The role of genetic resources for sustainable and productive grassland agriculture

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Overview

- Introduction on plant genetic resources
- Characteristics of forage crop PGR
  - Red clover and Italian ryegrass
- Conservation of PGR
  - *Ex situ* and *in situ* conservation
- Value of permanent grassland as a reservoir of PGR
  - Ecotype populations of forage grasses

Conclusions
Introduction

PLANT GENETIC RESOURCES
Plant Genetic Resources - PGR

Definition

„The diversity of genetic material contained in traditional varieties and modern cultivars grown by farmers as well as crop wild relatives and other wild plant species that can be used for food, feed or other domestic and industrial purposes“

Significance

- Prerequisite for selection (human or natural) and the improvement of populations

- Targeted conservation and sustainable use of PGR is the key to improving agricultural productivity, food security and poverty alleviation (FAO, 1996)
Characterisation of PGR

Aims
- Identification of valuable variation (unique and / or useful)
- Minimising conservation efforts (core collections, removal of duplicates)

Methods
- Phenotypic characteristics (flowering time, growth characteristics…)
- Molecular genetic markers (isozymes, SSR, SNP)
CHARACTERISTICS OF FORAGE CROP PGR
PGR of forage crop species

- Co-existence of cultivated and wild forms of many grassland species (e.g. clover, ryegrass, fescue)
  - Wild forms that co-evolved with cultivated forms
  - Feral forms that originated from cultivated forms but escaped and persisted in the natural environment
  - Cultivars, landraces, ecotypes and wild populations form important PGR for forage crop species

- Generally high genetic variability within populations due to the out-crossing pollination system of many species

- For targeted utilisation of PGR, detailed knowledge on the structure of available PGR is indispensible
Red clover – origin and history

- Centre of origin: Mediterranean basin

- Grass-clover production spread from Flanders and Brabant (~1600) across Europe

- On-farm seed production
  - Landraces
  - Mattenklee

- Targeted breeding from 1920
Cultivars, landraces, wild populations

Swiss wild clover

Wild clover from Flanders and Brabant (Dutch wild clover)

Mattenklee landraces

‘Old cultivars’ from Flanders and Brabant (Dutch landraces)

Mattenklee cultivars

Field clover cultivars

Cultivars, landraces, wild populations
Molecular genetic characterisation

- 120 Red clover populations
  - Swiss wild clover populations (13)
  - Mattenklee landraces (89)
  - Mattenklee cultivars (6)
  - Dutch wild clover populations (4)
  - Dutch landraces (2)
  - Field clover cultivars (6)

- Genetic fingerprinting using 212 polymorphic AFLP markers
  - two bulked samples of 20 plants per population
  - Calculation of genetic distance, multivariate data analysis
Relationship among red clover groups

- Mattenklee landraces
- Mattenklee cultivars
- Field clover cultivars
- Dutch wild clover
- Dutch landraces
- Swiss wild clover

Nei’s genetic distances
Red clover

- Mattenklee landraces and Swiss wild clover populations are valuable genetic resources
- Ancestry of Mattenklee is rather found in introduced germplasm than in wild clover
- The close relationship between Mattenklee landraces and cultivars reflects breeding efforts

Cultivated and wild forms of red clover
- Co-evolved together
- Are clearly distinct
Origin and history of Italian ryegrass

Ryegrasses
- Centre of origin: Mediterranean basin
- Expansion from the fertile crescent 10’000 years ago

Italian ryegrass (*Lolium multiflorum* Lam.)
- Introduced to Northern Europe from Italy in the earlier 19th century
- Used intensively in leys for hey and silage production
- Ecotype populations in semi-natural, permanent grassland
Genetic diversity of Italian ryegrass

Aim
- Investigate the genetic diversity within and among ecotypes and cultivars of Italian ryegrass

Method
- Plant material
  - 12 ecotype populations from Swiss semi-natural grassland
  - 4 cultivars (Axis, Oryx CH; Abercomo UK; Barlizzi I)
  - 23 individuals per population
- Molecular genetic analyses
  - 24 SSR markers
  - Multivariate statistics
Genetic structure of Italian ryegrass populations

No distinct grouping of Italian ryegrass ecotype populations and cultivars
Italian ryegrass

- Generally high diversity within populations and low population differentiation
- Italian ryegrass ecotypes and cultivars in Switzerland seem to form one large genepool

Ecotypes of Italian ryegrass

- represent feral populations of cultivated forms rather than wild populations
- still present a valuable reservoir of genetic diversity for further improvement of Italian ryegrass cultivars
CONSERVATION OF PGR
Ex situ conservation of PGR

- Conservation in gene banks
  - Svalbard Global Seed Vault
    - Capacity for 4.5 mio seed samples
    - Underground in permafrost mountains

- Several major PGR collections for forage crops
  - More than 100’000 holdings
  - European Cooporative Programme for Plant Genetic Resources (ECPGR)
    - 7348 L. perenne and 1255 L. multiflorum accessions
    - Natural and wild populations under represented
    - Description often limited to passport data
**In situ** conservation of PGR

- **In situ** conservation of wild relatives, ecotypes and landraces in their natural environment

- Enabling genetic evolution by maintaining the environment which has driven the development of the distinctive properties of the PGR

- Particularly important for forage crop species
  - Co-existence of cultivated and natural forms
  - High need for adaptability of populations
Ecotype populations of forage grasses

- Exemplify the potential of natural selection
- Are a highly valuable source of genetic variation
  - Starting material for forage plant breeding
  - Genetic resources to rejuvenate the breeding material

