Chapter 29
Recent Achievements in Breeding for Turf Quality Under Biotic and Abiotic Stress

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Abstract The genetic gain from breeding of turf varieties of *Festuca rubra*, *Poa pratensis, Lolium perenne* was assessed using data from 204 candivars entered into Norwegian/SCANTURF variety (VCU) testing from 1986 to 2007, and 675 varieties entered into the French/GEVES variety testing from 1982 to 2010. Among the three subspecies of *Festuca rubra*, ssp. *litoralis* and ssp. *rubra s*howed the strongest improvements in overall turf quality in the Nordic (0.67 % per year) and GEVES programs (0.99 % per year), respectively. The main reasons for these improvements were better winter hardiness and resistance to *Microdochium nivale* in ssp. *litoralis* and better persistency associated with higher tiller density in ssp. *rubra*. For *Poa pratensis* there was no gain in turf quality in France, but a significant improvement (0.94 % per year) associated with higher density, finer leaves and less height growth in the Nordic program, which, unlike the GEVES trials, included trials at low (10–20 mm) mowing height. *Lolium perenne* showed significant improvement in both programs and all characters studied, but the progress was smaller for persistency, overall winter hardiness and resistance to red thread than for tiller density, wear tolerance and tolerance to rust.

Keywords Kentucky bluegrass • Perennial ryegrass • Red fescue • Turf quality • Variety testing

Introduction

Breeding of cool-season grasses for turf started after World War II and was intensified with the introduction of Plant Breeders Rights and the initiation of programs for systematic evaluation and publication of national variety lists in the 1960s (van

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Wijk 1993; Casler 2006; Sampoux et al. 2012). The activity of the publically funded testing programs reached a maximum in the 1980s. Since then, public funding of variety testing has mostly been withdrawn as the European Union only requires testing for Distinctness, Uniformity and Stability (DUS-criteria), and no documentation of the Value of Cultivation and Use (VCU-criteria) for inclusion on the common European list.

When variety testing started in the 1960s, most so-called 'turf' varieties were chosen based on seed availability and agricultural merit. It is therefore not surprising that significant improvements in typical turf characteristics such as tiller density, leaf fineness and height growth (leaf extension rate) were made during the first two to three decades of turfgrass breeding (Van Wijk 1993). For perennial ryegrass (*Lolium perenne* L.), Sampoux et al. (2012) recently documented that this progress had continued for varieties released after 1990. For other species there is less documentation of genetic progress over the past 25 years.

Based on results from the Norwegian/SCANTURF and GEVES testing networks, the objective of this paper is to document and discuss improvements in variety performance of the most important cool-season turfgrasses in two contrasting climatic regions during the period 1982–2012. Although data on disease resistance was not available from the Nordic region, the title of the paper reflects the increasing importance of biotic and abiotic stress tolerance in turfgrass breeding and evaluation programs.

Materials and Methods

The best way to evaluate genetic improvements by plant breeding is to compare in the same field trials the performance of varieties released over an extended period of time. To the best of our knowledge, the only study taking this precise, but expensive approach is the study by Sampoux et al. (2012) on perennial ryegrass. For the purpose of this paper, we took a different, yet commonly used approach (e.g. van Wijk 1993; Duller et al. 2010), i.e. to reexamine data from individual variety trials succeeding one another, but with the same variety/varieties included as control(s).

Data from the Nordic Region

In 1986, 1990, 1995 and 1999, publically-funded turfgrass variety trials in red fescue (*Festuca rubra* L., including three subspecies), Kentucky bluegrass (*Poa pratensis* L.) and perennial ryegrass were established at five sites in Norway. There were also a few entries of colonial bentgrass (*Agrostis capillaris* L.), hard fescue (*Festuca trachyphylla* Hack.), sheep's fescue (*Festuca ovina* L.) and tufted hairgrass (*Deschampsia cespitosa* L.), but too few to evaluate genetic progress. Varieties were rated in the sowing year plus three evaluation years, both in ordinary lawn trials with a mowing height of 3–4 cm and an annual fertilizer input of 120–180 kg ha^{-1} of N (all five sites), and in a short-cut lawn trial with a mowing height of 10–20 mm

Table 29.1 Number of entries (excluding controls) in Norwegian and SCANTURF varieties trials seeded from 1986 to 2007

	Norwegian testing					SCANTURF		
	1986	1990	1995	1999	2003	2005	2007	Total
Chewings fescue	8	15	5	6	5	9	8	56
Slender creeping red fescue	7	2	3	1	1	3	3	20
Strong creeping red fescue	6	6	8	2	3	2	1	28
Kentucky bluegrass	15	15	9	5	7	5	2	58
Perennial ryegrass	7	6	6	8	3	6	6	42
Total	43	44	31	22	19	25	20	204

(one site only). The characters used for calculation of genetic progress were overall turf quality (visual merit, scale 1–9, where 9 is best turf), tiller density (scale 1–9, where 9 is highest density), leaf fineness (scale 1–9, where 9 is finest leaves), summer color (darkness, scale 1–9 where 9 is darkest turf), height growth (cm per season) and winter damage (percent of plot area; this includes both winter diseases and abiotic winter damage). In the last round of this national program seeded in 2003, the number of test sites was reduced from five to two and the low-cut trial was sacrificed for cost reasons.

