

Predicting the harvest date of silage maize based on whole crop or cob dry matter contents

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Abstract

In Germany, it is recommended to harvest silage maize at a whole-crop dry matter (DM) content (GTS) of 32 to 36% and a cob DM content (KTS) of about 55%. Predicting harvest date may be challenging for sites with a high risk of summer drought. Harvesting silage maize at the optimum stage of development is a prerequisite for maximising yield, forage quality and resource-use efficiency. This is especially challenging for sites that have frequent summer droughts, which cause fast maturation of the stover. The objectives of the current study were to evaluate the predicting ability of three modelling approaches: the semi-mechanistic MaisProg model, simulating GTS and KTS, and a temperature-sum driven tool (PAGF) predicting KTS. The study was based on an 8-year field experiment, conducted at Paulinenaue, north-eastern Germany, where maize hybrids were harvested weekly from August until silage maturity. The results revealed that, under conditions of frequent summer droughts, MaisProg-GTS seems less suitable, as indicated by an unsatisfactory correlation coefficient (0.68). Better model fit was achieved by the KTS-based approaches (MaisProg: 0.92, PAGF: 0.96). In particular, PAGF showed a higher correlation for early harvest date predictions (mid/late August), which is advantageous in terms of arranging the hiring of contractors.

Keywords: *Zea mays*, model, temperature sum, MaisProg

Introduction

In Germany, maize silage plays an increasingly important role in feeding systems for high-yielding dairy cows as well as in intensive beef production. According to recommendations (Lütke-Entrup *et al.*, 2013), silage maize should be harvested at the stage of physiological maturity BBCH 87 (Meier, 2001) when the kernel dry matter (DM) content is about 55-60%. This allows feeding value of maize for ruminants and forage yield to be maximised, conservation, and maize resource-use efficiency to be increased. Under the growth conditions and for maize hybrids grown in Germany, this developmental stage is characterised by a whole-crop DM content (GTS) of 32 to 36% and a cob DM content (KTS) of about 55%. The MaisProg harvest time prognosis tool, based on GTS, has been implemented nationwide in 2005 (www.maisprog.de; Herrmann *et al.*, 2006) to improve maize silage quality. While it has shown good agreement between observed and predicted GTS for most environments, a higher prediction error was found for a site (Paulinenaue, northeastern Germany) with sandy soil and rather low and unevenly distributed precipitation, where even limited drought periods can cause a fast maturation of the stover (Schuppenies and Pickert, 2000). For such conditions, KTS might be a more suitable indicator of silage maturity than GTS. The objectives of the current study, therefore, were to evaluate the predictive ability of three approaches, the semi-mechanistic MaisProg model, calculating (1) GTS and (2) KTS based on weather variables, plant-available soil water and hybrid characteristics, and (3) a temperature-sum driven tool (PAGF) predicting KTS.

Materials and methods

The study is based on a multi-year field experiment (2007-2014) conducted at Paulinenaue, north-eastern Germany (latitude 52 ° 68' N; longitude 12 ° 72' E) on a sandy soil, with a mean annual temperature of 9 °C, a mean annual precipitation of 520 mm, where three maize hybrids (Salgado, early; Lukas, mid-early; PR39F58, mid-late) were grown at a crop density of 8 plants m⁻² in four rows with a row width of 0.75 m and a plot length of 30 m. Crop development was monitored in terms of silking date, BBCH 65. The GTS and KTS were determined at four to five dates after silking, respectively. To this end, four samples of ten plants were harvested by hand at a cutting height of 0.15 m from the two central rows of each plot at each sampling date. Fresh weight of the whole crops was measured. Then, the samples were separated into cob and stover. For the cobs, fresh weight was recorded and DM content was determined after drying at 105 °C for 36 hours. The DM content of the stover was determined after chopping and drying at 105 °C.

