# Early sowing as a means of drought escape in sunflower: effects on vegetative and reproductive stages

**Clémentine Allinne[1,2], Nedjoua Ghoribi[4], Pierre Maury[1,2], Rhym Maougal[4], Ahmad Sarrafi[3,2], Nadia Ykhlef [4], Philippe Grieu[1,2]**

[1]INRA, UMR 1248 AGIR, F-31326 Castanet Tolosan, France.
[2]ENSAT-INP, F-31326 Castanet Tolosan, France.
[3]SP2E, F-31326 Castanet Tolosan, France.
[4]Biotechnologies Végétales, Université de Mentouri, 25000 Constantine, Algeria.

**ABSTRACT**

Drought occurring mainly during the flowering period is responsible for a substantial decrease in the production in sunflower. The hypothesis that early sowing of sunflower would increase the probabilities of avoiding warm and dry period during the reproductive stage was tested. Nevertheless, early sowing is associated with low temperature during the first development stages. Phenological determinations were performed to study the effect of early sowing on the vegetative and reproductive periods. A sunflower population of recombinant inbred lines (RILs) was studied in two sites (France and Algeria) during 2007 at normal sowing date (control) and one-month earlier sowing. Phenostage observations were determined from emergence to harvest. Weather data with rainfall and temperatures were daily recorded. Cumulative growing degree day requirements for each phenological stage were calculated. Earliness of flowering was observed in the two sites when sunflower genotypes were sown one-month earlier in the season. Differences in thermal time requirement for sunflower development observed between sites and between early and control sowings could be explained by variations in base temperature values and/or photoperiod effect. A significant variability between genotypes was observed for sunflower development. The genotype ranking was not affected by early sowing for vegetative stage on the two sites, but during the post-flowering stage in Algeria, high temperatures and dry conditions occurring during this period considerably reduced their variability in the phenostage (R6-R9) and modified the genotype ranking. Genetic basis of sunflower phenostages response to early sowing must be explored in terms of genetic variability for temperature x photoperiod interactions.

**Key words**: drought escape – early sowing – *Helianthus annuus* L. – low temperatures – phenological stage – sunflower.

## INTRODUCTION

Two main strategies are considered to increase sunflower productivity of non irrigated cropping systems. The first consists of selecting genotypes tolerant to dehydration during the water deficit conditions. Poormohammad Kiani et al. (2007a, b) have studied physiological traits of sunflower under drought conditions and differential expression of water stress-associated genes in order to supply tools for drought tolerance selection. Another way is to modify cultural practices to avoid drought at flowering stage. In French cropping systems, most farmers sow around 15 April and flowering takes place under high evaporative demand and scant rainfall. Consequently, the crop is often subject to water deficit and yield decrease. A possible alternative strategy for avoiding drought at flowering is to sow earlier, at times of lower evaporative demand. Early sowing including winter planting was tested in several Mediterranean countries (Gimeno et al., 1989; De La Vega et al., 2002; Flagella et al., 2002). It was shown that this approach allowed to increase water availability (Barros et al. 2004; Soriano et al. 2004). Therefore, the yield was increased (Hadjichrisyodoulou et al., 1987; Gimeno et al., 1989; Tenteiro et al. 1994; Anastasi et al. 2000). However, a major disadvantage of growing crops during low-evaporative-demand periods is the common association between low evaporation and low temperature.

The aim of the present work was to determine the effect of early sowing on vegetative and reproductive stages in a population of 100 recombinant inbred lines (RILs) of sunflower with a large genetic variability, through two experiments conducted in contrasted pedoclimatic conditions (France and Algeria).

