THE INFLUENCE OF PHOTOPERIOD AND TEMPERATURE ON THE TIMING OF THE ONTOGENETIC SEQUENCE OF SUNFLOWER.

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ABSTRACT

Sunflower (Helianthus annuus L.) breeders must often consider the problem of synchronizing anthesis of inbreds to be crossed. This problem could possibly be resolved with prediction models using historical weather data for each planting location.

An understanding of the association between timing of the ontogenetic sequence and environmental factors needs to be developed to construct such models. Recent reports have shown that the timing of ontogeny of sunflower can be influenced by both temperature and photoperiod.

Data on temperature and photoperiod responses were obtained on a number of Canadian and United States hybrids and inbred lines at North Dakota State University from greenhouse, growth chamber and field plantings. To obtain a wide range of temperatures and photoperiods, the field locations covered latitudes from Argentina to Alaska, including a site in Hawaii.

Photoperiodic behavior of the genotypes tested, indicated that sunflower can show day-neutral, short-day, long-day or ambiphotoperiodic responses.

The results from model testing indicated that temperature alone can be used to predict anthesis, when photoperiod at emergence is within a range of about 14.5 to 16 hours. If photoperiod at emergence is within 11 to 13 hours, rate of development decreases significantly. These results can have important application in winter nursery locations eg., Hawaii. Conversely photoperiods of 24 hours (Alaska) increase development rate if temperature is not too low.

INTRODUCTION

Synchronization of anthesis of sunflower (Helianthus annuus L.) inbred lines to be crossed is often a problem for breeders. This problem might be resolved by using predictive models with historical weather data for planting locations. A biological understanding of the association between timing of the ontogenetic sequence and environmental factors needs to be developed to construct such models and have them broadly applicable. Hammer et al. (1982) proposed a model to predict the rate of sunflower development from temperature and photoperiod. It proved successful in the prediction of flowering time for commercial cultivars in Australia.

This paper reports the response of a diverse range of sunflower genotypes from the United States and Canada to photoperiod and temperature, together with recommendations for the reconstruction of the Hammer et al. (1982) model to predict their rate of development.

MATERIALS AND METHODS

The majority of the studies were located at North Dakota State University, Fargo, North Dakota (latitude 46° 54' N elevation 183 m). The number of days to emergence (VE), bud visible (R1) and anthesis (R5) were recorded in greenhouse, growth chamber, and field plantings of the sixteen sunflower genotypes listed in Figures 1 through 4. Genotypes Sunfola 68-2 and Hysun 30 are Australian, the others are from the United States and Canada. Growth stage classifications used were proposed by Schneiter and Miller (1981).

Greenhouse studies

The initial greenhouse planting (December 1981) was timed to have VE coincide with the shortest photoperiod (PP) of the year. Subsequent plantings were made each time natural PP changed by one hour and were continued for two years. Supplementary lighting in the winter months was from high pressure sodium lamps. Six replications of each genotype (one plant per two liter pot) were randomly placed in the greenhouse at each planting. The relationship between PP at VE and the number of days from VE to R1 (recorded under a day/night temperature regime of 18/16 C) was determined by least squares regression. Cluster analysis (Ward 1963) grouped genotypes with similar response to PP.

Growth chamber studies

The genotypes were grown in two chambers and subjected to light treatments of: (1) 12 hours fluorescent and incandescent light, (2) 14 hours fluorescent and incandescent and (3) 12 hours fluorescent and incandescent, plus a two hour exposure to incandescent only. Mean quantum flux density 65 cm below the lights was 429 and 5 μ Einstein m^{-2} s^{-1} with all lights and incandescent lights, respectively. The light treatments were applied with chamber day/night air temperatures of 28/22 and 18/15 C. Plants were grown to R1 only. Full factorial analyses of variance with linear contrasts were used in data analysis.

Field studies

Field plantings were made in 1982 and 1983 at locations listed in Figure 5. A total of 43 plantings were made mostly with two replications each. Correlations evaluated the association of temperature (recorded near the sites) and PP to number of days from VE to R1. Genotypes were grouped for similar response to temperature using a nonparametric ranking method (Conover 1980).