MaisProg is one of few models that not only predicts DM production but also provides a comprehensive simulation of various forage quality parameters (Herrmann *et al.*, 2005). It consists of two dynamically interacting sub-models for DM production and quality development driven by plant and soil characteristics, weather data, and soil water availability. Calculations start at sowing for the whole crop and at predicted silking for the cob. Following an AGPM approach (AGPM, 1990) in the PAGF model, the daily mean temperature contribution, $T_d = t_x - t_b$, was calculated, based on the daily mean temperature $t_x = 0.5 (t_{min} + t_{max})$ and the base temperature $t_b = 6$ °C. For t_{max} values exceeding 30 °C, t_{max} was set to 30 °C, if t_x was less than 6 °C, T_d was set to 0 °C. The relationship between temperature sum and KTS has been calibrated based on multi-year field experiments conducted from 1984 to 2004 (Hertwig and Schuppenies, 2008). Starting at the observed silking date, BBCH 65, independent of the hybrid, a temperature sum of 625 °C is required to achieve BBCH 87 and a KTS of 55%. The goodness of the model predictions was assessed by the root mean square error (RMSE) and the coefficient of correlation.

Results and discussion

The different model approaches were validated in two steps. First, a retrospective analysis revealed that for all sampling dates, including all approaches, it was possible to predict GTS and KTS of silage maize with a relatively small average difference of less than 0.5% compared to the measured DM contents. However, the KTS approaches showed a better agreement between observed and simulated values, as indicated by lower RMSE and higher correlation coefficient values (Table 1). There was only marginal impact of hybrid or of year on model performance (data not shown). For farmers, the predictive ability of the models in the period 3 to 4 weeks ahead of silage maturity (mid-August to the end of August) is the most relevant, since appointments with contractors are made then. Thus, in a second step, we evaluated the model performance for sampling dates in mid- or late August. As expected, the goodness of model-fit was less for the earlier date of prediction and a larger differentiation among the different model approaches became apparent. While the simulated whole crop DM contents deviated substantially from the observed values, satisfactory agreement was found for the cob DM content predicted by MaisProg-KTS, while best model-fit was achieved by PAGF-KTS. The better performance can be attributed to several reasons. First of all, PAGF-KTS simulations start at the observed silking dates instead of simulated silking as in MaisProg-KTS. Furthermore, PAGF-KTS was developed for the specific region of north-eastern Germany, while MaisProg was calibrated with data from all over Germany.

Conclusions

The better performance of the KTS-based approaches compared to MaisProg-GTS indicate that under the conditions of frequent summer droughts, the dynamics of stover DM content is difficult to reflect in model algorithms. For early prediction of silage maturity, which is interesting for the management of large farms with varying environmental conditions or where contractors do most of the harvesting,

Table 1. Results of model validation for MaisProg-GTS, MaisProg-KTS and PAGF-KTS, based on data collected at Paulinenaue, north-eastern Germany, during 2007 to 2014.¹

	DM content measured (%)	DM content predicted (%)	RMSE	Correlation coefficient
All dates of prediction (n=117)				
MaisProg-GTS	28.9	29.0	4.82	0.68
MaisProg-KTS	46.7	47.1	3.71	0.92
PAGF-KTS	46.7	46.4	2.81	0.96
Prediction late August (n=24)				
MaisProg-GTS	27.8	28.6	4.22	0.44
MaisProg-KTS	45.5	46.2	3.85	0.74
PAGF-KTS	45.5	45.1	2.50	0.92
Prediction mid August (n=24)				
MaisProg-GTS	24.8	26.0	3.26	0.42
MaisProg-KTS	38.6	39.1	4.83	0.71
PAGF-KTS	38.6	38.0	2.71	0.93

¹ DM = dry matter; PAGF = temperature-sum driven tool (predicting KTS); KTS = cob DM content; GTS = whole-crop DM content; RMSE = root mean square error.

visual assessment of silking date can improve prediction accuracy. This, however, will require more effort by farmers and/or advisers.

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