Adaptation to future climate: vernalization time, day length and temperature as regulators of growth and yield formation in forage grasses

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NOFOCGRAN
The importance of forage grasses to Nordic agriculture

✓ The **cheapest** source of energy for ruminants
✓ **Well-adapted** to Nordic conditions, high yielding
✓ Every **Finn** eat 2-3 kg of silage/day ..
✓ 30-70% of cultivated area in Finland
Climate change and management

- Longer growing period
  = more harvests?
- Summer drought
  = major yield from the 1st and last harvests?
- Shorter winter, less snow cover
  = perennial ryegrass, festulolium?
  = less/more winterkill?
How many harvests?
Which species and genotypes?
## Experiments 2009-2013

<table>
<thead>
<tr>
<th>Growth chamber</th>
<th><strong>Species</strong></th>
<th><strong>Species</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vernalization, day length</strong> and yield formation – 1st harvest</td>
<td>Timothy (Southern - Northern origin)</td>
<td>Tiller types, heading date, vrn-genes</td>
</tr>
<tr>
<td><strong>Critical day length and temperature</strong> – 3rd harvest (5, 10, 15°C, 12 ja 14 h)</td>
<td>Timothy, perennial ryegrass, festulolium, meadow fescue (Southern – Northern origin)</td>
<td>Growth (height, tillers and leaves), WSC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Field</th>
<th><strong>Species</strong></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Winter hardiness and vernalization (2009-2013)</strong></td>
<td>Timothy, perennial ryegrass, festulolium, meadow fescue</td>
<td>Freezing tolerance LT50, heading date, tiller types, yield</td>
</tr>
<tr>
<td><strong>Fall growth (2013-14)</strong></td>
<td>Perennial ryegrass, festulolium, meadow fescue, timothy</td>
<td>Freezing tolerance LT50, WSC, yield (1-3 harvests and fall growth)</td>
</tr>
</tbody>
</table>
### Winter conditions 2009-2013 Helsinki

<table>
<thead>
<tr>
<th></th>
<th>2009-2010</th>
<th>2010-2011</th>
<th>2011-2012</th>
<th>2012-2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP length, days (2050, if only HP starts changes)</td>
<td>73</td>
<td>44</td>
<td>106</td>
<td>50</td>
</tr>
<tr>
<td>CDD5 accumulation during hardening period</td>
<td>103</td>
<td>59</td>
<td>141</td>
<td>60</td>
</tr>
<tr>
<td>CDD5 net accumulation during hardening period (= FH-COLD)**</td>
<td>70</td>
<td>36</td>
<td>58</td>
<td>15</td>
</tr>
<tr>
<td>Permanent snow cover</td>
<td>111</td>
<td>147</td>
<td>88</td>
<td>139</td>
</tr>
</tbody>
</table>

*CDD5 = cold degree days (0<T(°C)≤5)

**FH-COLD = ΣCDD5(HP) - ΣDD5(HP) (at the end of hardening period), where DD5 = degree days during hardening period using 5 °C as base temperature.

Korhonen et al. 2014
www.helsinki.fi/yliopisto
Nofocgran 2014
Samples to greenhouse once a month during winter 2009-2013

VIIKKI

Kuva: Juha Luhtanen

YLISTARO

Kuva: MTT Ylistaro
Freezing tolerance (LT50) timothy

<table>
<thead>
<tr>
<th>Year</th>
<th>CCD5</th>
<th>FH-COLD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009-10</td>
<td>103</td>
<td>70</td>
</tr>
<tr>
<td>2010-11</td>
<td>59</td>
<td>36</td>
</tr>
<tr>
<td>2011-12</td>
<td>141</td>
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</tr>
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<td>60</td>
<td>15</td>
</tr>
</tbody>
</table>
Development of vernalization in timothy
Variation in vernalization requirement in timothy – too long winters

✓ Genotypes of Southern origin do not have vernalization requirement
✓ Associated with faster development, better regrowth and lower winter hardiness
Yield formation in grasses

Vernalization synchronizes tiller development in spring, day length and temperature control growth and growth cessation in fall.