Since 2005, turfgrass testing for the five countries Finland, Sweden, Denmark, Iceland and Norway is carried out through the joint SCANTURF program. Unlike the former national programs, SCANTURF is funded entirely by entrance fees. In the test rounds starting 2005 and 2007, from which data have been used for this paper, the program included seven trial sites throughout the Nordic region. Two of the seven trials were cut at fairway mowing height (15 mm), the others at 3–4 cm. Species, turfgrass maintenance and assessments were the same as in the former Norwegian program. See www.scanturf.org for more information.

From 1986 to 2007, a total of 204 new varieties (excluding controls) of the five species/subspecies were entered into the trials (Table 29.1). The highest numbers were entered in 1986 and 1990. Unlike in most other European testing programs, the highest numbers were not of perennial ryegrass, but of chewings fescue (*F. rubra* ssp. *commutata*) and Kentucky bluegrass. This reflects the importance of winter-hardy species for the Nordic region.

Control varieties of red fescue and Kentucky bluegrass in all trials were ‘Center’ and ‘Conni’, respectively. These varieties were top-ranked in Norwegian testing from 1981 to 1985 and soon became among the most widely used turfgrass varieties in the Nordic countries. ‘Center’ was used as reference also for slender and strong creeping red fescue (*F. rubra* ssp. *litoralis* (syn. *trichophylla*) and *F. rubra* ssp. *rubra*, respectively) as these subspecies did not have any checks in the trials starting 1986. Unfortunately the same continuity in use of one specific control variety did not exist in perennial ryegrass. In the first trials, candidates were compared mainly with ‘Barclay’, later mainly with ‘Mondial’, and in the SCANTURF trials mainly with ‘Ronja’. Overlaps between control varieties in the different trials nevertheless allowed us to establish a secure reference level for perennial ryegrass.

To estimate genetic gain in various characters, we calculated relative figures with the control variety reference level as 100. These relative figures were related to the

Table 29.2 Number of entries (excluding controls) in GEVES variety trials seeded from 1982 to 2010

	1982–1985	1986–1990	1991–1995	1996–2000	2001–2005	2006–2010	Total
Perennial ryegrass	16	55	78	55	53	58	313
Kentucky bluegrass	7	27	23	9	14	7	87
Chewings fescue	4	23	18	24	16	17	102
Strong creeping red fescue	5	15	24	24	17	16	101
Slender creeping red fescue	3	17	14	13	15	10	72
Total	35	137	155	125	115	108	675

starting year of the different trials using simple linear regression. Regression slopes (=genetic progress) were presented when correlations were significant at $P<0.05$.

Data from France

Contrary to other national authorities in Europe, GEVES maintains VCU testing as a criterion for inclusion on the French list of turfgrass varieties. For this paper we used results from VCU trials starting every year from 1982 to 2010. In 2008 the GEVES network was extended to include test sites in Spain (Mediterranean zone), Ireland (oceanic zone), Netherlands and Germany (Sub continental zone), Hungary (continental zone) and Norway (Nordic zone) (Lassalvy et al. 2012). Thus, the number of sites varied from six in 1983 to fourteen in 2010. A total 675 varieties were evaluated, almost half of them perennial ryegrass (Table 29.2).

Unlike the Nordic trials, GEVES trials were only evaluated for 2 years after the sowing year. Characters recorded were mostly the same, but there was no assessment of overall winter damage or turf height growth in the GEVES trials. In return, the GEVES protocol included persistency by the end of the each trial, tolerance to football-type wear, establishment rate (turf coverage 2 months after sowing) and tolerance to the most important turfgrass diseases. In this paper, these characters will be emphasized in order to complement data from the Nordic region. Contrary to the Norwegian/SCANTURF trials, where turfgrass height growth and winter damage were recorded in absolute terms (high value = poor performance), disease resistance in the GEVES trials was always evaluated on a scale from 1 to 9, where 9 is the most resistant turf.

