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# Simulation of oat development cycle by photoperiod and temperature

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**Key words:**
*Avena sativa*
succession system
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**A B S T R A C T**

The simulation of oat development cycle can be used in the planning of agricultural practices. The aim of the study was to simulate and validate the duration of oat development cycle by photoperiod, temperature and coefficients of development of wheat for use in the WE-Streck model, considering different doses of N-fertilizer and systems of succession of high and low C/N ratio. The study was conducted in 2015 in a randomized block design with four replicates in a 4 x 2 factorial scheme, corresponding to N rates (0, 30, 60 and 120 kg $ha^{-1}$) and oat cultivars (Barbarasul and Brisasul), respectively, in the soybean/oat and maize/oat systems. The duration of the stages from emergence to anthesis and from anthesis to maturation of oats was simulated in the WE-Streck model. The minimum, optimum and maximum temperatures that effectively simulate the oat development cycle were 4, 22 and 30 °C from emergence to anthesis and 15, 25 and 35 °C from anthesis to maturation, respectively. The intermediate-cycle oat development was efficiently simulated by the WE-Streck model using coefficients developed for wheat, with vegetative and reproductive cycles estimated at 89 and 43 days, respectively.

**Palavras-chave:**
*Avena sativa*
sistema de sucessão
nitrogênio
modelo WE-Streck

## Simulação do ciclo de desenvolvimento da aveia por fotoperíodo e temperatura

**R E S U M O**

A simulação do ciclo de desenvolvimento da aveia pode ser utilizada no planejamento de práticas agrícolas. Objetivou-se simular e validar a duração do ciclo de desenvolvimento da aveia por intermédio de fotoperíodo, temperatura e coeficientes de desenvolvimento do trigo para uso no modelo WE-Streck, considerando diferentes doses de N-fertilizante e sistemas de sucessão de alta e reduzida relação C/N. O estudo foi conduzido em 2015, em delineamento de blocos casualizados com 4 repetições em esquema fatorial 4 x 2 para doses de nitrogênio (0, 30, 60 e 120 kg $ha^{-1}$) e cultivares de aveia (Barbarasul e Brisasul), respectivamente, no sistema soja/aveia e milho/aveia. No modelo WE-Streck foi simulada a duração das fases emergência à antese e antese à maturação da aveia. As temperaturas mínima, ótima e máxima que simulam com eficiência o ciclo de desenvolvimento da aveia da emergência à antese, foram 4, 22 e 30 °C, respectivamente e da antese à maturação 15, 25 e 35 °C, respectivamente. A simulação do desenvolvimento da aveia de ciclo médio pelo modelo WE-Streck foi eficiente usando coeficientes desenvolvidos para o trigo, com ciclo vegetativo e reprodutivo estimado em 89 e 43 dias, respectivamente.

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## Introduction

White oat cultivation is an important alternative in the agricultural exploitation in Southern Brazil (Castro et al., 2012; Hawerroth et al., 2014). Therefore, the simulation of the duration of wheat development cycle becomes a significant tool in the planning of agricultural practices (Rosa et al., 2009; Castro et al., 2012).

Wang & Engel (1998) developed the model called WE, to estimate the duration of wheat development cycle. These authors considered the nonlinear effects of air temperature, photoperiod and vernalization. Streck et al. (2003) modified the WE model by dividing the vegetative cycle of wheat into two subphases (emergence to terminal spikelet; terminal spikelet to anthesis) and the reproductive cycle into one phase (anthesis to maturation), through combinations of cardinal temperatures. According to Alberto et al. (2009), these modifications improved the simulation of wheat development stages, and the model was called WE-Streck. These authors used the WE-Streck model to simulate new coefficients of development in Brazilian wheats.

Air temperature and photoperiod are meteorological elements that interfere with the development of grasses (Castro et al., 2012). Nitrogen, for being the most required nutrient, also modifies the duration of the oat development stages (Flores et al., 2012; Pietro-Souza et al., 2013). Since wheat and oat are similar species regarding the development cycle (Baier et al., 1988), the coefficients estimated for wheat by Streck et al. (2003) and Alberto et al. (2009) in the WE-Streck model can be employed in the simulation of the oat development cycle under conditions of N application.

This study aimed to simulate and validate the duration of the oat development cycle by photoperiod and temperature, using coefficients of wheat development for use in the WE-Streck model, considering different N fertilizer doses and succession systems of high and reduced C/N ratio.

