Pre-breeding in Forages on the Nordic Scene

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Agricultural University of Iceland
Outline of talk

• Does intraspecific genetic diversity matter in forage crops?
• Do we need to increase the genetic diversity in our breeding material?
• What has been done so far jointly in the Nordic region in the way of pre-breeding?
• How can we use material from pre-breeding projects?
• What about the future?
Does intraspecific genetic diversity matter in forage crops?
Intraspecific genetic diversity matters

- Diversity can improve yield stability in stressful and heterogeneous environments
- Landraces and natural ecotypes of grassland species generally contain ample intra-specific genetic variation.
- This allows for rapid adaptation to changing environmental conditions.
Engmo timothy from Northern Norway used to have superior winter survival in the north to Grindstad (landrace imported from Scotland in the 1860s):

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Engmo</td>
<td>75</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Grindstad</td>
<td>24</td>
<td>21</td>
<td></td>
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</table>

(From Schjelderup et al., Euphytica 1994)
Timothy from Northern Norway is no longer surviving best in the north!
Bodin and Vega: Northern cultivars

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</thead>
<tbody>
<tr>
<td>Bodin/Vega (t DM ha⁻¹)</td>
<td>8.5</td>
<td>9.3</td>
<td>8.3</td>
<td>8.8</td>
<td>10.8</td>
<td>11.3</td>
<td>10.0</td>
</tr>
<tr>
<td>Grindstad (Relative)</td>
<td>97</td>
<td>98</td>
<td>97</td>
<td>102</td>
<td>102</td>
<td>107</td>
<td>110</td>
</tr>
</tbody>
</table>

(Results from official variety testing. From A. Larsen via O.A. Rognli)

Reasons?
Genetic changes/adaptation in Grindstad?
Climatic changes in the north? Milder autumns stressing northern cultivars?
Do we need to increase the genetic diversity in our breeding material?
• Erosion of genetic diversity in sown grasslands as commercial cultivars have replaced landraces and natural ecotypes
  – DUS testing; small no. of parental genotypes
• This can restrict the adaptive potential in a changing climate and, thus, adaptive evolution.
• We need a broad genetic base in order to extend the cultivation of valuable species especially at the margin of their distribution.
What has been done so far jointly in the Nordic region in the way of pre-breeding?
Agroclimatic zones

- Makes it sensible to join forces across borders.
- SNP initiated (pre) breeding activities in forages for the north in 1981.

(From Hólmgeir Björnsson, 1993)
Common problems

• Short and variable growing season
• Winter damage
• Poor adaptation of grass cultivars bred for more southerly conditions.
• Small seed market, local breeding efforts uneconomical.
Extensive variety trials in the northern regions

<table>
<thead>
<tr>
<th></th>
<th>P. pratense</th>
<th>P. pratensis</th>
<th>F. pratensis</th>
<th>F. rubra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety (V)</td>
<td>896**</td>
<td>381***</td>
<td>3259***</td>
<td>22175***</td>
</tr>
<tr>
<td>V x Location (L)</td>
<td>356</td>
<td>2072***</td>
<td>1052***</td>
<td>2930***</td>
</tr>
<tr>
<td>VxY₁</td>
<td>668</td>
<td>810</td>
<td>1451***</td>
<td>4958***</td>
</tr>
<tr>
<td>LxVxY₁</td>
<td>415</td>
<td>1032***</td>
<td>427</td>
<td>1416*</td>
</tr>
<tr>
<td>VxY₂</td>
<td>278</td>
<td>2237***</td>
<td>816*</td>
<td>604</td>
</tr>
<tr>
<td>LxVxY₂</td>
<td>359*</td>
<td>1082***</td>
<td>344</td>
<td>1112</td>
</tr>
</tbody>
</table>
Common breeding of timothy

SNORRI
Registered 2006

Problem!
In common ownership
The main aim was to provide well-adapted breeding material with a wide genetic base for further cultivar development adapted to the northern regions.
Four different base populations:

• **A**: Commercial diploid varieties (10 populations)
• **B**: Diploid breeding material and wild populations from NGB (12 populations)
• **C**: Commercial tetraploid varieties (5 populations)
• **D**: Material with a broad genetic background (238 populations)
Breeding methods:

- Recurrent mass selection at four sites and under three different management treatments.
- Tandem selection under controlled conditions for resistance to frost and snow mould (*Microdochium nivale* and *Sclerotinia borealis*).
Output from NordKlöver
No. of breeding populations:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection in the field</td>
<td>28</td>
<td>10</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td><em>Fusarium</em> resistance</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><em>Sclerotinia</em> resistance</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Frost resistance</td>
<td>2</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>36</td>
<td>13</td>
<td>26</td>
<td>8</td>
</tr>
</tbody>
</table>

A total number of 83 populations
How can we use material from pre-breeding projects?
In further breeding: NordKlöver material at Graminor

- NordKlöver (NK) material used in 18% of pair crosses carried out by from 1998.
- At least 36 candivars currently under internal testing (Bjørke, Løken og Vågønes/Holt) contain NK material.
- Unclear at present whether they will become registered cultivars – have not reached there yet!
- “NK material is now a not insignificant part of our breeding material”

(Petter Marum, pers. comm., 8 February 2011)
In making ‘new landraces’

“On-farm conservation of the forage species timothy, meadow fescue and red clover – generation of new landraces in Norway”
Initiatied in 2003
• A seed mixture of the three composites used to establish plots at seven locations across Norway during 2007 and 2008.
• Meadows managed according to local practice.
• First seed harvested at five locations in 2010.
• Will be used to establish new meadows and made available for further research.
For biodiversity studies in forage ecosystems

NK material (D population) included in a multinational research collaboration (COST Action 852)
• Can composite populations provide a platform for further and sustained positive effects of mixing species?
• Do single varieties display a lower level of ‘within population’ genetic diversity than composite populations?
• Can composite populations adapt quickly to diverse environments?
Comparison of molecular diversity for the red clover cultivar Fanny and two composite populations (NK and Central European mixture)

<table>
<thead>
<tr>
<th>Population</th>
<th>Proportion of polymorphic loci</th>
<th>Gene diversity averaged over loci (Hj)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NK (D pop)</td>
<td>0.66</td>
<td>0.196</td>
</tr>
<tr>
<td>CE</td>
<td>0.65</td>
<td>0.201</td>
</tr>
<tr>
<td>Fanny</td>
<td>0.72</td>
<td>0.218</td>
</tr>
</tbody>
</table>

(From Collins et al., unpublished)
Survivor populations after three years of natural selection in Svalöf, Sweden

(From Collins et al., unpublished)
What about the future?
Future requirements in the Nordic region
Long term climate change

- Extended growth season combined with milder and rainier autumns and winters.
- Do we need exotic material into our current breeding stock – new genetic resources – for future cultivar development?

Temperature and precipitation change between 1980 to 1999 and 2080 to 2099, averaged over 21 models.

(Christensen et al., 2007. IPCC Report)
Current Nordic initiatives

- Phenotypic and molecular characterisation of genetic resources of Nordic timothy (NKJ)
- Climatic adaptation of different species and varieties of grass and clover in the West-Nordic countries (NORA)
Future requirements in the Nordic region
Short term
Increased profitability for farmers NOW
- More (reliable) DM yields and better forage quality
Nordic PPP on Pre-breeding

- Emphasis on improving forage quality
- Two proposals on the table:
  - To study how forage fibre quality can be improved to increase the value as high energy source for ruminants
  - To develop ONE selection index that is based on forage yield in kg DM and parameters of forage quality.
To be discussed further...