The set of control varieties in the GEVES trials was not constant from 1982 to 2010 in any of the species. There were, however, always overlaps allowing us to estimate missing values for control varieties that were not included in a specific year. To estimate genetic gain in various characters, we calculated relative figures with the mean of control varieties used in the 1995 trials as 100. These varieties were chewings fescue ‘Enjoy’, slender creeping red fescue ‘Dawson’ and ‘Manoir’, strong creeping red fescue ‘Ensylva’ and ‘Pernille’, Kentuky bluegrass ‘Broadway’ and ‘Parade’, and perennial ryegrass ‘Numan’, ‘Repell’ and ‘Troubadour’.

Results and Discussion

Red Fescue

Low requirements for fertilizers, irrigation and fungicides makes red fescue an appropriate species for sustainable and Integrated Pest Management (IPM) of turfgrass areas. This is especially relevant in relation to EU directive 2009/128/EG which calls for a strong reduction or even prohibition of pesticide use in certain turfgrass areas (Strandberg et al. 2012). Major constraint limiting expanded use of red fescue has been the species' limited tolerance to heat and wear (Rummele et al. 2003). Among the three subspecies, chewings fescue has traditionally been the most popular in the Nordic countries as it represents the best combination of good winter survival, disease resistance and high density, while strong creeping red fescue has been the most widely used i southern Europe due to better color retention during summer drought.

There are conflicting results among the two test regions regarding genetic improvement in the three subspecies of red fescue. For the Nordic region (Table 29.3a) a significant increase in turf quality was achieved only in slender creeping red fescue and this was accompanied by equally significant increases in tiller density and reductions in winter damage. In 1986, varieties of slender creeping red fescue were, on average, 13 % behind chewings fescue 'Center' in turf quality, but in 2007 they were only 3 % behind.

In contrast to the results from the Nordic region, both the present results from GEVES (Table 29.3b) and those reported for the period 1975–92 (van Wijk 1993), suggest stronger improvements in turf quality and persistency for strong creeping red fescue than for the two other subspecies.

This probably reflects that different aspects contribute to persistency in climatically different regions. In the Nordic countries it is undoubtedly winterhardiness, including tolerance to pink snow mold (*Microdochium nivale*), which is in agreement with Table 29.2b showing significant improvements in this character only for the slender creeping type of red fescue. In France persistency is probably more related to tiller density, as discussed by Sampoux et al. (2012) for perennial ryegrass. The significant reduction in tolerance to red thread (*Laetisaria fuciformis*) among strong creeping red fescue varieties in the GEVES trials is probably also a reflection of the increase in tiller density of this subspecies.

Kentucky Bluegrass

Because of its winter hardiness and persistency, Kentucky bluegrass has always been a widely-used species in the Nordic region. Due to apomixis, breeding of Kentucky bluegrass is, however, more complicated and less predictable than for outcrossing grasses (e.g. Funk 2000), and the falling number of varieties submitted for

Table 29.3a Simple correlation coefficients between year of entry into variety testing and scores for turfgrass characters relative to control varieties in Norwegian/SCANTURF trials 1986–2007

Norway/SCANTURF	Visual turf quality	Tiller density	Leaf fineness	Summer color	Turf height growth	Winter damage
Chewings fescue						
Correlation	0.17 ns	0.30*	–0.14 ns	–0.10 ns	–0.29*	–0.58***
Annual change	–	0.25 %	–	–	–0.29	–5 %
Slender creeping red fescue						
Correlation	0.78***	0.79***	0.39 ns	0.37 ns	–0.44 ns	–0.74***
Annual change	0.67 %	0.76 %	–	–	–	–17 %
Strong creeping red fescue						
Correlation	0.19 ns	0.12 ns	0.07 ns	0.12 ns	–0.30 ns	–0.44**
Annual change	–	–	–	–	–	–7 %
Kentucky bluegrass						
Correlation	0.72***	0.56***	0.43***	0.16 ns	–0.54***	–0.05 ns
Annual change	0.94 %	0.64 %	0.50 %	–	–0.61 %	–
Perennial ryegrass						
Correlation	0.66***	0.68***	0.42***	0.59***	–0.58***	–0.34*
Annual change	0.64 %	0.80 %	0.53 %	0.72 %	–0.83 %	–2 %

Annual changes (%) (=slope of regression) was indicated for correlations significant at $P<0.05$

Table 29.3b Simple correlation coefficients between year of entry into variety testing and scores for turfgrass characters relative to control varieties in GEVES trials 1982–2009