## Material and Methods

The study was carried out at the field in 2015, in Augusto Pestana-RS, Brazil (28° 26' 30" S; 54° 00' 58" W). The soil of the experimental area is classified as typic dystroferric Red Latosol and the climate of the region, according to Köppen's classification, is Cfa, with hot summer without dry season. Ten days before sowing, soil chemical analysis was performed, showing the following chemical characteristics (Tedesco et al., 1995): i) maize/oat system (pH = 6.5, P = 35.4 mg $dm^{-3}$, K = 260 mg $dm^{-3}$, OM = 3.4%, Al = 0 cmolc $dm^{-3}$, Ca = 6.8 $cmol_c$ $dm^{-3}$ and Mg = 3.1 $cmol_c$ $dm^{-3}$) and; ii) soybean/oat system (pH = 6.1, P = 32.9 mg $dm^{-3}$, K = 200 mg $dm^{-3}$, OM = 3.5%, Al = 0 $cmol_c$ $dm^{-3}$, Ca = 6.3 $cmol_c$ $dm^{-3}$ and Mg = 2.5 $cmol_c$ $dm^{-3}$).

Sowing was performed in the first week of June using a seeder-fertilizer machine to set a plot of 5 rows with length of 5 m and spacing of 0.20 m between rows, forming an experimental unit of 5 $m^2$. The fungicide Tebuconazole, with commercial name of FOLICUR® CE, was applied at the dose of 0.75 L $ha^{-1}$. The weeds were controlled with the herbicide metsulfuron-methyl, with commercial name of ALLY®, at the dose of 2.4 g $ha^{-1}$ of the commercial product and additional weeding, always when necessary. The experiments received, at sowing, 60 and 50 kg $ha^{-1}$ of $P_2O_5$ and $K_2O$ based on the contents of P and K in the soil for an expected grain yield of 3 t $ha^{-1}$, respectively, and 10 kg $ha^{-1}$ of N as basal (except in the standard experimental unit), while the rest was applied to contemplate the proposed doses of the nutrient as top-dressing in the indicated stage of expanded fourth leaf.

The experimental design was randomized blocks with four replicates, in a 4 x 2 factorial scheme for the doses of N fertilizer (0, 30, 60 and 120 kg $ha^{-1}$), with urea as the source, and oat cultivars (Barbarasul and Brisasul), respectively, totaling 32 experimental units per succession system of high and reduced residual-N release, maize/oat and soybean/oat, respectively. The tested cultivars have small size and intermediate cycle of development.

The definition of the cycle in days, from emergence to anthesis (EM-AN) and anthesis to maturation (AN-MT), considered the mean of the development stages of both cultivars, obtained through a careful observation analysis at the field, by two evaluators. The date of emergence was considered when 50% of the seedlings of each plot were visible above the soil. The date of the anthesis stage was considered when 50% of the plants of each plot had the panicle exposed and the date of beginning of maturation was defined when 50% of the plants of the plot showed yellow flag leaf and hard grain mass. The meteorological data of air temperature were daily obtained through the Automatic Total Station, 200 m away from the experiment.

In the WE-Streck model used in wheat, the vegetative development cycle from emergence (EM) to anthesis (AN) is subdivided into the subphases, from emergence (EM) to terminal spikelet (TS) and from terminal spikelet (TS) to anthesis (AN). The model also includes the coefficient of daily development (r). The accumulation of the r values is used to define the development stage (Dr = Σr). The emergence stage considers Dr = 0, the stage of terminal spikelet, Dr = 0.4, anthesis, Dr = 1, and maturation, Dr = 2.

The model of the duration of development for the EM-ET subphase in wheat is:

$$r = r_{max,v1} \cdot f(T) \cdot f(P) \cdot f(V) \quad (1)$$

where:

$r_{max,v1}$ - maximum coefficient of daily development during the EM-ET subphase under optimal conditions of temperature, photoperiod and vernalization; and,

f(T), f(P) and f(V) - response functions for temperature, photoperiod and vernalization, respectively, which vary from 0 to 1.

