Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.
Development of a decision support system to determine the best maize (Zea mays. L) hybrid - planting date option under typical New Zealand management systems

A thesis presented in partial fulfilment of the requirements for the degree of

**Doctor of Philosophy**

in

Plant Science

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New Zealand

ROWLAND TSIMBA

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ABSTRACT

A study was conducted with the aim of developing a decision support tool in the form of a crop simulation model, to help New Zealand (NZ) farmers make informed hybrid-specific decisions to optimise maize (*Zea mays* L.) yields through selection of the best hybrid for a given planting date (PD) and location. Field experiments were established (2006-2007) in four environments (ENVs) to generate data to modify and evaluate the CERES-Maize model. Planting between 20 September and 13 October (Waikato) or 6 November (Manawatu) maximised grain yields while the respective PDs for achieving highest silage yields were 9-15 October or 23 October. Optimum PDs varied seasonally. For instance, a 1°C mean temperature (spring) decrease advanced optimum PD by 1-2 wk. A base temperature of 8°C (*T*_b8) led to adequate estimates of thermal durations for the pre-flowering phase while *T*_b0 was more satisfactory during grain filling.

After minor model modifications using Waikato and Manawatu field data, CERES-Maize was successfully adapted for NZ conditions. Maize yields were simulated across eight contrasting ENVs using 31 yr weather data (1978-2009). High irradiance and moderate temperatures during grain filling resulted in the highest yields. This coincided with 1-18 October PDs. Temperatures <18°C and >25°C and irradiance <17 MJ m⁻² d⁻¹ during grain filling significantly reduced yields. Low spring temperatures also reduced leaf expansion, minimising source capacity. Planting date windows to achieve ≥95% of yield maxima ranged from 1-7 wk. Silage crops, warmer ENVs or early hybrids had wider planting windows and less crop failure risk when planted late. With early or late planting, yield reductions were greater in higher latitude ENVs where spring and autumn temperatures and radiation were much lower. Due to higher assimilate demand, late hybrids were generally more stress prone, whereas early hybrids were sink limited.

