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Influence of pluriannual weather conditions on parameters of sunflower growth modeling in Southwestern France.

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As already published, the EPIC model can give a correct simulation of sunflower growth and production, but some parameters must be adjusted to climatic conditions *and varietal types : minimum and optimal growth temperatures* (T°b, T°opt), radiation use efficiency (RUE), potential leaf area index (DMLA), harvest index (HI). The variations of these parameters among the annual climates of a S.W. France situation was observed by cropping the hybrid cv. Pharaon without any shortage of water, mineral nutrition or pest damage during 5 years characterized by a large range of climate variations : the average daily temperature during the cycle varied from 18.0 to 20.6°C, and the potential evapotranspiration (PET) from 4.8 to 7.1 mm.day^{-1}. The total biomass productions reached 12 to 18.5 t.ha^{-1} and the achen yields 4.3 to 5.4 t.ha^{-1}. To fit the experimental data of growth and development of the cooler year (18°C, 4.3 mm PET daily), the well fit parameters appear : T°b = 5° ; T°opt = 23°; RUE = 3.0 g.MJ^{-1}; DMLA = 9.0. For the warmest year, the same respective values are 6°, 27°, 2.2 g.MJ^{-1}, 4. Such parameters describing the climatic effect of each year were tested in other various experimental treatments involving water stress and N shortage, and a good accuracy between simulated and observed data was found. This demonstrates an adaptation of the plant morphology and functioning to the environment, which should be taken into account for improving the modeling accuracy.

INTRODUCTION

Modeling is the most efficient way to synthetize the knowledge on crop growth, development and production, but the use of mechanistic models requires a careful choice for the values attributed to the main parameters governing growth **(Whisler et al., 1986)**. Plants are susceptible of a certain adaptation to environmental conditions of temperature and light **(Bourdu et Prioul, 1974)**, and in addition the ratio between vegetative and reproductive organs is not constant, especially for sunflower. Then the basic and optimal temperatures of growth (T°b, T°opt), the radiation use efficiency (RUE, conversion of the intercepted radiation energy into biomass), maximun leaf area index (DMLA) and harvest index (HI) can vary in some extent among cultivars, and for a given one among years and locations **(Kiniry et al., 1992)**. That requires model calibrations for environments, and the accuracy of simulations quite depends on such calibrations.

The EPIC model **(Williams et al., 1984, 1989)** has already been used with success for sunflower modeling **(Cabelguenne et al., 1990 ; Kiniry et al., 1992)**. In order to precise the influence of annual climates on the above mentioned parameters, a same cultivar has been cropped for five years in S-W France near Toulouse, without any damage of pests, and in some treatments without any shortage of water and mineral supply. We compare to the experimental data the simulation made with standard parameters, or with values empirically selected for each climatic year.

MATERIAL AND METHODS

The hybrid cv. Pharaon was cropped in populations of 8-10 plants.m^{-2} planted near April 1 either in fields for 1986, 1989, 1990 (fine mixed, mesic Haplustalf soil), or for 1987, 1988 in large lysimeters previously described **(Blanchet et al., 1988)**. The main climatic characters of these years are indicated in table 1 : 1988 was rather typical of the location, 1987 fresh, 1986 mild temperature with little rain, 1989 and 90 warm and dry. On the controls, sufficient fertilizations and irrigations preventing any noticeable wilting or stress were supplied. Various other treatments, already described **(Blanchet et al., 1987, 1988, 1990 ; Texier et al., 1990 ; Texier, 1991)**, involved different water and N stress. Each year, at the 12 leaves stage, 25 typical plants were selected in each treatment for their height, stem diameter and homogeneous environment, and tagged. On 6 of them the leaf area was measured by the non-destructive method of **Pouzet and Bugat (1985)** at intervals of about 10 days all along the cycle. At the successive stages bud apparition ("star stage"), beginning and end of anthesis, 4 other tagged plants were harvested and sampled to measure the weights of organs, and at maturity the same sampling was practiced on the remaining plants, completed by a combine harvest. The main characters of these plants are also indicated by table 1 for the control treatments.

Table 1 : Main characters of the climate, growth and production without water or mineral stress during the five years. Standard deviations of plant measurements : ± 8 % during vegetation, ± 5 % at maturity.