The simulation of the oat development cycle disregarded f(V), because in the ET-AN subphase there is no significant effect of vernalization on the tested genotypes. Therefore, for the simulation of the EM-AN phase in oat, the model becomes:

$$r = r_{max,v2} \cdot f(T) \cdot f(P) \quad (2)$$

where:

$r_{max,v2}$ - maximum coefficient of development during the EM-AN phase under optimal conditions of temperature and photoperiod.

The reproductive cycle in the phase of anthesis to maturation of wheat (AN-MT) is not influenced by photoperiod (Wang & Engel, 1998). Thus, only the effect of the temperature function is considered. This model was integrally used to determine the reproductive cycle of oat:

$$r = r_{max,r} \cdot f(T) \tag{3}$$

where:

$r_{max,r}$ - maximum coefficient of development for the AN-MT phase under optimal conditions of temperature.

The value of the temperature function f(T) varies from 0 to 1, calculated by the function:

$$\begin{cases} f(T) = 0, & T < TC_{min} \\ f(T) = \dfrac{2(T - TC_{min})^{\alpha}(TC_{opt} - TC_{min})^{\alpha} - (T - TC_{min})^{2\alpha}}{(TC_{opt} - TC_{min})^{2\alpha}}, & TC_{min} \le T \le TC_{max} \\ f(T) = 0 & T > TC_{max} \end{cases} \tag{4}$$

$$\alpha = \frac{\ln 2}{\ln\left[\dfrac{(TC_{max} - TC_{min})}{(TC_{opt} - TC_{min})}\right]}$$

where:

$TC_{min}$, $TC_{opt}$ and $TC_{max}$ - minimum, optimum and maximum cardinal temperatures for the development, respectively; and,

T - air temperature, calculated in degrees Celsius (°C).

Daily temperature is an input datum for the calculation of the temperature response function f(T) (Wang & Engel, 1998), calculated using the arithmetic mean of the daily values of minimum and maximum temperature. There is no development when the temperature is below $TC_{min}$ or above $TC_{max}$, and the development is maximum when the temperature is equal to $TC_{opt}$.

The photoperiod function f(P) was calculated through:

$$f(P) = 1 - \exp\left[-\omega(P - P_c)\right] \tag{5}$$

$$\omega = \frac{4}{\left|P_{opt} - P_c\right|} \tag{6}$$

where:

P - current photoperiod in hours (h);

$P_{opt}$ - optimal photoperiod of the crop (h);

$P_c$ - critical photoperiod of the crop (h), below which there is no plant development; and,

ω - coefficient of crop sensitivity to the photoperiod ($h^{-1}$).

This study with oat used the coefficients of $r_{max,v}$ and $r_{max,r}$ developed for wheat cultivars by Streck et al. (2003) and Alberto et al. (2009), according to Table 1.

The values of $P_c$ and $P_{ot}$ used in the model were 8 and 15 h, respectively (Alberto et al., 2009; Castro et al., 2012). The values of $TC_{min}$, $TC_{opt}$ and $TC_{max}$, were proposed based on data found in the literature (Castro et al., 2012; Spasova et al., 2013; Oliveira et al., 2014) and suggested by the authors of this study (Table 2).

Table 1. Coefficients used to calculate oat development in the development cycles of emergence-anthesis and anthesis-maturation

| Development cycle | Model coefficients (r) | |
|---|---|---|
| | Streck | Alberto |
| Emergence-anthesis (EM-AN) | 0.0294 | 0.0135 |
| | 0.0349 | 0.0189 |
| | - | 0.0710 |
| | - | 0.0910 |
| Anthesis-maturation (AN-MT) | 0.04545 | 0.0317 |
| | - | 0.0330 |
| | - | 0.0382 |
| | - | 0.0441 |

r - development coefficient

Table 2. Combinations of minimum, optimum and maximum cardinal temperatures for oat development in the phases EM-AN and AN-MT

| Combinations of temperatures | Cardinal temperatures (°C) | | |
|---|---|---|---|
| | Minimum temperature ($T_{min}$) | Optimum temperature ($T_{opt}$) | Maximum temperature ($T_{max}$) |
| Emergence-anthesis (EM-AN) | | | |
| T1 | 0 | 13 | 32 |
| T2 | 0 | 20 | 26 |
| T3 | 4 | 22 | 30 |
| Anthesis-maturation (AN-MT) | | | |
| T4 | 4 | 22 | 30 |
| T5 | 9 | 20 | 30 |
| T6 | 15 | 25 | 35 |