## MATERIALS AND METHODS

*Plant material and field experiments*

A population of 98 RILs of sunflower (*Helianthus annuus*) and their parents RHA 266 and PAC2 (Flores Berrios et al., 2000; Poormohammad Kiani et al., 2007a) were used to investigate early sowing in term of vegetative and reproductive stages. Genotypes were tested in two locations: in France (Toulouse: 43°31'46,94" N; 1°29'59,71" E) and in Algeria (Constantine: 36°16'17.65"N; 6°40'13.01"E). In France, field experimentation was conducted at INRA station of Auzeville, and in Algeria at CNCS station of El-Khroub. For the last ten years, the French site had low temperatures in winter and the Algerian site had warm and dry conditions during summer (Fig. 1). Weather data were obtained from Meteo France.

In 2007, RIL population was sown on two dates in both sites: 14 March (early sowing: ES-F) and 19 April (control sowing:CS-F) in France and 3 March (early sowing ES-A) and 26 March (control sowing: CS-A) in Algeria. Three replications by sowing date were performed. Each replication consisted of two rows 3m long, with 50cm between rows and 25cm between plants in rows, giving a total number of about 24 plants per experimental unit.

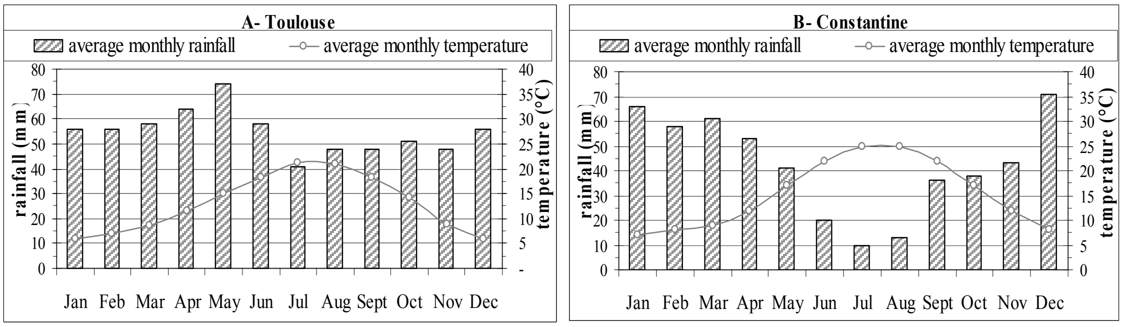


**Fig 1**. Average monthly temperatures and average monthly rainfalls (mean of the last 10 years) in the two experimental sites (Toulouse in France and Constantine in Algeria).

*Phenological measurement*

Plant development was recorded according to the definition of growth stage system of Schneiter and Miller (1981). Dates were obtained for 100% emergence (VE), 50% of plants at beginning of flowering (R5), 50% of plants at complete flowering (R6), 50% of plants at physiological maturity (R9) and 50% of plants at harvest. The results were recorded as Vegetative Period (VP) from sowing to R5 and Post-Flowering Period (PFP) from R5 to harvest.

Daily maximum and minimum temperatures and rainfall were recorded at each site. Cumulative growing degree days (°Cd) were calculated as the sum of the average daily temperature minus base temperature of 4.8°C (Granier and Tardieu, 1998).

*Statistical analysis*

Statistical analyses were performed with SPSS for Window (11.0.1). Sowing date, location and genotype effects were tested using ANOVA procedure. Correlation between control and early sowing for vegetative period (VP) and post-flowering period (PFP) in cumulative growing degree days were performed in France and in Algeria sites. Moreover, correlations between VP and PFP were realized for each sowing date in both sites.

## RESULTS

*Sunflower development (vegetative and reproductive stages)*

The two sites (France and Algeria) presented substantial differences during the growing season: colder at the first phenostages and warmer during post-flowering stage in Algeria (Fig. 2A). Fig. 2B shows that the total of time cycle length was significantly different between the two controls even if differs for only 5 days with 130 days in France and 125 days in Algeria. Vegetative development period represented 62% of total duration in France vs. 72% in Algeria. In fact, time to emergence (sowing-VE) was twice longer in Algeria compared with France. Temperatures corresponding to sowing-VE were inferior in Algeria (13°C) than France (15°C) (Fig. 2A). The time between VE and R5 stage did not differ with, respectively, 73 days and 74 days in France and Algeria. The post-flowering period (PFP) with respect to sowing-harvest duration was proportionally shorter in Algerian location. With the same flowering time (10 days), the period from R6 to harvest differed between the two sites (9 days more for R6-R9 in France, and 5 days more for R9-harvest in Algeria).

