

## Risk assessment for frost killing of winter sugar beet by modeling the crown temperature

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### Introduction

The cultivation of sugar beet as a winter crop in Central Europe will require tolerance against severe frost. Despite a high risk for frost killing in large parts of Europe, high survival rates of August-sown crops were observed, if the taproot tissue temperature did not fall below a threshold value of -6 °C (Reinsdorf & Koch, 2013). The objectives of our study were (i) to develop a regression model that accurately estimates the temperature of the crown tissue from readily available weather data, (ii) to quantify the risk of frost killing for potential growing regions in Central Europe.

### Material & Methods

#### Field Trials

- 2 Sites: Göttingen, Lower Saxony, continental  
Kiel, Schleswig -Holstein, maritime
- 3 Years: 2009/10, 2010/11, 2011/12

#### Measurements

- Temperature during winter (air, soil, taproot tissue)
- Plant survival after winter

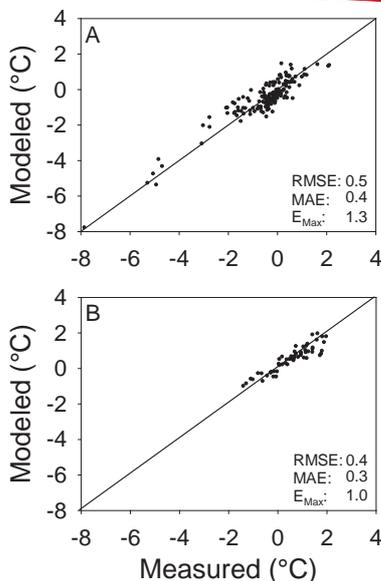
#### Risk assessment

- DWD weather data of winter seasons 1991/92 – 2010/11
- Growing regions: Göttingen (51°30'N, 9°57'E); Cologne (50°52'N, 7°10'E); Kiel (54°23'N, 10°09'E); Regensburg (49°03'N, 12°06'E)
- Frost killing occurrence:  $iR_{Min} < -6$  °C

#### Multiple linear regression analyses

- **Response** variable: daily minimum taproot tissue temperature,  $iR_{Min}$
- **Regressors**: daily mean air temperature,  $A_M$ ; yesterday's mean air temperature,  $A_M P1$ ; daily mean temperature at 5 cm soil depth,  $iS_M$ ; daily snow depth,  $SN$ ; 2-fold interactions
- **Data**: November - March incl. only those days with  $iS_M \leq 2$  °C; data splitting for model parameterization (n: 155) and validation (n: 156); additional independent data set for model validation (n: 56)

### Prediction Model



Model equation:

$$iR_{Min} = -0.46 + 0.71 iS_M + 0.14 A_M + 0.06 A_M P1 + 0.03 SN - 0.06 iS_M * A_M P1 + 0.01 A_M * A_M P1$$

- $iR_{Min}$  was accurately predicted from the weather parameters  $A_M$ ,  $A_M P1$ ,  $iS_M$ ,  $SN$  and its 2-fold interactions
- The prediction error at sub-zero temperatures was small
- $iR_{Min}$  tended to be overestimated
- Only few observations were below  $iR_{Min} = -2$  °C
- A bigger data base would further improve the accuracy of the model

**Figure 1.** Measured versus modeled  $iR_{Min}$  (A,B). Validation data set, n = 156 (A). Additional independent validation data set, n = 56 (B). RMSE, root mean squared error (°C). MAE, mean absolute error (°C).  $E_{Max}$ , maximum error (°C).

### Risk Assessment

**Table 1.** Number and percentage of years of frost killing ( $iR_{min} = -6$  °C) predicted for the winter seasons 1991/92 - 2010/11 at Cologne, Göttingen, Kiel and Regensburg. Numbers in brackets indicate predicted frost killing for the worst case scenario of systematically overestimating  $iR_{Min}$  by 1.3 °C ( $E_{Max}$ ).

	Cologne	Göttingen	Kiel	Regensburg
	----- 1991/92 – 2010/11 -----			
No. of frost killings	1 (2)	3 (7)	4 (5)	3 (7)
% of frost killing	5% (10%)	15% (35%)	20% (25%)	15% (35%)

Site	$iS_M$ (°C)	$A_M$ (°C)	$SN$ (cm)
Cologne	3.8 a	4.0 a	0.4 c
Göttingen	2.6 b	2.5 c	1.0 b
Kiel	2.7 b	2.8 b	1.2 b
Regensburg	1.7 c	0.9 d	2.9 a

**Table 2.** Average daily mean temperature of soil ( $iS_M$ ) and air ( $A_M$ ), and snow ( $SN$ ) depth from November to February 1991/92 - 2010/11

- Suitability for winter beet cultivation clearly differs between potential growing regions
- The risk for frost killing is much lower at locations with a mild winter climate compared to more continental European regions

### Conclusions

Frost killing of beet plants can be properly assessed with an easily applicable regression model, predicting the temperature of the taproot crown tissue from standard weather data. The long-term risk of sugar beet killing frost temperatures can be assessed from past weather data. Our investigations clearly show that a reliable site-specific assessment of the frost killing risk is a prerequisite for the farmer's decision on winter beet cultivation in temperate climate.