T - Combination of minimum, optimum and maximum temperature in the indicated development cycle

## Results and Discussion

According to Figure 1, during the oat development cycle the meteorological variations were adequate for the crop, with higher rainfall in days that preceded the application of N fertilizer, leading to moisture content favorable to N fertilization. In addition, the rainfall volume and distribution were adequate in the entire cultivation period. The lowest monthly rainfall was equal to 46.5 mm (September) and the highest one to 223.8 mm (August), with mean rainfall in the total cycle of 175 mm. The mean monthly temperature varied from 7.9 °C (June) to 25 °C (October), while the highest daily maximum temperature was 34 °C (September) and the lowest daily maximum was -3.5 °C (July). The photoperiod varied by 10.2 h in the emergence phase, 11.7 h for anthesis and 12.8 h for maturation (data not shown). The record of these meteorological conditions helps in the calibration and evaluation of the models (Streck et al., 2003).

According to Gonçalves et al. (2010), oat development depends on the local climatic conditions. Pedro Júnior et al. (2004) report that the duration of the cycle of cool-season cereals cultivated in South Brazil is mainly due to air temperature, which is more effective in the duration of the period from emergence to flowering. According to Leite et al. (2012), the maximum temperature for oat development is 35 °C and the minimum is 0 °C, confirming the adequate climate condition obtained during the study (Figure 1). Gonçalves et al. (2010) comment that the increase in rainfall leads to easier decomposition of soil cover, bringing benefits in the release of nutrients, especially residual N, for the use by plants in succession.