RESULTS

Greenhouse studies

The association between number of days from VE to R1 and PP at VE was significant ($P<0.05$ to $P<0.001$), with the exception of genotypes RHA 274, RHA 276 and HA 290. Plots of the relationships for similar PP response groups are presented in Figure 1.

The considerable delay in time from VE to R1 resulting from PPs 11 through 13 hours for many of the genotypes is of particular interest. Figure 2 was prepared by considering only PPs of 12 and 16 hours to simplify comparison with the growth chamber and field results.

Growth chamber studies

The main purpose of the growth chamber studies was to investigate further the VE to R1 time delay for 11 through 13 hour PPs. Light x genotype and temperature x genotype interactions were significant ($p<0.001$), but light x temperature x genotype was not significant. Genotypes could not be grouped for temperature response, as distinct differentiations between groups were not expressed. Linear contrasts showed that the apparent differences in response to 12 vs. 14 hours (treatments 1 and 2) shown in Figure 3, were significant for genotypes A, C, G, H, I, M, N, O and P. This comparison was for PPs with differing durations of photosynthetically active radiation (PAR). Very similar results were obtained with contrasts of treatments 1 vs. 3 (same duration of PAR).

Field studies

Photoperiod at VE for most plantings was within 14.5 to 16 hours. Correlations indicated temperature alone to be responsible for differing rates of development within this range of photoperiods. Photoperiods at VE for Molokai were slightly over 11 hours and mean temperature from VE to R1 was within 20 to 22 C. The genotypes exhibited the highest rate of development at Fairbanks when PP at VE was 24 hours with mean VE to R1 temperature of 20 to 22 C. Data for plantings with PP at VE from 11 through 16 hours having a mean VE to R1 temperature range of 20 to 22 C are presented in figure 4.

Temperature response groups were classed as (1) very quick, (2) quick, (3) medium and (4) slow. Using the letter code of figures 2 to 4 to represent genotypes, the temperature response groups were as follows:
for VE to R1 (1) B, F, L, J; (2) O, M, P; (3) A, D, G, I, K, N; (4) C, E, H;
for R1 to R5 (1) D, G, J; (2) B, F, H, L, P; (3) C, E, K, N, O; and (4) A, M, I.

DISCUSSION

The PP groups in Figure 1 are classified according to Vince-Prue (1975) as follows: A) short-day to long-day; B), C) and D) ambiphotoperiodic; E) day-neutral; F) short-day; and G) short-day to day-neutral. Figures 2, 3 and 4 show much similarity between the greenhouse, growth chamber and field results for genotypic response to PP.

The results presented in the figures are for PPs having differing durations of PAR and therefore any differences in genotypic response to PP cannot be attributed to photoperiodism alone. True photoperiodism must also be a factor as evidenced by the similar results in the growth chamber treatment contrasts 1) vs. 2) compared with 1) vs. 3). Whether PP effects are attributed to photoperiodism or to differences in the duration of photosynthesis, they are real and must be considered in

prediction models.

The field studies have shown that if PP at VE is within 14.5 to 16 hours the models could be based on temperature alone. This is consistent with the Hammer et al. (1982) model. However, the field studies also supported the conclusions from the greenhouse and growth chamber studies, i.e., PPs of 11 through 13 hours can considerably delay the rate of development of a number of genotypes and must be incorporated into the models, if sunflower is grown in locations having PP at VE within this range. Within the practical planting times for the locations considered in these studies, Molokai and Weslaco would require a temperature x PP model (Figure 5). Similarly PP must be considered for predictions at Fairbanks, but because PP causes a more rapid rate of development.

The genotypes showed variable response to temperature in both the growth chamber and field studies. Hammer et al. (1982) successfully used a single temperature relationship for the cultivars on which they based their model. The classification of the genotypes into variable temperature response groups requires that new rate of development - temperature response functions be constructed.

CONCLUSIONS

If prediction models for anthesis of sunflower genotypes are to be useful to breeders, the effect of PP on development rate must be included. This is particularly true for Hawaii and southern Texas (both popular winter nursery locations for North American breeders), as PPs at VE probably will be within the critical 11 to 13 hour range. If PP at VE is about 14.5 to 16 hours, a common range for the major U.S.A. summer production areas, temperature based models should suffice.

