1.11 | 0.21 |

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 153 | 4 | 0.09 | 0.04 | 0.03 | 0.01 | 2.66 |
| 2 | 167 | 4 | 0.15 | 0.08 | 0.04 | 0.24 | 4.50 |
| 3 | 181 | 4 | 0.16 | 0.10 | 0.05 | 0.51 | 4.67 |
| 4 | 195 | 4 | 0.14 | 0.10 | 0.07 | 0.82 | 4.08 |
| 5 | 209 | 4 | 0.10 | 0.09 | 0.06 | 0.99 | 2.99 |
| 6 | 223 | 4 | 0.06 | 0.07 | 0.04 | 1.10 | 1.90 |
| 7 | 237 | 4 | 0.05 | 0.08 | 0.03 | 1.31 | 1.47 |
| 8 | 251 | 4 | 0.02 | 0.05 | 0.03 | 1.24 | 0.74 |
| 9 | 265 | 4 | 0.02 | 0.06 | 0.02 | 1.23 | 0.67 |
| 10 | 279 | 4 | 0.01 | 0.04 | 0.01 | 1.07 | 0.22 |

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 153 | 5 | 0.07 | 0.02 | 0.01 | 0.00 | 2.12 |
| 2 | 167 | 5 | 0.16 | 0.08 | 0.05 | 0.08 | 4.84 |
| 3 | 181 | 5 | 0.20 | 0.13 | 0.05 | 0.30 | 6.11 |
| 4 | 195 | 5 | 0.19 | 0.16 | 0.06 | 0.58 | 5.70 |
| 5 | 209 | 5 | 0.17 | 0.15 | 0.07 | 1.00 | 5.07 |
| 6 | 223 | 5 | 0.14 | 0.19 | 0.06 | 1.24 | 4.17 |
| 7 | 237 | 5 | 0.10 | 0.15 | 0.05 | 1.31 | 3.04 |
| 8 | 251 | 5 | 0.08 | 0.14 | 0.05 | 1.47 | 2.41 |
| 9 | 265 | 5 | 0.06 | 0.18 | 0.03 | 1.55 | 1.84 |
| 10 | 279 | 5 | 0.02 | 0.14 | 0.01 | 1.46 | 0.41 |

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 153 | 6 | 0.08 | 0.03 | 0.02 | 0.00 | 2.49 |
| 2 | 167 | 6 | 0.17 | 0.10 | 0.08 | 0.03 | 5.19 |
| 3 | 181 | 6 | 0.19 | 0.15 | 0.09 | 0.19 | 5.84 |
| 4 | 195 | 6 | 0.20 | 0.19 | 0.11 | 0.42 | 6.03 |
| 5 | 209 | 6 | 0.17 | 0.25 | 0.11 | 0.75 | 5.21 |
| 6 | 223 | 6 | 0.14 | 0.20 | 0.08 | 0.99 | 4.09 |
| 7 | 237 | 6 | 0.11 | 0.23 | 0.07 | 0.98 | 3.23 |
| 8 | 251 | 6 | 0.08 | 0.19 | 0.06 | 1.16 | 2.39 |
| 9 | 265 | 6 | 0.05 | 0.18 | 0.04 | 1.43 | 1.37 |
| 10 | 279 | 6 | 0.03 | 0.15 | 0.03 | 1.02 | 0.77 |

Gmelig Meyling, H.D. & K.B.A. Bodlaender, 1981.
Varietal differences in growth, development and tuber production of potatoes.
Netherlands journal of Agricultural Science, 29, 113 - 127.

Appendix F2c. Field experiment data of 4 potato varieties at Varseveld, the Netherlands, 1971, (Caesar et al., 1981)

| | | | | |
|---|---|---|---|---|
| Varieties | 1=Ostara | early, ware | 3=Alpha | late, ware |
| | 2=Rheinhort | early, ware | 4=Condea | late, ware |

J. day nr. = Julian day number

NPL 40.000
Field example 6 pl
plant date: 28 April
emergence date 18 May

| harvest nr. | harvest date | J. day nr. |
|---|---|---|
| 1 | 2-Jun | 153 |
| 2 | 16-Jun | 167 |
| 3 | 30-Jun | 181 |
| 4 | 14-Jul | 195 |
| 5 | 28-Jul | 209 |
| 6 | 11-Aug | 223 |
| 7 | 25-Aug | 237 |
| 8 | 8-Sep | 251 |
| 9 | 22-Sep | 265 |
| 10 | 30-Sep | 273 |

Table F2c. Measured dry matter production of leaves (WLVms), stems (WSTms), storage organ (WSOms) and total underground organs (und) and calculated leaf area index (LAIca) of 4 potato varieties during the growing season of 1971 at Varseveld.

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 153 | 1 | 0.04 | 0.01 | 0.01 | 0.00 | 1.06 |
| 2 | 167 | 1 | 0.11 | 0.05 | 0.01 | 0.08 | 3.24 |
| 3 | 181 | 1 | 0.16 | 0.08 | 0.02 | 0.27 | 4.90 |
| 4 | 195 | 1 | 0.17 | 0.09 | 0.01 | 0.62 | 4.96 |
| 5 | 209 | 1 | 0.13 | 0.10 | 0.01 | 0.94 | 3.96 |
| 6 | 223 | 1 | 0.09 | 0.07 | 0.01 | 1.03 | 2.84 |

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 153 | 2 | 0.06 | 0.02 | 0.03 | 0.00 | 1.74 |
| 2 | 167 | 2 | 0.12 | 0.06 | 0.08 | 0.05 | 3.53 |
| 3 | 181 | 2 | 0.23 | 0.15 | 0.19 | 0.21 | 6.86 |
| 4 | 195 | 2 | 0.21 | 0.14 | 0.16 | 0.54 | 6.23 |
| 5 | 209 | 2 | 0.10 | 0.12 | 0.14 | 0.76 | 3.12 |
| 6 | 223 | 2 | 0.10 | 0.11 | 0.12 | 0.91 | 2.87 |

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 153 | 3 | 0.02 | 0.01 | 0.00 | 0.00 | 0.74 |
| 2 | 167 | 3 | 0.09 | 0.04 | 0.01 | 0.01 | 2.84 |
| 3 | 181 | 3 | 0.22 | 0.15 | 0.02 | 0.08 | 6.63 |
| 4 | 195 | 3 | 0.24 | 0.21 | 0.02 | 0.33 | 7.33 |
| 5 | 209 | 3 | 0.24 | 0.21 | 0.02 | 0.52 | 7.12 |
| 6 | 223 | 3 | 0.20 | 0.21 | 0.02 | 0.69 | 5.89 |
| 7 | 237 | 3 | 0.16 | 0.19 | 0.02 | 1.20 | 4.93 |
| 8 | 251 | 3 | 0.14 | 0.22 | 0.03 | 1.40 | 4.27 |
| 9 | 265 | 3 | 0.11 | 0.15 | 0.06 | 1.33 | 3.19 |
| 10 | 273 | 3 | 0.10 | 0.11 | 0.05 | 1.26 | 3.15 |

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 153 | 4 | 0.04 | 0.01 | 0.01 | 0.00 | 1.25 |
| 2 | 167 | 4 | 0.11 | 0.06 | 0.02 | 0.01 | 3.21 |
| 3 | 181 | 4 | 0.18 | 0.16 | 0.02 | 0.06 | 5.48 |
| 4 | 195 | 4 | 0.18 | 0.21 | 0.02 | 0.22 | 5.53 |
| 5 | 209 | 4 | 0.19 | 0.28 | 0.02 | 0.47 | 5.71 |
| 6 | 223 | 4 | 0.20 | 0.33 | 0.02 | 0.79 | 6.11 |
| 7 | 237 | 4 | 0.14 | 0.27 | 0.03 | 0.94 | 4.27 |
| 8 | 251 | 4 | 0.12 | 0.28 | 0.03 | 1.14 | 3.75 |
| 9 | 265 | 4 | 0.08 | 0.18 | 0.05 | 1.22 | 2.51 |
| 10 | 273 | 4 | 0.12 | 0.17 | 0.08 | 1.21 | 3.61 |

Caesar, K., K.B.A. Bodlaender, C. Hunicken, L. Roer & M. Umaerus, 1981.
Growth of four potato varieties under different ecological conditions.
Report of a working group of the section physiology of the European Association for Potato Research, Berlin.

Appendix F2d. Field experiment data of 4 potato varieties at Varseveld, the Netherlands, 1972, (Caesar et al., 1981)

Varieties 1=Ostara early, ware 3=Alpha late, ware
2=Rheinhort early, ware 4=Condea late, ware

J. day nr. = Julian day number

NPL 40.000
Field example 10 pl
plant date 15 April
emergence date 24 May

| harvest nr. | harvest date | J. day nr. |
|---|---|---|
| 1 | 7-Jun | 159 |
| 2 | 21-Jun | 173 |
| 3 | 5-Jul | 187 |
| 4 | 19-Jul | 201 |
| 5 | 2-Aug | 215 |
| 6 | 16-Aug | 229 |
| 7 | 30-Aug | 243 |
| 8 | 13-Sep | 257 |
| 9 | 27-Sep | 271 |
| 10 | 11-Oct | 285 |

Table F2d. Measured dry matter production of leaves (WLVms), stems (WSTms), storage organ (WSOms) and total underground organs (und) and calculated leaf area index (LAIca) of 4 potato varieties during the growing season of 1972 at Varseveld.

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 159 | 1 | 0.08 | 0.03 | 0.01 | 0.01 | 2.51 |
| 2 | 173 | 1 | 0.19 | 0.08 | 0.03 | 0.16 | 5.69 |
| 3 | 187 | 1 | 0.19 | 0.10 | 0.03 | 0.37 | 5.70 |
| 4 | 201 | 1 | 0.15 | 0.09 | 0.03 | 0.70 | 4.56 |
| 5 | 215 | 1 | 0.13 | 0.10 | 0.02 | 0.89 | 3.92 |
| 6 | 229 | 1 | 0.07 | 0.08 | 0.02 | 1.22 | 2.09 |

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 159 | 2 | 0.04 | 0.01 | 0.01 | 0.00 | 1.28 |
| 2 | 173 | 2 | 0.17 | 0.07 | 0.03 | 0 03 | 5.12 |
| 3 | 187 | 2 | 0.21 | 0.13 | 0.03 | 0.13 | 6.25 |
| 4 | 201 | 2 | 0.17 | 0.14 | 0.04 | 0.36 | 5.02 |
| 5 | 215 | 2 | 0.15 | 0.18 | 0.03 | 0.64 | 4.56 |
| 6 | 229 | 2 | 0.05 | 0.11 | 0.01 | 0.86 | 1.64 |

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 159 | 3 | 0.04 | 0.01 | 0.01 | 0.00 | 1.33 |
| 2 | 173 | 3 | 0.17 | 0.06 | 0.03 | 0.02 | 5.12 |
| 3 | 187 | 3 | 0.21 | 0.13 | 0.03 | 0.11 | 6.39 |
| 4 | 201 | 3 | 0.22 | 0.22 | 0.05 | 0.31 | 6.52 |
| 5 | 215 | 3 | 0.18 | 0.27 | 0.04 | 0.60 | 5.42 |
| 6 | 229 | 3 | 0.19 | 0.31 | 0.03 | 0.77 | 5.63 |
| 7 | 243 | 3 | 0.16 | 0.31 | 0.03 | 1.03 | 4.74 |
| 8 | 257 | 3 | 0.17 | 0.33 | 0.03 | 1.26 | 5.03 |
| 9 | 271 | 3 | 0.17 | 0.33 | 0.04 | 1.57 | 5.18 |
| 10 | 285 | 3 | 0.10 | 0.33 | 0.03 | 1.60 | 2.87 |

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 159 | 4 | 0.05 | 0.02 | 0.01 | 0.00 | 1.52 |
| 2 | 173 | 4 | 0.17 | 0.09 | 0.03 | 0.02 | 5.10 |
| 3 | 187 | 4 | 0.17 | 0.15 | 0.03 | 0.04 | 5.19 |
| 4 | 201 | 4 | 0.18 | 0.24 | 0.05 | 0.18 | 5.41 |
| 5 | 215 | 4 | 0.16 | 0.32 | 0.04 | 0.33 | 4.87 |
| 6 | 229 | 4 | 0.16 | 0.40 | 0.04 | 0.42 | 4.92 |
| 7 | 243 | 4 | 0.17 | 0.39 | 0.03 | 0.83 | 5.03 |
| 8 | 257 | 4 | 0.17 | 0.39 | 0.04 | 1.03 | 5.06 |
| 9 | 271 | 4 | 0.14 | 0.47 | 0.04 | 1.13 | 4.34 |
| 10 | 285 | 4 | 0.13 | 0.48 | 0.02 | 1.27 | 3.77 |

Caesar, K., K.B.A. Bodlaender, C. Hunicken, L. Roer & M. Umaerus, 1981.
Growth of four potato varieties under different ecological conditions.
Report of a working group of the section physiology of the European Association for Potato Research, Berlin.

Appendix F2e. Field experiment data of 4 potato varieties at Varseveld, the Netherlands, 1973, (Caesar et al., 1981)

| Varieties | | | | |
|---|---|---|---|---|
| | 1=Ostara | early, ware | 3=Alpha | late, ware |
| | 2=Rheinhort | early, ware | 4=Condea | late, ware |

J. day nr. = Julian day number

NPL 40.000
Field example 10 pl
plant date 13 April
emergence date 24 May

| harvest nr. | harvest date | J. day nr. |
|---|---|---|
| 1 | 6-Jun | 157 |
| 2 | 20-Jun | 171 |
| 3 | 4-Jul | 185 |
| 4 | 18-Jul | 199 |
| 5 | 1-Aug | 213 |
| 6 | 15-Aug | 227 |
| 7 | 29-Aug | 241 |
| 8 | 12-Sep | 255 |
| 9 | 26-Sep | 269 |
| 10 | 10-Oct | 283 |

Table F2e. Measured dry matter production of leaves (WLVms), stems (WSTms), storage organ (WSOms) and total underground organs (und) and calculated leaf area index (LAIca) of 4 potato varieties during the growing season of 1973 at Varseveld.

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 157 | 1 | 0.04 | 0.01 | 0.01 | 0.00 | 1.33 |
| 2 | 171 | 1 | 0.12 | 0.04 | 0.02 | 0.14 | 3.48 |
| 3 | 185 | 1 | 0.13 | 0.05 | 0.02 | 0.35 | 3.86 |
| 4 | 199 | 1 | 0.14 | 0.04 | 0.02 | 0.60 | 4.05 |
| 5 | 213 | 1 | 0.12 | 0.05 | 0.02 | 0.74 | 3.47 |
| 6 | 227 | 1 | 0.05 | 0.03 | 0.01 | 0.97 | 1.44 |

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 157 | 2 | 0.04 | 0.01 | 0.01 | 0.00 | 1.31 |
| 2 | 171 | 2 | 0.11 | 0.04 | 0.03 | 0.07 | 3.40 |
| 3 | 185 | 2 | 0.15 | 0.06 | 0.03 | 0.31 | 4.36 |
| 4 | 199 | 2 | 0.17 | 0.07 | 0.04 | 0.59 | 5.04 |
| 5 | 213 | 2 | 0.16 | 0.07 | 0.03 | 0.76 | 4.91 |
| 6 | 227 | 2 | 0.08 | 0.05 | 0.02 | 0.98 | 2.26 |

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 157 | 3 | 0.03 | 0.01 | 0.01 | 0.00 | 0.86 |
| 2 | 171 | 3 | 0.13 | 0.04 | 0.03 | 0.04 | 3.75 |
| 3 | 185 | 3 | 0.16 | 0.07 | 0.03 | 0.24 | 4.77 |
| 4 | 199 | 3 | 0.22 | 0.10 | 0.05 | 0.44 | 6.54 |
| 5 | 213 | 3 | 0.20 | 0.13 | 0.03 | 0.54 | 6.07 |
| 6 | 227 | 3 | 0.20 | 0.15 | 0.03 | 0.82 | 5.99 |
| 7 | 241 | 3 | 0.19 | 0.18 | 0.04 | 1.10 | 5.61 |
| 8 | 255 | 3 | 0.16 | 0.15 | 0.04 | 1.30 | 4.78 |
| 9 | 269 | 3 | 0.12 | 0.12 | 0.04 | 1.36 | 3.61 |
| 10 | 283 | 3 | 0.07 | 0.13 | 0.02 | 1.47 | 2.22 |

| harvest | J. day nr. | variety | WLVms kg/m2 | WSTms kg/m2 | und kg/m2 | WSOms kg/m2 | LAIca m2/m2 |
|---|---|---|---|---|---|---|---|
| 1 | 157 | 4 | 0.04 | 0.12 | 0.01 | 0.00 | 1.27 |
| 2 | 171 | 4 | 0.12 | 0.20 | 0.11 | 0.02 | 3.70 |
| 3 | 185 | 4 | 0.16 | 0.23 | 0.17 | 0.20 | 4.83 |
| 4 | 199 | 4 | 0.19 | 0.20 | 0.23 | 0.34 | 5.73 |
| 5 | 213 | 4 | 0.18 | 0.23 | 0.31 | 0.47 | 5.33 |
| 6 | 227 | 4 | 0.15 | 0.34 | 0.24 | 0.72 | 4.37 |
| 7 | 241 | 4 | 0.14 | 0.38 | 0.22 | 0.88 | 4.30 |
| 8 | 255 | 4 | 0.13 | 0.39 | 0.22 | 1.20 | 3.93 |
| 9 | 269 | 4 | 0.10 | 0.53 | 0.18 | 1.19 | 3.12 |
| 10 | 283 | 4 | 0.04 | 0.61 | 0.11 | 1.10 | 1.29 |

Caesar, K., K.B.A. Bodlaender, C. Hunicken, L. Roer & M. Umaerus, 1981.
Growth of four potato varieties under different ecological conditions.
Report of a working group of the section physiology of the European Association for Potato Research, Berlin.

Appendix F2f. Growth and development of on farm potato crops in the United Kingdom at 1984.

SOIL: sandy to medium loam.
Variety: Maris Piper
Maincrop, unsprouted

Table F2f1. Dates and day numbers of planting, 50% emergence and canopy closure of irrigated (but not to a potential yield) on farm potato crops within regions of the United Kingdom (1984) and weather stations used for calibration.
pd = planting date
cc = canopy closure
E50 = 50% emergence
J. day nr. = Julian day number
W.s. = weather station used for calibration

| Region | W.s. | pd | J. day nr. | E50 | J.day nr. | cc | J. day nr. |
|---|---|---|---|---|---|---|---|
| Scotland | 3066 | 29-Apr | 119 | 29-May | 149 | 4-Jul | 185 |
| Northern | | 16-Apr | 106 | 1-Jun | 152 | - | - |
| East Midlands | 3354 | 1-Apr | 91 | 23-May | 143 | 4-Jul | 185 |
| East Anglia | 3590 | 11-Apr | 101 | 25-May | 145 | 7-Jul | 188 |
| South West | | 29-Mar | 88 | 13-May | 133 | 19-Jun | 170 |
| South East | 3649 | 26-Mar | 85 | 16-May | 136 | 27-Jun | 180 |

Table F2f2. Planting, 50% emergence and canopy closure date and day number, total dry matter at canopy closure, measured fresh and dry yield, harvest index and calculated tuber dry matter percentage of unsprouted ware potato at Dundee (1984).
pd = planting date
cc = canopy closure
E50 = 50% emergence
HD = haulm destruction
(T)DM = (total) dry matter
J. day nr. = Julian day number

| | pd | J. day nr. | E50 | J. day nr. | obs. cc | J. day nr. | TDMcc (t/ha) | pl-HD (t/ha) | obs. fresh yield (t/ha) | obs. dry yield (t/ha) | obs. HI% | tuber DM% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 13-Apr | 103 | 28-May | 148 | - | - | - | 7.6 | 27.4 | 6.7 | 87.6 | 24.3 |
| 3 | 17-Apr | 107 | 30-May | 150 | 15-Jul | 196 | 5.7 | 10.7 | 33.9 | 8.9 | 83.8 | 26.3 |
| 5 | 15-Apr | 105 | 26-May | 146 | 8-Jul | 189 | 4.6 | 13.7 | 50.1 | 11.5 | 84.1 | 22.9 |
| 6 | 16-Apr | 106 | 29-May | 149 | 18-Jul | 199 | 5.5 | 9.9 | 31.9 | 8.3 | 83.8 | 25.9 |
| 8 | 26-Apr | 116 | 27-May | 147 | 8-Jul | 189 | 5.4 | 13.0 | 48.7 | 9.7 | 74.7 | 20.0 |
| 9 | 23-Apr | 113 | 29-May | 149 | 8-Jul | 189 | 5.1 | 10.2 | 32.7 | 8.3 | 81.5 | 25.5 |