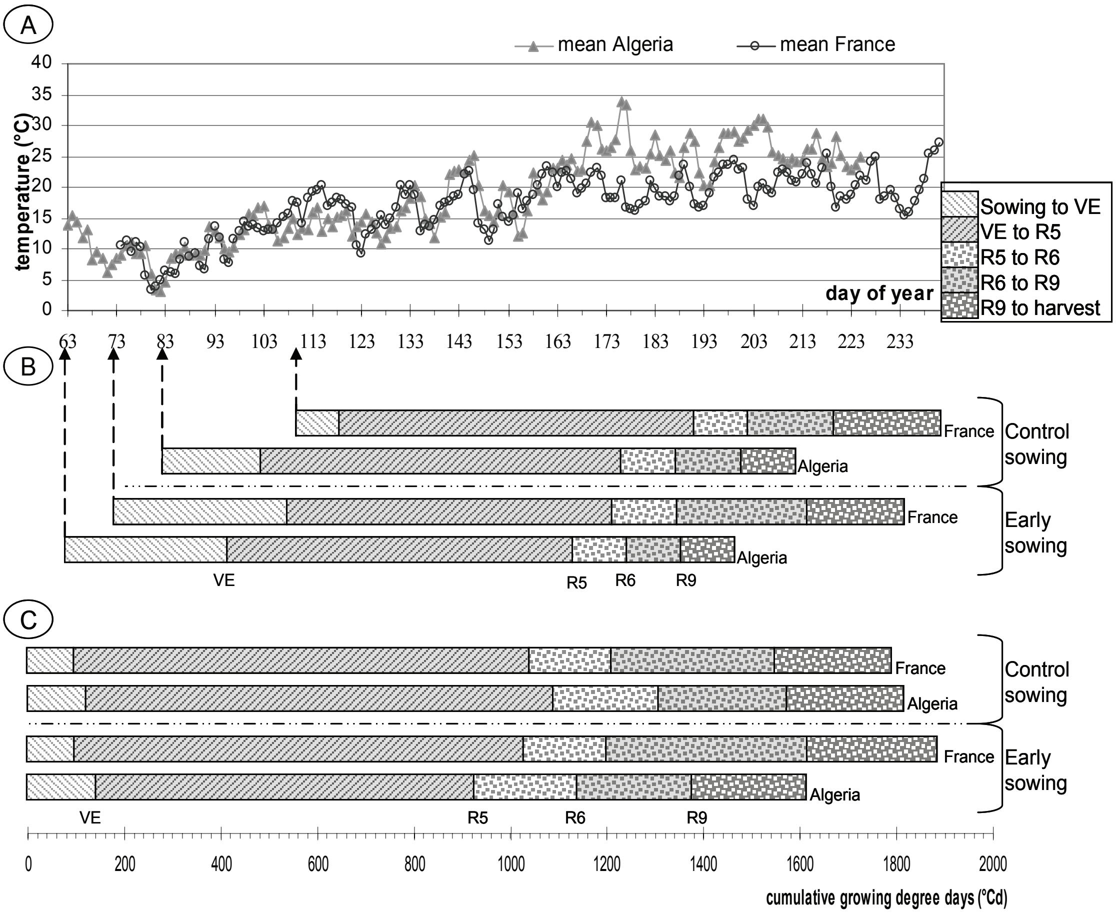


**Fig 2**. Mean temperature for control and early sowing in France and Algeria (A). Sunflower phenostages in relation to day of year (B) or to cumulative growing degree days with tb = 4.8°C (C).