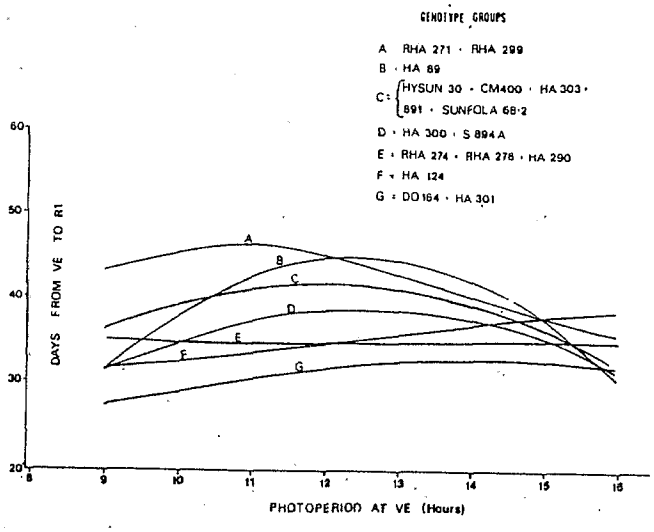

Figure 1 Response to photoperiod for genotype groups Greenhouse data

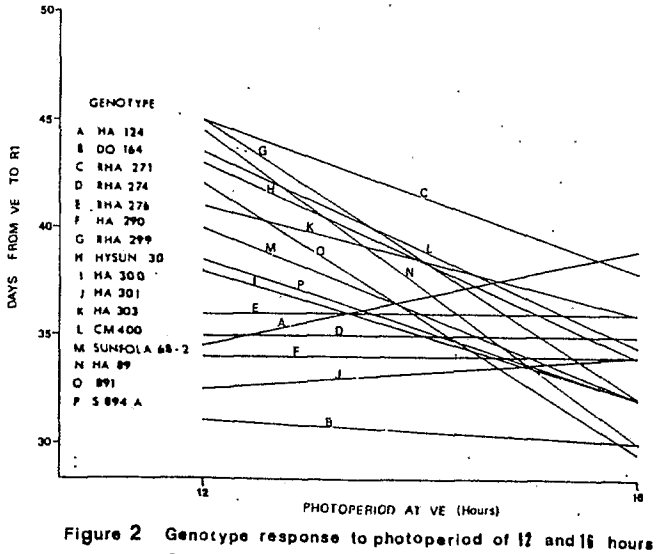

Figure 2 Genotype response to photoperiod of 12 and 16 hours Greenhouse data.

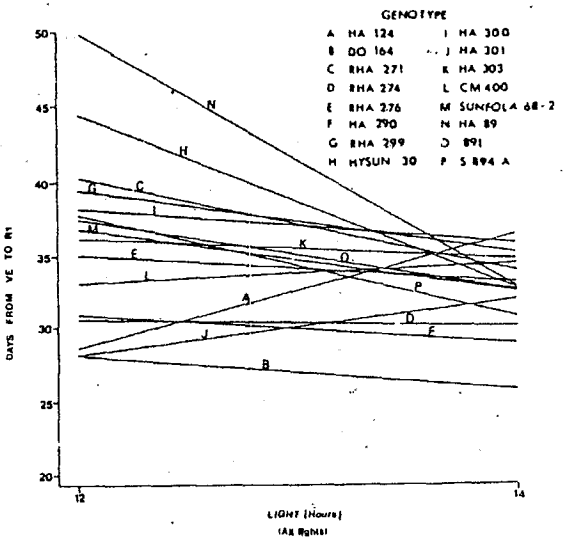

Figure 3 Genotype response to light treatments (fluorescent + incandescent) of 12 and 14 hours - Growth Chamber data