Table F2f3. Planting and haulm destruction date and day number, fresh yield and expected dry matter yield, harvest index and tuber dry matter percentage of potato varieties in 6 places of the United Kingdom in 1984.
pd = planting date
HD = haulm destruction
DM = dry matter
J. day nr. = Julian day number
W.s. = weather station used for calibration

| | cultivar | pd | J. day nr. | HD | J. day nr. | fresh yield t/ha | dry matter exp.yield t/ha | HI% | tuber DM% |
|---|---|---|---|---|---|---|---|---|---|
| Scotland | Cara | 23-Apr | 113 | 24-Aug | 236 | 49.0 | 13.4 | 75.0 | 27.4 |
| W.s. 3066 | Maris Piper | 22-Apr | 112 | 14-Sep | 257 | 46.9 | 9.4 | 75.0 | 20.0 |
| | Maris Piper | 23-Apr | 113 | 13-Sep | 256 | 65.0 | 13.8 | 75.0 | 21.2 |
| | Pentland Squire | 30-Apr | 120 | 9-Aug | 221 | 47.3 | 8.1 | 67.5 | 17.2 |
| | Pentland Squire | 17-Apr | 107 | 10-Sep | 253 | 61.5 | 12.6 | 72.2 | 20.5 |
| | Home Guard | 13-Apr | 103 | 31-Jul | 212 | 35.0 | 7.2 | 69.8 | 20.5 |
| | Estima | 19-Apr | 109 | 8-Aug | 220 | 39.6 | 8.0 | 84.5 | 20.3 |
| | Maris Piper | 26-Apr | 116 | 20-Aug | 232 | 58.3 | 12.3 | 75.0 | 21.1 |
| | Wilja | 19-Apr | 109 | 13-Sep | 256 | 54.6 | 10.2 | 78.2 | 18.6 |
| | Pentland Javelin | 22-Apr | 112 | 6-Aug | 218 | 59.2 | 10.8 | 75.0 | 18.2 |
| Northern | | | | | | | | | |
| | Maris Piper | 21-Apr | 111 | 31-Aug | 243 | 37.7 | 9.2 | 83.5 | 24.4 |
| | Pentland Squire | 16-Apr | 106 | 25-Sep | 268 | 45.0 | 10.2 | 75.0 | 22.7 |
| | Pentland Squire | 8-Apr | 98 | 21-Aug | 233 | 61.1 | 14.5 | 75.0 | 23.7 |
| East Midlands | | | | | | | | | |
| W.s. 3354 | Record | 3-Apr | 93 | 30-Sep | 273 | 80.6 | 16 | 75.0 | 20.4 |
| | Record | 20-Mar | 79 | 10-Sep | 253 | 55.2 | 13 | 75.0 | 23.5 |
| | Record | 12-Apr | 102 | 27-Sep | 270 | 50.5 | 11 | 75.0 | 22.1 |
| | Record | 22-Mar | 112 | 1-Oct | 274 | 52.9 | 12 | 75.0 | 23.3 |
| | Maris Piper | 20-Apr | 110 | 12-Sep | 255 | 55.0 | 11 | 75.0 | 20.0 |
| | Maris Piper | 5-Apr | 95 | 14-Sep | 257 | 57.9 | 12 | 75.0 | 20.0 |
| | Record | 4-Apr | 94 | 5-Sep | 248 | 57.6 | 11 | 75.0 | 19.4 |
| | Record | 4-Apr | 94 | 5-Sep | 248 | 28.4 | 6 | 75.0 | 21.6 |
| East Anglia | | | | | | | | | |
| W.s. 3590 | Wilja | 15-Apr | 105 | 10-Sep | 253 | 61.2 | 12.2 | 75.0 | 20.0 |
| | Wilja | 10-May | 130 | 11-Oct | 284 | 66.8 | 13.4 | 75.0 | 20.0 |
| South West | | | | | | | | | |
| | Maris Piper | 5-Apr | 95 | 11-Sep | 254 | 88.1 | 17.4 | 75.0 | 19.8 |
| | Wilja | 23-Mar | 113 | 6-Sep | 249 | 59.9 | 12.0 | 75.0 | 20.0 |
| | Wilja | 22-Mar | 112 | 14-Aug | 226 | 52.4 | 10.5 | 75.0 | 20.0 |
| South East | Estima | 16-Mar | 75 | 19-Jul | 200 | 37.2 | 7.4 | 75.0 | 19.8 |
| W.s. 3649 | Wilja | 15-Mar | 74 | 2-Aug | 214 | 37.0 | 9.6 | 75.0 | 25.9 |

T.D. Heilbronn, D.K.L. MacKerron, 1984.
Diagnosis of ways in which the growth and development of farm crops of potato differ from the potential delimited by temperature and radiation.
Potato Marketing Board report nr 2.

# Appendix F3:
# Region specific data of potato

Table F3a1 Calibrated temperature sums and life span of leaves of potato crop types.
TSUM = temperature sum from emergence to 150 or 200 °Cd
TSUM = temperature sum from 150 or 200 °Cd to harvest
SPAN = life span of leaves growing at 35 °C.

| crop type | TSUM1 °Cd | TSUM2 °Cd | SPAN d |
|---|---|---|---|
| 0701 | 150 | 1550 | 37 |
| 0702 | 150 | 1675 | 37 |
| 0703 | 150 | 1800 | 40 |
| 0704 | 200 | 1800 | 40 |

Table F3a2 Occurrence of planting day of potato crop types in regions within countries of the European Community.
J. day nr. = Julian day number.

| crop type | country | NUTS codes per region | planting J. day nr. |
|---|---|---|---|
| 0701 | Germany | R1 | 105 |
| | France N | R21, R22, R23, R24, R25 | 105 |
| | the Netherlands | R4 | 105 |
| | Belgium | R5 | 105 |
| | Luxembourg | R6 | 105 |
| | United Kingdom | R7 | 115 |
| | Ireland | R8 | 105 |
| | Denmark | R9 | 105 |
| 0702 | France S | R26, R27, R28 | 105 |
| 0703 | Italy N | R31, R32, R33, R34, R35, R36 | 105 |
| 0704 | Italy S | R37, R38, R39, R3A, R3B | 105 |
| | Greece | RA | 65 |
| | Spain | RB | 115 |
| | Portugal | RC | 115 |

Table F3b Calibrated parameters of the initial crop-specific data file (Appendix F1) of potato.

```
** emergence
TSUMEM   =  200.               ! temperature sum from sowing to emergence [C° d]

** phenology
TSUM1    =   150.              ! temperature sum from emergence to anthesis [C° d]
TSUM2    =  1550.              ! temperature sum from anthesis to maturity [C° d]
DTSMTB   =   0.00,    0.00,    ! daily increase in temp. sum
             2.00,    0.00,    ! as function of av. temp. [C°; C° d]
            13.00,   11.00
            30.00,   28.00
** initial
TDWI     =  75.0               ! initial total crop dry weight [kg ha-1]

** green area
SPAN     =  37.                ! life span of leaves growing at 35 C° [d]

** partitioning
FRTB     =  0.00    0.20       ! fraction of total dry matter to roots
            1.00    0.20       ! as a function of DVS [-; kg kg-1]
            1.27
            1.36    0.00
            2.00    0.00
FLTB     =  0.00    0.80       ! fraction of above-gr. dry matter to leaves
            1.00    0.80       ! as a function of DVS [-; kg kg-1]
            1.27    0.00
            1.36
            2.00    0.00
FSTB     =  0.00    0.20       ! fraction of above-gr. dry matter to stems
            1.00    0.20       ! as a function of DVS [-; kg kg-1]
            1.27    0.25
            1.36
            2.00    0.00
FOTB     =  0.00    0.00       ! fraction of above-gr. dry matter to stor. org.
            1.00    0.00       ! as a function of DVS [-; kg kg-1]
            1.27    0.75
            1.36    1.00
            2.00    1.00
```

# Appendix F4:

## Crop calendar of potato

Table F4. Planting, start tuber growth and harvest day (Julian day number) and chosen temperature sums of potato for regions within the European Community.

TSUM1 = chosen temperature sum from emergence to start tuber growth, base temperature of 2°C.
TSUM2 = chosen temperature sum from start tuber growth to harvest, base temperature of 2°C.
Temperature sum from sowing to emergence is 170°Cd, base temperature of 3°C.
J. day nr. = Julian day number

| NUTS code | grid cell | planting J. day nr. | start tuber growth J. day nr. | harvest J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region |
|---|---|---|---|---|---|---|---|---|
| R11 | 4135 | 105 | -1 | 278 | 150 | 1550 | Germany | Schleswig-Holstein |
| R12 | 4035 | 105 | -1 | 253 | 150 | 1550 | | Hamburg |
| R13 | 3834 | 105 | -1 | 253 | 150 | 1550 | | Niedersachsen |
| R14 | 3933 | 105 | -1 | 278 | 150 | 1550 | | Bremen |
| R15 | 3531 | 105 | -1 | 278 | 150 | 1550 | | Nordrhein-Westfalen |
| R16 | 3333 | 105 | -1 | 278 | 150 | 1550 | | Hessen |
| R17 | 3231 | 105 | -1 | 278 | 150 | 1550 | | Rheinland-Pfalz |
| R18 | 2934 | 105 | -1 | 278 | 150 | 1550 | | Baden-Württemberg |
| R19 | 3037 | 105 | -1 | 278 | 150 | 1550 | | Bayern |
| R1A | 3131 | 105 | -1 | 278 | 150 | 1550 | | Saarland |
| R21 | 2924 | 105 | -1 | 258 | 150 | 1550 | France | Île de France |
| R22 | 3125 | 105 | -1 | 258 | 150 | 1550 | | Bassin Parisien |
| R23 | 3325 | 105 | -1 | 258 | 150 | 1550 | | Nord - Pas-de-Calais |
| R24 | 2830 | 105 | -1 | 258 | 150 | 1550 | | Est |
| R25 | 2817 | 105 | -1 | 258 | 150 | 1550 | | Ouest |
| R26 | 2020 | 105 | -1 | 258 | 150 | 1675 | | Sud-Ouest |
| R27 | 2227 | 105 | -1 | 258 | 150 | 1675 | | Centre-Est |
| R28 | 1826 | 105 | -1 | 258 | 150 | 1675 | | Mediterranée |
| R31 | 2132 | 105 | -1 | 238 | 150 | 1800 | Italy | Nord Ovest |
| R32 | 2235 | 105 | -1 | 238 | 150 | 1800 | | Lombardia |
| R33 | 2339 | 105 | -1 | 248 | 150 | 1800 | | Nord Est |
| R34 | 2037 | 105 | -1 | 238 | 150 | 1800 | | Emilia-Romagna |
| R35 | 1740 | 105 | -1 | 248 | 150 | 1800 | | Centro |
| R36 | 1439 | 105 | -1 | 238 | 150 | 1800 | | Lazio |
| R37 | 1242 | 105 | -1 | 238 | 150 | 1800 | | Campania |
| R38 | 1247 | 105 | -1 | 258 | 150 | 1800 | | Abruzzi-Molise |
| R39 | 1345 | 105 | -1 | 248 | 150 | 1800 | | Sud |
| R3A | 541 | 105 | -1 | 238 | 150 | 1800 | | Sicilia |
| R3B | 1134 | 105 | -1 | 238 | 150 | 1800 | | Sardegna |
| R41 | 3930 | 105 | -1 | 263 | 150 | 1800 | the Netherlands | Noord-Nederland |
| R42 | 3730 | 105 | -1 | 263 | 150 | 1800 | | Oost-Nederland |
| R45 | 3628 | 105 | -1 | 263 | 150 | 1800 | | Zuid-Nederland |
| R47 | 3626 | 105 | -1 | 263 | 150 | 1800 | | West-Nederland |
| R51 | 3426 | 105 | -1 | 288 | 150 | 1800 | Belgium | Vlaams Gewest |
| R52 | 3329 | 105 | -1 | 288 | 150 | 1800 | | Region Wallone |
| R6 | 3129 | 105 | -1 | 288 | 150 | 1800 | Luxembourg | |
| R71 | 4419 | 115 | -1 | 288 | 150 | 1800 | United Kingdom | North |
| R72 | 4220 | 115 | -1 | 288 | 150 | 1800 | | Yorkshire and Humberside |
| R73 | 4020 | 115 | -1 | 288 | 150 | 1800 | | East Midlands |
| R74 | 3822 | 115 | -1 | 288 | 150 | 1800 | | East Anglia |
| R75 | 3620 | 115 | -1 | 278 | 150 | 1800 | | South East |
| R76 | 3515 | 115 | -1 | 278 | 150 | 1800 | | South West |
| R77 | 3818 | 115 | -1 | 288 | 150 | 1800 | | West Midlands |
| R78 | 4118 | 115 | -1 | 288 | 150 | 1800 | | North West |
| R79 | 3816 | 115 | -1 | 278 | 150 | 1800 | | Wales |
| R7A | 4918 | 115 | -1 | 278 | 150 | 1800 | | Scotland |
| R7B | 4513 | 115 | -1 | 278 | 150 | 1800 | | Northern Ireland |
| R8 | 4414 | 105 | -1 | 278 | 150 | 1800 | Ireland | |
| R9 | 4534 | 105 | -1 | 258 | 150 | 1800 | Denmark | |
| RA11 | 1562 | 65 | -1 | 344 | 200 | 1800 | Greece | Anatoliki Makedonia, Thraki |
| RA12 | 1457 | 65 | -1 | 344 | 200 | 1800 | | Kentriki Makedonia |
| RA13 | 1254 | 65 | -1 | 344 | 200 | 1800 | | Dytriki Makedonia |
| RA14 | 1057 | 65 | -1 | 344 | 200 | 1800 | | Thessalia |
| RA15 | 1458 | 65 | -1 | 344 | 200 | 1800 | | Anatoliki Makedonia |
| RA18 | 1562 | 65 | -1 | 344 | 200 | 1800 | | Thraki |

Table F4. Planting, start tuber growth and harvest day (Julian day number) and chosen temperature sums of potato for regions within the European Community.

TSUM1 = chosen temperature sum from emergence to start tuber growth, base temperature of 2°C.
*TSUM2 = chosen temperature sum from start tuber growth to harvest, base temperature of 2°C.*
Temperature sum from sowing to emergence is 170°Cd, base temperature of 3°C.
*J. day nr. = Julian day number*

| NUTS code | grid cell | planting J. day nr. | start tuber growth J. day nr. | harvest J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region |
|---|---|---|---|---|---|---|---|---|
| RA2 | 956 | 65 | -1 | 344 | 200 | 1800 | Greece | Kentriki Ellada |
| RA3 | -1 | 65 | -1 | -1 | 200 | 1800 | | Attiki |
| RA4 | -1 | 65 | -1 | -1 | 200 | 1800 | | Nisia |
| RB1 | 1907 | 115 | -1 | 232 | 200 | 1800 | Spain | Noroeste |
| RB2 | 1517 | 115 | -1 | 232 | 200 | 1800 | | Noreste |
| RB3 | 1312 | 115 | -1 | 232 | 200 | 1800 | | Madrid |
| RB4 | 1011 | 115 | -1 | 232 | 200 | 1800 | | Centro |
| RB5 | 1219 | 115 | -1 | 232 | 200 | 1800 | | Este |
| RB6 | 610 | 115 | -1 | 232 | 200 | 1800 | | Sur |
| RC1 | 1605 | 115 | -1 | 238 | 200 | 1800 | Portugal | Continente |

Reference

MacKerron, D.K.L., 1992.
Agrometeorological aspects of forecasting yields of potato within the E.C., Volume 1 and 2.
Joint Research Centre, Luxembourg, 247 p.

-1 means: no data available or no potato grown

# Appendix G:

## Field bean (*Vicia faba* L.)

# Appendix G1:
## Initial crop-specific data file of field bean

CROP DATA FILE for use with WOFOST Version 5.0, January 1990

```
crop identity
!CRPNAM    = Field Bean, (Vicia faba L.), (FBE.NEW)
ICROP      = 8

** emergence
TBASEM     =   0.0              ! lower threshold temp. for emergence [C°]
TEFFMX     =  20.0              ! max. eff. temp. for emergence [C°]
TSUMEM     =100.                ! temperature sum from sowing to emergence [C° d]

** phenology
IDSL       =  0                 ! indicates whether pre-anthesis development depends
                                ! on temp. (=0), daylength (=1) , or both (=2)
DLO        = -99.0              ! optimum daylength for development [hr]
DLC        = -99.0              ! critical daylength (lower threshold) [hr]
TSUM1      =   833.             ! temperature sum from emergence to anthesis [C° d]
TSUM2      =  1351.             ! temperature sum from anthesis to maturity [C° d]
DTSMTB     =   0.00,    0.00,   ! daily increase in temp. sum
              20.00,   22.50,   ! as function of av. temp. [C°; C° d]
              25.00,   25.00,
              35.00,   25.00

DVSEND     =  2.00              ! development stage at harvest (= 2.0 at maturity [-])

** initial
TDWI       =  45.00             ! initial total crop dry weight [kg ha-1]
LAIEM      =   0.0350           ! leaf area index at emergence [ha ha-1]
RGRLAI     =   0.0110           ! maximum relative increase in LAI [ha ha-1 d-1]

** green area
SLATB      =  0.00,   0.0031,   ! specific leaf area
              0.10,   0.0036,   ! as a function of DVS [-; ha kg-1]
              0.50,   0.0042,
              2.00,   0.0042
SPA        =   0.000            ! specific pod area [ha kg-1]
SSA        =   0.000            ! specific stem area [ha kg-1]
SPAN       =  25.               ! life span of leaves growing at 35 C° [d]
TBASE      =   0.0              ! lower threshold temp. for ageing of leaves [C°]
```

** assimilation

| | | | | |
|---|---|---|---|---|
| KDIF | = | 0.800 | | ! extinction coefficient for diffuse visible light [-] |
| EFF | = | 0.48 | | ! light-use effic. single leaf [kg ha$^{-1}$ hr$^{-1}$ J$^{-1}$ m$^{2}$ s] |
| AMAXTB | = | 0.00, | 35.00, | ! maximum leaf CO2 assimilation rate |
| | | 1.50, | 35.00, | ! as function of DVS [-; kg ha$^{-1}$ hr$^{-1}$] |
| | | 1.90, | 0.00 | |
| | | 2.00, | 0.00 | |
| | | | | |
| TMPFTB | = | 0.00, | 0.01, | ! reduction factor of AMAX |
| | | 10.00, | 0.59, | ! as function of av. temp. [C°; -] |
| | | 15.00, | 0.76, | |
| | | 20.00, | 0.93, | |
| | | 25.00, | 1.00, | |
| | | 30.00, | 0.92, | |
| | | 35.00, | 0.84, | |
| | | 40.00, | 0.75 | |
| | | | | |
| TMNFTB | = | 0.00, | 0.00, | ! red. factor of gross assim. rate |
| | | 3.00, | 1.00 | ! as function of low min. temp. [C°; -] |

** conversion of assimilates into biomass

| | | | | |
|---|---|---|---|---|
| CVL | = | 0.608 | | ! efficiency of conversion into leaves [kg kg$^{-1}$] |
| CVO | = | 0.591 | | ! efficiency of conversion into storage org. [kg kg$^{-1}$] |
| CVR | = | 0.659 | | ! efficiency of conversion into roots [kg kg$^{-1}$] |
| CVS | = | 0.631 | | ! efficiency of conversion into stems [kg kg$^{-1}$] |

** maintenance respiration

| | | | | |
|---|---|---|---|---|
| Q10 | = | 2.0 | | ! rel. incr. in resp. rate per 10 C°temp. incr. [-] |
| RML | = | 0.0270 | | ! rel. maint. resp. rate leaves [kg CH2O kg$^{-1}$ d$^{-1}$] |
| RMO | = | 0.0050 | | ! rel. maint. resp. rate stor.org. [kg CH2O kg$^{-1}$ d$^{-1}$] |
| RMR | = | 0.0100 | | ! rel. maint. resp. rate roots [kg CH2O kg$^{-1}$ d$^{-1}$] |
| RMS | = | 0.0150 | | ! rel. maint. resp. rate stems [kg CH2O kg$^{-1}$ d$^{-1}$] |
| RFSETB | = | 0.00, | 1.00, | ! red. factor for senescence |
| | | 2.00, | 1.00 | ! as function of DVS [-; -] |