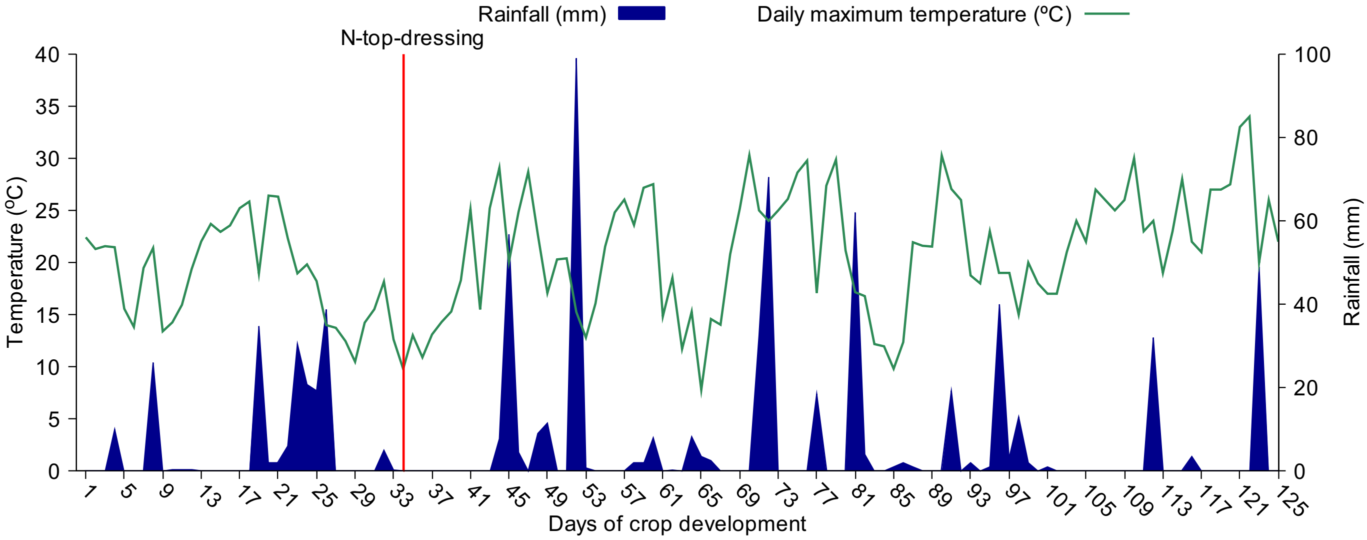


Figure 1. Rainfall and maximum temperature in the oat cultivation cycle

Table 3 presents the values of the development cycles observed at the field, in days, from emergence to anthesis (EM-AN) and from anthesis to maturation (AN-MT). It should be pointed out that, in the soybean/oat and maize/oat systems, regardless of the cultivars, the EM-AN phase lasted for 91 days on average, while the AN-MT phase lasted for 41 days. Based on the sum of the development stages, the total cycle (from anthesis to maturation) lasted for 131 days. Although the N fertilizer acts decisively on oat development, the doses of the nutrient did not show alterations in the reduction or delay of the development cycle, and only the cultivar Barbarasul in the maize/oat system, at the doses of 0 and 30 kg N ha$^{-1}$, indicated a reduction of 3 days in the EM-AN phase and a delay of 3 days in the AN-MT phase, in comparison to the other doses. Therefore, the condition of N restriction in the combination of reduced N fertilizer dose and system of reduced residual-N release promotes a small increment of the vegetative cycle and reduction of the reproductive cycle. In general, the differences observed in the development due to the doses of N fertilizer and succession system were not significant.

Table 3. Actual values obtained at the field of days from emergence to anthesis and from anthesis to maturation of the oat cultivars in different succession systems

| Cultivar | N dose (kg ha$^{-1}$) | Emergence-Anthesis (days) | Anthesis-Maturation (days) |
|---|---|---|---|
| Soybean/oat system | | | |
| Barbarasul | 0 | 92 | 41 |
| | 30 | 92 | 41 |
| | 60 | 91 | 40 |
| | 120 | 92 | 40 |
| Brisasul | 0 | 91 | 41 |
| | 30 | 90 | 41 |
| | 60 | 91 | 41 |
| | 120 | 91 | 40 |
| Mean (Barbarasul + Brisasul) | - | 91 | 41 |
| Maize/oat system | | | |
| Barbarasul | 0 | 93 | 38 |
| | 30 | 93 | 38 |
| | 60 | 90 | 41 |
| | 120 | 91 | 40 |
| Brisasul | 0 | 92 | 41 |
| | 30 | 90 | 41 |
| | 60 | 90 | 41 |
| | 120 | 91 | 40 |
| Mean (Barbarasul + Brisasul) | - | 91 | 41 |

According to Hawerroth et al. (2014), white oat cultivars have a compensatory effect between the vegetative and reproductive periods, in relation to the full development cycle, stabilizing the full development cycle, a fact also observed under the actual cultivation conditions. Carvalho et al. (2009) and Oliveira et al. (2011) comment that the period from emergence to maturation of short-cycle oat has mean duration of 118 to 120 days, respectively. However, the thermal oscillations in the cultivation years and the photoperiod may modify the duration of the development of this species (Castro et al., 2012; Leite et al., 2012).

Table 4 presents the coefficients of wheat development obtained by Streck et al. (2003) and Alberto et al. (2009) that best adjusted to the oat development stages, in the different combinations of temperature and days of simulated development. Each combination of temperature (T1, T2, T3, T4, T5 and T6) resulted in a different number of days of simulated development. Compared with the data obtained at the field, there is a difference of at most 6 days for the vegetative

Table 4. Coefficients adjusted to the oat development stages in the different combinations of temperature and days of simulated development

| Combinations of adjusted temperatures | Indicated coefficient | Days of the simulated development |
|---|---|---|
| Emergence-Anthesis (EM-AN) | | |
| T1 | 0.0189 | 91 |
| T2 | 0.0294 | 97 |
| T3 | 0.0294 | 89 |
| Anthesis-Maturation (AN-MT) | | |
| T4 | 0.04545 | 46 |
| T5 | 0.04545 | 52 |
| T6 | 0.04545 | 43 |
| Emergence-Maturation (EM-MT) | | |
| T3 - T4 | 0.0294 - 0.04545 | 135 |
| T3 - T5 | 0.0294 - 0.04545 | 141 |
| T3 - T6 | 0.0294 - 0.04545 | 132 |

T - Combination of minimum, optimum and maximum temperature in the indicated development cycle

cycle (EM-AN) and maximum of 12 days for the reproductive cycle (AN-MT).

The simulated results are similar to those found in wheat by Alberto et al. (2009), who obtained estimated values varying from 1.2 to 7.3 days for the stage from maturation to terminal spikelet, from 3.5 to 8.1 days for the stage from terminal spikelet to anthesis and from 6.3 to 12 days for the stage from anthesis to maturation, as well as Streck et al. (2003), who studied winter wheat and found that the estimates of the stages varied from 3 to 8 days.