Whereas total cycle length differed between France and Algeria, there was no significant difference for cumulative growing degree days with, respectively, 1857 and 1871°Cd (Fig. 2C). Cumulative growing degree days required for vegetative period (VP) was higher in Algeria than in France. We observed that weather conditions at sowing differed between locations: (average daily temperatures 3°C colder in Algeria vs. France). For the post-flowering period (PFP), sunflowers in Algeria needed fewer cumulative degree days, in spite of superior thermal requirement for flowering. Cumulative growing degree days required for R6-R9 period was diminished (- 86 °Cd) in Algeria vs. France.

The cumulative growing degree days of vegetative period was negatively correlated with post-flowering period in France with a Pearson correlation coefficient of -0,739. On the contrary there was no significant correlation in Algeria location between VP and PFP.

*Effect of early sowing on phenostages*
In France, early sowing was one month before control, and crop was harvested with only one week in advance as shown in Fig. 2B. Total cycle duration was longer for 22% on early sowing comparatively to control sowing (159 days vs. 130 days for control sowing). In Algeria, total cycle duration of early sowing was only 8% longer than control sowing. It was sown 3 weeks before the control and harvested 13 days before the control. Proportion of VP in total cycle was mildly longer than in control. In both sites sowing to emergence period increased (multiplied by four in France and by two in Algeria), and emergence to flowering period decreased in response to early sowing.

Thermal time requirement for sunflower development in early sowing compared to control sowing was different between French and Algerian locations, except for flowering duration (from R5 to R6) (Fig. 2C). In France, we observed an increase in the thermal time requirement for the total cycle in response to early sowing. Vegetative stage and PFP present a significant correlation between control and early sowing of -0.336**. On the contrary, in Algeria, early sowing necessitated less cumulative degree days for total cycle (186 °Cd less than control) despite increasing the thermal time requirement for emergence (Fig. 2C).