** partitioning

| | | | | |
|---|---|---|---|---|
| FRTB | = | 0.00, | 0.50, | ! fraction of total dry matter to roots |
| | | 0.54, | 0.30, | ! as a function of DVS [-; kg kg$^{-1}$] |
| | | 1.00, | 0.20, | |
| | | 1.20, | 0.00, | |
| | | 2.00, | 0.00 | |
| FLTB | = | 0.00, | 0.50, | ! fraction of above-gr. DM to leaves |
| | | 0.54, | 0.60, | ! as a function of DVS [-; kg kg-1] |
| | | 1.00, | 0.25, | |
| | | 1.20, | 0.04, | |
| | | 1.42, | 0.02, | |
| | | 1.51, | 0.00, | |
| | | 2.00, | 0.00 | |

```
FSTB      =  0.00,     0.50,     ! fraction of above-gr. DM to stems
             0.54,     0.40,     ! as a function of DVS [-; kg kg-1]
             1.00,     0.50,
             1.20,     0.25,
             1.42,     0.14,
             1.51,     0.01,
             1.71,     0.00,
             2.00,     0.00
FOTB      =  0.00,     0.00,     ! fraction of above-gr. DM to stor. org.
             0.54,     0.00,     ! as a function of DVS [-; kg kg-1]
             1.00,     0.25,
             1.20,     0.71,
             1.42,     0.84,
             1.51,     0.99,
             1.71,     1.00
             2.00,     1.00

** death rates
PERDL     =  0.030               ! max. rel. death rate of leaves due to water stress
RDRRTB    =  0.00,     0.000,    ! rel. death rate of stems
             1.50,     0.000,    ! as a function of DVS [-; kg kg-1 d-1]
             1.5001,   0.020,
             2.00,     0.020
RDRSTB    =  0.00,     0.000,    ! rel. death rate of roots
             1.50,     0.000,    ! as a function of DVS [-; kg kg-1 d-1]
             1.5001,   0.020,
             2.00,     0.020

** water use
CFET      =  1.00                ! correction factor transpiration rate [-]
DEPNR     =  4.5                 ! crop group number for soil water depletion [-]
IAIRDU    =  0                   ! air ducts in roots present (=1) or not (=0)

** rooting
RDI       =   10.                ! initial rooting depth [cm]
RRI       =    0.8               ! maximum daily increase in rooting depth [cm d-1]
RDMCR     =  100.                ! maximum rooting depth [cm]

** nutrients
** maximum and minimum concentrations of N, P, and K in storage organsin vegetative organs
   [kg kg-1]
NMINSO    =  0.0300 ;  NMINVE  =  0.0080
NMAXSO    =  0.0490 ;  NMAXVE  =  0.0250
PMINSO    =  0.0026 ;  PMINVE  =  0.0008
PMAXSO    =  0.0060 ;  PMAXVE  =  0.0040
KMINSO    =  0.0080 ;  KMINVE  =  0.0100
KMAXSO    =  0.0200 ;  KMAXVE  =  0.0300
YZERO     =  0.                  ! max. amount veg. organs at zero yield [kg ha-1]
NFIX      =  0.75                ! fraction of N-uptake from biol. fixation [kg kg-1]
```

# Appendix G2:

## Field experiment data of field bean

Appendix G2a. Day number of sowing, emergence, canopy closure, flowering start, end and average flowering, opening of the canopy and maturity grain yield, harvest index and total dry matter production of non irrigated field bean field experiments with the variety Minica for serval locations within Western Europe from 1980 to 1989.
d.m. = dry matter
J. day nr. = Julian day number

| Location | year | sow.d. J.day nr. | em.d. J.day nr. | can.clo. J.day nr. | start flow. J.day nr. | end flow. J.day nr. | aver. flow. J.day nr. | can.ope. J.day nr. | maturity J.day nr. | d.m.grain yield t/ha | HI | total d.m. yield t/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 Dijon | 80 | 63 | 0 | | 140 | 168 | 154 | | 214 | 4.51 | 63 | 7.15 |
| 3 Dijon | 81 | 78 | 94 | | 139 | 167 | 153 | | 221 | 4.31 | 59 | 7.27 |
| 3 Dijon | 82 | 62 | 97 | | 137 | 158 | 148 | | 200 | 4.21 | 65 | 6.52 |
| 3 Dijon | 85 | | | | 153 | 184 | 168 | | 229 | 4.34 | 44 | 9.77 |
| 3 Dijon | 86 | | | | 171 | 195 | 183 | | 237 | 4.55 | 52 | 8.69 |
| 3 Dijon | 87 | | | | 161 | 186 | 173 | | 241 | 3.79 | 56 | 4.95 |
| 3 Dijon | 89 | | 89 | 0 | 138 | 173 | 155 | 0 | 203 | 4.10 | 53 | 7.81 |
| average | | 68 | | | | | 162 | | 221 | | | |
| 5 Dundee | 80 | 98 | 115 | | 157 | 189 | 173 | | 261 | 3.85 | 51 | 7.64 |
| 5 Dundee | 81 | 96 | 113 | | 159 | 189 | 174 | | 245 | 5.21 | 49 | 10.56 |
| 5 Dundee | 82 | 82 | 107 | | 150 | 172 | 161 | | 220 | 3.60 | 65 | 5.58 |
| 5 Dundee | 85 | | | | 161 | 194 | 177 | | 272 | 2.79 | 41 | 6.87 |
| 5 Dundee | 86 | | | | 166 | 190 | 178 | | 253 | 1.98 | 40 | 4.94 |
| 5 Dundee | 87 | | | | 175 | 198 | 186 | | 300 | 4.14 | 50 | 8.33 |
| 5 Dundee | 89 | | 121 | 176 | 163 | 176 | 169 | 200 | 226 | 3.53 | 60 | 5.92 |
| average | | 92 | | | | | 174 | | 254 | | | |
| 7 Hohenheim | 80 | 77 | 0 | | 154 | 176 | 165 | | 0 | 4.62 | 32 | 14.45 |
| 7 Hohenheim | 81 | 84 | 0 | | 150 | 176 | 163 | | 0 | 4.17 | 51 | 8.34 |
| 7 Hohenheim | 82 | 90 | 128 | | 154 | 173 | 163 | | 218 | 3.84 | 67 | 5.76 |
| 7 Hohenheim | 85 | | | | 156 | 187 | 172 | | 250 | 4.65 | 45 | 10.33 |
| 7 Hohenheim | 86 | | | | 161 | 182 | 171 | | 228 | 4.91 | 49 | 10.11 |
| 7 Hohenheim | 87 | | | | 161 | 187 | 174 | | 252 | 5.26 | 45 | 11.69 |
| 7 Hohenheim | 89 | | 106 | 145 | 146 | 163 | 155 | 205 | 221 | 5.61 | 67 | 8.39 |
| average | | 84 | | | | | 166 | | 234 | | | |
| 18 Wageningen | 80 | 84 | 119 | | 151 | 179 | 165 | | 261 | 6.04 | 64 | 9.44 |
| 18 Wageningen | 81 | 99 | 126 | | 153 | 180 | 167 | | 244 | 6.07 | 65 | 9.34 |
| 18 Wageningen | 82 | 85 | 113 | | 148 | 168 | 158 | | 223 | 4.54 | 61 | 7.45 |
| 18 Wageningen | 85 | | | | 164 | 199 | 182 | | 261 | 6.31 | 61 | 10.35 |
| 18 Wageningen | 86 | | | | 168 | 191 | 180 | | 255 | 3.62 | 56 | 6.50 |
| 18 Wageningen | 87 | | | | 160 | 185 | 173 | | 241 | 5.20 | 55 | 9.52 |
| 18 Wageningen | 89 | | 121 | 125 | 146 | 175 | 161 | 139 | 238 | 6.32 | 68 | 9.25 |
| average | | 89 | | | | | 169 | | 246 | | | |
| 10 NOP | 80 | 81 | 108 | | 147 | 179 | 163 | | 247 | 5.78 | 60 | 9.64 |
| 10 NOP | 81 | 98 | 118 | | 152 | 185 | 169 | | 251 | 5.05 | 54 | 9.36 |
| 10 NOP | 82 | 90 | 116 | | 155 | 187 | 171 | | 246 | 8.05 | 60 | 13.41 |
| 10 NOP | 85 | | | | 166 | 191 | 179 | | 277 | 6.18 | 56 | 11.04 |
| 10 NOP | 86 | | | | 169 | 180 | 175 | | 261 | 7.37 | 65 | 11.27 |
| 10 NOP | 87 | | | | 162 | 184 | 173 | | 245 | 5.72 | 51 | 11.22 |
| average | | 89 | | | | | 171 | | 255 | | | |
| 1 Cambridge | 80 | 65 | 86 | | 144 | 176 | 160 | | 222 | 4.50 | 56 | 7.99 |
| 1 Cambridge | 81 | 103 | 121 | | 153 | 182 | 168 | | 263 | 3.03 | 58 | 5.20 |
| 1 Cambridge | 85 | | | | 154 | 182 | 168 | | 247 | 4.17 | 52 | 7.98 |
| 1 Cambridge | 86 | | | | 156 | 175 | 165 | | 229 | 2.78 | 56 | 5.02 |
| 1 Cambridge | 87 | | | | 150 | 182 | 166 | | 246 | 2.93 | 45 | 6.48 |
| average | | 84 | | | | | 165 | | 241 | | | |
| 4 Dublin | 85 | | | | 157 | 184 | 171 | | 261 | 3.61 | 59 | 6.15 |
| 4 Dublin | 86 | | | | 168 | 0 | 84 | | 286 | 4.62 | 59 | 7.99 |
| 4 Dublin | 87 | | | | 156 | 187 | 171 | | 255 | 3.03 | 0 | 0.00 |
| 4 Dublin | 89 | | 120 | 158 | 155 | 179 | 167 | 197 | 227 | 5.00 | 0 | |
| average | | | | | | | 148 | | 257 | | | |

Appendix G2a. Day number of sowing, emergence, canopy closure, flowering start, end and average flowering, opening of the canopy and maturity grain yield, harvest index and total dry matter production of non irrigated field bean field experiments with the variety Minica for serval locations within Western Europe from 1980 to 1989.
d.m. = dry matter
J. day nr. = Julian day number

| Location | year | sow.d. | em.d. | can.clo. | start flow. | end flow. | aver. flow. | can.ope. | maturity | gry t/ha | HI | tot dm y t/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 Göttingen | 80 | 84 | 0 | | 158 | 183 | 171 | | 238 | 4.86 | 58 | 8.34 |
| 6 Göttingen | 81 | 92 | 0 | | 151 | 177 | 164 | | 247 | 4.75 | 52 | 9.22 |
| 6 Göttingen | 82 | 83 | 0 | | 151 | 174 | 163 | | 238 | 5.12 | 67 | 7.60 |
| 6 Göttingen | 89 | | 116 | 159 | 146 | 169 | 158 | 207 | 213 | 4.82 | 64 | 7.49 |
| average | | 86 | | | | | 164 | | 234 | | | |
| 11 Nottingham | 85 | | | | 158 | 183 | 171 | | 244 | 5.56 | 44 | 12.76 |
| 11 Nottingham | 86 | | | | 160 | 178 | 169 | | 220 | 3.94 | 45 | 8.72 |
| 11 Nottingham | 87 | | | | 152 | 179 | 166 | | 240 | 4.24 | 45 | 9.53 |
| 11 Nottingham | 89 | | 113 | 149 | 153 | 172 | 162 | 210 | 215 | 4.39 | 65 | 6.76 |
| average | | | | | | | 167 | | 230 | | | |
| 13 Roskilde | 85 | | | | 167 | 194 | 181 | | 270 | 4.57 | 0 | 0.00 |
| 13 Roskilde | 86 | | | | 172 | 188 | 180 | | 243 | 3.44 | 50 | 6.82 |
| 13 Roskilde | 87 | | | | 177 | 203 | 190 | | | 4.30 | 60 | 7.14 |
| 13 Roskilde | 89 | | 123 | 163 | 157 | 178 | 168 | 205 | 220 | 2.71 | 59 | 4.62 |
| average | | | | | | | 180 | | | | | |
| 16 Vienna irrigated | 80 | 93 | 117 | | 154 | 172 | | | 215 | 3.30 | 50 | 6.57 |
| 16 Vienna irrigated | 81 | 86 | 103 | | 146 | 161 | | | 203 | 3.50 | 47 | 7.48 |
| 16 Vienna irrigated | 85 | | | | 147 | 165 | | | 206 | 4.05 | 51 | 7.89 |
| 16 Vienna irrigated | 86 | | | | 140 | 160 | | | 206 | 1.76 | 60 | 2.97 |
| 16 Vienna irrigated | 87 | | | | 155 | 175 | | | 208 | 3.72 | 49 | 7.62 |
| 17 Vienna not irrigat | 80 | 93 | 117 | | 154 | 172 | | | 214 | 2.98 | 53 | 5.69 |
| 17 Vienna not irrigat | 81 | 86 | 103 | | 147 | 163 | | | 195 | 1.87 | 46 | 4.09 |
| 17 Vienna not irrigat | 85 | | | | 142 | 166 | | | 210 | 4.67 | 61 | 7.70 |
| 17 Vienna not irrigat | 86 | | | | 146 | 165 | | | 212 | 2.70 | 46 | 5.83 |
| 17 Vienna not irrigat | 87 | | | | 143 | 166 | | | 227 | 4.79 | 48 | 10.02 |
| Vienna | 89 | | 93 | 153 | 134 | 157 | | 187 | 192 | 3.30 | 54 | 6.15 |
| 2 Carlow | 89 | | 108 | 176 | 149 | 179 | | 192 | 227 | 3.63 | 65 | 5.58 |
| 9 Kiel | 89 | | 120 | 162 | 154 | 171 | | 199 | 219 | 4.41 | 57 | 7.73 |
| 12 Rennes | 89 | | 100 | 138 | 141 | 163 | | 183 | 198 | 2.92 | 43 | 6.76 |
| 14 Thornhang | 89 | | 93 | 139 | 139 | 168 | | 195 | 212 | 5.00 | 59 | 8.42 |

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3 Ebmeyer, E., 1986.
Some results of the 1985 EC Joint Field Bean Test. Vorträge für Planzenzüchtung 11, 151 - 157.

Appendix G2a. (continued) Number of plants per square meter, plant length, number of stems, roots and pods per plant, protein percentage of seeds, weight of 1000 bean seeds, number of seeds and nods per plant of the field bean field experiments with the variety Minica for several location in Western Europe from 1980 to 1989.

| Location | year | pl/m2 | pl lngt | no st/pl | no rts/pl | no pds/pl | prot % | gw 1000 | seeds/ plant | nods/ plant |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 Dijon | 80 | 30.7 | 72 | 1.13 | 3.7 | 4.7 | 31.2 | 925.3 | | |
| 3 Dijon | 81 | 40.0 | 91 | 1.17 | 3.4 | 4.2 | 30.3 | 938.7 | | |
| 3 Dijon | 82 | 53.3 | 68 | 1.03 | 3.1 | 4.1 | 31.1 | 781.7 | | |
| 3 Dijon | 85 | 29.5 | 131 | 1.08 | | 5.1 | 26.9 | 821.5 | 19.0 | 4.6 |
| 3 Dijon | 86 | 28.8 | 110 | 1.05 | | 7.0 | 31.4 | 819.8 | 22.4 | 5.0 |
| 3 Dijon | 87 | 47.8 | 128 | 1.30 | | 3.9 | 28.3 | 902.2 | 13.1 | 3.8 |
| 3 Dijon | 89 | 56.8 | 83 | | | | | 775.3 | | |
| average | | | | | | | | | | |
| 5 Dundee | 80 | 36.0 | 117 | 1.20 | 5.3 | 6.0 | 30.0 | 658.3 | | |
| 5 Dundee | 81 | 36.0 | 131 | 1.20 | 3.9 | 4.6 | 23.3 | 844.3 | | |
| 5 Dundee | 82 | 44.7 | 48 | 1.27 | 2.4 | 3.3 | 0.0 | 835.3 | | |
| 5 Dundee | 85 | 62.7 | 128 | 1.00 | | 2.3 | 27.4 | 671.1 | 7.0 | 2.3 |
| 5 Dundee | 86 | 62.7 | 96 | 1.00 | | 2.6 | 26.8 | 574.9 | 9.5 | 2.3 |
| 5 Dundee | 87 | 37.7 | 157 | 1.43 | | 6.6 | 26.1 | 801.8 | 24.8 | 5.8 |
| 5 Dundee | 89 | 51.7 | 75 | | | | | 736.8 | | |
| average | | | | | | | | | | |
| 7 Hohenheim | 80 | 31.3 | 0 | 1.43 | 6.0 | 6.7 | 30.9 | 882.7 | | |
| 7 Hohenheim | 81 | 40.0 | 122 | 0.00 | 3.6 | 4.0 | 28.0 | 975.0 | | |
| 7 Hohenheim | 82 | 37.3 | 85 | 1.30 | 7.6 | 8.7 | 29.7 | 839.0 | | |
| 7 Hohenheim | 85 | 38.7 | 146 | 1.00 | | 5.2 | 29.5 | 790.9 | 19.3 | 4.8 |
| 7 Hohenheim | 86 | 42.0 | 116 | 1.01 | | 3.6 | 32.0 | 1034.5 | 14.0 | 3.4 |
| 7 Hohenheim | 87 | 30.7 | 137 | 1.10 | | 4.8 | 28.8 | 978.6 | 17.1 | 4.3 |
| 7 Hohenheim | 89 | 44.5 | 77 | | | | | 917.3 | | |
| average | | | | | | | | | | |
| 18 Wageningen | 80 | 18.3 | 120 | 1.90 | 8.7 | 10.3 | 32.3 | 998.0 | | |
| 18 Wageningen | 81 | 19.7 | 99 | 1.37 | 5.1 | 7.1 | 32.3 | 1150.0 | | |
| 18 Wageningen | 82 | 21.7 | 82 | 1.57 | 5.7 | 7.9 | 28.8 | 877.7 | | |
| 18 Wageningen | 85 | 24.0 | 110 | 1.07 | | 5.9 | 33.5 | 1182.8 | 24.5 | 4.8 |
| 18 Wageningen | 86 | 20.0 | 64 | 1.23 | | 4.6 | 33.2 | 1241.8 | 20.2 | 3.6 |
| 18 Wageningen | 87 | 20.0 | 120 | 1.67 | | 6.1 | 32.1 | 1183.5 | 23.8 | 3.8 |
| 18 Wageningen | 89 | 26.0 | 68 | | | | | 1186.4 | | |
| average | | | | | | | | | | |
| 10 NOP | 80 | 18.0 | 135 | 1.70 | 9.4 | 10.2 | 31.1 | 896.0 | | |
| 10 NOP | 81 | 19.3 | 117 | 1.13 | 7.3 | 8.5 | 30.1 | 919.0 | | |
| 10 NOP | 82 | 20.7 | 116 | 1.30 | 8.2 | 9.9 | 31.9 | 1190.3 | | |
| 10 NOP | 85 | 23.7 | 149 | 1.10 | | 7.3 | 31.6 | 1022.1 | 28.4 | 6.6 |
| 10 NOP | 86 | 23.0 | 99 | 1.07 | | 7.4 | 30.5 | 1242.8 | 28.6 | 5.1 |
| 10 NOP | 87 | 20.7 | 145 | 1.87 | | 8.3 | 31.9 | 1105.1 | 31.9 | 4.9 |
| average | | | | | | | | | | |
| 1 Cambridge | 80 | 20.0 | 74 | 2.23 | 7.0 | 10.6 | 27.8 | 813.0 | | |
| 1 Cambridge | 81 | 25.0 | 83 | 1.07 | 4.1 | 6.7 | 26.3 | 845.0 | | |
| 1 Cambridge | 85 | 44.3 | 126 | 1.15 | | 4.5 | 27.7 | 966.9 | 17.9 | 4.4 |
| 1 Cambridge | 86 | 39.0 | 71 | 1.05 | | 3.2 | 25.9 | 1013.0 | 11.1 | 2.2 |
| 1 Cambridge | 87 | 35.0 | 132 | 1.03 | | 5.4 | 25.9 | 509.8 | 19.9 | 4.4 |
| average | | | | | | | | | | |
| 4 Dublin | 85 | 17.3 | 97 | 1.73 | | 14.0 | 29.5 | 846.3 | 53.5 | 9.4 |
| 4 Dublin | 86 | 20.7 | 106 | 1.50 | | 6.5 | 30.4 | 999.6 | 24.9 | 5.2 |
| 4 Dublin | 87 | 17.7 | 0 | 0.00 | | 0.0 | 29.2 | 1076.8 | 0.0 | 0.0 |
| 4 Dublin | 89 | 23.0 | 0 | | | | | 0.0 | | |
| average | | | | | | | | | | |

Appendix G2a. (continued) Number of plants per square meter, plant length, number of stems, roots and pods per plant, protein percentage of seeds, weight of 1000 bean seeds, number of seeds and nods per plant of the field bean field experiments with the variety Minica for several location in Western Europe from 1980 to 1989.

| Location | year | pl/m2 | pl lngt | no st/pl | no rts/pl | no pds/pl | prot % | gw 1000 | seeds/ plant | nods/ plant |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 Göttingen | 80 | 26.0 | 120 | 1.20 | 4.4 | 5.2 | 32.5 | 1063.0 | | |
| 6 Göttingen | 81 | 26.0 | 117 | 1.27 | 5.3 | 6.0 | 30.6 | 929.3 | | |
| 6 Göttingen | 82 | 25.7 | 88 | 1.17 | 4.5 | 6.0 | 30.5 | 977.0 | | |
| 6 Göttingen | 89 | 35.8 | 64 | | | | | 916.3 | | |
| average | | | | | | | | | | |
| 11 Nottingham | 85 | 74.7 | 136 | 1.13 | | 3.4 | 21.0 | 1002.0 | 11.6 | 3.1 |
| 11 Nottingham | 86 | 56.0 | 86 | 1.07 | | 5.2 | 23.7 | 817.5 | 14.7 | 3.4 |
| 11 Nottingham | 87 | 50.0 | 113 | 1.03 | | 2.7 | 27.6 | 1026.4 | 10.1 | 2.5 |
| 11 Nottingham | 89 | 53.8 | 62 | | | | | 798.7 | | |
| average | | | | | | | | | | |
| 13 Roskilde | 85 | 38.5 | 95 | 1.00 | | 5.8 | 32.0 | 1025.3 | 24.6 | 4.6 |
| 13 Roskilde | 86 | 37.0 | 60 | 1.25 | | 5.9 | 22.9 | 920.5 | 22.4 | 3.5 |
| 13 Roskilde | 87 | 28.0 | 93 | 1.43 | | 12.1 | 27.6 | 892.1 | 43.6 | 7.5 |
| 13 Roskilde | 89 | 45.8 | 67 | | | | | 714.9 | | |
| average | | | | | | | | | | |
| 16 Vienna irrigated | 80 | 43.7 | 83 | 1.57 | 4.1 | 5.2 | 27.6 | 646.0 | | |
| 16 Vienna irrigated | 81 | 35.7 | 77 | 1.40 | 3.9 | 5.3 | 29.4 | 749.0 | | |
| 16 Vienna irrigated | 85 | 44.3 | 87 | 1.13 | | 7.0 | 29.6 | 520.4 | 25.1 | 5.0 |
| 16 Vienna irrigated | 86 | 47.3 | 50 | 1.05 | | 4.1 | 27.3 | 653.7 | 15.4 | 3.3 |
| 16 Vienna irrigated | 87 | 41.8 | 107 | 1.08 | | 4.5 | 29.5 | 660.1 | 18.3 | 3.4 |
| 17 Vienna not irrigat | 80 | 41.3 | 60 | 1.30 | 3.4 | 4.4 | 26.6 | 698.0 | | |
| 17 Vienna not irrigat | 81 | 42.3 | 53 | 1.40 | 2.5 | 3.5 | 28.8 | 892.0 | | |
| 17 Vienna not irrigat | 85 | 47.3 | 79 | 1.15 | | 4.4 | 30.8 | 705.7 | 17.8 | 3.7 |
| 17 Vienna not irrigat | 86 | 59.0 | 87 | 1.00 | | 2.6 | 34.6 | 672.5 | 8.2 | 2.2 |
| 17 Vienna not irrigat | 87 | 53.0 | 140 | 1.03 | | 3.2 | 30.7 | 759.2 | 11.4 | 3.1 |
| Vienna | 89 | 48.0 | 66 | | | | | 829.5 | | |
| 2 Carlow | 89 | 31.7 | 73 | | | | | 796.3 | | |
| 9 Kiel | 89 | 37.0 | 70 | | | | | 812.8 | | |
| 12 Rennes | 89 | 42.7 | 97 | | | | | 810.7 | | |
| 14 Thornhang | 89 | 39.7 | 102 | | | | | 884.0 | | |

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Appendix G2b. Results of field bean experiments of 1985, '86 and '88 in Wageningen.

