IMPROVING PREDICTIONS OF LEAF APPEARANCE IN POTATO[1]

Nereu Augusto Streck[2], Isabel Lago[3], Fabiana Luiza Matielo[4], Dilson Antonio Bisognin[2], Jacso Dellai[4]

ABSTRACT - The purpose of this study was to improve the simulation of the main stem number of emerged leaves in potato. A linear (phyllochron) and a non-linear multiplicative model (WE model) were used to predict the main stem number of emerged leaves (NL) and were compared using independent data from field experiments with eleven planting dates over two years (2003 and 2004) in Santa Maria, RS, Brazil. The WE model was a better predictor of NL (RMSE=2.75 leaves) than the phyllochron model (RMSE=5.49 leaves).

INTRODUCTION

The simulation of leaf appearance rate (LAR) and the number of accumulated or emerged leaves on a main stem (NL) is an important part of many crop simulation models. The NL is an excellent measure of plant development, is related to leaf area, to the timing of some developmental stages (Streck et al., 2003), and, in potato, to branching (Vos & Biemond, 1992). One approach to predict the appearance of individual leaves is to use the phyllochron concept, defined as the time interval between the appearance of successive tip leaves (Klepper et al, 1982; Kirby, 1995). The time needed for the appearance of one leaf can be expressed in thermal time (TT), measured in units of degree days (ºC d). Therefore, the phyllochron has units of ºC d / leaf. However, the TT approach has been criticized because there are different ways to calculate TT, which can cause different results from the same data (McMaster & Wilhelm, 1997), and because of the assumption of a linear response of development to temperature, which is not biologically realistic (Shaykewich, 1995).

One way to overcome the disadvantages of the TT approach is to use non-linear temperature response functions (Streck et al., 2003) and multiplicative models (Wang & Engel, 1998). Streck et al. (2003) modified the Wang and Engel (1998) and improved the prediction of leaf appearance in winter wheat.

The objective of this study was to improve the simulation of the number of main stem emerged leaves in potato.

MATERIAL AND METHODS

Field experiments were carried out at Santa Maria RS, Brazil, with the potato cultivar Asterix. There were a total of 14 planting dates in 2003 and 2004. The experimental design was a complete randomized block design with four replications. The number of leaves on one main stem/mother tuber was measured in 6 plants from 2 central rows twice a week. It was assumed that a leaf was visible when its apical leaflet was 1cm in length (Cao & Tibbitts, 1995)

Daily TT was calculated by:

$$TT=(Topt-Tb).(T-Tb)/(Topt-Tb) \text{ when } Tb<T\leq Topt \text{ and } (Topt-Tb).(Tmax-T)/(Tmax-Topt) \text{ when } Topt<T\leq Tmax$$

where Tb is the base temperature (7ºC), Topt is the optimum temperature (21ºC), and Tmax is the maximum temperature (30ºC) for leaf appearance rate in potato (Sands et al. 1979), and T is the mean daily temperature calculated from the average of minimum and maximum air temperatures.

The number of leaves was linearly regressed against accumulated TT and the phyllochron was estimated by the inverse of the slope (angular coefficient) of the linear regression using data from four planting dates (21 Jan 2003, 12 Feb 2003, 28 Feb 2003, and 27 Mar 2003) and estimated as 18.4 (±4.19) ºC.day leaf^{-1}.

The WE model (Wang & Engel, 1998) for potato has the general form (since there is no photoperiod or vernalization response):

$$LAR = LAR_{max}\, f(T)$$

where LAR is the daily leaf appearance rate (leaves day^{-1}), LAR_{max} is the maximum daily leaf appearance rate (leaves day^{-1}) and f(T) is a dimensionless temperature response function (0-1) for LAR. The f(T) is a beta function:

$$f(T) = [2(T-T_{min})^{\alpha}(T_{opt}-T_{min})^{\alpha}-(T-T_{min})^{2\alpha}]/(T_{opt}-T_{min})^{2\alpha}$$

$$\alpha = \ln 2/\ln[(T_{max}-T_{min})/(T_{opt}-T_{min})]$$

where T_{min}, T_{opt}, and T_{max} are the cardinal temperatures (minimum, optimum, and maximum) for LAR in potato, assumed 7ºC, 21ºC and 30ºC (Sands et al. 1979), and T is the mean daily temperature calculated from the average of minimum and maximum air temperatures.

The LAR_{max} using the NL data from four planting dates (21 Jan 2003, 12 Feb 2003, 28 Feb 2003, and 27 Mar 2003) was estimated as 0.872 (±0.13) leaves day^{-1}.

The number of emerged leaves (NL) on the main stem, was calculated by accumulating the daily LAR values (i.e. at a daily time step), starting at emergence, i.e., NL=ΣLAR.

The values of NL predicted by the phyllochron approach and the WE model were compared with the observed values from eleven planting dates, which were independent data sets. The statistic used to evaluate model performance was the root mean square error (RMSE), calculated as (Janssen and Heuberger, 1995):

$$RMSE = [\Sigma(p_i - o_i)^2/n]^{0.5}$$

where p = predicted data, o = observed data, and n = number of observations.

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[2] Depto. de Fitotecnia (DF), Centro de Ciências Rurais (CCR), Universidade Federal de Santa Maria (UFSM), 97105-900, Santa Maria, RS, Brasil. (*nstreck1@smail.ufsm.br*)
[3] DF, CCR, UFSM, Santa Maria, RS, Brasil. Bolsista de Iniciação Científica da FAPERGS.
[4] DF, CCR, UFSM, Santa Maria, RS, Brasil. Bolsistas de pós-graduação (PPG Agronomia) da CAPES.

RESULTS AND DISCUSSION

The WE model was a better predictor of potato NL (RMSE=2.75 leaves) than the phyllochron model (RMSE=5.49 leaves) (Figure 1).

The better performance of the WE model compared to the phyllochron was probably because plant development response to temperature is non-linear rather than linear (Shaykewich, 1995).

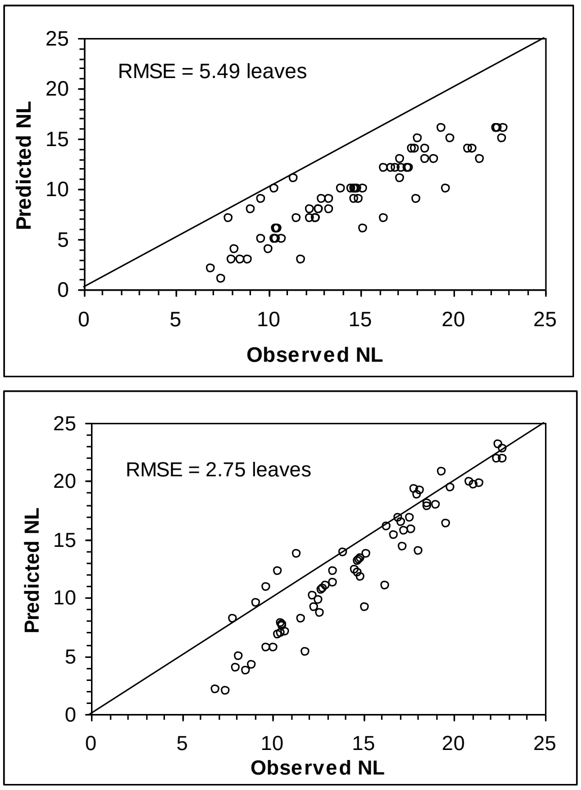

Figure 1. Observed versus predicted leaf number (NL) of potato. Predicted NL was calculated using the phyllochron concept (upper pannel) and with the WE model (lower pannel).

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