A NON-DESTRUCTIVE METHOD TO DETERMINE FLORAL INITIATION IN SUNFLOWER

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ABSTRACT

Most studies of phenological development in sunflower have taken bud visible as a surrogate for floral initiation (FI, stage 1.3, Marc and Palmer 1978 *J Expt Bot* 29: 367). This simplification introduces serious limitations when interpreting the influence of environmental factors on the reproductive development of this species.

This paper presents a non-destructive method to estimate sunflower FI based on the association between leaf number at FI and final leaf number. A theoretical relationship between these variables was developed, and tested in glasshouse and field experiments. The model performed consistently with a range of genotypes under contrasting environments (range of photoperiod at emergence: 11.5 - 15.9 h; range of mean daily temperature for the time from emergence to FI: 13.6 - 27.6 °C and mean short-wave irradiance: 4.7 - 28.9 MJ m^{-2} d^{-1}).

INTRODUCTION

It has been proposed that the range of photoperiodic responses observed for sunflower in the phase emergence-bud visible, i.e. neutral, short-day, long-day and ambiphotoperiodic, could be explained if the periods emergence-FI and FI-bud visible are analysed separately[1]. Determination of FI, however, requires laborious inspection of plant apices. For this reason, most studies of phenological development in sunflower have taken bud visible as a surrogate for FI. It would be useful, therefore, to develop a non-destructive method that estimates the time of FI.

Aitken[2] reported linear relationships between leaf number at FI (LN_{fi}) and final leaf number (FLN) for cereals that could be used to estimate the time of FI. This paper presents a non-destructive method to estimate sunflower FI based on the relationship between LN_{fi} and FLN. A theoretical relationship between these variables is developed and tested using data from glasshouse and field experiments.

THEORETICAL RELATIONSHIP BETWEEN LN_{FI} AND FLN

Fig. 1 schematises the dynamics of leaf initiation and leaf appearance in sunflower. The rate of leaf primordia initiation (RPI, leaves/°C d) is assumed invariable with ontogeny[4,5]. Thus, FLN is

$$FLN = TT_{fi} * RPI + k \quad (1)$$

where TT_{fi} is thermal time from emergence to FI [base temperature 4 °C[6]], and k is the number of leaf primordia in the embryo.

The rate of leaf appearance (RLA) changes with leaf position (Fig. 1). Villalobos and Ritchie[6] showed that the rate increases from RLA_1 for the first 6 leaves to RLA_2 for leaves above the 6th node. The thermal time when RLA changes is indicated as x_o in Fig. 1. Thus, LN_{fi} can be expressed as

$$LN_{fi} = x_0 * RLA_1 + (TT_{fi}-x_0) * RLA_2 \quad (2a)$$

if FI takes place after the change in RLA (i.e. $x_0 \leq TT_{fi}$, Fig. 1a), and

$$LN_{fi} = TT_{fi} * RLA_1 \quad (2b)$$

if FI takes place before the change in RLA (i.e. $x_0 > TT_{fi}$, Fig. 1b).

Rearranging eqs (1) and (2) and defining $a_1 = x_0 * (RLA_1 - RLA_2) - k * RLA_2/RPI$, $b_1 = RLA_2/RPI$, $a_2 = - k * RLA_1/RPI$ and $b_2 = RLA_1/RPI$, leaf number at FI is:

$$LN_{fi} = a_1 + b_1 * FLN \quad \text{if } x_0 \leq TT_{fi} \quad (3a)$$

$$LN_{fi} = a_2 + b_2 * FLN \quad \text{if } x_0 > TT_{fi} \quad (3b)$$

Assuming that x_0=240 °C d, RLA_1= 0.025 leaves/°C d, RLA_2= 0.043 leaves/°C d [6], RPI = 0.069 leaves/°C d [7] and k=2 [8], parameters of eq. (3) are: a_1 = -5.6 [leaves]; b_1 = 0.62 [dimensionless]; a_2 = -0.70 [leaves]; b_2 = 0.36 [dimensionless].

METHODS

To test the model [eq. (3)], FLN and LN_{fi} were determined for a series of genotypes grown in a wide range of environmental conditions. Eighth hybrids (894, Arbung-E353, Florasol, S-530, Solmega, Sungro-380, Sungro-385, Sunwheat-101) and four inbred lines (B1, B21, HA-89 and SD-2B) were used. Photoperiod at emergence ranged from 11.5 to 15.9 h. Mean daily temperature for the time from emergence to FI of the slowest-developing cultivar ranged from 13.6 to 27.6 °C, and mean short-wave irradiance from 4.7 to 28.9 MJ m^{-2} d^{-1}.

The scale of Marc and Palmer [9] was used to determine floral score (FS). Leaf number (leaf length > 1 cm) and FS were established on one plant per cultivar every two-three days until the first sign of differentiation was observed. Frequency and number of samples were intensified afterwards to quantify the relationship between LN and FS for each genotype and experiment. Linear regressions between these variables were fitted [0.70 < r < 0.98 [7]] and LN_{fi} was taken as LN at FS = 1.3 [5] using the fitted equations (n ≥ 6). Final leaf number was counted at anthesis (n ≥ 6).