Table G2b. Dry matter leaf, stem, pod and total dry matter weight and specific leaf area during the growing season of field bean. The outdoor pot experiments were carried out in Wageningen in 1985, '86 and '88. The pots experiments were irrigated.
J. day nr. = Julian day number
d.m. = dry matter
SLA = specific leaf area

| year | intermediate harvest J. day nr. | d.m. leaf weight kg/ha | d.m. stem weight kg/ha | d.m. pod weight kg/ha | d.m. total weight kg/ha | SLA ha/kg |
|---|---|---|---|---|---|---|
| 1985 | 24 | 96 | 32 | - | 128 | 0.00208 |
| | 38 | 494 | 315 | - | 809 | 0.00236 |
| | 45 | 935 | 960 | - | 1895 | 0.00228 |
| | 65 | 1946 | 3488 | 92 | 5526 | 0.00303 |
| | 85 | 2432 | 5066 | 1936 | 9434 | 0.00300 |
| | 105 | 2020 | 4626 | 7888 | 14534 | 0.00314 |
| 1986 | 21 | 144 | 59 | - | 203 | 0.00310 |
| | 39 | 817 | 766 | 65 | 1648 | 0.00328 |
| | 53 | 1646 | 2657 | 335 | 4658 | 0.00311 |
| | 67 | 1799 | 3399 | 3265 | 8454 | 0.00341 |
| | 81 | | | | | 0.00314 |
| 1988 | 40 | 968 | 1147 | - | 2115 | 0.00362 |
| | 61 | 1759 | 3618 | 129 | 5506 | 0.00377 |
| | 81 | 1743 | 4848 | 2897 | 9488 | 0.00310 |
| | 102 | 1255 | 4699 | 7707 | 13661 | 0.00189 |

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Quantification of SO2 effects on physiological processes, plant growth and crop production.
Proefschrift Wageningen, 201 p.

# Appendix G3:

## Region specific data of field bean

Table G3 Occurrence of sowing day of field bean in regions within countries of the European Community.
J. day nr. = Julian day number.

| crop type | country | NUTS codes per region | sowing J. day nr. |
|---|---|---|---|
| 0801 | Germany | R1, 1A | 85 |
| | France | R2 | 70 |
| | Italy N | R31, R32, R33, R34, R35, R36 | 70 |
| | the Netherlands | R4 | 90 |
| | Belgium | R5 | 90 |
| | Luxembourg | R6 | 85 |
| | United Kingdom | R7 | 85 |
| | Ireland | R8 | 85 |
| | Denmark | R9 | 85 |
| | Italy S | R37, R38, R39, R3A, R3B | 335 |
| | Greece | RA | 335 |
| | Spain | RB1, RB2, RB3, RB4 | 95 |
| | Spain | RB5, RB6 | 335 |
| | Portugal | RC | 335 |

# Appendix G4:

## Crop calendar of field bean

Table G4. Sowing, flowering and harvest day (Julian day number) and calculated temperature sums of field bean for regions within the European Community. Each NUTS region contains several grid cells. The temperture sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calculated temperature sum from emergence to flowering, base temperature of 0°C.
TSUM2 = calculated temperature sum from flowering to harvest, base temperature of 0°C.
Temperature sum from sowing to emergence is 100°Cd, base temperature of 0°C.
J. day nr. = Julian day number

| NUTS code | grid number | sowing J. day nr. | flowering J. day nr. | harvest J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|---|
| R11 | 4135 | *85* | *180* | *244* | 931 | 1085 | Germany | Schleswig-Holstein | |
| R12 | 4035 | *85* | *180* | *244* | 957 | 1087 | | Hamburg | |
| R13 | 3834 | 86 | 164 | 234 | 733 | 1198 | | Niedersachsen | 1 |
| R15 | 3531 | *86* | *164* | *234* | 786 | 1239 | | Nordrhein-Westfalen | |
| R16 | 3333 | *86* | *164* | *234* | 795 | 1260 | | Hessen | |
| R17 | 3231 | *84* | *166* | *234* | 809 | 1189 | | Rheinland-Pfalz | |
| R18 | 2934 | 84 | 166 | 234 | 832 | 1230 | | Baden-Württemberg | 1 |
| R19 | 3037 | *84* | *166* | *234* | 776 | 1189 | | Bayern | |
| R1A | 3131 | *84* | *166* | *234* | 815 | 1195 | | Saarland | |
| R21 | 2924 | *68* | *162* | *221* | 962 | 1096 | France | Île de France | |
| R22 | 3125 | *68* | *162* | *221* | 891 | 1043 | | Bassin Parisien | |
| R23 | 3325 | *68* | *162* | *221* | 843 | 1004 | | Nord - Pas-de-Calais | |
| R24 | 2830 | 68 | 162 | 221 | 853 | 1057 | | Est | 1 |
| R25 | 2817 | *68* | *162* | *221* | 969 | 1079 | | Ouest | |
| R26 | 2020 | *68* | *162* | *221* | 1075 | 1190 | | Sud-Ouest | |
| R27 | 2227 | *68* | *162* | *221* | 979 | 1175 | | Centre-Est | |
| R28 | 1826 | *68* | *162* | *221* | 1243 | 1354 | | Mediterranée | |
| R31 | 2132 | -1 | -1 | -1 | -1 | -1 | Italy | Nord Ovest | |
| R32 | 2235 | -1 | -1 | -1 | -1 | -1 | | Lombardia | |
| R33 | 2339 | -1 | -1 | -1 | -1 | -1 | | Nord Est | |
| R34 | 2037 | -1 | -1 | -1 | -1 | -1 | | Emilia-Romagna | |
| R35 | 1740 | -1 | -1 | -1 | -1 | -1 | | Centro | |
| R36 | 1439 | -1 | -1 | -1 | -1 | -1 | | Lazio | |
| R37 | 1242 | -1 | -1 | -1 | -1 | -1 | | Campania | |
| R38 | 1247 | -1 | -1 | -1 | -1 | -1 | | Abruzzi-Molise | |
| R39 | 1345 | *332* | *62* | *140* | 686 | 1004 | | Sud | |
| R3A | 541 | *332* | *62* | *140* | 929 | 1020 | | Sicilia | |
| R3B | 1134 | *332* | *62* | *140* | 892 | 1031 | | Sardegna | |
| R41 | 3930 | 89 | 170 | 250 | 744 | 1265 | the Netherlands | Noord-Nederland | 1 |
| R42 | 3730 | *89* | *170* | *250* | 828 | 1354 | | Oost-Nederland | |
| R45 | 3628 | *89* | *170* | *250* | 827 | 1348 | | Zuid-Nederland | |
| R47 | 3626 | *89* | *170* | *250* | 791 | 1334 | | West-Nederland | |
| R51 | 3426 | *89* | *170* | *250* | 884 | 1415 | Belgium | Vlaams Gewest | |
| R52 | 3329 | *89* | *170* | *250* | 800 | 1343 | | Region Wallone | |
| R6 | 3129 | -1 | -1 | -1 | -1 | -1 | Luxembourg | | |
| R71 | 4419 | *92* | *174* | *254* | 461 | 946 | United Kingdom | North | |
| R72 | 4220 | *92* | *174* | *254* | 722 | 1211 | | Yorkshire and Humberside | |
| R73 | 4020 | *84* | *165* | *241* | 652 | 1149 | | East Midlands | |
| R74 | 3822 | *84* | *165* | *241* | 678 | 1201 | | East Anglia | |
| R75 | 3620 | 84 | 165 | 241 | 672 | 1190 | | South East | 1 |
| R76 | 3515 | *84* | *165* | *241* | 588 | 1060 | | South West | |
| R77 | 3818 | *84* | *165* | *241* | 652 | 1158 | | West Midlands | |
| R78 | 4118 | *84* | *165* | *241* | 666 | 1146 | | North West | |
| R79 | 3816 | *84* | *165* | *241* | 478 | 960 | | Wales | |
| R7A | 4918 | 92 | 174 | 254 | 56 | 475 | | Scotland | 1 |
| R7B | 4513 | *85* | *148* | *257* | 380 | 1389 | | Northern Ireland | |
| R8 | 4414 | *85* | 148 | 257 | 449 | 1543 | Ireland | | 1 |
| R9 | 4534 | *85* | 180 | 244 | 808 | 985 | Denmark | | 1 |
| RA11 | 1561 | *332* | *62* | *140* | 521 | 1002 | Greece | Anatoliki Makedonia, Thraki | |
| RA12 | 1457 | *332* | *62* | *140* | 435 | 938 | | Kentriki Makedonia | |
| RA13 | 1254 | *332* | *62* | *140* | 223 | 685 | | Dytriki Makedonia | |
| RA14 | 1256 | *332* | *62* | *140* | 397 | 901 | | Thessalia | |
| RA15 | 1458 | *332* | *62* | *140* | 508 | 997 | | Anatoliki Makedonia | |
| RA18 | 1562 | *332* | *62* | *140* | 580 | 1029 | | Thraki | |
| RA2 | 956 | *332* | *62* | *140* | 424 | 815 | | Kentriki Ellada | |
| RA3 | 1057 | *332* | *62* | *140* | 585 | 1018 | | Attiki | |
| RA4 | 263 | *332* | *62* | *140* | 824 | 1090 | | Nisia | |

Table G4. Sowing, flowering and harvest day (Julian day number) and calculated temperature sums of field bean for regions within the European Community. Each NUTS region contains several grid cells. The temperture sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calculated temperature sum from emergence to flowering, base temperature of 0°C.
TSUM2 = calculated temperature sum from flowering to harvest, base temperature of 0°C.
Temperature sum from sowing to emergence is 100°Cd, base temperature of 0°C.
*J. day nr.* = Julian day number

| NUTS code | grid number | sowing J. day nr. | flowering J. day nr. | harvest J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|---|
| RB1 | 1907 | -1 | -1 | -1 | -1 | -1 | Spain | Noroeste | |
| RB2 | 1517 | -1 | -1 | -1 | -1 | -1 | | Noreste | |
| RB3 | 1312 | -1 | -1 | -1 | -1 | -1 | | Madrid | |
| RB4 | 1011 | -1 | -1 | -1 | -1 | -1 | | Centro | |
| RB5 | 1219 | *332* | *62* | *140* | 879 | 1075 | | Este | |
| RB6 | 610 | 332 | 62 | 140 | 791 | 1094 | | Sur | 2 |
| RC1 | 1605 | *332* | *62* | *140* | 751 | 947 | Portugal | Continente | |

References

1 Ebmeyer, E 1984
Results of the Joint Faba Bean and Pea trials of the years 1980-1982. In: P.D. Hebblewaite, T.C.K. Dawkins, M.C. Heath & G. Lockwood (Eds), Vicia faba: agronomy, physiology and breeding, Martinus Nijhoff/ Dr. W. Junk Publishers, The Hague, 169-176.

Ebmeyer E., 1986
Some results of the 1985 EC Joint Field Bean test. Vorträge für Pflanzenzüchtung 11, 151-157.

Dantuma , G., E. von Kittlitz, M. Frauen & D.A. Bond, 1983.
Yield, yield stability and measurements of morphological and phenological characters of faba bean (Vicia faba L.) varieties grown in a wide range of environments in Western Europe. Zeitschrift für Pflanzenzüchtung 90, 85-105.

2 Martínez, A.M., 1988.
Variedades de Habas; Campaña:87/88
Red Andaluza de Experimentacion Agraria, Sevilla, 32 p.

*Italic printed numbers are estimated.*
-1 means: no data available or no field beans grown.

# Appendix H:

## Soybean (*Glysine max* (L.) Merrill)

# Appendix H1:
# Initial crop-specific data file of soybean

CROP DATA FILE for use with WOFOST Version 5.4, June 1992

| | | | | |
|---|---|---|---|---|
| crop identity | | | | |
| !CRPNAM | = | Soybean (*Glycine max* (L.) Merrill) | | |
| | | | | |
| ** emergence | | | | |
| TBASEM | = | 7.0 | | ! lower threshold temp. for emergence [C°] |
| TEFFMX | = | 22.0 | | ! max. eff. temp. for emergence [C°] |
| TSUMEM | = | 100. | | ! temperature sum from sowing to emergence [C° d] |
| | | | | |
| ** phenology | | | | |
| IDSL | = | 0 | | ! indicates whether pre-anthesis development depends |
| | | | | ! on temp. (=0), daylength (=1) , or both (=2) |
| DLO | = | -99. | | ! optimum daylength for development [hr] |
| DLC | = | -99. | | ! critical daylength (lower threshold) [hr] |
| TSUM1 | = | 700. | | ! temperature sum from emergence to anthesis [C° d] |
| TSUM2 | = | 1000. | | ! temperature sum from anthesis to maturity [C° d] |
| DTSMTB | = | 0.00, | 0.00, | ! daily increase in temp. sum |
| | | 7.00, | 0.00, | ! as function of av. temp. [C°; C° d] |
| | | 30.00, | 23.00, | |
| | | 45.00, | 38.00 | |
| DVSEND | = | 2.00 | | ! development stage at harvest (= 2.0 at maturity [-]) |
| | | | | |
| ** initial | | | | |
| TDWI | = | 120.0 | | ! initial total crop dry weight [kg $ha^{-1}$] |
| LAIEM | = | 0.0163 | | ! leaf area index at emergence [ha $ha^{-1}$] |
| RGRLAI | = | 0.0070 | | ! maximum relative increase in LAI [ha $ha^{-1}$ $d^{-1}$] |
| | | | | |
| ** green area | | | | |
| SLATB | = | 0.00, | 0.0014, | ! specific leaf area |
| | | 0.45, | 0.0025, | ! as a function of DVS [-; ha $kg^{-1}$] |
| | | 0.90, | 0.0025, | |
| | | 2.00, | 0.0007 | |
| SPA | = | 0.000 | | ! specific pod area [ha $kg^{-1}$] |
| SSA | = | 0.000 | | ! specific stem area [ha $kg^{-1}$] |
| SPAN | = | 23. | | ! life span of leaves growing at 35 C° [d] |
| TBASE | = | 7.0 | | ! lower threshold temp. for ageing of leaves [C°] |
| | | | | |
| ** assimilation | | | | |
| KDIF | = | 0.500 | | ! extinction coefficient for diffuse visible light [-] |
| EFF | = | 0.40 | | ! light-use effic. single leaf [kg $ha^{-1}$ $hr^{-1}$ $J^{-1}$ $m^2$ s] |

```
AMAXTB   =  0.00,   37.00,   ! maximum leaf CO2 assimilation rate
            1.70,   37.00,   ! as function of DVS [-; kg ha-1 hr-1]
            2.00,    0.00
TMPFTB   =  0.00,    0.00,   ! reduction factor of AMAX
           10.00,    0.30,   ! as function of av. temp. [C°; -]
           20.00,    0.60,
           25.00,    0.80,
           30.00,    1.00,
           35.00,    1.00
TMNFTB   =  0.00,    0.00,   ! red. factor of gross assim. rate
            3.00,    1.00    ! as function of low min. temp. [C°; -]

** conversion of assimilates into biomass
CVL      =  0.680            ! efficiency of conversion into leaves [kg kg-1]
CVO      =  0.720            ! efficiency of conversion into storage org. [kg kg-1]
CVR      =  0.720            ! efficiency of conversion into roots [kg kg-1]
CVS      =  0.690            ! efficiency of conversion into stems [kg kg-1]

** maintenance respiration
Q10      =  2.0              ! rel. incr. in resp. rate per 10 C°temp. incr. [-]
RML      =  0.030            ! rel. maint. resp. rate leaves [kg CH2O kg-1 d-1]
RMO      =  0.010            ! rel. maint. resp. rate stor.org. [kg CH2O kg-1 d-1]
RMR      =  0.010            ! rel. maint. resp. rate roots [kg CH2O kg-1 d-1]
RMS      =  0.015            ! rel. maint. resp. rate stems [kg CH2O kg-1 d-1]
RFSETB   =  0.00,    1.00,   ! red. factor for senescence
            2.00,    1.00    ! as function of DVS [-; -]

** partitioning
FRTB     =  0.00,    0.50,   ! fraction of total dry matter to roots
            0.75,    0.10,   ! as a function of DVS [-; kg kg-1]
            1.50,    0.00,
            2.00,    0.00
FLTB     =  0.00,    0.75,   ! fraction of above-gr. DM to leaves
            1.00,    0.75,   ! as a function of DVS [-; kg kg-1]
            1.15,    0.60,
            1.30,    0.46,
            1.50,    0.27,
            1.70,    0.00,
            2.00,    0.00
FSTB     =  0.00,    0.25,   ! fraction of above-gr. DM to stems
            1.00,    0.25,   ! as a function of DVS [-; kg kg-1]
            1.15,    0.27,
            1.30,    0.27,
            1.50,    0.28,
            1.70,    0.00,
            2.00,    0.00
```

| | | | | |
|---|---|---|---|---|
| FOTB | = | 0.00, | 0.00, | ! fraction of above-gr. DM to stor. org. |
| | | 1.00, | 0.00, | ! as a function of DVS [-; kg $kg^{-1}$] |
| | | 1.15, | 0.13, | |
| | | 1.30, | 0.27, | |
| | | 1.50, | 0.45, | |
| | | 1.70, | 1.00, | |
| | | 2.00, | 1.00 | |

** death rates

| | | | | |
|---|---|---|---|---|
| PERDL | = | 0.030 | | ! max. rel. death rate of leaves due to water stress |
| RDRRTB | = | 0.00, | 0.000, | ! rel. death rate of stems |
| | | 1.50, | 0.000, | ! as a function of DVS [-; kg $kg^{-1}$ $d^{-1}$] |
| | | 1.5001, | 0.020, | |
| | | 2.00, | 0.020 | |
| RDRSTB | = | 0.00, | 0.000, | ! rel. death rate of roots |
| | | 1.50, | 0.000, | ! as a function of DVS [-; kg $kg^{-1}$ $d^{-1}$] |
| | | 1.5001, | 0.020, | |
| | | 2.00, | 0.020 | |

** water use

| | | | |
|---|---|---|---|
| CFET | = | 1.00 | ! correction factor transpiration rate [-] |
| DEPNR | = | 5.0 | ! crop group number for soil water depletion [-] |
| IAIRDU | = | 0 | ! air ducts in roots present (=1) or not (=0) |

** rooting

| | | | |
|---|---|---|---|
| RDI | = | 10. | ! initial rooting depth [cm] |
| RRI | = | 1.2 | ! maximum daily increase in rooting depth [cm $d^{-1}$] |
| RDMCR | = | 120. | ! maximum rooting depth [cm] |

** nutrients

** maximum and minimum concentrations of N, P, and K in storage organsin vegetative organs [kg kg-1]

| | | | | | | |
|---|---|---|---|---|---|---|
| NMINSO | = | 0.0350 ; | NMINVE | = | 0.0070 | |
| NMAXSO | = | 0.0560 ; | NMAXVE | = | 0.0220 | |
| PMINSO | = | 0.0027; | PMINVE | = | 0.0011 | |
| PMAXSO | = | 0.0080 ; | PMAXVE | = | 0.0052 | |
| KMINSO | = | 0.0120 ; | KMINVE | = | 0.0070 | |
| KMAXSO | = | 0.0260 ; | KMAXVE | = | 0.0240 | |
| YZERO | = | 0. | | | | ! max. amount veg. organs at zero yield [kg $ha^{-1}$] |
| NFIX | = | 0.75 | | | | ! fraction of N-uptake from biol. fixation [kg $kg^{-1}$] |

# Appendix H2:

## Field experiment data of soybean

Appendix H2a. Dry matter biomass and yield production of well irrigated field experiments of INRA, Toulouse (Auzeville) of soybean in 1985.

