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Estimating leaf appearance rate and phyllochron in safflower (*Carthamus tinctorius L.*)

Estimativa da taxa de aparecimento de folhas e do filocrono em cártamo (*Carthamus tinctorius L.*)

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- NOTE -

ABSTRACT

*Safflower may be an interesting option for the flower market, either as fresh or dried cut flower. Estimating the leaf appearance rate and the phyllochron (the time interval between the appearance of successive leaves) is important for calculating the number of emerged leaves (NL) on the plant, which is an excellent measure of plant development. The objective of this study was to estimate the leaf appearance rate and the phyllochron in safflower (**Carthamus tinctorius** L.). An experiment was conducted in Santa Maria, RS, Brazil, inside an 8 x 15m plastic greenhouse. Sowing was on 03 October 2003 and emergence was on 08 October 2003. The experimental design was a randomized complete block design with three replications. The main stem NL was measured twice a week from 24 October 2003 to 15 November 2003 in four plants per replication. Daily growing degree days above a base temperature (5°C) and accumulated thermal time (TT) were calculated. The NL was linearly regressed against TT. The angular coefficient of the linear regression is the LAR (leaves/ °C day) and the phyllochron (°C days leaf^{-1}) was estimated by the inverse of the angular coefficient of the linear regression. The LAR was 0.0467 ± 0.0203 leaves °C^{-1} day and the phyllochron was 25.5 ± 14.6°C days leaf^{-1}.*

Key words: leaf *emergence, thermal time, safflower.*

RESUMO

Cártamo pode ser uma alternativa para o mercado de flores, podendo ser comercializada como flor fresca ou seca. A estimativa da taxa de aparecimento de folhas (LAR) e do filocrono (tempo necessário para o aparecimento de folhas sucessivas) é importante no cálculo do número de folhas emergidas (NL) na planta, o qual é uma excelente medida de tempo vegetal. O objetivo deste trabalho foi estimar a taxa de aparecimento de folhas e o filocrono em cártamo (Carthamus tinctorius L.). Foi realizado um experimento em Santa Maria, RS, em estufa plástica de 8 x 15m. A semeadura foi em 03 de outubro de 2003 e a emergência foi em 08 de outubro de 2003. O delineamento experimental foi o de blocos ao acaso com três repetições. O NL na haste principal foi medido durante o período de 24 de outubro a 15 de novembro de 2003. Foi calculado o número de graus dia diário acima de uma temperatura base (5°C) e a soma térmica acumulada (TT). Foi realizada uma análise de regressão linear entre NL e TT. O coeficiente angular da regressão linear é a LAR (folhas °C^{-1} dia) e o filocrono (°C dia folha^{-1}) foi estimado pelo inverso do coeficiente angular da regressão linear. A LAR foi 0,0467 ± 0,0203 folhas °C^{-1} dia e o filocrono foi 25,5 ± 14,6°C dia folha^{-1}.

Palavras-chave: *emergência de folhas, soma térmica, cártamo.*

Safflower (***Carthamus tinctorius*** L.), Asteraceae family, an annual crop, is native of Asia, where it is widely grown for textile dyeing and for an edible oil, which is extracted from the seeds (POLUNIN, 1991). Safflower has high ornamental value in Europe

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(MULLER FLOWERSEEDS, 1998). Major markets for safflower include fresh and dried cut flowers (STEVENS, 1998). In North America and Latin America, safflower is used mainly for oil (GAYETTO et al., 1999; OELKE et al., 2004). It is estimated that about 0.85 million ha are cultivated with safflower world wide (FAOSTAT, 2004). In Brazil, safflower is not used for oil and it is little known for ornamental purpose.

Flowers are an increasing market in Brazil. Brazilian flower production is concentrated in the São Paulo State, with about 70% of the national flower production. Rio Grande do Sul State is an emerging center in area and number of flower growers (BATISTA, 2000). Safflower may be an interesting flower crop for this emerging center, either as fresh or dried cut flower.

Leaf appearance rate (LAR) is the number of leaves that become visible on a stem per unit time (STRECK et al., 2003). The calculation of LAR is an important component of many crop simulation models (e.g. AMIR & SINCLAIR, 1991). The integration of LAR on the main stem over time gives the number of emerged leaves (NL) on the plant main stem, which is an excellent measure of plant development. The main stem NL is related to tiller appearance (KLEPPER et al., 1982; RICKMAN & KLEPPER, 1991; McMASTER et al., 1991) and to the timing of certain key plant developmental stages (BROOKING et al., 1995; CALDERINI et al., 1996; ROBERTSON et al., 1996; JAMIESON et al., 1998). Accurately calculating the appearance of individual leaves and the rate of leaf area expansion also has an impact on calculating light interception and absorption by the canopy, canopy photosynthesis, and therefore, accumulation of dry matter and yield (AMIR & SINCLAIR, 1991; HODGES & RITCHIE, 1991; McMASTER et al., 1991).