- **Spring yield**
  - ✔ Vernalized tillers
  - ✔ Rapid development and lignification
  - ✔ Quality can be predicted
  - ✔ Mainly GEN tillers (Virkajärvi et al. 2012)

- **Regrowth**
  - ✗ Non-vernalized tillers
  - ✗ Decreasing day length
  - ✗ Growth cessation, cold acclimation
  - ✗ Mainly VEG tillers, but significant proportion of ELON tillers (Virkajärvi et al. 2012)
Variation in vernalization response in timothy

Main tiller height (cm)
What if we want 3rd or 4th harvests in fall and still ensure good overwintering?

Shorter day length and warmer temperature in the future?
Growth at 15°C, 12 - 14 h DL

New variety, shorter DL requirement
Strong response to Shorter DL

Accumulation of biomass also in SD

Biomass (g)

BOR S  BOR N  Sleipnir  BOR 1  Grindstad

PRG S  PRG N  FL S  FL N

15 °C/12 h  15 °C/14 h
Low T and DL controls height growth in timothy

Other species, no height growth of non-vernalized tillers
Jokela ym. 2013
Physiol. Plantarum
Control of carbohydrate metabolism varies between species

<table>
<thead>
<tr>
<th></th>
<th>Start (mg/g)</th>
<th>12 h (mg/g)</th>
<th>14 h (mg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOR S</td>
<td>87.2 ± 1.7</td>
<td>22.2 ± 0.4</td>
<td>29.9 ± 1.8</td>
</tr>
<tr>
<td>BOR N</td>
<td>99.4 ± 2.9</td>
<td>93.4 ± 0.4</td>
<td>104.2 ± 1.4</td>
</tr>
<tr>
<td>Sleipnir</td>
<td>120.8 ± 0.3</td>
<td>46.2 ± 0.9</td>
<td>45.3 ± 0.5</td>
</tr>
<tr>
<td>BOR 1</td>
<td>81.1 ± 0.4</td>
<td>34.9 ± 0.2</td>
<td>37.4 ± 0.4</td>
</tr>
<tr>
<td>Grindstad</td>
<td>86.3 ± 9.1</td>
<td>34.4 ± 0.6</td>
<td>43.8 ± 1.5</td>
</tr>
<tr>
<td>PRG S</td>
<td>101.8 ± 2.4</td>
<td>7.0 ± 0.2</td>
<td>26.4 ± 0.4</td>
</tr>
<tr>
<td>PRG N</td>
<td>74.1 ± 3.1</td>
<td>10.1 ± 1.1</td>
<td>29.4 ± 0.1</td>
</tr>
<tr>
<td>FL S</td>
<td>57.6 ± 1.5</td>
<td>29.4 ± 0.2</td>
<td>59.2 ± 2.3</td>
</tr>
<tr>
<td>FL N</td>
<td>70.0 ± 0.2</td>
<td>21.0 ± 1.3</td>
<td>54.8 ± 1.0</td>
</tr>
<tr>
<td>FP E</td>
<td>81.7 ± 1.9</td>
<td>31.5 ± 0.4</td>
<td>54.1 ± 0.3</td>
</tr>
<tr>
<td>FP P</td>
<td>68.9 ± 0.5</td>
<td>19.3 ± 0.1</td>
<td>54.3 ± 2.7</td>
</tr>
</tbody>
</table>

Shorter daylength did not reduce WSC in timothy

Short day reduces WSC in PRG, FL and MF
Conclusions

- Genetic variation exists between and within species in important traits for adaptation
  - Winter hardiness
  - Vernalization requirement
  - Day length requirement
  - Response to elevated temperature
- What is the management strategy in the future?
  - How many harvests? When?
  - More pastures?
Kiitos!

Ministry of Agriculture and Forestry

NordForsk

Finnish cultural Foundation

Oiva Kuusisto Foundation

Boreal Plant Breeding Ltd