However, in the EM-AN phase (Table 4), the combination T1 with 0, 13 and 32 °C of minimum, optimum and maximum temperatures, respectively, and development coefficient of 0.0189, efficiently simulated the predictability of the vegetative cycle in 91 days. In addition, for the reproductive cycle, the combination of temperature T6 with minimum, optimum and maximum temperatures of 15, 25 and 35 °C, respectively, and coefficient of 0.4545, showed the best simulation of the duration of the AN-MT phase, with 43 days. Analyzing the full development cycle, the combination T3 for the EM-AN phase with minimum, optimum and maximum temperatures of 4, 22 and 30 °C, respectively, and development coefficient of 0.0294, along with the combination T6 for the AN-MT phase with minimum, optimum and maximum temperatures of 15, 25 and 35 °C, respectively, and coefficient of 0.04545, showed the best simulation of the full period of oat development, with 89 days for the vegetative cycle and 43 days for the reproductive cycle, and total cycle of 132 days, similar to the results obtained at the field, 131 days.

According to Castro et al. (2012), in the maturation stage the crop requires high temperatures and low relative humidity, which explains the fact that the combination of higher temperatures of the AN-MT phase was the most appropriate for the simulation. Leite et al. (2012) claim that the interannual variability of mean temperature influences the cycle of the crops, advancing or delaying the stages of their development. According to Alberto et al. (2009), higher temperatures can accelerate plant development, advancing the data of occurrence of AN-MT. Due to physiological reasons, it is known that each species has a minimum temperature, below which the growth is negligible or null, and the same occurs with the maximum temperature (Villa Nova et al., 2007). Combinations of meteorological variables along with coefficients of the species allow to simulate the development stages of the plants and predict important stages for the use of agronomic techniques. According to Erpen et al. (2013), it is expected that the air temperature in the future can be higher than the current one, exposing the oat crop to temperatures above $T_{opt}$ with higher frequency, qualifying the possibility of using the WE-Streck model.

## Conclusions

1. The minimum, optimum and maximum temperatures that efficiently simulate the oat development cycle were 4, 22 and 30 °C from emergence to anthesis and 15, 25 and 35 °C from anthesis to maturation, respectively.

2. The intermediate-cycle oat development was efficiently simulated by the WE-Streck model using coefficients developed for wheat, with vegetative and reproductive cycles estimated at 89 and 43 days, respectively.

## Literature Cited


Alberto, C. M.; Streck, N. A.; Walter, L. C.; Rosa, H. T.; Menezes, N. L. de; Heldwein, A. B. Modelagem do desenvolvimento de trigo considerando diferentes temperaturas cardinais e métodos de cálculo da função de resposta à temperatura. Pesquisa Agropecuária Brasileira, v.44, p.545-553, 2009. http://dx.doi.org/10.1590/S0100-204X2009000600001

Baier, A. C.; Floss, E. L.; Aude, M. I. S. As lavouras de inverno 1: aveia, centeio, triticale, colza, alpiste. Rio de Janeiro: Globo, 1988. p.107-130.

Carvalho, F. I. F. de; Oliveira, A. C. de; Valério, I. P.; Benin, G.; Schmidt, D. A. M.; Hartwig, I.; Ribeiro, G.; Silveira, G. da. Barbarasul: A high-yielding and lodging-resistant white oat cultivar. Crop Breeding and Applied Biotechnology, v.9, p.96-99, 2009. http://dx.doi.org/10.12702/1984-7033.v09n01a13

Castro, G. S. A.; Costa, C. H. M. da; Ferrari Neto, J. Ecofisiologia da aveia branca. Scientia Agraria Paranaensis, v.11, p.1-15, 2012. http://dx.doi.org/10.18188/1983-1471/sap.v11n3p1-15

Erpen, L; Streck, N. A.; Uhlmann, L. O.; Langner, J. A.; Winck, J. E. M.; Gabriel, L. F. Estimativa das temperaturas cardinais e modelagem do desenvolvimento vegetativo em batata-doce. Revista Brasileira de Engenharia Agrícola e Ambiental, v.17, p.1230-1238, 2013. http://dx.doi.org/10.1590/S1415-43662013001100015

Flores, R. A.; Urquiaga, S. S.; Alves, B. J. R.; Collier, L. S.; Morais, R. F. de; Prado, R. de M. Adubação nitrogenada e idade de corte na produção de matéria seca do capim-elefante no Cerrado. Revista Brasileira de Engenharia Agrícola e Ambiental, v.16, p.1282-1288, 2012. http://dx.doi.org/10.1590/S1415-43662012001200004

Gonçalves, S. L.; Saraiva, O. F.; Torres, E. Influência de fatores climáticos na decomposição de resíduos culturais de aveia e trigo. Londrina: Embrapa Soja, 2010. 27p.

