EFFECTS OF TEMPERATURE AND PHOTOPERIOD ON PLANT LEAF AREA IN SUNFLOWER

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Abstract

Data on the responses of plant leaf area to daily mean temperature and photoperiod were generated from seven monthly plantings of four sunflower (Heliantus annuus L.) hybrids of varying photoperiodic sensitivity, and functions were fitted to the relative green leaf area : thermal time relationships in pre- and in post-anthesis. Green leaf areas were expressed as a proportion of potential leaf area (pre-anthesis) and leaf area at anthesis (post-anthesis). Potential leaf area is a cultivar dependent characteristic. Time from emergence to anthesis could be succesfully estimated using the model of Hammer et al. (1982), which requires information on daily mean temperature, photoperiod and cultivar photoperiodic sensitivity. It is shown that reasonable estimates of leaf area of three cultivars sown in another year and location could be generated using the above-mentioned functions.

Introduction

Crop leaf area index is an important determinant of the partitioning of evapotranspiration between evaporation and transpiration. We are involved in developing a water balance model of the sunflower crop for use in determining the water availability patterns of marginal areas for sunflower cropping on the basis of simple climatic, soil and crop characteristics. Temperature can affect plant leaf area through it effects on the rates of leaf generation, on leaf expansion and on leaf senescence, and some of these have been studied in sunflower by Rawson and Hindmarsh (1982). The contribution of each leaf to plant total leaf area is also modified by its position on the stem (e.g. Sinclair, 1984). In determinate plants such as commercial sunflower cultivars, temperature and (in some cultivars) photoperiod can modulate leaf area generation through their effects on the duration of the vegetative period (Goyne and Hammer, 1982; Rawson and Hindmarsh, 1982). We have attempted to describe the result of these various interactions by using a thermal time approach to plant total leaf area dynamics, handling the effects of temperature and photoperiod on plant development through their effects on the duration of the emergence-anthesis period. Cultivar differences in maximum leaf area were also distinguished.

Materials and Methods

Observations of leaf area were made on plants sown in seven succesive monthly sowings from April to October 1983, at the Facultad de Agronomía, Universidad de Buenos Aires. Pre-incubated seed (48 hours at 25°C) was sown in 6.60 m-long plots of three 0.70-m rows with 0.30 m between plants. During the growth cycle, between four and six observations of leaf area per plant (A) were made, individual leaf area being estimated from measurements of leaf width (Pereyra et al., 1982). These measurements were made on the 10 central plants of the central row of each plot. Four hybrids, one phptoperiod insensitive and the others of varying sensitivity, were sown at Buenos Aires. Some data collected for a single sowing of two inbred sunflower lines at Junín, Prov. de Buenos Aires (Hall et al., 1985) was also used. At both locations daily temperature readings were taken in screens within 500 m of the experimental site. Daylength was obtained from the Smithsonian Meteorological Tables (1951). Mean daily temperature (T) during the growth cycles of the Buenos Aires planting varied between 6.1 and 31.0 °C, and photoperiod (PP) between 9.7 and 14 hours/day. Hybrid development as a function of temperature and photoperiod was described using the model of Hammer et al. (1982) which gave satisfactory estimates of the duration of the emergence-first anthesis (E-FA) period for all cultivars (Fig. 1). Photoperiod sensitivity could be handled by changes in the C_5 parameter of the model. Main characteristics of the hybrids planted at Buenos Aires are given in Table 1.

Figure 1. Observed vs. expected days from emergence to first anthesis. Estimated values from the model of Hammer et al. (1982). Solid line shows 1:1 ratio, dotted line fitted regression. Coding : (●) cv. P75; (○) cv. A15xR90; (▲) cv. Contiflor 3; (△) cv. Contiflor. In all figures significance of r^2 values are given as *** (P=0.001).