Years with increasing temperatures	1987	1986	1988	1990	1989
climate during growth (daily averages) :					
Temperature, °C	18,0	18,5	18,6	20,4	20,6
Vapor pressure deficit, %	24,2	28,7	23,0	30,7	29,7
Insolations, hours	7,02	7,97	6,72	8,61	8,95
Potentiel evapotransp. PET, mm.day^{-1}	4,81	4,98	5,33	6,31	7,11
Water deficit : PET-rain, mm.day^{-1}	3,1	4,4	3,9	4,7	6,7
Growth and production :					
Leaf area index begin anthesis	7,3	4,1	7,0	3,8	4,0
Shoots DM, t.ha^{-1}					
- begin anthesis	9,1	8,8	9,0	7,5	7,6
- maturity	18,5	13,2	15,9	12,5	12,0
Mature achens, t.ha^{-1}	5,59	4,12	5,36	4,50	4,33
Harvest index	0,30	0,31	0,34	0,36	0,36

The simulation of growth, development and production was realized by the EPIC model (version 1910), improved by **Quinones et al. (1990)** in introducing the distinction of the phases of the cycle in which crop parameters were adjusted, and new values for root system characters, the harvest index determinism and some other adaptations described in the mentioned publication. The potential evapotranspiration (PET) was computed in the model by the Penman-Monteith relation ; admitting a water requirement of sunflower of 1,2 PET (**Hattendorf et al., 1988**), the water consunption was simulated at ± 5 %. The standard parameters T°b, T°opt, RUE, DMLA and HI previously established (**Cabelguenne et al., 1990**) were firstly used, then an empirical research of better adapted values of them was made for each year in order to fit as exactly as possible the observed growth kinetics and final productions of the control treatments. Finally these yearly selected parameters were applied to the simulation of the 6 to 20 other experimental treatments of each year involving various water and N shortages. The mean square errors of prediction (MSE) of the simulations were calculated for each year, converted into absolute ($\sqrt{MSE}$) and relative errors, and compared to the precisions obtained with standard parameters, and with the standard deviations of the experimental values.

RESULTS

For the control treatments of each year, figure 1A indicates the evolution of the shoots biomass as a function of degrees.days after emergence, and the sums of temperature corresponding to the main phenological stages with their standard deviations among years. Regarding these sums, the development does not present large yearly variations. Growth is much more differenciated, especially near and after anthesis. The total biomass is the highest in the fresh and wet climate 1987, followed by the moderate temperature and water deficit of 1988. The average temperature of 1986 is quite similar to 1988, but the VPD and water deficits are marked, and growth is reduced ; *it is the same for the warmer years 1989 et 1990.* These three dry years 1986-89-90 restrain the leaf area, but it remains sufficient around anthesis for an efficient radiation interception without drastic consequences on achens production.

To simulate growth as exactly as possible then requires a modulation of some main parameters, as indicated by figure 1B. The basic and optimal temperatures are reduced for 1987, with high RUE and DMLA. The other extreme values fitting the experimental data concern the warmest year 1989, with a T°opt 27°C, low RUE and DMLA. The values are intermediate for the other years, and for 1988 close to the previously

Table 2 ; Range of (TDM) and plot yields within the various experimental treatments of the five years, and comparison of the mean absolute errors of simulation (MAES) obtained with standard and yearly selected parameters (For relative errors (MRE), the mean in simulations is calculated as the average of the yearly mean absolute errors divided by the average of TDM or yields ; the relative experimental "error" is deduced of the average of the standard deviations of the combine yields of 3 plots replicates, either in the most stressed treatments or in the less stressed ones).

Year	1986	1987	1988	1989	1990	MAES	MRE (%)
Number of treatments	11	16	14	20	6	67	
Experimental data, t.ha^{-1} :							
TDM minimum (stressed treat.)	3,3	13,5	10,2	3,8	7,7	-	
maximum (no stress)	13,2	18,5	15,9	12,5	12,0	-	
Yield, minimum (stressed)	1,34	3,92	3,04	1,15	2,63	-	± 29
maximum (no stress)	4,18	6,58	5,36	4,33	4,50	-	± 5
Simulation, mean error, t.ha^{-1} :							
TDM, parameters standard	1,19	4,58	1,27	2,03	1,27	2,21	± 20
yearly selected	0,77	1,54	1,02	1,58	1,02	1,19	± 11
Yield, parameters standard	0,44	1,31	0,61	0,60	0,64	0,72	± 20
yearly selected	0,32	0,68	0,55	0,46	0,30	0,46	± 13