Hawerroth, M. C.; Barbieri, R. L.; Silva, J. A. G. da; Carvalho, F. I. F de; Oliveira, A. C. de. Importância e dinâmica de caracteres na aveia produtora de grãos. Pelotas: Embrapa Clima Temperado, 2014. 59p. Documentos 376.

Leite, J. G. D. B.; Federizzi, L. C.; Bergamaschi, H. Mudanças climáticas e seus possíveis impactos aos sistemas agrícolas no Sul do Brasil. Revista Brasileira de Ciências Agrárias, v.7, p.337-343, 2012. http://dx.doi.org/10.5039/agraria.v7i2a1239

Oliveira, A. C. de; Crestani, M.; Carvalho, F. I. F. de; Silva, J. A. G. da; Valério, I. P.; Hartwig, I.; Benin, G.; Schmidt, D. A. M.; Bertan, I. Brisasul: A new high-yielding white oat cultivar with reduced lodging. Crop Breeding and Applied Biotechnology, v.11, p.370-374, 2011. http://dx.doi.org/10.1590/S1984-70332011000400012

Oliveira, L. V.; Ferreira, O. G. L.; Coelho, R. A. T.; Farias, P. P.; Silveira, R. F. Características produtivas e morfofisiológicas de cultivares de azevém. Pesquisa Agropecuária Tropical, v.44, p.191-197, 2014. http://dx.doi.org/10.1590/S1983-40632014000200011

Pedro Júnior, M. J.; Camargo, M. B. P. de; Moraes, A. V. de C.; Felício, J. C.; Castro, J. L. de. Temperatura-base, graus-dia e duração do ciclo para cultivares de triticale. Bragantia, v.63, p.447-453, 2004. http://dx.doi.org/10.1590/S0006-87052004000300015

Pietro-Souza, W.; Bonfim-Silva, E. M.; Schlichting, A. F.; Silva, M. de C. Desenvolvimento inicial de trigo sob doses de nitrogênio em Latossolo Vermelho de Cerrado. Revista Brasileira de Engenharia Agrícola e Ambiental. v.17, p.575-580, 2013. http://dx.doi.org/10.1590/S1415-43662013000600001

Rosa, H. T.; Walter, L. C.; Streck, N. A.; Alberto, C. M. Métodos de soma térmica e datas de semeadura na determinação de filocrono de cultivares de trigo. Pesquisa Agropecuária Brasileira, v.44, p.1374-1382, 2009. http://dx.doi.org/10.1590/S0100-204X2009001100002

Spasova, D.; Spasov, D.; Atanasova, B.; Ilievski, M.; Kuktanov, R.; Georgieva, T. Impact of the system of cultivation on the vegetative growth and reproductive development of oats. Bulgarian Journal of Agricultural Science, v.19, p.1047-1055, 2013.

Streck, N. A.; Weiss, A.; Xue, Q.; Baenziger, P. S. Improving predictions of developmental stages in winter wheat. Agricultural and Forest Meteorology, v.115, p.139-150, 2003. http://dx.doi.org/10.1016/S0168-1923(02)00228-9

Tedesco, M. J.; Gianello. C.; Bissani, C. A.; Bohnen, H.; Volkweiss, S. J. Análise de solo, plantas e outros materiais. 2.ed. Porto Alegre: UFRGS, 1995. 147p. Boletim Técnico, 5

Villa Nova, N. A.; Tonato, F.; Pedreira, C. G. S.; Medeiros, H. R. de. Método alternativo para cálculo da temperatura base de gramíneas forrageiras. Ciência Rural, v.37, p.545-549, 2007. http://dx.doi.org/10.1590/S0103-84782007000200039

Wang, E.; Engel, T. Simulation of phenological development of wheat crops. Agricultural Systems, v.58, p.1-24, 1998. http://dx.doi.org/10.1016/S0308-521X(98)00028-6