Planting date 17 April 1985 : day number 107.
Harvest date 25 September 1985: day number 268.

Thermal time with temperature base of 10 ˚Cd.

| | |
|---|---|
| emergence | 100 ˚Cd |
| flowering | 1100 ˚Cd |
| senescence | 1600 ˚Cd |
| maturity | 2500 ˚Cd |

| | |
|---|---|
| Maximum rooting depth | 1.7 m |
| Maximum LAI | 7.3 ha/ha |
| Maximum plant height | 1.0 m |

Table H2a. Dry matter production and leaf area index of soybean during the growing season of 1985 at Toulouse (INRA plot nr B5).
J. day nr. = Julian day number
LAI = leaf area index

| harvest date | J. day nr. | biomass kg/ha | biomass t/ha | LAI ha/ha |
|---|---|---|---|---|
| 10/6/85 | 161 | 510 | 0.51 | 0.98 |
| 24/6/85 | 175 | 1410 | 1.41 | 2.61 |
| 10/7/85 | 191 | 3640 | 3.64 | 6.00 |
| 24/7/85 | 205 | 7586 | 7.59 | 7.30 |
| 14/8/85 | 226 | 7200 | 7.20 | 4.20 |
| 23/8/85 | 235 | 7000 | 7.00 | 2.45 |

Harvest:

| | |
|---|---|
| total biomass: | 5950 kg/ha |
| total grain yield: | 2990 kg/ha |
| number of grains per m2: | 2165 |

Reference

Cabelguenne, M. INRA, Toulouse (Auzeville), 1992.

Appendix H2b. Dry matter biomass and yield production of well irrigated field experiments of INRA, Toulouse (Auzeville) of soybean in 1986.

Planting date 15 April 1986 : day number 105.
Harvest date 29 September 1986: day number 272.

Thermal time with temperature base of 10 °Cd.

| | |
|---|---|
| emergence | 100 °Cd |
| flowering | 1100 °Cd |
| senescence | 1600 °Cd |
| maturity | 2500 °Cd |

| | |
|---|---|
| Maximum rooting depth | 1.7 m |
| Maximum LAI | 6.6 ha/ha |
| Maximum plant height | 1.0 m |

Table H2b. Dry matter production and leaf area index of soybean during the growing season of 1986 at Toulouse (INRA plot nr F08).
J. day nr. = Julian day number
LAI = leaf area index

| harvest date | J. day nr. | biomass kg/ha | biomass t/ha | LAI ha/ha |
|---|---|---|---|---|
| 27/5/86 | 147 | 280 | 0.28 | 0.48 |
| 12/6/86 | 163 | 745 | 0.75 | 1.25 |
| 30/6/86 | 181 | 2590 | 2.59 | 4.21 |
| 16/7/86 | 197 | 3420 | 3.42 | 4.07 |
| 7/8/86 | 219 | 7995 | 8.00 | 6.25 |
| 19/8/86 | 231 | 11215 | 11.22 | 6.61 |
| 29/8/86 | 241 | 7100 | 7.10 | 6.53 |

Harvest:

| | |
|---|---|
| total biomass: | 6230 kg/ha |
| total grain yield: | 3080 kg/ha |
| number of grains per m2: | 2120 |

Reference

Cabelguenne, M. INRA, Toulouse (Auzeville), 1992.

# Appendix H3:
# Region specific data of soybean

Table H3a1 Calibrated temperature sums of soybean crop types.
TSUMEM = temperature sum from sowing to emergence
TSUM1 = temperature sum from emergence to flowering
TSUM2 = temperature sum from flowering to maturity/harvest.

| crop type | TSUMEM °Cd | TSUM1 °Cd | TSUM2 °Cd |
|---|---|---|---|
| 0901 | 70 | 350 | 850 |
| 0902 | 70 | 350 | 950 |
| 0903 | 70 | 300 | 900 |
| 0904 | 70 | 500 | 1100 |
| 0905 | 80 | 500 | 1100 |
| 0906 | 90 | 500 | 1300 |

Table H3a2 Occurrence of sowing, flowering and maturity day of soybean crop types in regions within countries of the European Community.
J. day nr. = Julian day number

| crop type | country | NUTS codes of region | sowing J. day nr. | flowering J. day nr. | maturity J. day nr. |
|---|---|---|---|---|---|
| 0901 | N.France | R21, R22, R23 | 118 | 176 | 268 |
| 0902 | C. France | R24, R25 | 118 | 176 | 268 |
| 0903 | N.Spain | RB1 | 120 | 166 | 248 |
| 0904 | France | R26, R27, R28 | 110 | 170 | 268 |
| 0905 | Italy | R3 | 120 | 166 | 238 |
| 0906 | Spain | RB2, RB3, RB4 | 120 | 171 | 258 |
| | | RB5, RB6 | 120 | 166 | 253 |
| | Greece | RA | 110 | 176 | 263 |

Table H3b Calibrated parameters of the initial crop-specific data file (Appendix H1) of soybean.

** initial
RGRLAI = 0.010 ! maximum relative increase in LAI [ ha $ha^{-1}$ $d^{-1}$]
RGRLAI = 0.007 ! for crop type 0904 to 0906

** assimilation
KDIF = 0.800 ! extinction coefficient for diffuse visible light [-]

AMAXTB = 0.00, 29.00, ! maximum leaf CO2 assimilation rate
1.70, 29.00, ! as function of DVS [-; kg $ha^{-1}$ $hr^{-1}$]
2.00, 0.00

** conversion of assimilates into biomass
CVL = 0.720 ! efficiency of conversion into leaves [kg $kg^{-1}$]
CVO = 0.480 ! efficiency of conversion into storage org. [kg $kg^{-1}$]
CVR = 0.720 ! efficiency of conversion into roots [kg $kg^{-1}$]
CVS = 0.690 ! efficiency of conversion into stems [kg $kg^{-1}$]

** maintenance respiration
RML = 0.030 ! rel. maint. resp. rate leaves [kg CH2O $kg^{-1}$ $d^{-1}$]
RMO = 0.017 ! rel. maint. resp. rate stor.org. [kg CH2O $kg^{-1}$ $d^{-1}$]
RMR = 0.010 ! rel. maint. resp. rate roots [kg CH2O $kg^{-1}$ $d^{-1}$]
RMS = 0.015 ! rel. maint. resp. rate stems [kg CH2O $kg^{-1}$ $d^{-1}$]

** partitioning 0901, 0902 and 0903

| DVS | FRTB kg $kg^{-1}$ | FLTB kg $kg^{-1}$ | FSTB kg $kg^{-1}$ | FOTB kg $kg^{-1}$ |
|---|---|---|---|---|
| 0.00 | 0.65 | 0.70 | 0.30 | 0.00 |
| 0.75 | 0.35 | | | |
| 1.00 | 0.15 | 0.70 | 0.30 | 0.00 |
| 1.15 | | 0.60 | 0.25 | 0.15 |
| 1.30 | | 0.43 | 0.10 | 0.47 |
| 1.50 | 0.00 | 0.15 | 0.10 | 0.75 |
| 2.00 | 0.00 | 0.00 | 0.00 | 1.00 |

** partitioning 0904 , 0905 and 0906

| DVS | FRTB kg $kg^{-1}$ | FLTB kg $kg^{-1}$ | FSTB kg $kg^{-1}$ | FOTB kg $kg^{-1}$ |
|---|---|---|---|---|
| 0.00 | 0.65 | 0.70 | 0.30 | 0.00 |
| 0.75 | 0.45 | | | |
| 1.00 | 0.20 | 0.70 | 0.30 | 0.00 |
| 1.15 | | 0.60 | 0.25 | 0.15 |
| 1.30 | | 0.43 | 0.10 | 0.47 |
| 1.50 | 0.00 | 0.15 | 0.10 | 0.75 |
| 1.70 | | 0.07 | 0.03 | 0.90 |
| 2.00 | 0.00 | 0.00 | 0.00 | 1.00 |

## Appendix H4:

## Crop calendar of soybean

Table H4. Sowing, start flowering, maturity and harvest day (Julian day number) and calculated temperature sums of soybean for regions within the European Community. Each NUTS region contains several grid cells. The temperture sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calaulated temperature sum from emergence to start flowering, base temperature of 7°C.
TSUM2 = calculated temperature sum from start flowering to maturity, base temperature of 7°C.
Temperature sum from sowing to emergence is 100°Cd, base temperature of 7°C.
J. day nr. = Julian day number

precocity class 0

| NUTS code | grid cell | sowing J. day nr. | start flowering J. day nr. | maturity J. day nr. | harvest J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|---|---|
| R1 | 4135 | -1 | -1 | -1 | -1 | -1 | -1 | Germany | | 2 |
| R21 | 2924 | -1 | -1 | -1 | -1 | -1 | -1 | France | Île de France | 3 |
| R22 | 2926 | -1 | -1 | -1 | -1 | -1 | -1 | | Bassin Parisien | 3 |
| R23 | 3325 | -1 | -1 | -1 | -1 | -1 | -1 | | Nord - Pas-de-Calais | 3 |
| R241 | 2930 | -1 | -1 | -1 | -1 | -1 | -1 | | Lorraine | 3 |
| R242 | 2831 | -1 | -1 | -1 | -1 | -1 | -1 | | Alsace | 3 |
| R243 | 2629 | -1 | -1 | -1 | -1 | -1 | -1 | | Franche-Comte | 3 |
| R251 | 2719 | -1 | -1 | -1 | -1 | -1 | -1 | | Pays de la Loire | 3 |
| R252 | 2916 | -1 | -1 | -1 | -1 | -1 | -1 | | Bretagne | 3 |
| R253 | 2420 | 118 | *176* | | 268 | 359 | 1070 | | Poitou-Charentes | 3 |
| R2611 | 2626 | 118 | *176* | | 268 | 314 | 993 | | Dordogne | 3 |
| R2612 | 2118 | 115 | *170* | | 245 | 368 | 978 | | Gironde | 3 |
| R2613 | 2018 | 115 | *170* | | 245 | 362 | 977 | | Landes | 3 |
| R2614 | 2020 | -1 | -1 | -1 | -1 | -1 | -1 | | Lot-et-Garonne | 3 |
| R2615 | 1818 | 115 | *181* | | 245 | 473 | 824 | | Pyrénées-Atlantiques | 3, 4 |
| R2621 | 1721 | 115 | *170* | | 245 | 310 | 931 | | Ariège | 3 |
| R2622 | 1924 | -1 | -1 | -1 | -1 | -1 | -1 | | Aveyron | 3 |
| R2623 | 1821 | 115 | *170* | | 245 | 362 | 1025 | | Haute-Garonne | 3 |
| R2624 | 1820 | 115 | *170* | | 245 | 343 | 974 | | Gers | 3 |
| R2625 | 2022 | 118 | *176* | | 268 | 375 | 1106 | | Lot | 3 |
| R2626 | 1719 | -1 | -1 | -1 | -1 | -1 | -1 | | Hautes-Pyrénées | 3 |
| R2627 | 1922 | -1 | -1 | -1 | -1 | -1 | -1 | | Tarn | 3 |
| R2628 | 1921 | -1 | -1 | -1 | -1 | -1 | -1 | | Tarn-et-Garonne | 3 |
| R2631 | 2222 | -1 | -1 | -1 | -1 | -1 | -1 | | Corrèze | 3 |
| R2632 | 2323 | -1 | -1 | -1 | -1 | -1 | -1 | | Creuse | 3 |
| R2633 | 2321 | -1 | -1 | -1 | -1 | -1 | -1 | | Haute-Vienne | 3 |
| R2711 | 2328 | -1 | -1 | -1 | -1 | -1 | -1 | | Ain | 3 |
| R2712 | 2327 | 118 | *176* | | 268 | 385 | 1123 | | Ardèche | 3 |
| R2713 | 2028 | 118 | *176* | | 268 | 303 | 1048 | | Drôme | 3 |
| R2714 | 2228 | -1 | -1 | -1 | -1 | -1 | -1 | | Isère | 3 |
| R2715 | 2326 | -1 | -1 | -1 | -1 | -1 | -1 | | Loire | 3 |
| R2716 | 2327 | -1 | -1 | -1 | -1 | -1 | -1 | | Rhône | 3 |
| R2721 | 2425 | -1 | -1 | -1 | -1 | -1 | -1 | | Allier | 3 |
| R2722 | 2124 | -1 | -1 | -1 | -1 | -1 | -1 | | Cantal | 3 |
| R2723 | 2125 | -1 | -1 | -1 | -1 | -1 | -1 | | Haute-Loire | 3 |
| R2724 | 2324 | -1 | -1 | -1 | -1 | -1 | -1 | | Puy-de-Dôme | 3 |
| R2811 | 1723 | -1 | -1 | -1 | -1 | -1 | -1 | | Aude | 3 |
| R2812 | 1926 | -1 | -1 | -1 | -1 | -1 | -1 | | Gard | 3 |
| R2813 | 1824 | -1 | -1 | -1 | -1 | -1 | -1 | | Hérault | 3 |
| R2814 | 2025 | -1 | -1 | -1 | -1 | -1 | -1 | | Lozère | 3 |
| R2815 | 1623 | -1 | -1 | -1 | -1 | -1 | -1 | | Pyrénées-Orientales | 3 |
| R2821 | 1929 | -1 | -1 | -1 | -1 | -1 | -1 | | Alpes-de-Hautes-Provence | 3 |
| R2822 | 2029 | -1 | -1 | -1 | -1 | -1 | -1 | | Hautes-Alpes | 3 |
| R2823 | 1830 | -1 | -1 | -1 | -1 | -1 | -1 | | Alpes-Maritimes | 3 |
| R2824 | 1827 | -1 | -1 | -1 | -1 | -1 | -1 | | Bouches-du-Rhône | 3 |
| R2825 | 1729 | -1 | -1 | -1 | -1 | -1 | -1 | | Var | 3 |
| R2826 | 1927 | -1 | -1 | -1 | -1 | -1 | -1 | | Vaucluse | 3 |
| R311 | 2132 | 120 | 166 | 238 | 248 | 354 | 1224 | Italy | Nord Ovest | 1 |
| R32 | 2235 | 120 | 166 | 238 | 248 | 393 | 1280 | | Lombardia | 1 |
| R332 | 2237 | 120 | 166 | 238 | 248 | 403 | 1291 | | Veneto | 1 |
| R333 | 2439 | 120 | 166 | 238 | 248 | 106 | 703 | | Friuli-Venezia Giulia | 1 |
| R34 | 2037 | 120 | 166 | 238 | 248 | 416 | 1363 | | Emilia-Romagna | 1 |
| R35 | 1740 | 120 | 166 | 238 | 248 | 318 | 1194 | | Centro | 1 |

Table H4. Sowing, start flowering, maturity and harvest day (Julian day number) and calculated temperature sums of soybean for regions within the European Community. Each NUTS region contains several grid cells. The temperture sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calaulated temperature sum from emergence to start flowering, base temperature of 7°C.
TSUM2 = calculated temperature sum from start flowering to maturity, base temperature of 7°C.
Temperature sum from sowing to emergence is 100°Cd, base temperature of 7°C.
J. day nr. = Julian day number

precocity class 0

| NUTS code | grid cell | sowing J. day nr. | start flowering J. day nr. | maturity J. day nr. | harvest J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|---|---|
| R36 | 1439 | 120 | 166 | 238 | 248 | 391 | 1315 | Italy | Lazio | 1 |
| R37 | 1242 | -1 | -1 | -1 | -1 | -1 | -1 | | Campania | 1 |
| R38 | 1247 | -1 | -1 | -1 | -1 | -1 | -1 | | Abruzzi-Molise | 1 |
| R39 | 1345 | -1 | -1 | -1 | -1 | -1 | -1 | | Sud | 1 |
| R3A | 541 | -1 | -1 | -1 | -1 | -1 | -1 | | Sicilia | 1 |
| R3B | 1134 | -1 | -1 | -1 | -1 | -1 | -1 | | Sardegna | 1 |
| R4 | 3930 | -1 | -1 | -1 | -1 | -1 | -1 | the Netherlands | | 2 |
| R5 | 3426 | -1 | -1 | -1 | -1 | -1 | -1 | Belgium | | 2 |
| R6 | 3129 | -1 | -1 | -1 | -1 | -1 | -1 | Luxembourg | | 2 |
| R7 | 4419 | -1 | -1 | -1 | -1 | -1 | -1 | United Kingdom | | 2 |
| R8 | 4414 | -1 | -1 | -1 | -1 | -1 | -1 | Ireland | | 2 |
| R9 | 4534 | -1 | -1 | -1 | -1 | -1 | -1 | Denmark | | 2 |
| RA11 | 1561 | -1 | -1 | -1 | -1 | -1 | -1 | Greece | Anatoliki Makedonia, Thraki | 1 |
| RA12 | 1457 | 110 | 176 | 268 | 258 | 629 | 1322 | | Kentriki Makedonia | 1 |
| RA13 | 1254 | -1 | -1 | -1 | -1 | -1 | -1 | | Dytriki Makedonia | 1 |
| RA14 | 1256 | 110 | 176 | 268 | 258 | 607 | 1307 | | Thessalia | 1 |
| RA15 | 1458 | 110 | 176 | 268 | 258 | 679 | 1384 | | Anatoliki Makedonia | 1 |
| RA18 | 1562 | 110 | 176 | 268 | 258 | 711 | 1413 | | Thraki | 1 |
| RA2 | 956 | 110 | 176 | 268 | 258 | 498 | 1149 | | Kentriki Ellada | 1 |
| RA3 | 1057 | 110 | 176 | 268 | 258 | 705 | 1400 | | Attiki | 1 |
| RA4 | 263 | -1 | -1 | -1 | -1 | -1 | -1 | | Nisia | 1 |
| RB1 | 1907 | -1 | -1 | -1 | -1 | -1 | -1 | Spain | Noroeste | 1 |
| RB2 | 1517 | *120* | *166* | | *248* | 388 | 1360 | | Noreste | |
| RB3 | 1312 | -1 | -1 | -1 | -1 | -1 | -1 | | Madrid | 1 |
| RB4 | 1011 | *120* | *166* | | *258* | 345 | 1534 | | Centro | |
| RB5 | 1219 | -1 | -1 | -1 | -1 | -1 | -1 | | Este | 1 |
| RB6 | 610 | 135 | *171* | 258 | 258 | 390 | 1611 | | Sur | 1 |
| RC1 | 1605 | -1 | -1 | -1 | -1 | -1 | -1 | Portugal | Continente | 2 |

References


1 Narciso, G. P. Ragni & A. Venturi, 1992.
Agrometeorological aspects of crops in Italy, Spain and Greece.
A summary review for common and durum wheat, barley, maize, rice, sugar beet, sunflower, soya bean, rape, potato, cotton, olive and grape crops.
Joint Research Centre, Commission of the European Communities, 195-218.

remarks: Maturity = commercial ripeness
irrigation not at flowering but at emergence or before flowering.
irrigation should take place when the A.W.C. is around 45%.
rooting depth 200 cm.
max LAI at flowering °-9

2 Eurostat, 1989. EUROSTAT, Agricultural Statistical Yearbook.
Statistical office of the European Communities Luxembourg, Bruxelles.

3 Arnaud, F. & E. Prudon, 1986, Choix des types variétaux et du peuplement selon les regions.
Le Soja, Physiologie de la plante et adaptation aux conditions françaises. CETIOM, Paris.

4 Ecochard, R., 1986. La sensibilite du soja a la photoperiode et a la thermoperiode.
Le Soja, Physiologie de la plante et adaptation aux conditions françaises. CETIOM, Paris.


-1 means: no data available or no soybean grown
*125* means: value estimated

## Appendix I:

## Winter oilseed rape (*Brassica napus* L. ssp. *oleifera* (Metzg.) Sinsk.)

# Appendix I1:

## Initial crop-specific data file of winter oilseed rape

CROP DATA FILE for use with WOFOST Version 5.0, January 1990

crop identity

!CRPNAM = Oilseed rape (*Brassica napus* L. ssp. *oleifera* (Metzg.) Sinsk.)