RESULTS

Fig. 2 shows that the relationship between observed LN_{fi} (range from 4 to 20 leaves) and observed FLN (range from 12 to 42 leaves) was in agreement with the theoretical model [eq. (3)]. A quantitative test of the model was performed by regressing observed vs estimated LN_{fi} (Fig. 2, inset). The latter was calculated using eq. (3) and observed FLN. The regression had an r = 0.94. The slope (1.01, s.e. = 0.08) and intercept (-0.33, s.e. = 0.89) were not significantly different from 1 and 0 respectively (both P > 0.7).

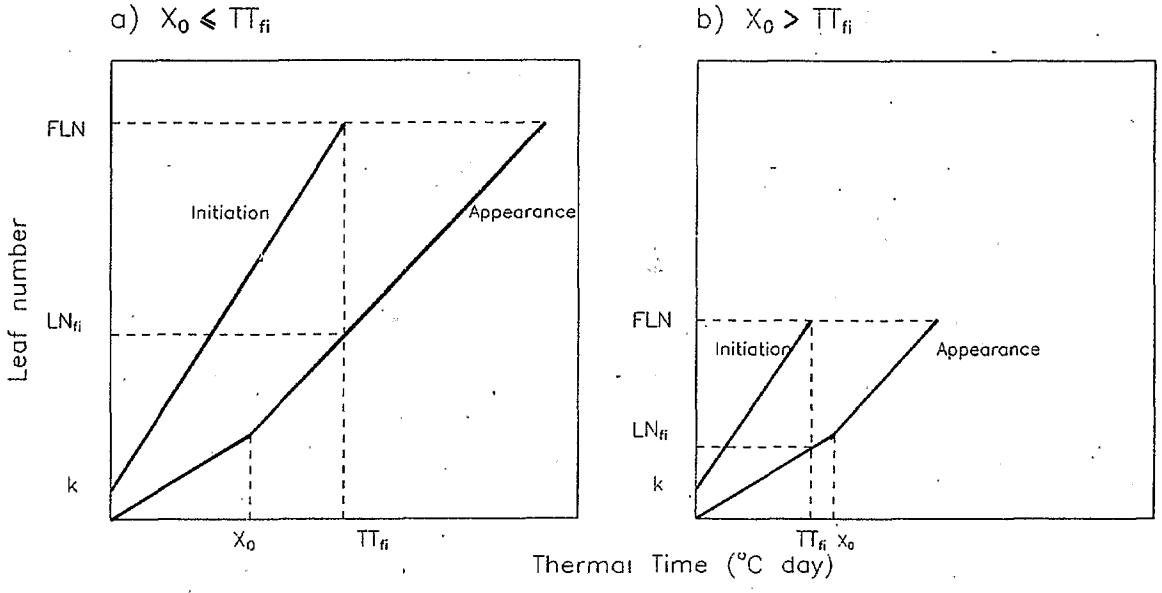

Fig. 1. Dynamics of leaf initiation and leaf appearance with sunflower ontogeny. See text for explanation.

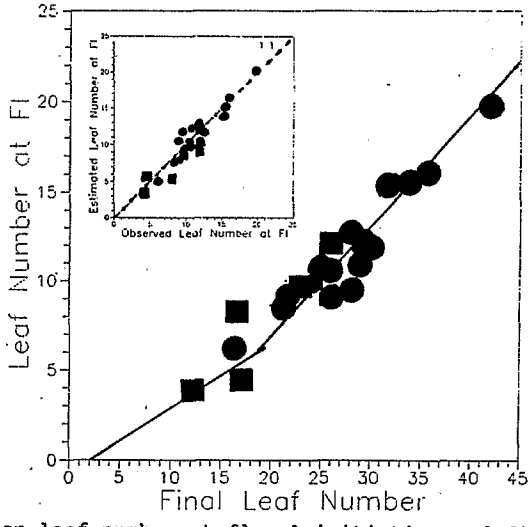

Fig 2. Relationship between leaf number at floral initiation and final leaf number. Solid line represents eqs (3a) and (3b). Data from glasshouse (squares) and field (circles) experiments. Standard error of mean FLN < 1.3 leaves; standard error of mean LN_{fi} < 0.6 leaves. Inset shows the relationship between observed and estimated LN_{fi}.

DISCUSSION

The consistency of the model under contrasting environments and with a range of genotypes (Fig. 2) is indicative of a stable relationship between RLA and RPI [eq.(3)]. Marc and Palmer[5] pointed out that sunflower floral development takes place in the central part of the apex while leaf primordia are initiated on the flanks. These authors concluded that the determination of leaf number and floral initiation are relatively independent processes because they are spatially separated. The present study, however, supports the hypothesis that leaf initiation, leaf appearance and floral initiation are related processes in sunflower. Consistent relationships between these processes have been found for other species although the mechanisms of this co-ordination remain speculative[10].

In conclusion, this study has shown that there is a stable relationship between LN_{fi} and FLN in sunflower. The relationship provides the basis for a non-destructive method to estimate, 'a posteriori', the time of sunflower FI. Final leaf number is the input required to estimate LN_{fi} and records of progress of leaf appearance are necessary to establish the time when LN_{fi} was attained. The model is currently being used to investigate the heritability of sunflower photoperiodic response for the time of floral initiation.

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