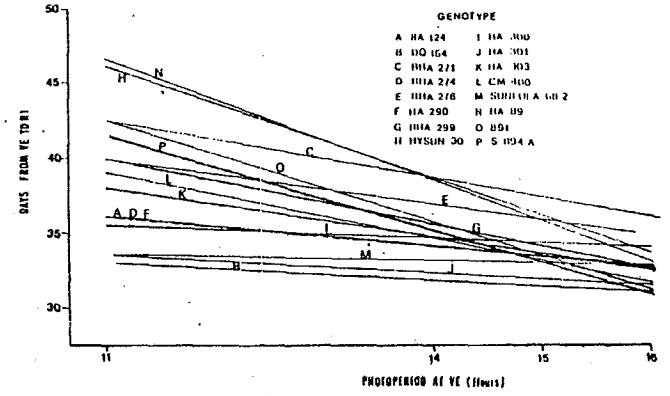

Figure 4 Genotype response to photoperiod for field data in the 20 - 22 C temperature range.

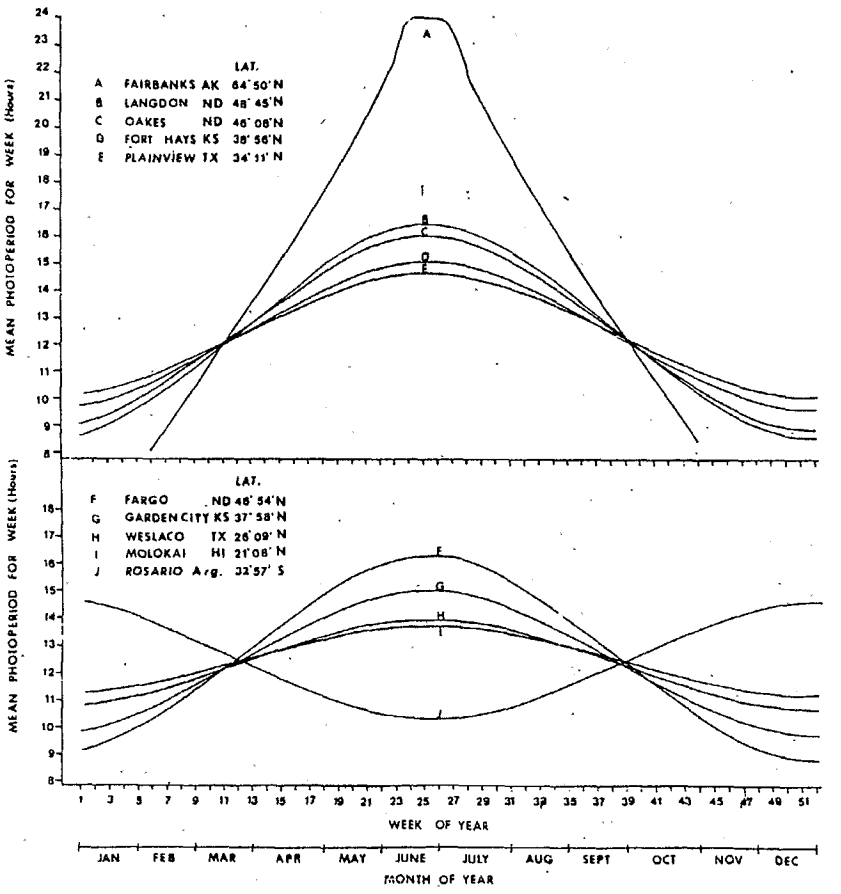

Figure 5 Weekly mean photoperiod for field sites.

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REFERENCES

CONOVER, W.J. 1980 Practical Nonparametric Statistics. Second Edition. John Wiley and Sons, New York.

HAMMER, G.L., GOYNE, P.J., and WOODRUFF, D.R. 1982. Phenology of sunflower cultivars. III. Models for prediction in field environments. Australian Journal of Agricultural Research 33, 263-274.

SCHNEITER, A.A. and MILLER, J.F. 1981. Description of sunflower growth stages. Crop Science 21, 901-903.

VINCE-PRUE, D. 1975. Photoperiodism in Plants. McGraw-Hill, New York.

WARD, J.H. 1963 Hierarchical grouping to optimize an objective function. Journal of the American Statistics Association 58, 236-244.