** emergence

| | | | | |
|---|---|---|---|---|
| TBASEM | = | -10.0 | | ! lower threshold temp. for emergence [C°] |
| TEFFMX | = | 30.0 | | ! max. eff. temp. for emergence [C°] |
| TSUMEM | = | 0. | | ! temperature sum from sowing to emergence [C° d] |

** phenology

| | | | | |
|---|---|---|---|---|
| IDSL | = | 2 | | ! indicates whether pre-anthesis development depends |
| | | | | ! on temp. (=0), daylength (=1) , or both (=2) |
| DLO | = | 16.0 | | ! optimum daylength for development [hr] |
| DLC | = | 10.0 | | ! critical daylength (lower threshold) [hr] |
| TSUM1 | = | 240. | | ! temperature sum from emergence to anthesis [C° d] |
| TSUM2 | = | 600. | | ! temperature sum from anthesis to maturity [C° d] |
| DTSMTB | = | 0.00, | 0.00, | ! daily increase in temp. sum |
| | | 4.00, | 0.00, | ! as function of av. temp. [C°; C° d] |
| | | 35.00, | 31.00 | |
| | | 45.00, | 31.00 | |
| DVSEND | = | 2.00 | | ! development stage at harvest (= 2.0 at maturity [-]) |

** initial

| | | | | |
|---|---|---|---|---|
| TDWI | = | 244.0 | | ! initial total crop dry weight [kg $ha^{-1}$] |
| LAIEM | = | 0.3000 | | ! leaf area index at emergence [ha $ha^{-1}$] |
| RGRLAI | = | 0.5000 | | ! maximum relative increase in LAI [ha $ha^{-1}$ $d^{-1}$] |

** green area

| | | | | |
|---|---|---|---|---|
| SLATB | = | 0.00, | 0.0022, | ! specific leaf area |
| | | 2.00, | 0.0019, | ! as a function of DVS [-; ha $kg^{-1}$] |
| SPA | = | 0.000 | | ! specific pod area [ha $kg^{-1}$] |
| SSA | = | 0.000 | | ! specific stem area [ha $kg^{-1}$] |
| SPAN | = | 17. | | ! life span of leaves growing at 35 C° [d] |
| TBASE | = | 0.0 | | ! lower threshold temp. for ageing of leaves [C°] |

** assimilation

| | | | | |
|---|---|---|---|---|
| KDIF | = | 0.540 | | ! extinction coefficient for diffuse visible light [-] |
| EFF | = | 0.50 | | ! light-use effic. single leaf [kg $ha^{-1}$ $hr^{-1}$ $J^{-1}$ $m^2$ s] |

| | | | | |
|---|---|---|---|---|
| AMAXTB | = | 0.00, | 40.00, | ! maximum leaf CO2 assimilation rate |
| | | 0.80, | 40.00, | ! as function of DVS [-; kg $ha^{-1}$ $hr^{-1}$] |
| | | 1.00, | 30.00, | |
| | | 1.20, | 40.00, | |
| | | 1.40, | 40.00, | |
| | | 2.00, | 0.00 | |
| TMPFTB | = | 0.00, | 0.00, | ! reduction factor of AMAX |
| | | 10.00, | 1.00, | ! as function of av. temp. [C°; -] |
| | | 30.00, | 1.00, | |
| | | 35.00, | 0.00 | |
| TMNFTB | = | 0.00, | 0.00, | ! red. factor of gross assim. rate |
| | | 1.00, | 0.00, | ! as function of low min. temp. [C°; -] |
| | | 4.00, | 1.00 | |

** conversion of assimilates into biomass

| | | | |
|---|---|---|---|
| CVL | = | 0.720 | ! efficiency of conversion into leaves [kg $kg^{-1}$] |
| CVO | = | 0.450 | ! efficiency of conversion into storage org. [kg $kg^{-1}$] |
| CVR | = | 0.720 | ! efficiency of conversion into roots [kg $kg^{-1}$] |
| CVS | = | 0.690 | ! efficiency of conversion into stems [kg $kg^{-1}$] |

** maintenance respiration

| | | | | |
|---|---|---|---|---|
| Q10 | = | 2.0 | | ! rel. incr. in resp. rate per 10 C°temp. incr. [-] |
| RML | = | 0.0300 | | ! rel. maint. resp. rate leaves [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RMO | = | 0.0100 | | ! rel. maint. resp. rate stor.org. [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RMR | = | 0.0100 | | ! rel. maint. resp. rate roots [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RMS | = | 0.0150 | | ! rel. maint. resp. rate stems [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RFSETB | = | 0.00, | 1.00, | ! red. factor for senescence |
| | | 2.00, | 1.00 | ! as function of DVS [-; -] |

** partitioning

| | | | | |
|---|---|---|---|---|
| FRTB | = | 0.00, | 0.20, | ! fraction of total dry matter to roots |
| | | 0.30, | 0.20, | ! as a function of DVS [-; kg $kg^{-1}$] |
| | | 1.00, | 0.00, | |
| | | 2.00, | 0.00 | |
| FLTB | = | 0.00, | 0.70, | ! fraction of above-gr. DM to leaves |
| | | 0.20, | 0.70, | ! as a function of DVS [-; kg kg-1] |
| | | 0.30, | 0.50, | |
| | | 0.70, | 0.30, | |
| | | 1.00, | 0.15, | |
| | | 1.19, | 0.15, | |
| | | 1.20, | 0.00, | |
| | | 2.00, | 0.00 | |

```
FSTB     =  0.00,    0.30,    ! fraction of above-gr. DM to stems
            0.20,    0.30,    ! as a function of DVS [-; kg kg-1]
            0.30,    0.50,
            0.70,    0.70,
            1.00,    0.85,
            1.19,    0.55,
            1.20,    0.70,
            1.35,    0.30,
            1.70,    0.00,
            2.00,    0.00
FOTB     =  0.00,    0.00,    ! fraction of above-gr. DM to stor. org.
            1.00,    0.00,    ! as a function of DVS [-; kg kg-1]
            1.19,    0.30,
            1.20,    0.30,
            1.35,    0.70,
            1.70,    1.00,
            2.00,    1.00

** death rates
PERDL    =  0.030             ! max. rel. death rate of leaves due to water stress
RDRRTB   =  0.00,    0.000,   ! rel. death rate of stems
            1.50,    0.000,   ! as a function of DVS [-; kg kg-1 d-1]
            1.5001,  0.020,
            2.00,    0.020
RDRSTB   =  0.00,    0.000,   ! rel. death rate of roots
            1.00,    0.000,   ! as a function of DVS [-; kg kg-1 d-1]
            1.0001,  0.020,
            1.40,    0.030,
            2.00,    0.040
** water use
CFET     =  1.00              ! correction factor transpiration rate [-]
DEPNR    =  4.5               ! crop group number for soil water depletion [-]
IAIRDU   =  0                 ! air ducts in roots present (=1) or not (=0)

** rooting
RDI      =  10.               ! initial rooting depth [cm]
RRI      =   1.2              ! maximum daily increase in rooting depth [cm d-1]
RDMCR    = 125.               ! maximum rooting depth [cm]

** nutrients
** maximum and minimum concentrations of N, P, and K in storage organsin vegetative organs
   [kg kg-1]
NMINSO   =  0.0150 ;  NMINVE  =  0.0055
NMAXSO   =  0.0390 ;  NMAXVE  =  0.0100
PMINSO   =  0.0026 ;  PMINVE  =  0.0008
PMAXSO   =  0.0056 ;  PMAXVE  =  0.0020
KMINSO   =  0.0070 ;  KMINVE  =  0.0095
KMAXSO   =  0.0165 ;  KMAXVE  =  0.0190
YZERO    =  0.                ! max. amount veg. organs at zero yield [kg ha-1]
NFIX     =  0.00              ! fraction of N-uptake from biol. fixation [kg kg-1]
```

# Appendix I2:

## Field experiment data of winter oilseed rape

Table I2. Dates and day numbers of sowing, emergence, start of flowering and harvest and grain yield of non irrigated oilseed rape (variety Jet Neuf) field experiments in Dijon, France, from 1983 to 1990.
emerg. = emergence
(st.) flow. = (start) flowering
J. day nr. = Julian day number

| harvest year 1984 | sowing date | sowing J. day nr. | emerg. date | emerg. J. day nr. | start flowering date | st.flow. J. day nr. | end flowering date | end flow. J. day nr. | harvest date | harvest J. day nr. | yield t/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | 2.8 |
| | 8/9/83 | 251 | 14/9/83 | 257 | 30/4/84 | 122 | 5/6/84 | 158 | 23/7/84 | 206 | 3.4 |
| | | | | | | | | | | | 3.3 |
| | 20/9/83 | 263 | 25/9/83 | 268 | 1/5/84 | 123 | 9/6/84 | 162 | 29/7/84 | 212 | 2.4 |
| | 10/9/83 | 253 | 13/9/83 | 256 | 1/5/84 | 123 | 5/6/84 | 158 | 23/7/84 | 206 | 3.1 |
| | 26/8/83 | 238 | 31/8/83 | 243 | 1/5/84 | 123 | 9/6/84 | 162 | 30/7/84 | 213 | 3.5 |
| | 27/8/83 | 239 | 3/9/83 | 246 | 30/4/84 | 122 | 9/6/84 | 162 | 23/7/84 | 206 | 3.4 |
| | 31/8/83 | 243 | 5/9/83 | 248 | 30/4/84 | 122 | 5/6/84 | 158 | 22/7/84 | 205 | 3.0 |
| | 7/9/83 | 250 | 12/9/83 | 255 | 30/4/84 | 122 | 5/6/84 | 158 | 22/7/84 | 205 | 3.5 |
| | 27/8/83 | 239 | 2/9/83 | 245 | 1/5/84 | 123 | 5/6/84 | 158 | 22/7/84 | 205 | 2.8 |
| | 8/9/83 | 251 | 16/9/83 | 259 | 30/4/84 | 122 | 9/6/84 | 162 | 24/7/84 | 207 | 3.4 |
| | 6/9/83 | 249 | 13/9/83 | 256 | 30/4/84 | 122 | 5/6/84 | 158 | 22/7/84 | 205 | 3.5 |
| | 24/8/83 | 236 | 29/8/83 | 241 | 30/4/84 | 122 | 5/6/84 | 158 | 22/7/84 | 205 | 2.5 |
| | 31/8/83 | 243 | 9/9/83 | 252 | 28/4/84 | 120 | 5/6/84 | 158 | 28/7/84 | 211 | 3.1 |
| | 14/9/83 | 257 | 21/9/83 | 264 | 29/4/84 | 121 | 5/6/84 | 158 | 21/7/84 | 204 | 3.3 |
| | 11/9/83 | 254 | 17/9/83 | 260 | 30/4/84 | 122 | 9/6/84 | 162 | 23/7/84 | 206 | 3.0 |
| | 29/8/83 | 241 | 5/9/83 | 248 | 28/4/84 | 120 | 5/6/84 | 158 | 24/7/84 | 207 | 3.4 |

| harvest year 1985 | sowing date | sowing J. day nr. | emerg. date | emerg. J. day nr. | start flowering date | st.flow. J. day nr. | end flowering date | end flow. J. day nr. | harvest date | harvest J. day nr. | yield t/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | 3.8 |
| | | | | | | | | | | | 3.8 |
| | | | | | | | | | | | 4.2 |
| | 4/9/84 | 249 | | | | | 26/5/85 | 146 | 24/7/85 | 205 | 3.8 |
| | | | | | | | | | | | 3.6 |
| | 8/9/84 | 253 | | | 2/5/85 | 122 | 27/5/85 | 147 | 22/7/85 | 203 | 3.6 |
| | | | | | | | | | | | 3.4 |
| | 30/8/84 | 244 | | | 2/5/85 | 122 | 27/5/85 | 147 | 20/7/85 | 201 | 3.1 |
| | | | | | | | | | | | 3.2 |
| | 4/9/84 | 249 | | | 3/5/85 | 123 | 2/6/85 | 153 | 23/7/85 | 204 | 3.4 |
| | | | | | | | | | | | 3.6 |
| | 12/9/84 | 257 | | | 5/5/85 | 125 | 27/5/85 | 147 | 24/7/85 | 205 | 3.2 |

| harvest year 1986 | sowing date | sowing J. day nr. | emerg. date | emerg. J. day nr. | start flowering date | st.flow. J. day nr. | end flowering date | end flow. J. day nr. | harvest date | harvest J. day nr. | yield t/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4/9/85 | 247 | | | 10/5/86 | 130 | 30/5/86 | 150 | 18/7/86 | 199 | 2.1 |
| | 28/8/85 | 240 | | | 10/5/86 | 130 | 27/5/86 | 147 | 18/7/86 | 199 | 1.5 |
| | 28/8/85 | 240 | | | 10/5/86 | 130 | 28/5/86 | 148 | 18/7/86 | 199 | 1.7 |

| harvest year 1987 | sowing date | sowing J. day nr. | emerg. date | emerg. J. day nr. | start flowering date | st.flow. J. day nr. | end flowering date | end flow. J. day nr. | harvest date | harvest J. day nr. | yield t/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5/9/86 | 248 | | | 1/5/87 | 121 | 28/5/87 | 148 | 25/7/87 | 206 | 3.3 |
| | 5/9/86 | 248 | | | 1/5/87 | 121 | 28/5/87 | 148 | 25/7/87 | 206 | 3.3 |
| | 6/9/86 | 249 | | | 28/4/87 | 118 | 26/5/87 | 146 | 24/7/87 | 205 | 3.7 |
| | 3/9/86 | 246 | | | 3/5/87 | 123 | 28/5/87 | 148 | 27/7/87 | 208 | 3.0 |

Table I2. Dates and day numbers of sowing, emergence, start of flowering and harvest and grain yield of non irrigated oilseed rape (variety Jet Neuf) field experiments in Dijon, France, from 1983 to 1990.
emerg. = emergence
(st.) flow. = (start) flowering
J. day nr. = Julian day number

| harvest year 1988 | sowing date | sowing J. day nr. | emerg. date | emerg. J. day nr. | start flowering date | st.flow. J. day nr. | end flowering date | end flow. J. day nr. | harvest date | harvest J. day nr. | yield t/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4/9/87 | 247 | 11/9/87 | 254 | 23/4/88 | 114 | 17/5/87 | 137 | 12/8/88 | 226 | 2.8 |
| | 4/9/87 | 247 | 11/9/87 | 254 | 26/4/88 | 117 | 16/5/87 | 136 | 12/8/88 | 226 | 1.7 |
| | 5/9/87 | 248 | 12/9/87 | 255 | 25/4/88 | 116 | 16/5/87 | 136 | 12/8/88 | 226 | 3.6 |
| | 6/9/87 | 249 | 13/9/87 | 256 | 18/4/88 | 109 | 16/5/87 | 136 | 21/8/88 | 235 | 2.5 |
| | 7/9/87 | 250 | 14/9/87 | 257 | 23/4/88 | 114 | 16/5/87 | 136 | 13/8/88 | 227 | 3.2 |
| | 14/9/87 | 257 | 30/9/87 | 273 | 26/4/88 | 117 | 16/5/87 | 136 | 12/8/88 | 226 | 2.3 |
| | 31/8/87 | 243 | 7/9/87 | 250 | 24/4/88 | 115 | 17/5/87 | 137 | 11/8/88 | 225 | 3.3 |
| | 2/9/87 | 245 | 9/9/87 | 252 | 14/4/88 | 105 | 16/5/87 | 136 | 9/8/88 | 223 | 3.3 |
| | 10/9/87 | 253 | 17/9/87 | 260 | 23/4/88 | 114 | 16/5/87 | 136 | 12/8/88 | 226 | 3.5 |
| | 3/9/87 | 246 | 10/9/87 | 253 | 21/4/88 | 112 | 16/5/87 | 136 | 12/8/88 | 226 | 1.6 |
| | 8/9/87 | 251 | 15/9/87 | 258 | 23/4/88 | 114 | 16/5/87 | 136 | 13/8/88 | 227 | 3.3 |
| | 29/9/87 | 272 | 15/10/87 | 288 | 21/4/88 | 112 | 17/5/87 | 137 | 10/8/88 | 224 | 1.8 |

Source
Palleau, J.P., 1991, CETIOM, Dijon.

Table I2. (continued) Total above ground dry matter before winter, at the beginning of spring and at flowering and the leaf area index at the beginning of March and at flowering of a non irrigarted field experiment of oilseed rape variety Jet Neuf, in Dijon, France from 1983 to 1990.
DM = total above ground dry matter
EH = before winter
SH = begin spring
J. day nr. = Julian day number
LAI = leaf area index

| EH date | EH J. day nr. | DM EH t/ha | SH date | SH J. day nr. | DM SH t/ha | flowering date | flowering J. day nr. | DM flowering t/ha | LAI begin March ha/ha | LAI flowering ha/ha | parcel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1.247 | | | 0.836 | | | 5.04 | 0.4 | 2.5 | 1 |
| 8/12/83 | 342 | 2.004 | 13/3/84 | 74 | 1.472 | 10/5/84 | 132 | 4.86 | 0.8 | 2.5 | 2 |
| | | 1.974 | | | 1.162 | | | 5.53 | 0.4 | 2.1 | 3 |
| 8/12/83 | 342 | 0.051 | 13/3/84 | 74 | 1.069 | 10/5/84 | 132 | 4.33 | 0.5 | 1.4 | 4 |
| 7/12/83 | 341 | 1.637 | 14/3/84 | 75 | 1.013 | 10/5/84 | 132 | 5.51 | 0.6 | 2.7 | 5 |
| 8/12/83 | 342 | 2.863 | 14/3/84 | 75 | 1.599 | 18/5/84 | 140 | 5.58 | 0.8 | 2.7 | 6 |
| 8/12/83 | 342 | 2.396 | 14/3/84 | 75 | 1.850 | 10/5/84 | 132 | 5.06 | 1.0 | 2.5 | 7 |
| 8/12/83 | 342 | 3.425 | 14/3/84 | 75 | 1.946 | 10/5/84 | 132 | 4.41 | 0.8 | 1.5 | 8 |
| 8/12/83 | 342 | 2.047 | 14/3/84 | 75 | 1.508 | 10/5/84 | 132 | 5.11 | 0.9 | 2.6 | 9 |
| 8/12/83 | 342 | 3.117 | 14/3/84 | 75 | 1.707 | 10/5/84 | 132 | 5.88 | 0.6 | 2.3 | 10 |
| 6/12/83 | 340 | 2.299 | 15/3/84 | 76 | 1.781 | 10/5/84 | 132 | 6.11 | 0.9 | 2.4 | 11 |
| 6/12/83 | 340 | 2.235 | 15/3/84 | 76 | 1.813 | 10/5/84 | 132 | 4.99 | 0.9 | 2.5 | 12 |
| 8/12/83 | 342 | 2.508 | 15/3/84 | 76 | 1.464 | 10/5/84 | 132 | 5.27 | 0.5 | 2.6 | 13 |
| 8/12/83 | 342 | 2.198 | 14/3/84 | 75 | 1.265 | 10/5/84 | 132 | 5.24 | 0.6 | 2.6 | 14 |
| 8/12/83 | 342 | 1.583 | 14/3/84 | 75 | 2.218 | 10/5/84 | 132 | 5.21 | 1.1 | 3.4 | 15 |
| 8/12/83 | 342 | 1.439 | 14/3/84 | 75 | 0.994 | 10/5/84 | 132 | 5.57 | 0.6 | 2.7 | 16 |
| 8/12/83 | 342 | 2.902 | 14/3/84 | 75 | 1.822 | 10/5/84 | 132 | 6.73 | 0.7 | 2.7 | 17 |

| EH date | EH J. day nr. | DM EH t/ha | SH date | SH J. day nr. | DM SH t/ha | flowering date | flowering J. day nr. | DM flowering t/ha | LAI LAI begin March ha/ha | LAI flowering ha/ha | parcel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1.670 | | | 1.340 | | | 5.20 | 1.1 | 3.1 | 13 |
| | | 1.360 | | | 0.770 | | | 4.51 | 0.7 | 2.5 | 14 |
| | | 2.690 | | | 1.270 | | | 6.24 | 0.8 | 4.6 | 15 |
| 5/12/84 | 340 | 2.610 | 12/3/84 | 72 | 1.430 | 6/5/85 | 126 | 6.86 | 1.1 | 3.6 | 16 |
| | | 2.300 | | | 1.100 | | | 6.66 | 1.1 | 3.9 | 17 |
| 5/12/84 | 340 | 2.600 | 12/3/84 | 72 | 1.520 | 6/5/85 | 126 | 6.20 | 1.0 | 3.3 | 18 |
| | | 1.310 | | | 0.650 | | | 5.31 | 0.5 | 3.2 | 19 |
| 5/12/84 | 340 | 1.780 | 12/3/84 | 72 | 0.900 | 6/5/85 | 126 | 6.08 | 0.5 | 2.5 | 20 |
| | | 1.090 | | | 0.660 | | | 3.93 | 0.5 | 2.3 | 21 |
| 5/12/84 | 340 | 2.610 | 12/3/84 | 72 | 1.420 | 6/5/85 | 126 | 7.82 | 0.9 | 3.9 | 22 |
| | | 1.530 | | | 1.010 | | | 4.94 | 0.8 | 2.5 | 23 |
| 5/12/84 | 340 | 1.390 | 12/3/84 | 72 | 0.850 | 6/5/85 | 126 | 5.22 | 0.5 | 2.3 | 24 |

| EH date | EH J. day nr. | DM EH t/ha | SH date | SH J. day nr. | DM SH t/ha | flowering date | flowering J. day nr. | DM flowering t/ha | LAI LAI begin March ha/ha | LAI flowering ha/ha | parcel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/12/85 | 346 | 1.300 | 26/3/86 | 85 | 1.280 | 20/5/86 | 140 | 5.82 | 0.9 | 1.5 | 17 |
| 12/12/85 | 346 | 1.850 | 26/3/86 | 85 | 0.950 | 20/5/86 | 140 | 4.13 | 0.7 | 1.2 | 18 |
| 12/12/85 | 346 | 3.590 | 26/3/86 | 85 | 2.770 | 20/5/86 | 140 | 6.80 | 1.5 | 2.1 | 19 |

| EH date | EH J. day nr. | DM EH t/ha | SH date | SH J. day nr. | DM SH t/ha | flowering date | flowering J. day nr. | DM flowering t/ha | LAI LAI begin March ha/ha | LAI flowering ha/ha | parcel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15/12/86 | 349 | 2.370 | 18/3/87 | 77 | 1.380 | 11/5/87 | 131 | 6.32 | 0.8 | 2.5 | 9 |
| 15/12/86 | 349 | 3.000 | 18/3/87 | 77 | 1.230 | 11/5/87 | 131 | 5.93 | 0.6 | 2.9 | 10 |
| 15/12/86 | 349 | 2.140 | 18/3/87 | 77 | 1.130 | 6/5/87 | 126 | 7.88 | 0.7 | 4.0 | 12 |
| 15/12/86 | 349 | 1.790 | 18/3/87 | 77 | 1.260 | 11/5/87 | 131 | 5.14 | 0.8 | 2.6 | 13 |