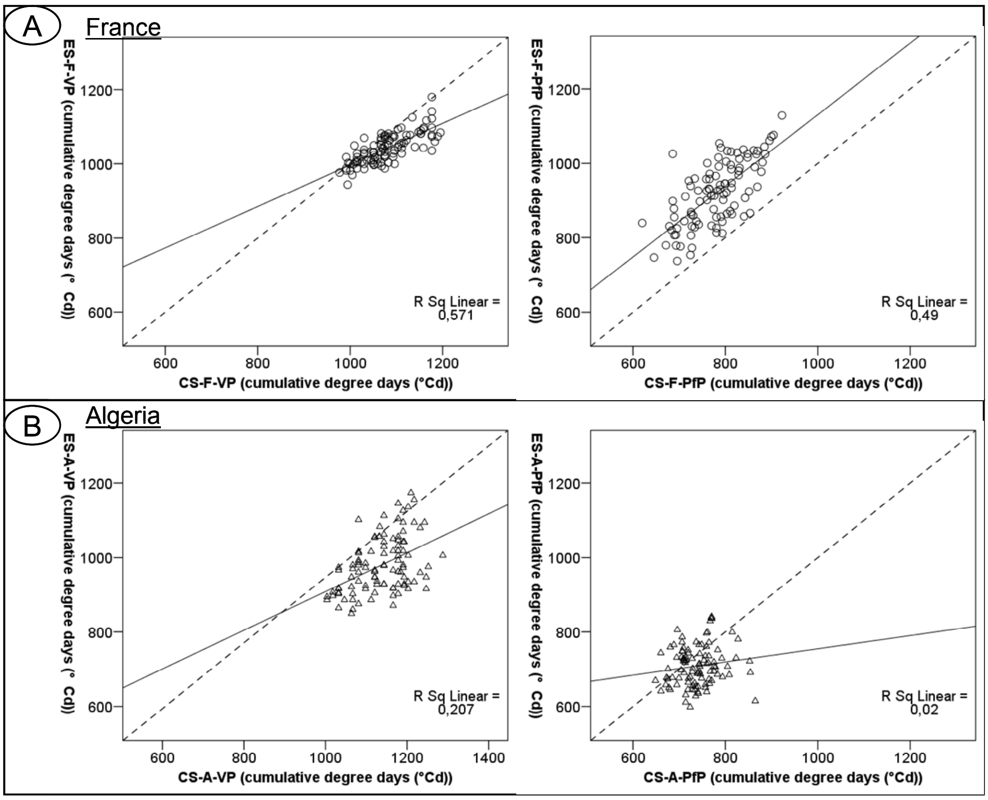


**Fig 3.** Correlation between control (CS) and early sowing (ES) for vegetative period (VP, left graphs) and post-flowering period (PFP, right graphs) in cumulative growing degree days: in France (A) and in Algeria (B).

*Genotypic variation among the 100 recombinant inbred lines of sunflower*
Differences among RILs were significant for vegetative period (VP) in all conditions (planting date and site). For example, VP in control sowing ranged from 977 °Cd to 1195 °Cd depending on genotypes in France, and similar amplitude was observed for early sowing. However, genetic differences were less pronounced for post-flowering period in Algeria (PFP ranges from 598 °Cd to 840 °Cd).

High significant correlations were observed between planting dates for vegetative period in both sites (Pearson correlation coefficient was equal to 0.571** and 0.207 in France and Algeria, respectively, Fig. 3). However, non significant correlation was observed between planting date for the post-flowering period in Algeria.

## DISCUSSION

Thermal time requirements for sunflower phenostages differed between control and early planting dates. We have shown in Fig. 2C that early sowing in France required more cumulative growing degree days than control sowing, whereas in Algeria early sowing required fewer cumulative growing degree days than control sowing. Cumulative growing degree days were calculated assuming the same base temperature in control and early treatments. Different base temperatures were used in the literature. The base temperature used by Hammer et al. (1982) for VE to R1 stage was 6.6°C whereas Villalobos and Ritchie (1992) and Aiken (2005) used a base temperature of 4 °C. Casadebaig et al. (2008) used a value of 4.8°C as in this study. The value of 4.8°C we have used was probably not suitable for forecasting sunflower phenostages under early sowing conditions.

Differences in the thermal time requirement for sunflower phenostages observed between sites and between early and control sowings could also be explained by photoperiod effect. Aiken (2005) has shown that field observations support earlier reports of long-day photoperiod response for sunflower development to the bud-visible (R1) phenostage; a short day response for development to maturity (R9) was most closely correlated with daylight at the floral initiation. Goyne and Schneiter (1987) have shown that photoperiods of 11 through 13h severely delay the rate of development for most genotypes. Therefore, Goyne et al. (1989) have shown no influence of a photoperiod within the range of 14.5h to 16.2h. In our experiments, daylength differences between early and control sowing and between locations were observed (data not shown). Further investigations on temperature x photoperiod interactions have to be conducted.

A significant variability between genotypes was observed for vegetative period and reproductive period (Fig. 3). Concerning the effect of early sowing on phenostage, we have shown in Fig. 3 that genotype ranking was not affected by early sowing for vegetative stage on the two sites. However, genotype ranking was not preserved for the control sowing during post-flowering stage in Algeria. During the grain filling period (R6-R9) high temperatures were observed in Algeria. Moreover, meteorological data showed that there was no rainfall in Algeria during this period. Drought occurring during this period considerably reduced the variability of the phenostage (R6-R9) and modified the genotype ranking.

Genetic basis of sunflower phenostages response to early sowing must be explored, in terms of genetic variability for base temperature and temperature x photoperiod interactions.

## ACKNOWLEDGEMENTS

The authors thank CMEP (Comité Mixte d'Evaluation et de Prospective de cooperation interuniversitaire franco-algérien) for supporting this work, Meteo France for Algerian weather data and Michel Labarrère for technical assistance.

## REFERENCES

Aiken, R.M. 2005. Applying thermal time scales to sunflower development. Agron. J. 97:746-754.

Anastasi U., M. Cammarata, and V. Abbate. 2000. Yield potential and oil quality of sunflower (oleic and standard) grown between autumn and summer. Italian J. Agron. 4:23-36.