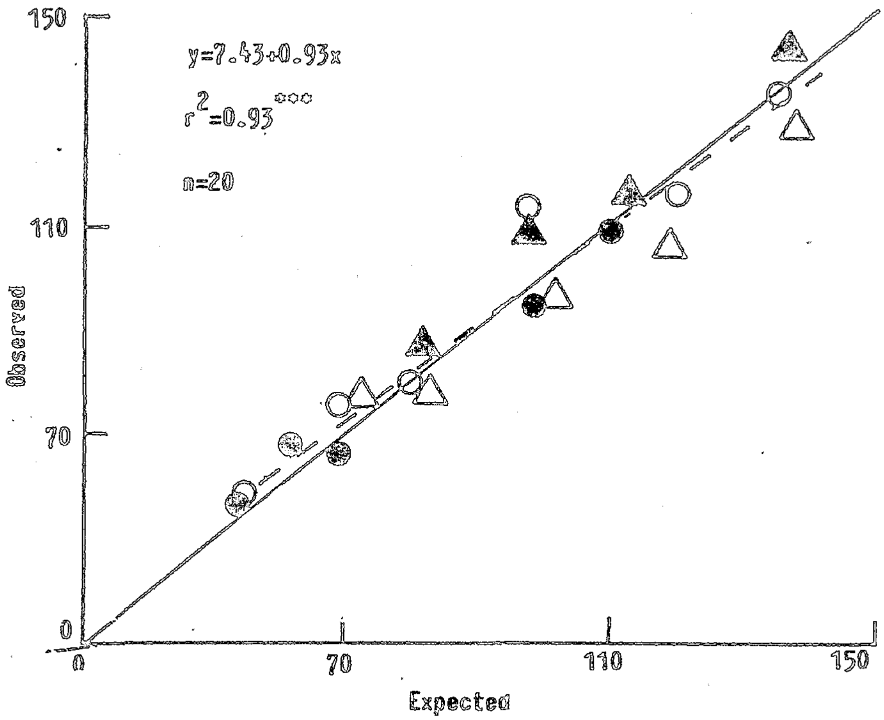


Table 1. Characteristics of hybrids planted at Buenos Aires and some effects of changes in sowing date. (1) and (2) are the parameters CULT and C_5, respectively, of Hammer et al. (1982). C_5 was estimated by succesive iterations. Units for E-FA and leaf area at anthesis are days and square cm/plant, respectively.

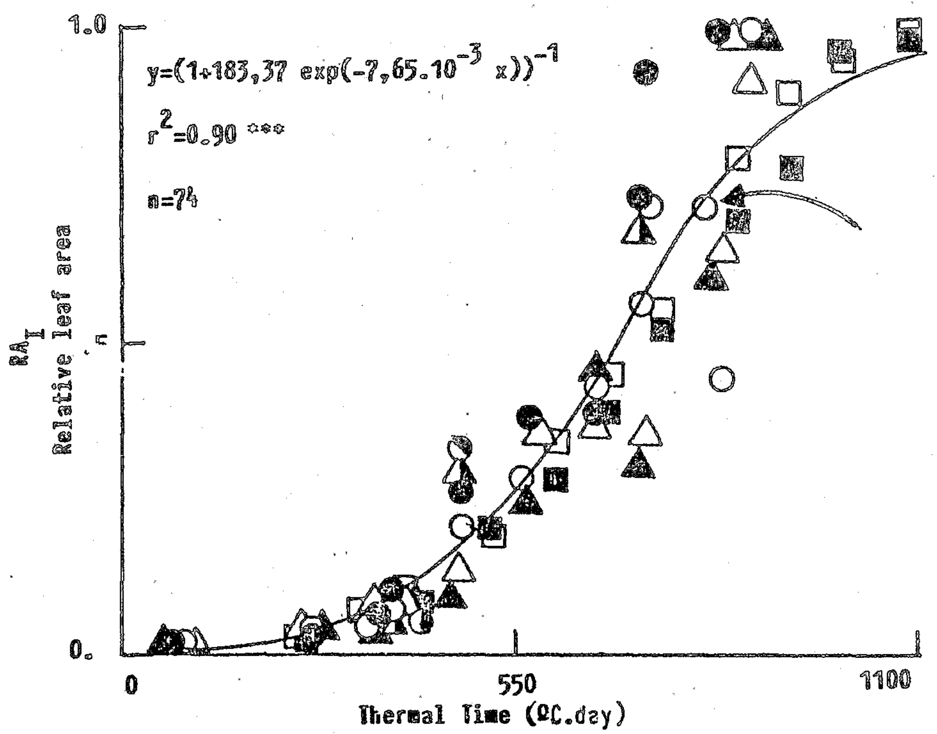
Hybrid	Photoperiodic response		E-FA		Leaf area at anthesis	
	Sensitivity	C_5	Min.	Max.	Min.	Max.
P75	no (0)	-	57	116	1375	4157
A15xR90	yes (1)	.26	58	135	1715	5040
Contiflor	yes (1)	.26	88	145	1823	6739
Contiflor 3	yes (1)	.31	78	129	1750	5197