Table I2. (continued) Total above ground dry matter before winter, at the beginning of spring and at flowering and the leaf area index at the beginning of March and at flowering of a non irrigarted field experiment of oilseed rape variety Jet Neuf, in Dijon, France from 1983 to 1990.
DM = total above ground dry matter
EH = before winter
SH = begin spring
J. day nr. = Julian day number
LAI = leaf area index

| EH date | EH J. day nr. | DM EH t/ha | SH date | SH J. day nr. | DM SH t/ha | flowering date | flowering J. day nr. | DM flowering t/ha | LAI begin March ha/ha | LAI flowering ha/ha | parcel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/12/87 | 345 | 2.330 | 10/3/88 | 71 | 2.120 | 2/5/88 | 124 | 6.85 | 0.9 | 3.1 | 1 |
| 11/12/87 | 345 | 0.860 | 10/3/88 | 71 | 0.990 | 2/5/88 | 124 | 4.10 | 0.5 | 2.0 | 2 |
| 11/12/87 | 345 | 1.900 | 10/3/88 | 71 | 2.740 | 2/5/88 | 124 | 9.79 | 1.3 | 4.5 | 3 |
| 11/12/87 | 345 | 1.670 | 10/3/88 | 71 | 2.510 | 2/5/88 | 124 | 8.17 | 1.4 | 3.8 | 4 |
| 11/12/87 | 345 | 1.870 | 10/3/88 | 71 | 1.950 | 2/5/88 | 124 | 9.34 | 0.9 | 3.9 | 5 |
| 11/12/87 | 345 | 0.190 | 10/3/88 | 71 | 0.390 | 2/5/88 | 124 | 4.57 | 0.3 | 2.5 | 6 |
| 11/12/87 | 345 | 1.280 | 10/3/88 | 71 | 1.600 | 2/5/88 | 124 | 6.44 | 0.8 | 2.7 | 7 |
| 11/12/87 | 345 | 1.790 | 15/3/88 | 76 | 2.240 | 25/4/88 | 117 | 5.58 | 1.0 | 2.7 | 8 |
| 11/12/87 | 345 | 1.240 | 10/3/88 | 71 | 1.610 | 2/5/88 | 124 | 8.16 | 1.0 | 3.8 | 9 |
| 11/12/87 | 345 | 0.940 | 10/3/88 | 71 | 0.930 | 2/5/88 | 124 | 6.14 | 0.5 | 3.3 | 10 |
| 11/12/87 | 345 | 1.830 | 10/3/88 | 71 | 2.030 | 2/5/88 | 124 | 8.92 | 1.0 | 4.7 | 11 |
| 11/12/87 | 345 | 0.183 | 15/3/88 | 76 | 0.630 | 2/5/88 | 124 | 5.48 | 0.5 | 2.2 | 12 |

Source
Palleau, J.P., 1991, CETIOM, Dijon.

# Appendix I3:
# Region specific data of winter oilseed rape

Table I3a Calibrated temperature sums and life span of leaves of winter oilseed crop types grown in regions within countries of the European Community, except Greece and Portugal due to lack of data.
TSUM1 = temperature sum from emergence to secundary tap root growth
TSUM2 = temperature sum from secundary tap root growth to harvest.
SPAN = life span of leaves growing at 35°C

| crop type | country | NUTS codes per region | TSUM1 °Cd | TSUM2 °Cd | SPAN d |
|---|---|---|---|---|---|
| 1001 | Germany | R1 | 240 | 600 | 17 |
| | France | R21,R22,R23,R24,R25 | | | |
| | Italy | R31,R32,R33,R34,R35,R36 | | | |
| | the Netherlands | R4 | | | |
| | Belgium | R5 | | | |
| | United Kingdom | R7 | | | |
| | Ireland | R8 | | | |
| | Denmark | R9 | | | |
| | Spain | RB1, RB2, RB3 | | | |
| 1002 | Southern Italy | R37,R38,R39,R3A,R3B | 200 | 700 | 25 |
| | Southern France | R26, R27, R28 | | | |
| 1003 | Southern Spain | RB4, RB5, RB4 | 190 | 900 | 28 |

Table I3b Calibrated parameters of the initial crop-specific data file (Appendix I1) of oilseed rape.

```
** initial
RGRLAI   = 0.0080            ! maximum relative increase in LAI [ha ha-1 d-1]

** assimilation
AMAXTB   = 0.00,   40.00,    ! maximum leaf CO2 assimilation rate
           0.80,   40.00,    ! as function of DVS [-; kg ha-1 hr-1]
           1.00,   30.00,
           1.20,   35.00,
           1.40,   20.00,
           2.00,    0.00

** maintenance respiration
RMO      = 0.0120            ! rel. maint. resp. rate stor.org. [kg CH2O kg-1 d-1]

** partitioning
```

| DVS | FRTB<br>kg kg$^{-1}$ | FLTB<br>kg kg$^{-1}$ | FSTB<br>kg kg$^{-1}$ | FOTB<br>kg kg$^{-1}$ |
|---|---|---|---|---|
| 0.00 | 0.20 | 0.60 | 0.40 | 0.00 |
| 0.20 | | 0.60 | 0.40 | |
| 0.30 | 0.20 | 0.40 | 0.60 | |
| 0.70 | | 0.20 | 0.80 | |
| 1.00 | 0.00 | 0.15 | 0.85 | 0.00 |
| 1.20 | | 0.00 | 0.70 | 0.30 |
| 1.35 | | | 0.30 | 0.70 |
| 1.70 | | | 0.00 | 1.00 |
| 2.00 | 0.00 | 0.00 | 0.00 | 1.00 |

# Appendix I4:

## Crop calendar of winter oilseed rape

Table I4. Full flowering, maturity and harvest day (Julian day number) and calculated temperature sums of winter oilseed rape for regions within the European Community. Each NUTS region contains several grid cells. The temperture sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calculated temperature sum from emergence to flowering, base temperature of 0°C.
TSUM2 = calculated temperature sum from flowering to maturity, base temperature of 2°C.
J. day nr. = Julian day number

| NUTS code | grid cell | full flowering J. day nr. | maturity J. day nr. | harvest J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|---|
| R11 | 4135 | 127 | 196 | 196 | 403 | 1002 | Germany | Schleswig-Holstein | |
| R12 | 4035 | 127 | 196 | 196 | 431 | 1014 | | Hamburg | |
| R13 | 3834 | 127 | 196 | 196 | 466 | 1038 | | Niedersachsen | |
| R14 | 3933 | 127 | 196 | 196 | 486 | 1040 | | Bremen | |
| R15 | 3531 | 127 | 196 | 196 | 607 | 1076 | | Nordrhein-Westfalen | 1 |
| R16 | 3333 | 127 | 196 | 196 | 530 | 1092 | | Hessen | |
| R17 | 3231 | 127 | 196 | 196 | 538 | 1054 | | Rheinland-Pfalz | |
| R18 | 2934 | 127 | 196 | 196 | 498 | 1085 | | Baden-Württemberg | |
| R19 | 3037 | 127 | 196 | 196 | 409 | 1047 | | Bayern | |
| R1A | 3131 | 127 | 196 | 196 | 541 | 1059 | | Saarland | |
| R21 | 2924 | 122 | 210 | 210 | 767 | 1451 | France | Île de France | 1 |
| R22 | 3125 | 122 | 210 | 210 | 673 | 1378 | | Bassin Parisien | 1 |
| R23 | 3325 | 123 | 213 | 213 | 646 | 1369 | | Nord - Pas-de-Calais | 1 |
| R241 | 2930 | 120 | 205 | 205 | 515 | 1300 | | Est | 1 |
| R242 | 2831 | 115 | 196 | 196 | 543 | 1286 | | Est | 1 |
| R25 | 2817 | -1 | -1 | -1 | -1 | -1 | | Ouest | |
| R26 | 2020 | -1 | -1 | -1 | -1 | -1 | | Sud-Ouest | |
| R27 | 2227 | -1 | -1 | -1 | -1 | -1 | | Centre-Est | |
| R28 | 1826 | -1 | -1 | -1 | -1 | -1 | | Mediterranée | |
| R31 | 2132 | 105 | 176 | | 762 | 1175 | Italy | Nord Ovest | 3 |
| R32 | 2235 | 105 | 176 | | 578 | 1230 | | Lombardia | 3 |
| R33 | 2339 | 105 | 176 | | 673 | 1258 | | Nord Est | 3 |
| R34 | 2037 | -1 | -1 | -1 | -1 | -1 | | Emilia-Romagna | 3 |
| R35 | 1740 | 95 | 156 | | 481 | 834 | | Centro | 3 |
| R36 | 1439 | 95 | 156 | | 855 | 945 | | Lazio | 3 |
| R37 | 1242 | -1 | -1 | -1 | -1 | -1 | | Campania | 3 |
| R38 | 1247 | 100 | 156 | | 939 | 900 | | Abruzzi-Molise | 3 |
| R39 | 1345 | 100 | 156 | | 877 | 913 | | Sud | 3 |
| R3A | 541 | -1 | -1 | -1 | -1 | -1 | | Sicilia | 3 |
| R3B | 1134 | -1 | -1 | -1 | -1 | -1 | | Sardegna | 3 |
| R41 | 3930 | 125 | 201 | 212 | 466 | 1059 | the Netherlands | Noord-Nederland | |
| R42 | 3730 | 125 | 201 | 212 | 568 | 1145 | | Oost-Nederland | |
| R45 | 3628 | -1 | -1 | -1 | -1 | -1 | | Zuid-Nederland | |
| R47 | 3626 | -1 | -1 | -1 | -1 | -1 | | West-Nederland | |
| R51 | 3426 | 125 | 201 | 212 | 693 | 1192 | Belgium | Vlaams Gewest | 1 |
| R52 | 3329 | 125 | 201 | 212 | 531 | 1125 | | Region Wallone | 1 |
| R6 | 3129 | 135 | 212 | 217 | 678 | 1235 | Luxembourg | | 1 |
| R71 | 4419 | 135 | 207 | 227 | 293 | 747 | United Kingdom | North | 2 |
| R72 | 4220 | 135 | 207 | 227 | 686 | 983 | | Yorkshire and Humberside | 2 |
| R73 | 4020 | 135 | 207 | 227 | 658 | 984 | | East Midlands | 2 |
| R74 | 3822 | 135 | 207 | 227 | 684 | 1018 | | East Anglia | 2 |
| R75 | 3620 | 135 | 207 | 227 | 690 | 1013 | | South East | 2 |
| R76 | 3515 | -1 | -1 | -1 | -1 | -1 | | South West | 2 |
| R77 | 3818 | 135 | 207 | 227 | 673 | 989 | | West Midlands | 2 |
| R78 | 4118 | 135 | 207 | 227 | 720 | 986 | | North West | 2 |
| R79 | 3816 | -1 | -1 | -1 | -1 | -1 | | Wales | 2 |
| R7A | 4918 | 135 | 207 | 227 | 16 | 337 | | Scotland | 2 |
| R7B | 4513 | 135 | 207 | 227 | 672 | 864 | | Northern Ireland | 2 |
| R8 | 4414 | -1 | -1 | -1 | -1 | -1 | Ireland | | 2 |
| R9 | 4534 | 135 | 207 | 227 | 369 | 996 | Denmark | | |

Table I4. Full flowering, maturity and harvest day (Julian day number) and calculated temperature sums of winter oilseed rape for regions within the European Community. Each NUTS region contains several grid cells. The temperture sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calculated temperature sum from emergence to flowering, base temperature of 0°C.
TSUM2 = calculated temperature sum from flowering to maturity, base temperature of 2°C.
J. day nr. = Julian day number

| NUTS code | grid cell | full flowering J. day nr. | maturity J. day nr. | harvest J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|---|
| RA11 | -1 | -1 | -1 | -1 | -1 | -1 | Greece | Anatoliki Makedonia, Thraki | 3 |
| RA12 | -1 | -1 | -1 | -1 | -1 | -1 | | Kentriki Makedonia | 3 |
| RA13 | -1 | -1 | -1 | -1 | -1 | -1 | | Dytriki Makedonia | 3 |
| RA14 | -1 | -1 | -1 | -1 | -1 | -1 | | Thessalia | 3 |
| RA15 | -1 | -1 | -1 | -1 | -1 | -1 | | Anatoliki Makedonia | 3 |
| RA18 | -1 | -1 | -1 | -1 | -1 | -1 | | Thraki | 3 |
| RA2 | -1 | -1 | -1 | -1 | -1 | -1 | | Kentriki Ellada | 3 |
| RA3 | -1 | -1 | -1 | -1 | -1 | -1 | | Attiki | 3 |
| RA4 | -1 | -1 | -1 | -1 | -1 | -1 | | Nisia | 3 |
| RB1 | 1907 | -1 | -1 | -1 | -1 | -1 | Spain | Noroeste | 3 |
| RB2 | 1517 | 105 | 196 | 181 | 924 | 1699 | | Noreste | 3 |
| RB3 | 1312 | -1 | -1 | -1 | -1 | -1 | | Madrid | 3 |
| RB4 | 1011 | *105* | *191* | *184* | 813 | 1519 | | Centro | 3 |
| RB5 | 1219 | 105 | 186 | 186 | 1148 | 1473 | | Este | 3 |
| RB6 | 610 | 85 | 156 | 166 | 843 | 1132 | | Sur | 3 |
| RC1 | 1605 | -1 | -1 | -1 | -1 | -1 | Portugal | Continente | |

References

1 Falisse, A. 1992.
Aspects Agrometeorologiques du Developpement des Cultures dans le Benelux et les Regions Voisines.
Etude pour la Betterabe Sucrière, le Colza, le Pois, le Froment et l'Avoine.
Centre Commun de Recherche, 151-184.

2 Hough, M.N., 1990
Agrometeorological aspects of crops in the United Kingdom and Ireland.
A review for Sugar Beet, Oilseed Rape, Peas, Wheat, Barley, Oats, Potatoes, Apples and Pears.
Joint Research Centre, Commission of the European Communities, 65-104.

remark: at harvest 12 - 15% moisture coefficient in seed

3 Narciso, G. P. Ragni & A. Venturi, 1992.
Agrometeorological aspects of crops in Italy, Spain and Greece.
A summary review for common and durum wheat, barley, maize, rice, sugar beet, sunflower, soya bean, rape, potato, cotton, olive and grape crops.
Joint Research Centre, Commission of the European Communities, 195-218.

remarks: commercial ripeness
colza is irrigated in RB2 and RB5.

-1 means: no data available or no winter oilseed rape grown
*-1* means: production probably of less importance (own interpretation)
*125* means: personal guess

# Appendix J:

## Field experiment data of sunflower (*Helianthus annuus* L.)

# Appendix J1: Initial crop-specific data file of sunflower

CROP DATA FILE for use with WOFOST Version 5.0, January 1990

crop identity

| | | | | |
|---|---|---|---|---|
| !CRPNAM | = | Sunflower (*Helianthus annuus* L.) | | |
| ICROP | = | 11 | | |

** emergence

| | | | | |
|---|---|---|---|---|
| TBASEM | = | 3. | | ! lower threshold temp. for emergence [C°], van Heemst 1988. |
| TEFFMX | = | 32. | | ! max. eff. temp. for emergence [C°] |
| | | | | ! adapted from van Heemst 1988 |
| TSUMEM | = | 130. | | ! temperature sum from sowing to emergence [C° d] |
| | | | | ! van Heemst, 1988. |

** phenology

| | | | | |
|---|---|---|---|---|
| IDSL | = | 0 | | ! indicates whether pre-anthesis development depends |
| | | | | ! on temp. (=0), daylength (=1) , or both (=2) |
| DLO | = | -99. | | ! optimum daylength for development [hr] |
| DLC | = | -99. | | ! critical daylength (lower threshold) [hr] |
| TSUM1 | = | 1050. | | ! temperature sum from emergence to anthesis [C° d] |
| TSUM2 | = | 1000. | | ! temperature sum from anthesis to maturity [C° d] |
| DTSMTB | = | 0.00, | 0.00, | ! daily increase in temp. sum |
| | | 2.00, | 0.00, | ! as function of av. temp. [C°; C° d] |
| | | 18.00, | 16.00, | |
| | | 40.00, | 38.00 | |
| DVSEND | = | 2.00 | | ! development stage at harvest (= 2.0 at maturity [-]) |

** initial

| | | | | |
|---|---|---|---|---|
| TDWI | = | 6.0 | | ! initial total crop dry weight [kg $ha^{-1}$] |
| LAIEM | = | 0.0053 | | ! leaf area index at emergence [ha $ha^{-1}$] |
| RGRLAI | = | 0.0294 | | ! maximum relative increase in LAI [ha $ha^{-1}$ $d^{-1}$] |

** green area

| | | | | |
|---|---|---|---|---|
| SLATB | = | 0.00, | 0.0035, | ! specific leaf area |
| | | 1.00, | 0.0025, | ! as a function of DVS [-; ha $kg^{-1}$] |
| | | 2.00, | 0.0025 | |
| SPA | = | 0.000 | | ! specific pod area [ha $kg^{-1}$] |
| SSA | = | 0.000 | | ! specific stem area [ha $kg^{-1}$] |
| SPAN | = | 40. | | ! life span of leaves growing at 35 C° [d] |
| TBASE | = | 3.0 | | ! lower threshold temp. for ageing of leaves [C°] |

** assimilation

| | | | | |
|---|---|---|---|---|
| KDIF | = | 0.900 | | ! extinction coefficient for diffuse visible light [-] |
| EFF | = | 0.40 | | ! light-use effic. single leaf [kg $ha^{-1}$ $hr^{-1}$ $J^{-1}$ $m^2$ s] |
| AMAXTB | = | 0.00, | 36.00, | ! maximum leaf CO2 assimilation rate |
| | | 1.22, | 36.00, | ! as function of DVS [-; kg $ha^{-1}$ $hr^{-1}$] |
| | | 2.00, | 12.00 | |
| TMPFTB | = | 0.00, | 0.00, | ! reduction factor of AMAX |
| | | 10.00, | 0.50, | ! as function of av. temp. [C°; -] |
| | | 20.00, | 1.00, | |
| | | 30.00, | 1.00, | |
| | | 40.00, | 0.50 | |
| TMNFTB | = | 0.00, | 0.00, | ! red. factor of gross assim. rate |
| | | 3.00, | 1.00 | ! as function of low min. temp. [C°; -] |

** conversion of assimilates into biomass

| | | | | |
|---|---|---|---|---|
| CVL | = | 0.590 | | ! efficiency of conversion into leaves [kg $kg^{-1}$] |
| CVO | = | 0.710 | | ! efficiency of conversion into storage org. [kg $kg^{-1}$] |
| CVR | = | 0.710 | | ! efficiency of conversion into roots [kg $kg^{-1}$] |
| CVS | = | 0.730 | | ! efficiency of conversion into stems [kg $kg^{-1}$] |

** maintenance respiration

| | | | | |
|---|---|---|---|---|
| Q10 | = | 2.0 | | ! rel. incr. in resp. rate per 10 C°temp. incr. [-] |
| RML | = | 0.0050 | | ! rel. maint. resp. rate leaves [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RMO | = | 0.023 | | ! rel. maint. resp. rate stor.org. [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RMR | = | 0.010 | | ! rel. maint. resp. rate roots [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RMS | = | 0.008 | | ! rel. maint. resp. rate stems [kg CH2O $kg^{-1}$ $d^{-1}$] |
| RFSETB | = | 0.00, | 1.00, | ! red. factor for senescence |
| | | 2.00, | 1.00 | ! as function of DVS [-; -] |

** partitioning

| | | | | |
|---|---|---|---|---|
| FRTB | = | 0.00, | 0.50, | ! fraction of total dry matter to roots |
| | | 0.65, | 0.50, | ! as a function of DVS [-; kg $kg^{-1}$] |
| | | 1.10, | 0.00, | |
| | | 2.00, | 0.00 | |
| FLTB | = | 0.00, | 0.70, | ! fraction of above-gr. DM to leaves |
| | | 0.85 | 0.50, | ! as a function of DVS [-; kg kg-1] |
| | | 0.91, | 0.41, | |
| | | 1.22, | 0.00, | |
| | | 2.00, | 0.00 | |
| FSTB | = | 0.00, | 0.30, | ! fraction of above-gr. DM to stems |
| | | 0.85, | 0.50, | ! as a function of DVS [-; kg kg-1] |
| | | 0.91, | 0.59, | |
| | | 1.22, | 0.28, | |
| | | 1.35, | 0.00, | |
| | | 2.00, | 0.00 | |

FOTB = 0.00, 0.00, ! fraction of above-gr. DM to stor. org.
0.85, 0.00, ! as a function of DVS [-; kg $kg^{-1}$]
0.91, 0.00,
1.22, 0.72,
1.35, 1.00,
2.00, 1.00

** death rates
PERDL = 0.030 ! max. rel. death rate of leaves due to water stress
RDRRTB = 0.00, 0.000, ! rel. death rate of stems
1.50, 0.000, ! as a function of DVS [-; kg $kg^{-1}$ $d^{-1}$]
1.5001, 0.020,
2.00, 0.020
RDRSTB = 0.00, 0.000, ! rel. death rate of roots
1.50, 0.000, ! as a function of DVS [-; kg $kg^{-1}$ $d^{-1}$]
1.5001, 0.020,
2.00, 0.020

** water use
CFET = 1.00 ! correction factor transpiration rate [-]
DEPNR = 3.5 ! crop group number for soil water depletion [-]
IAIRDU = 0 ! air ducts in roots present (=1) or not (=0)

** rooting
RDI = 10. ! initial rooting depth [cm]
RRI = 1.2 ! maximum daily increase in rooting depth [cm $d^{-1}$]
RDMCR = 150. ! maximum rooting depth [cm]

** nutrients
** maximum and minimum concentrations of N, P, and K in storage organsin vegetative organs [kg kg-1]
NMINSO = 0.0180 ; NMINVE = 0.0070
NMAXSO = 0.0450 ; NMAXVE = 0.0180
PMINSO = 0.0040 ; PMINVE = 0.0008
PMAXSO = 0.0100 ; PMAXVE = 0.0028
KMINSO = 0.0060 ; KMINVE = 0.0100
KMAXSO = 0.0200 ; KMAXVE = 0.0300
YZERO = 0. ! max. amount veg. organs at zero yield [kg $ha^{-1}$]
NFIX = 0.00 ! fraction of N-uptake from biol. fixation [kg $kg^{-1}$]

# Appendix J2:

## Field experiment data of sunflower

Appendix J2a. Total biomass, grain yield and leaf area index measurements of an irrigated sunflower field experiment at INRA, Toulouse (Auzeville), France in 1985.
J. day nr. = Julian day number
LAI = leaf area index

Planting date 1 April 1985 : day number 91.
Harvest date 9 September 1985: day number 252.