Another approach to calculate NL is through the concept of the phyllochron, which is the time interval between the appearance of successive leaves (KLEPPER et al, 1982; KIRBY, 1995). Time can be expressed in thermal time (TT), measured in units of degree-days (°C day), which is a better plant time descriptor than day of the year and number of days after sowing (GILMORE & ROGERS, 1958; RUSSELE et al., 1984; McMASTER & SMIKA, 1988).

A literature search yielded no previous studies aiming to quantify LAR and the phyllochron in safflower, which constituted the rationale for this effort. The objective of this study was to estimate the leaf appearance rate and the phyllochron in safflower.

An experiment was conducted at Santa Maria, RS, Brazil, (latitude: 29º43'S, longitude: 53º42'S and altitude: 95m) inside an 8 x 15m plastic greenhouse. Sowing was on 03 October 2003 and emergence was on 08 October 2003. Plants were well fertilized and irrigated as needed to avoid stress due to low soil nutrient and water.

The experimental design was a randomized complete block design with three replications. Each replication had $1m^2$ and was composed by eight rows of plants and six plants/row (48 plants m^{-2}). Plant spacing was 0.125m among rows and 0.165m among plants. Four plants located in the two center rows were randomly selected and tagged with colored wires after emergence. These plants were used to measure the visible main stem NL twice a week from 24 October 2003 to 15 November 2003.

Daily minimum and maximum air temperatures were recorded inside the plastic greenhouse throughout the experiment with a mercury-in-glass thermometer at 1.5m height. Daily growing degree-days (GDD, °C day) were calculated as (GILMORE & ROGERS, 1958; ARNOLD, 1960):

$$GDD = (Tmean - Tb) \,.\, 1 \text{ day} \qquad \{°C \text{ day}\} \qquad (1)$$

where Tmean is the mean air temperature calculated as the average of daily minimum and maximum air temperatures, and Tb is the base temperature, assumed 5°C. Two reasons contributed to adopt a Tb=5°C for safflower. The first reason is that a literature search yielded no value of Tb for this species. The second reason is that previous experience with growing this species in Santa Maria showed that it does not grow well in winter time and in summer time, but grows well in the spring (R.A. BELLÉ, personal communication). Winter crops (e.g. wheat) have a Tb around 0°C (STRECK et al., 2003) and summer crops (e.g. maize, sorghum, and soybean) have a Tb around 10°C (WARRINGTON & KANEMASU, 1983; MAJOR et al., 1990; SINCLAIR, 1986).

Accumulated thermal time (TT) from 24 October 2003 was calculated by:

$$TT = \Sigma GDD \qquad \{°C \text{ day}\} \qquad (2)$$

The NL was linearly regressed against TT. The angular coefficient of the linear regression is the LAR (leaves $°C^{-1}$ day) and the phyllochron (°C days/leaf) was estimated by the inverse of the angular coefficient of the linear regression, i.e. 1/LAR (KLEPPER et al., 1982; KIRBY, 1995).

There was a strong relationship (R^2=0.95 or greater) between NL and TT. The average LAR was 0.0467 ± 0.0203 leaves $°C^{-1}$ day and the average phyllochron was 25.5 ± 14.6°C days $leaf^{-1}$. The LAR and the phyllochron estimated in block I was at least two-fold lower or greater, respectively, than the estimates in blocks II and III. We were not able to come up with a reason for these differences, as soil conditions and plant emergence rate were similar among blocks.

Because no previous reports on LAR and phyllochron in safflower was found in the literature, we can only make comparisons of the values obtained in this study with other species. Moreover, comparisons of growth and developmental parameters based on thermal time need to be done at the same Tb. In summer field crops with a Tb=10°C, the phyllochron in maize, sorghum, and soybean were 45.2°C days leaf^{-1} (WARRINGTON & KANEMASU, 1983), 51.7°C days leaf^{-1} (MAJOR et al., 1990), and 55.5°C days leaf^{-1} (SINCLAIR, 1986), respectively. Using a Tb=10°C in safflower, the phyllochron in this study is 15.7°C days leaf^{-1}, indicating that leaves in safflower appear faster than in the field crops.

The estimation of LAR and phyllochron is a valuable step towards the development of a model for predicting leaf number and leaf area in safflower. We are currently working this research goal.

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