Results and Discussion

Two phases in the dynamics of leaf area were distinguished : I. Emergence-anthesis, and II. Post-anthesis (cf. Connor and Jones, 1982; Hernández and Orioli, 1982). The leaf area : thermal time relationship has been handled expressing A in relative terms (RA). Leaf area in phase I is expressed as RA_I, that is leaf area as a proportion of maximum potential leaf area (PA), the maximum value of A found for a given cultivar. PA is therefore a cultivar dependent factor. Leaf area in phase II, RA_{II}, is expressed as a fraction of leaf area observed at anthesis (AA), a cultivar and sowing time dependent value.

A single relationship between RA_I and thermal time (García Huidobro, 1982) elapsed from emergence TT_I , using a base temperature (Tb) of 6.6 °C (Hammer et al., 1982) could be used to describe all the data (Fig. 2), with the maximum values of RA_I being achieved at approximately 1100 °C.day. It should be noted that the effects of the environment on RA_I, operating directly on leaf area or indirectly through development, are implicit in this relationship : maximum leaf area is achieved at anthesis, but in order to achieve PA a thermal time equivalent to about 1100°C.day must elapse. These effects are illustrated by the arrow shown in Fig. 2 which shows the value of RA_I reached at anthesis by the hybrid A15xR90 planted in June, a value well below the potential for that cultivar. Thus the value of RA_I achieved at anthesis is modulated by thermal climate and, in photosensitive cultivars, by PP.

Figure 2. Relative pre-anthesis leaf area (1=cultivar potential leaf area) as a function of thermal time (Tb=6.6 °C) from emergence. Coding : (⊛) cv. P75; (○) cv. A15xR90; (▲) cv. Contiflor 3; (△) cv. Contiflor; (□) cv. B14; (▩) cv. R16.



The dynamics of leaf area after anthesis are dominated by the rate of senescence, and the relationship between RA_{II} and thermal time elapsed from anthesis TT_{II} (using Tb=0 °C, Anderson et al., 1978) is shown in Fig. 3. A single relationship provides an adequate description of data, although the fit is not as good as that obtained in phase I.

We have used the functions shown in Figs. 2 and 3 to estimate the dynamics of leaf area of three cultivars sown in 1983-84 at Junín, Prov. of Buenos Aires. Estimates of PA were not available, so leaf area at anthesis was used for this purpose. Fig. 4 shows the relationship between observed and estimated values of total leaf area per plant.

Figure 3. Relative post-anthesis leaf area (1=leaf area at anthesis) as a function of thermal time from anthesis (Tb=0 °C). Coding as in Fig. 2.