Thermal time with temperature base of 6 °Cd.

| | |
|---|---|
| emergence | 70 °Cd |
| flowering | 900 °Cd |
| senescence | 1200 °Cd |
| maturity | 1700 °Cd |

| | |
|---|---|
| Maximum rooting depth | 2.5 m |
| Maximum LAI | 4.4 (ha/ha) |
| Maximum plant height | 1.70 m |

Table J2a. Total biomass and leaf area index of sunflower during the growing season of 1985 (France).

| Intermediate harvest date | day number J. day nr. | biomass kg/ha | biomass t/ha | LAI ha/ha |
|---|---|---|---|---|
| 29/5/85 | 149 | 624 | 0.62 | 0.9 |
| 4/6/85 | 155 | 1374 | 1.37 | 1.7 |
| 10/6/85 | 161 | 2724 | 2.72 | 2.4 |
| 11/6/85 | 162 | 3084 | 3.08 | 2.5 |
| 18/6/85 | 169 | 5142 | 5.14 | 3.4 |
| 24/6/85 | 175 | 6960 | 6.96 | 3.8 |
| 1/7/85 | 182 | 11600 | 11.60 | 3.9 |
| 4/7/85 | 185 | 13490 | 13.49 | 4.4 |
| 17/7/85 | 198 | 13240 | 13.24 | 2.6 |
| 29/7/85 | 210 | 10854 | 10.85 | 2.4 |

Harvest:

| | |
|---|---|
| total biomass: | 9630 kg/ha |
| total grain yield fresh weight: | 2930 kg/ha |
| number of grains per m2: | 6629 |

Source
Cabelguenne, M., INRA, Toulouse, France, 1993.

Appendix J2b. Total biomass, grain yield and leaf area index measurements of an irrigated sunflower field experiment at INRA, Toulouse (Auzeville), France in 1986.
J. day nr. = Julian day number
LAI = leaf area index

Planting date 28 March 1986 : day number 87.
Harvest date 9 September 1986: day number 252.

Thermal time with temperature base of 6 °Cd.

| | |
|---|---|
| emergence | 70 °Cd |
| flowering | 900 °Cd |
| senescence | 1200 °Cd |
| maturity | 1700 °Cd |

| | |
|---|---|
| Maximum rooting depth | 2.5 m |
| Maximum LAI | 4.2 (ha/ha) |
| Maximum plant height | 1.70 m |

Table J2b. Total biomass and leaf area index of sunflower during the growing season of 1986 (France).

| Intermediate harvests date | day number J. day nr. | biomass kg/ha | biomass t/ha | LAI ha/ha |
|---|---|---|---|---|
| 17/5/86 | 137 | 114 | 0.11 | 0.1 |
| 28/5/86 | 148 | 552 | 0.55 | 0.9 |
| 9/6/86 | 160 | 2500 | 2.50 | 2.4 |
| 18/6/86 | 169 | 5500 | 5.50 | 3.3 |
| 4/7/86 | 185 | 12500 | 12.50 | 4.2 |
| 23/7/86 | 204 | 14200 | 14.20 | 2.3 |
| 7/8/86 | 219 | - | - | 2.0 |
| 20/8/86 | 232 | - | - | 0.6 |
| 1/9/86 | 244 | 11500 | 11.50 | 0.0 |

Harvest:

| | |
|---|---|
| total biomass: | 14610 kg/ha |
| total grain yield fresh weight: | 4680 kg/ha |
| number of grains per m2: | 9770 |

Source
Cabelguenne, M., INRA, Toulouse, France, 1993.

# Appendix J3:

# Region specific data of sunflower

Table J3a Occurrence of sowing, flowering and maturity day of sunflower in regions within countries of the European Community.
J. day nr. = Julian day number

| crop type | country | NUTS codes per region | sowing J. day nr. | flowering J. day nr. | maturity J. day nr. |
|---|---|---|---|---|---|
| 1101 | France | R2 | 95 | 190 | 252 |
| | Italy | R3 | 110 | 186 | 238 - 258 |
| | Centr. Spain | RB1, RB2, RB3, RB4 | 120 | 186 | 268 |
| | S. Spain | RB5, RB6 | 74 | 135 | 237 |
| | Greece | RA | 110 | 176 | 258 |

Table J3b Calibrated parameters of the initial crop-specific data file (Appendix J1) of sunflower.

```
** phenology
TSUM1   =  1050.    ! temperature sum from emergence to anthesis [C° d]
TSUM2   =  1000.    ! temperature sum from anthesis to maturity [C° d]

** green area
SPAN    =  30.               ! life span of leaves growing at 35 C° [d]

** conversion of assimilates into biomass
CVL     =  0.720             ! efficiency of conversion into leaves [kg kg-1]
CVO     =  0.450             ! efficiency of conversion into storage org. [kg kg-1]
CVR     =  0.720             ! efficiency of conversion into roots [kg kg-1]
CVS     =  0.690             ! efficiency of conversion into stems [kg kg-1]

** maintenance respiration
RML     =  0.0300            ! rel. maint. resp. rate leaves [kg CH2O kg-1 d-1]
RMO     =  0.0120            ! rel. maint. resp. rate stor.org. [kg CH2O kg-1 d-1]
RMR     =  0.0100            ! rel. maint. resp. rate roots [kg CH2O kg-1 d-1]
RMS     =  0.0150            ! rel. maint. resp. rate stems [kg CH2O kg-1 d-1]

** partitioning
FRTB    =  0.00,    0.50,    ! fraction of total dry matter to roots
           0.65,    0.50,    ! as a function of DVS [-; kg kg-1]
           1.10,    0.00,
           2.00,    0.00
FLTB    =  0.00,    0.50,    ! fraction of above-gr. DM to leaves
           0.85,    0.50,    ! as a function of DVS [-; kg kg-1]
           0.91,    0.41,
           1.00,    0.20,
           1.22,    0.00,
           2.00,    0.00
FSTB    =  0.00,    0.50,    ! fraction of above-gr. DM to stems
           0.85,    0.50,    ! as a function of DVS [-; kg kg-1]
           0.91,    0.59,
           1.00,    0.80,
           1.22,    0.28,
           1.35,    0.00,
           2.00,    0.00
FOTB    =  0.00,    0.00,    ! fraction of above-gr. DM to stor. org.
           0.85,    0.00,    ! as a function of DVS [-; kg kg-1]
           0.91,    0.00,
           1.00,    0.00,
           1.22,    0.72,
           1.35,    1.00,
           2.00,    1.00
```

# Appendix J4:

## Crop calendar of sunflower

Table J4. Sowing, flowering, maturity and harvest day (Julian day number) and calculated temperature sums of sunflower for regions within the European Community. Each NUTS region contains several grid cells. The temperture sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calculated temperature sum from emergence to flowering growth, base temperature of 6°C.
TSUM2 = calculated temperature sum from flowering to harvest, base temperature of 6°C.
Temperature sum from sowing to emergence is 130°Cd, base temperature of 3°C.
J. day nr. = Julian day number

| NUTS code | grid cell | sowing J. day nr. | flowering J. day nr. | maturity J. day nr. | harvest J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|---|---|
| R11 | 4135 | -1 | -1 | -1 | -1 | -1 | -1 | Germany | Schleswig-Holstein | 3 |
| R12 | 4035 | -1 | -1 | -1 | -1 | -1 | -1 | | Hamburg | 3 |
| R13 | 3834 | -1 | -1 | -1 | -1 | -1 | -1 | | Niedersachsen | 3 |
| R14 | 3933 | -1 | -1 | -1 | -1 | -1 | -1 | | Bremen | 3 |
| R15 | 3531 | -1 | -1 | -1 | -1 | -1 | -1 | | Nordrhein-Westfalen | 3 |
| R16 | 3333 | -1 | -1 | -1 | -1 | -1 | -1 | | Hessen | 3 |
| R17 | 3231 | -1 | -1 | -1 | -1 | -1 | -1 | | Rheinland-Pfalz | 3 |
| R18 | 2934 | -1 | -1 | -1 | -1 | -1 | -1 | | Baden-Württemberg | 3 |
| R19 | 3037 | -1 | -1 | -1 | -1 | -1 | -1 | | Bayern | 3 |
| R1A | 3131 | -1 | -1 | -1 | -1 | -1 | -1 | | Saarland | 3 |
| R21 | 2924 | *95* | *190* | | *252* | 639 | 785 | France | Ile de France | 4 |
| R22 | 3125 | *95* | *190* | | *252* | 565 | 729 | | Bassin Parisien | 4 |
| R23 | 3325 | -1 | -1 | -1 | -1 | -1 | -1 | | Nord - Pas-de-Calais | 3 |
| R241 | 2930 | *95* | *190* | | *252* | 543 | 721 | | Est | 4 |
| R242 | 2831 | *95* | *190* | | *252* | 654 | 803 | | Est | 4 |
| R25 | 2817 | *95* | *190* | | *252* | 624 | 770 | | Ouest | 4 |
| R26 | 2020 | *95* | *190* | | *252* | 756 | 883 | | Sud-Ouest | 4 |
| R27 | 2227 | *95* | *190* | | *252* | 688 | 861 | | Centre-Est | 4 |
| R28 | 1826 | *95* | *190* | | *252* | 954 | 1059 | | Mediterranée | 4 |
| R31 | 2132 | -1 | -1 | -1 | -1 | -1 | -1 | Italy | Nord Ovest | 1 |
| R32 | 2235 | -1 | -1 | -1 | -1 | -1 | -1 | | Lombardia | 1 |
| R332 | 2537 | 110 | 186 | 238 | 263 | 0 | 351 | | Veneto | 1 |
| R333 | 2338 | 110 | 186 | 238 | 263 | 712 | 1142 | | Friuli-Venezia Giulia | 1 |
| R34 | 2037 | 110 | 186 | 238 | 263 | 839 | 1341 | | Emilia-Romagna | 1 |
| R35 | 1740 | 110 | 186 | 258 | 263 | 676 | 1189 | | Centro | 1 |
| R36 | 1439 | 110 | 186 | 258 | 263 | 796 | 1312 | | Lazio | 1 |
| R37 | 1242 | -1 | -1 | -1 | -1 | -1 | -1 | | Campania | 1 |
| R38 | 1247 | 115 | 166 | | 243 | 473 | 1399 | | Abruzzi-Molise | 1 |
| R39 | 1345 | 115 | 166 | | 243 | 491 | 1432 | | Sud | 1 |
| R3A | 541 | 115 | 166 | 227 | 243 | 435 | 1296 | | Sicilia | 1 |
| R3B | 1134 | -1 | -1 | -1 | -1 | -1 | -1 | | Sardegna | 3 |
| R41 | 3930 | -1 | -1 | -1 | -1 | -1 | -1 | the Netherlands | Noord-Nederland | 2,3 |
| R42 | 3730 | -1 | -1 | -1 | -1 | -1 | -1 | | Oost-Nederland | 2,3 |
| R45 | 3628 | -1 | -1 | -1 | -1 | -1 | -1 | | Zuid-Nederland | 2,3 |
| R47 | 3626 | -1 | -1 | -1 | -1 | -1 | -1 | | West-Nederland | 2,3 |
| R51 | 3426 | -1 | -1 | -1 | -1 | -1 | -1 | Belgium | Vlaams Gewest | 2,3 |
| R52 | 3329 | -1 | -1 | -1 | -1 | -1 | -1 | | Region Wallone | 2,3 |
| R6 | 3129 | -1 | -1 | -1 | -1 | -1 | -1 | Luxembourg | | 2,3 |
| R71 | 4419 | -1 | -1 | -1 | -1 | -1 | -1 | United Kingdom | North | 2,3 |
| R72 | 4220 | -1 | -1 | -1 | -1 | -1 | -1 | | Yorkshire and Humberside | 2,3 |
| R73 | 4020 | -1 | -1 | -1 | -1 | -1 | -1 | | East Midlands | 2,3 |
| R74 | 3822 | -1 | -1 | -1 | -1 | -1 | -1 | | East Anglia | 2,3 |
| R75 | 3620 | -1 | -1 | -1 | -1 | -1 | -1 | | South East | 2,3 |
| R76 | 3515 | -1 | -1 | -1 | -1 | -1 | -1 | | South West | 2,3 |
| R77 | 3818 | -1 | -1 | -1 | -1 | -1 | -1 | | West Midlands | 2,3 |
| R78 | 4118 | -1 | -1 | -1 | -1 | -1 | -1 | | North West | 2,3 |
| R79 | 3816 | -1 | -1 | -1 | -1 | -1 | -1 | | Wales | 2,3 |
| R7A | 4918 | -1 | -1 | -1 | -1 | -1 | -1 | | Scotland | 2,3 |
| R7B | 4513 | -1 | -1 | -1 | -1 | -1 | -1 | | Northern Ireland | 2,3 |
| R8 | 4414 | -1 | -1 | -1 | -1 | -1 | -1 | Ireland | | 2,3 |
| R9 | 4534 | -1 | -1 | -1 | -1 | -1 | -1 | Denmark | | 2,3 |
| | | | | | | | | | | 2 |

Table J4. Sowing, flowering, maturity and harvest day (Julian day number) and calculated temperature sums of sunflower for regions within the European Community. Each NUTS region contains several grid cells. The temperture sums are calculated for the grid cell number given in the table (more information about grid cells is given in section 2.4).

TSUM1 = calculated temperature sum from emergence to flowering growth, base temperature of 6°C.
TSUM2 = calculated temperature sum from flowering to harvest, base temperature of 6°C.
Temperature sum from sowing to emergence is 130°Cd, base temperature of 3°C.
J. day nr. = Julian day number

| NUTS code | grid cell | sowing J. day nr. | flowering J. day nr. | maturity J. day nr. | harvest J. day nr. | TSUM1 °Cd | TSUM2 °Cd | country | region | source |
|---|---|---|---|---|---|---|---|---|---|---|
| Greece rainfed | | | | | | | | | | 2 |
| RA11 | 1561 | 110 | 176 | | 258 | 731 | 1497 | Greece | Anatoliki Makedonia, Thraki | |
| RA12 | 1457 | 110 | 176 | | 258 | 666 | 1405 | | Kentriki Makedonia | |
| RA13 | 1254 | 110 | 176 | | 258 | 431 | 1137 | | Dytiki Makedonia | |
| RA14 | 1256 | 110 | 176 | | 258 | 644 | 1390 | | Thessalia | |
| RA15 | 1458 | 110 | 176 | | 258 | 716 | 1467 | | Anatoliki Makedonia | |
| RA18 | 1562 | 110 | 176 | | 258 | 748 | 1496 | | Thraki | |
| RA2 | 956 | *-1* | *-1* | *-1* | *-1* | -1 | -1 | | Kentriki Ellada | |
| RA3 | 1057 | *-1* | *-1* | *-1* | *-1* | -1 | -1 | | Attiki | |
| RA4 | 263 | *-1* | *-1* | *-1* | *-1* | -1 | -1 | | Nisia | |
| Greece irrigated | | | | | | | | | | |
| RA11 | 1561 | 110 | 176 | | 258 | 731 | 1497 | Greece | Anatoliki Makedonia, Thraki | |
| RA12 | 1457 | 110 | 176 | | 258 | 666 | 1405 | | Kentriki Makedonia | |
| RA13 | 1254 | 110 | 176 | | 258 | 431 | 1137 | | Dytiki Makedonia | |
| RA14 | 1256 | 110 | 176 | | 258 | 644 | 1390 | | Thessalia | |
| RA15 | 1458 | 110 | 176 | | 258 | 716 | 1467 | | Anatoliki Makedonia | |
| RA18 | 1562 | 110 | 176 | | 258 | 748 | 1496 | | Thraki | |
| RA2 | 956 | *-1* | *-1* | *-1* | *-1* | -1 | -1 | | Kentriki Ellada | |
| RA3 | 1057 | *-1* | *-1* | *-1* | *-1* | -1 | -1 | | Attiki | |
| RA4 | 263 | *-1* | *-1* | *-1* | *-1* | -1 | -1 | | Nisia | |
| RB1 | 1907 | -1 | -1 | -1 | -1 | -1 | -1 | Spain | Noroeste | 3 |
| RB2 | 1517 | 105 | 166 | 258 | 258 | 515 | 1602 | | Noreste | |
| RB3 | 1312 | 120 | 186 | 268 | 273 | 588 | 1383 | | Madrid | |
| RB41 | 1610 | 120 | 186 | 268 | 273 | 493 | 1251 | | Castilia-León | |
| RB42 | 1013 | 120 | 186 | 268 | 273 | 658 | 1476 | | Castilia-La Manche | |
| RB43 | 1107 | *-1* | 135 | 238 | *-1* | -1 | -1 | | Extremadura | |
| RB5 | 1219 | 95 | 176 | 268 | 278 | 760 | 1749 | | Este | |
| RB611 | 513 | 74 | 135 | 238 | 238 | 245 | 1692 | | Almeria | |
| RB612 | 407 | 74 | 135 | 238 | 238 | 414 | 1584 | | Cadiz | |
| RB613 | 710 | 74 | 135 | 238 | 238 | 370 | 1819 | | Cordoba | |
| RB614 | 610 | 120 | 186 | 268 | 273 | 811 | 1669 | | Granada | |
| RB615 | 707 | 74 | 135 | 238 | 238 | 465 | 1901 | | Huelva | |
| RB616 | 711 | 120 | 186 | 268 | 273 | 870 | 1749 | | Jaen | |
| RB617 | 609 | 74 | 135 | 238 | 238 | 380 | 1819 | | Málaga | |
| RB618 | 606 | 74 | 135 | 238 | 238 | 473 | 1794 | | Sevilla | |
| RC1 | 1605 | *120* | *186* | | *273* | 567 | 1224 | Portugal | Continente | |


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Joint Research Centre, Commission of the European Communities, 195-218.

remarks: maturity = commercial ripeness
early sown sunflower is a maincrop in Spain

2 Eurostat, 1989, EUROSTAT, Agricultural Statistical yearbook, 1989.
Statistical office of the European Communities Luxembourg, Bruxelles.

3 EUROSTAT, Regions. Land use statistics, crop production statistics of a specific year grouped by region. Statistical data on diskette. Area of 1988.

4 Assumed from field experiments of Toulouse (Auzeville), 1985,1986 INRA.


-1 means: no data available or no sunflower grown
*-1* means: production probably of less importance (own interpretation)
*125* means: value estimated