A multiple-linear regression equation based on temperature and relative humidity was established to estimate field grain drydown. Another relationship based on the Gompertz model was also developed to estimate silage maturity using thermal time. These functions were used to enhance CERES-Maize’s ability to predict harvest maturity. To simplify data collection for the model, linear and non-linear models for relationships between tassel initiation and leaf number; total plant leaf area and area of the largest leaf; and leaf tip number and fully expanded leaves were also established.
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<th>Description</th>
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<tr>
<td>ADF</td>
<td>Acid detergent fibre</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
</tr>
<tr>
<td>ASI</td>
<td>Anthesis-silking interval</td>
</tr>
<tr>
<td>BOP</td>
<td>Bay of Plenty</td>
</tr>
<tr>
<td>CEC</td>
<td>Cation exchange capacity</td>
</tr>
<tr>
<td>CGR</td>
<td>Crop growth rate</td>
</tr>
<tr>
<td>CGR_{ES}</td>
<td>CGR for the emergence-silking interval</td>
</tr>
<tr>
<td>CGR_{SS}</td>
<td>CGR for the silking to silage harvest interval</td>
</tr>
<tr>
<td>CP</td>
<td>Crude protein</td>
</tr>
<tr>
<td>CRM</td>
<td>Comparative relative maturity</td>
</tr>
<tr>
<td>CV</td>
<td>Coefficient of variation</td>
</tr>
<tr>
<td>DM</td>
<td>Dry matter</td>
</tr>
<tr>
<td>dNDF</td>
<td>Digestible neutral detergent fibre</td>
</tr>
<tr>
<td>EL</td>
<td>Ear leaf</td>
</tr>
<tr>
<td>ENV</td>
<td>Environment</td>
</tr>
<tr>
<td>G2</td>
<td>Potential kernel number per plant</td>
</tr>
<tr>
<td>G3</td>
<td>Potential kernel growth rate under optimum conditions (mg d(^{-1}))</td>
</tr>
<tr>
<td>GY</td>
<td>Grain yield</td>
</tr>
<tr>
<td>HI</td>
<td>Harvest index</td>
</tr>
<tr>
<td>IPAR</td>
<td>Intercepted photosynthetically active radiation</td>
</tr>
<tr>
<td>k</td>
<td>Light extinction coefficient</td>
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<td>Leaf area</td>
</tr>
<tr>
<td>LAI</td>
<td>Leaf area index</td>
</tr>
<tr>
<td>LN</td>
<td>Leaf number</td>
</tr>
<tr>
<td>N</td>
<td>Nitrogen</td>
</tr>
<tr>
<td>NDF</td>
<td>Neutral detergent fibre</td>
</tr>
<tr>
<td>NIRS</td>
<td>Near-infrared spectroscopy</td>
</tr>
<tr>
<td>NIWA</td>
<td>National Institute of Water and Atmospheric Research</td>
</tr>
<tr>
<td>NZ</td>
<td>New Zealand</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>P1</td>
<td>Thermal time from emergence to end of juvenile phase</td>
</tr>
<tr>
<td>P2</td>
<td>Photoperiod sensitivity coefficient</td>
</tr>
<tr>
<td>P5</td>
<td>Thermal time from silking to physiological maturity</td>
</tr>
<tr>
<td>P&lt;sub&gt;c&lt;/sub&gt;</td>
<td>Critical value of daylength</td>
</tr>
<tr>
<td>PAR</td>
<td>Photosynthetically active radiation</td>
</tr>
<tr>
<td>PD</td>
<td>Planting date</td>
</tr>
<tr>
<td>PHINT</td>
<td>Phyllochron interval</td>
</tr>
<tr>
<td>PM</td>
<td>Physiological maturity</td>
</tr>
<tr>
<td>PRFT</td>
<td>Photosynthetic reduction factor</td>
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<tr>
<td>PTQ</td>
<td>Photothermal quotient</td>
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<tr>
<td>r</td>
<td>Correlation coefficient</td>
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<tr>
<td>R</td>
<td>Reproductive stage</td>
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<tr>
<td>r&lt;sup&gt;2&lt;/sup&gt;</td>
<td>Coefficient of determination</td>
</tr>
<tr>
<td>R&lt;sup&gt;2&lt;/sup&gt;</td>
<td>Coefficient of multiple determination</td>
</tr>
<tr>
<td>RGFIL</td>
<td>Grain growth rate</td>
</tr>
<tr>
<td>RMSE</td>
<td>Root mean square error</td>
</tr>
<tr>
<td>RUE</td>
<td>Radiation use efficiency</td>
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<tr>
<td>SE</td>
<td>Standard error</td>
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<tr>
<td>SLPF</td>
<td>Soil fertility factor</td>
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<tr>
<td>SY</td>
<td>Silage yield</td>
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<tr>
<td>T&lt;sub&gt;b&lt;/sub&gt;</td>
<td>Base temperature</td>
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<tr>
<td>TI</td>
<td>Tassel initiation</td>
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<tr>
<td>T&lt;sub&gt;max&lt;/sub&gt;</td>
<td>Daily maximum temperature</td>
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<tr>
<td>T&lt;sub&gt;min&lt;/sub&gt;</td>
<td>Daily minimum temperature</td>
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<tr>
<td>T&lt;sub&gt;ml&lt;/sub&gt;</td>
<td>Maximum lethal temperature</td>
</tr>
<tr>
<td>T&lt;sub&gt;opt&lt;/sub&gt;</td>
<td>Optimum temperature</td>
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<tr>
<td>TT</td>
<td>Thermal time</td>
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<tr>
<td>V</td>
<td>Vegetative stage</td>
</tr>
<tr>
<td>VE</td>
<td>Seedling emergence stage</td>
</tr>
<tr>
<td>Y&lt;sub&gt;c&lt;/sub&gt;</td>
<td>% Yield change from maximum</td>
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