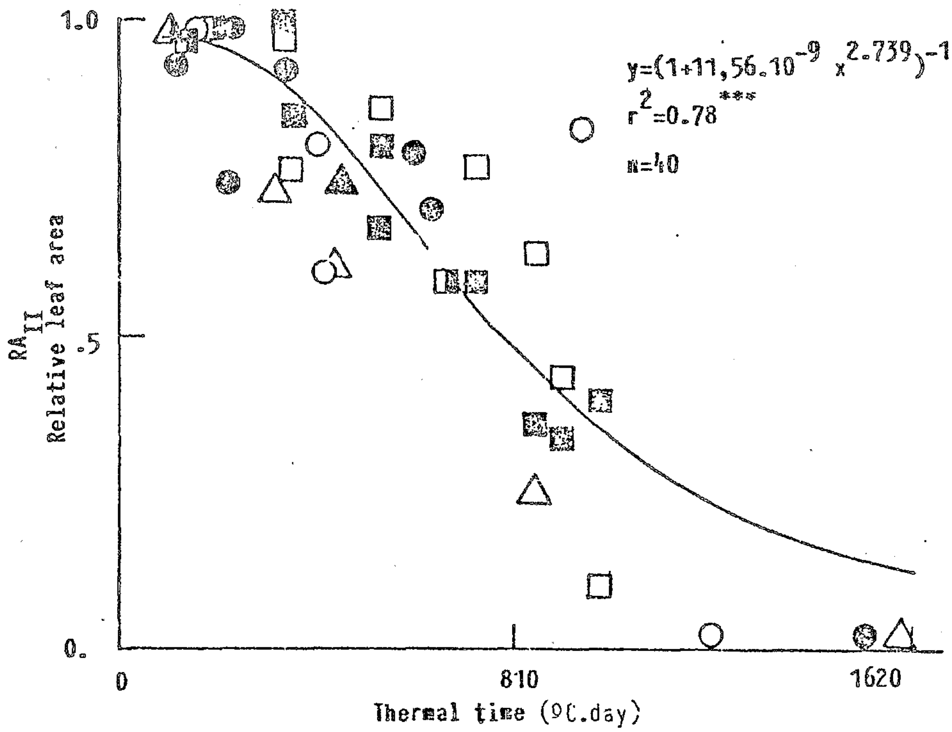
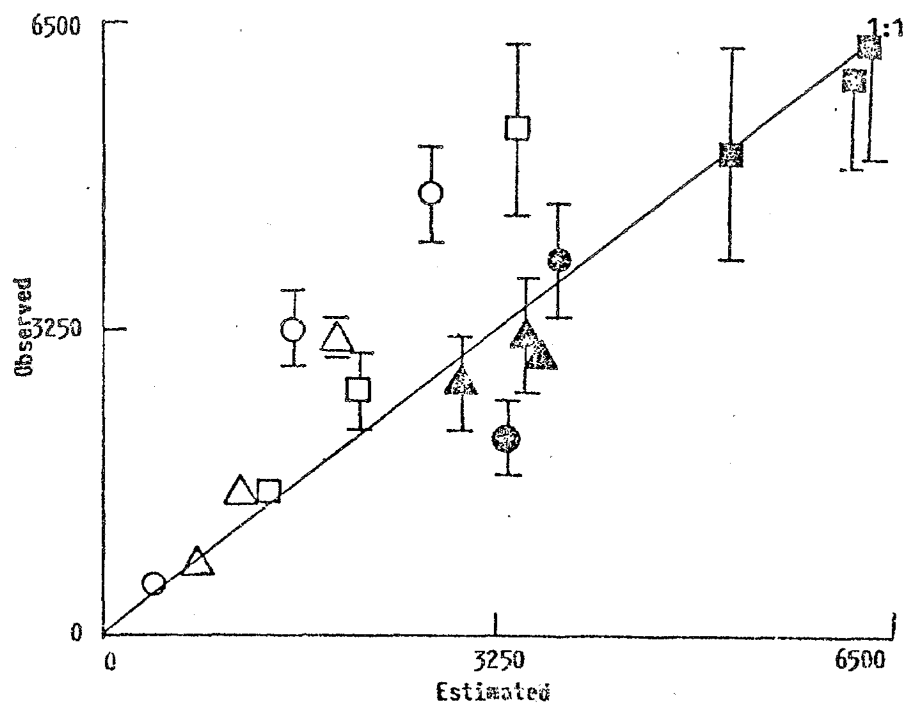


Figure 4. Relationship between observed and estimated leaf area per plant ($cm^2.plant^{-1}$) of cultivars P75 (circles), B14 (squares) and R16 (triangles) for observations made before (open symbols) and after (closed symbols) anthesis. Vertical bars indicates ± 1 S.E..



We conclude that these functions can be used to generate acceptable approximations of the leaf area data needed for water balance models. Evolution of leaf area per plant can be estimated for this purpose, at least for a given density, on the basis of maximum leaf area for the appropiate cultivar, daily mean temperature, and time from emergence to anthesis. For the cultivars we examined at Buenos Aires, this last datum could be estimated as a function of T and PP using the model of Hammer et al. (1982).

Acknowledgements

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