Barros J.F.C., M. De Carvalho, and G. Basch. 2004. Response of sunflower (*Helianthus annuus* L.) a sowing date and plant density under Mediterranean conditions. Eur. J. Agron. 21:347-356.

Casadebaig, P., P. Debaeke, and J. Lecoeur. 2008. Thresholds for leaf expansion and transpiration response to soil water deficit in a range of sunflower genotypes. Eur. J. Agron. ( in press)

De La Vega, A.J., and A.J. Hall. 2002. Effects of planting date, genotype, and their interactions on sunflower yield. II. Components of oil yield. Crop Sci. 42:1202-1210.

Flagella, Z., T. Rotunno, E. Di, Tarantino, R. Caterina, and A. De Caro. 2002. Changes in seed yield and oil fatty acid composition of high oleic sunflower (*Helianthus annuus* L.) hybrids in relation to the sowing date and the water regime. Eur. J. Agron. 17:221-230.

Flores Berrios, E., L. Gentzbittel, H. Kayyal, G. Alibert, and A. Sarrafi. 2000. AFLP mapping of QTLs for in vitro organogenesis traits using recombinant inbred lines in sunflower (*Helianthus annuus* L.). Theor. Appl. Genet. 101:1299-1306.

Gimeno, V., J.M. Fernández-Martínez, and E. Fereres. 1989. Winter planting as a means of drought escape in sunflower. Field Crops Res. 22:307-316.

Goyne, P.J., and A.A. Schneiter. 1987. Photoperiod influence on development in sunflower genotypes. Agron. J. 79:704-709.

Goyne, P.J., A.A. Schneiter, K.C. Cleary, R.A. Creelman, W.D. Steg-meier, and F.J. Wooding. 1989. Sunflower genotype response to photoperiod and temperature in field environments. Agron. J. 81:826-831.

Granier, C., and F. Tardieu. 1998. Is thermal time adequate for expressing the effects of temperature on sunflower leaf development? Plant Cell Environ. 21:695-703.

Hadjichristodoulou, A. 1987. Trials with winter-sown sunflower. Helia 10:57-61.

Hammer, G.L., P.J. Goyne, and D.R. Woodruff. 1982. Phenology of sunflower cultivars: III. Models for prediction in field environments. Aust. J. Agric. Res. 33:263-274.

Poormohammad Kiani, S., P. Grieu, P. Maury, T. Hewezi, L. Gentzbittel, and A. Sarrafi. 2007a. Genetic variability for physiological traits under drought conditions and differential expression of water stress-associated genes in sunflower (*Helianthus annuus* L.). Theor. Appl. Genet. 14:193-207.

Poormohammad Kiani, S., P. Talia, P. Maury, P. Grieu, R. Heinz, A. Perrault, V.Nishinakamasu, E. Hopp, L. Gentzbittel, N. Paniego, and A. Sarrafi. 2007b. Genetic analysis of plant water status and osmotic adjustment in recombinant inbred lines of sunflower under two water treatments. Plant Sci. 172:773-787

Schneiter, A.A., and J.F. Miller. 1981. Description of sunflower growth. stages. Crop Sci. 21:901-903.

Soriano, M.A., F. Orgaz, F.J. Villalobos, and E. Fereres. 2004. Efficiency of water use of early plantings of sunflower. Eur. J. Agron 21:465-476.

SPSS for Windows, Rel. 11.0.1. 2001. Chicago: SPSS Inc. http://www.spss.com/terms.htm.

Tenreino, P.C., P.A. Pinto, R.P. Braga, and M.R. Rodrigues. 1994. Winter sowing and higher population as dry-farming strategies on sunflower crop (*Helianthus annuus* L.). In: Proc. 3rd ESA Congress, Abano, Padova, Italy.

Villalobos, F.J., and J.T. Ritchie. 1992. The effect of temperature on leaf emergence rates of sunflower genotypes. Field Crops Res. 29:37-46.