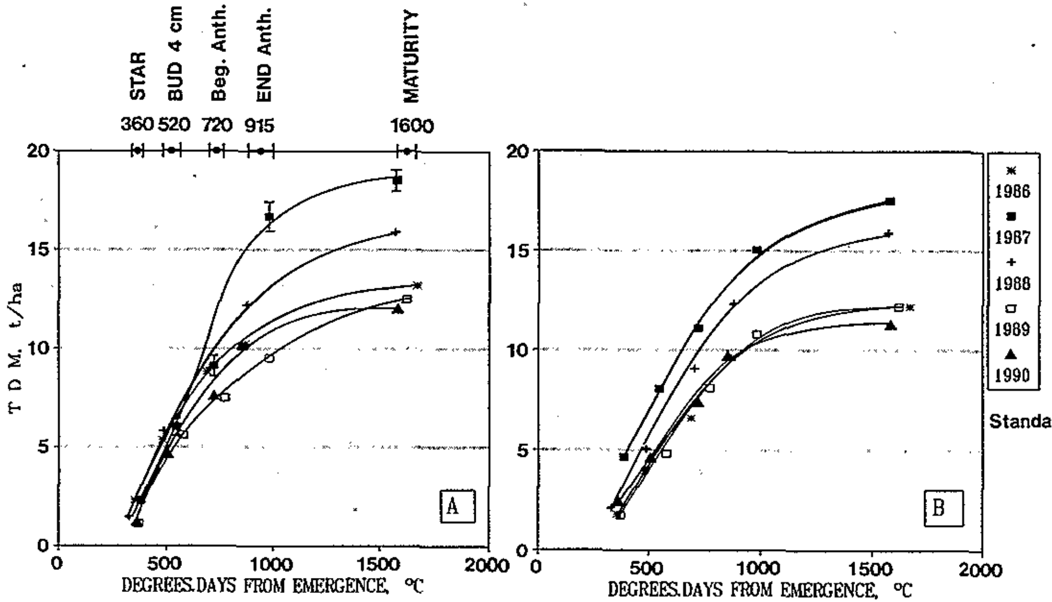
established standards. Such variations agree with the conceptions of **Bourdu and Prioul (1974)** who demonstrated a substantial range of climatic plant adaptation. They are necessary to obtain a correct agreement between figures 1A and 1B, comparing the observed and simulated data.

To test the validity of that yearly modulation of parameters, only established with the data of control plants, we can now consider the various experimental treatments involving different water and N stress, with a large range of growths and yields (table 2).

Compared to the standard parameters, the yearly selected ones greatly improve the simulation accuracy, especially for the extreme climates 1987 fresh and 1989 warm. For the average of the five years and all treatments, the mean error is decreased from about 50 % on TDM and 35 % on yield, and the relative error is now nearly 11-13 %. The detail of the results shows that this error is generally greater under severe stresses environments, with little water and N availabilities and low yields. It decreases when conditions bring near an optimum. This fact is not surprising : we stated in our experiments that the yield variability among plots replicates was much greater in poor conditions, as briefly summarized on table 2 ; probably we reach here a great difficulty of appreciation of the soil variability and micro-heterogeneity. The mean variability among 3 plots replicates into an experiment with a large range of conditions is about 10-12 %, and we approach by simulation with yearly selected parameters the same precision.

DISCUSSION AND CONCLUSIONS

This large group of results concerning quite different cropping conditions of climatic years, soils, fertilizations and irrigations illustrates both the ability of modeling to simulate the growth and production of sunflower in various environments, and the precautions of calibration required for an expected precision. Of course this precision depends on the objectives and scales of study, and on the available imput data. For a good accuracy, the adaptation of the plant morphology and functionning to the local and yearly environment has to be taken into account. The difficulty is how to choice convenient parameters. Synthetic and reliable characters seem to be the average temperature and PET of the cycle, with an additional sight on the climate of early stages, where is primed the growth kinetics. Of course the special characters of varietal types, such as vigor, cold tolerance, architecture, must also be considered. The soil characteristics are equally essential, especially if water is a limiting factor. If all these characters can be gathered, the precision of simulation can approach that of the current experimentation.



	T°b	T°opt	RUE	DMLA
✱ 1986	6°	23°	2,6	6
■ 1987	5°	23°	3,0	9
+ 1988	6°	25°	2,2	8
□ 1989	6°	27°	2,2	4
▲ 1990	6°	25°	2,2	5
Standard :	6°	25°	2,5	5

Figure 1 : Measured (A) and simulated (B) kinetics of growth without any water or mineral stress ; standard parameters and values adjusted for each year.

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