GEVES	Visual turf quality	Establishment rate	Wear tolerance	Persist-ency	Toler-ance to rust	Toler-ance to *M.nivale*	Tolerance to red thread
Chewings fescue							
Correlation	0.67***	0.18 ns	0.43***	0.31**	0.26*	0.12 ns	0.25*
Annual change	0.50 %	–	0.75 %	0.17 %	0.25 %	–	0.12 %
Slender creeping red fescue							
Correlation	0.65***	0.27*	0.42***	–0.23 ns	0.11 ns	0.46***	0.22 ns
Annual change	0.52 %	0.21 %	0.85 %	–	–	0.60 %	–
Strong creeping red fescue							
Correlation	0.82***	0.57***	0.58***	0.71***	0.22*	0.01 ns	–0.40***
Annual change	0.99 %	0.59 %	1.14 %	1.01 %	0.24 %	–	–0.29 %
Kentucky bluegrass							
Correlation	0.07 ns	–0.07 ns	–0.12 ns	–0.24*	0.20 ns	–0.05 ns	–0.28 ns
Annual change	–	–	–	–0.41 %	–	–	–0.10 %
Perennial ryegrass							
Correlation	0.80***	0.61***	0.65***	0.32***	0.62***	0.47***	0.21***
Annual change	0.74 %	0.27 %	0.54 %	0.20 %	0.93 %	0.68 %	0.09 %

Annual changes (%) (=slope of regression) was indicated for correlations significant at $P<0.05$
Significance levels:***: $P<0.001$, **:$P<0.01$, *:$P<0.05$, ns: not significant

testing in the Nordic region (Table 29.1) may perhaps be taken as an indication of a shift in breeding investments to other species. For southern parts of Europe, this is also confirmed by the results from GEVES showing virtually no gain in overall turf quality and even negative trends for some of the specific characters (Table 29.3b). Another explanation for this lack of progress may be the excellent variety 'Cocktail' which was registered by GEVES in 1991 and later included as a control variety.

Unlike GEVES, Nordic testing shows improvements in turf quality, tiller density, leaf fineness and height growth of Kentucky bluegrass on level with those in perennial ryegrass (Table 29.3a). For the best varieties, these improvements seem to be more prevalent in the trials with mowing height 2 cm or lower than in the ordinary lawn trials cut at 3–4 cm. When 'Limousine' was first introduced in Norwegian variety testing in 1990, it was more or less in a class of its own, but since 2005, it has been accompanied by other high-density, fine-leaved varieties such as 'Kaitos', 'Linares' and several others. However, as suggested by the negative trend in persistency in the GEVES trials, it may be speculated that many of the newer varieties are not particularly adapted to the heat, drought and biotic stresses encountered at lower latitudes. From North America, there is evidence that even 'dwarf' varieties of Kentucky bluegrass become more susceptible to *Drecslera* leaf spot and rust if mowing heights are reduced below 2 cm (Ebdon 2008; Jordan and Lyons 2010).

Perennial Ryegrass

With a European seed consumption of 33,000 t (Sampoux et al. 2012) it is not surprising that more efforts are put into breeding of perennial ryegrass than of any other species. Numerous varieties are released every year, and both the Nordic and GEVES testing programs showed significant improvements in turf quality, tiller density, leaf fineness, height growth, wear tolerance and rust tolerance as also reported by Duller et al. (2010), Nijenstein (2010) and Sampoux et al. (2012). Unlike the other species, the Nordic trials also suggest that perennial ryegrass varieties have, on average, become darker, although this trend, inspired from North America (Thorogood 2003) is not necessarily an advantage in lawns, fairways and sports fields that tend to be invaded by light-colored annual bluegrass (*Poa annua*). More importantly, the GEVES trials suggest a significant gain in persistency and tolerance to *M.nivale*, and the Nordic trials suggest a gain in winter hardiness, although these improvements were smaller than for the aforementioned characters. In spite of indications that improved turfgrass varieties with shorter subcrown internode lengths have better frost tolerance than old varieties with longer internodes (Casler 2006), most evidence to date shows little or no improvement in the winter hardiness of perennial ryegrass (van Wijk 1993; Thorogood 2003; Sampoux et al. 2012). Winter hardiness is indeed a complex trait involving tolerance to both abiotic and biotic stresses (Thorogood 2003), but research is underway detecting quantitative trait loci (QTLs) and associated physiological mechanisms that may eventually lead to improved winter hardiness in this species (DaCosta et al. 2011; Hulke et al. 2012; Rognli 2013). A different and perhaps faster approach is the introduction of tetraploid turf type ryegrasses. Such varieties do not have the same density and leaf fineness as diploid varieties, but preliminary SCANTURF observations in spring 2013. showed the tetraploid variety 'Double' to be more tolerant to gray snow mold (*Typhula incarnata*) than its diploid counterparts.

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