... but little is known about

- genetic diversity among ecotype populations
- agronomic performance compared to current cultivars
- influence of characteristics of collection sites on diversity and agronomic potential of ecotype populations
VALUE OF PGR FROM PERMANENT GRASSLAND
Materials and Methods

- 20 ecotype populations and 4 cultivars of Italian ryegrass and meadow fescue

Map of Switzerland showing distribution of Meadow fescue and Italian ryegrass:
- Meadow fescue
- Italian ryegrass

Legend:
- MP: Plateau
- JU: Jura
- NA: Foothills of Northern Alps

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Materials and Methods

- Collection of >50 individual plants per population
  - Seed multiplication

- Analysis of genetic diversity
  - Molecular markers (SSRs)
  - Morphological descriptors
    - 60 plants / pop
    - 16 descriptors (UPOV)

- Agronomic evaluation
  - Plot trials: 2 locations, 3 replications, 2 harvest years, 5 cuts
  - Row trial: 1 high altitude location
Genetic diversity of meadow fescue

- **Morphological descriptors**

- **Separation: cultivars – ecotype populations (Factors 1 & 3)**

- **Separation: ecotypes of Swiss plateau – Northern foothills of Alps – Jura/Randen (Factor 2)**

- Congruent with SSR analysis
Genetic diversity of Italian ryegrass

- Morphological descriptors
- No clear separation of ecotype populations and cultivars
- No clear separation of ecotype populations
- Congruent with SSR analysis
Dry matter yield of Italian ryegrass

![Bar chart showing dry matter yield relative to trial mean of 100% for different cuts and years.](chart.png)

- **first full year (H1)**: 100 (n.s.), 98
- **2nd full year (H2)**: 101**, 96
- **first spring cut**: 101**, 94***
- **summer cuts**: 100*, 97

*Significance codes: * p < 0.1, ** p < 0.05, *** p < 0.01, n.s. = not significant.
Dry matter yield of meadow fescue

DM yield relative, trial mean=100 %

- first full year (H1)
- 2nd full year (H2)
- first spring cut
- summer cuts

<table>
<thead>
<tr>
<th></th>
<th>1st full year</th>
<th>2nd full year</th>
<th>First spring cut</th>
<th>Summer cuts</th>
</tr>
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<tbody>
<tr>
<td>H1</td>
<td>98</td>
<td>96</td>
<td>97</td>
<td>97</td>
</tr>
<tr>
<td>H2</td>
<td>111</td>
<td>122</td>
<td>111</td>
<td>121</td>
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*** indicates statistical significance at the 0.001 level.
Agronomic performance

- Agronomic performance of ecotype populations is comparable to that of cultivars
  - Some Italian ryegrass ecotypes clearly outperform cultivars
  - Average performance of meadow fescue ecotypes does not reach cultivars but is highly variable
  - Disease resistance and spring growth is promising for many ecotype populations and justifies their use in breeding

- Significant ecotype population x location interaction suggest strong adaptation of meadow fescue to specific environments which is also reflected in the distinct genetic relationships among populations
Valuable sites for *in situ* conservation

Temperature  
Soil moisture  
Irradiance  
Fertilization  
Cutting regime  
Grazing regime

Environment  
Management

Grassland species  
Forage plant genotypes

Long term natural selection

Typical association of species  
Typical population of genotypes

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## Influence of botanical composition

Ecotypes from meadows with lower nature value perform agronomically superior

<table>
<thead>
<tr>
<th>Management</th>
<th>Associations</th>
<th>Italian ryegrass</th>
<th>Meadow fescue</th>
</tr>
</thead>
<tbody>
<tr>
<td>over-intensive</td>
<td>Poa trivialis-Ranunculetum repentis</td>
<td>2 0.60</td>
<td>4 -1.14</td>
</tr>
<tr>
<td>very intensive</td>
<td>Lolietum multiflori</td>
<td>5 0.53</td>
<td>5 -0.95</td>
</tr>
<tr>
<td>intensive</td>
<td>Trifolio repentis-Alopecuretum</td>
<td>2 0.20</td>
<td></td>
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<tr>
<td>rather intensive</td>
<td>Dactylis-Heracleum meadow (Arrhenatherion)</td>
<td>6 -0.11</td>
<td>4 -1.14</td>
</tr>
<tr>
<td>rather extensive</td>
<td>Lolio perennis-Arrhenatheretum</td>
<td>4 0.01</td>
<td>5 -0.95</td>
</tr>
<tr>
<td>extensive</td>
<td>Festuca-Agroston</td>
<td>4 0.01</td>
<td>5 -0.95</td>
</tr>
<tr>
<td>very extensive</td>
<td>Mesobromion</td>
<td>7 -1.91</td>
<td>7 -1.91</td>
</tr>
</tbody>
</table>

1) Positive (favourable) difference to mean of cultivars; > 0.2 = threshold for recommendation
CONCLUSIONS
Conservation of valuable plant genetic resources both ex situ in gene banks and in situ in grassland habitats is essential for sustainable and productive grassland agriculture.

Permanent grassland provide valuable reservoirs of genetic resources for breeding and conservation of biodiversity.

Nutrient poor, extensively utilized sites are of high value for the conservation of biodiversity but tend to harbour ecotypes of forage species of lower agronomical value.

Efforts to conserve genetic resources in permanent grassland should therefore include nutrient rich, intensively utilized sites.
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