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SCANTURF - Evaluation of turfgrass varieties for lawns and sports grounds in Scandinavia

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Abstract

SCANTURF is a joint Nordic programme for turfgrass variety testing, set up in 2005 and funded by variety entrance fees only. It replaced and simplified the former government-funded national evaluation programmes in Finland, Sweden, Denmark and Norway. The programme includes testing of all cool-season grasses on lawn/fairways at 15–20 mm mowing height ("lawn trials") and optional testing of *Poa pratensis* L. and *Lolium perenne* L. on simulated football pitches with wear, mowed at 30 mm ("wear trials"). Since 2013, the program has regarded the Nordic countries as one trial zone with three test sites: Tystofte Denmark (55°15′ N, 11°20′ E), Landvik, Norway (58°21' N, 8°32' E) and Ylistaro, Finland (62°57′ N, 22°31' E). Wear trials are carried out at the intermediate location Landvik only. Candidate varieties are tested against two reference varieties of the same species or subspecies. In the lawn trials, candidate varieties are evaluated for visual merit (overall turfgrass quality), winter damage, winter color, diseases and daily height growth at all three locations and for tiller density, fineness of leaves, in-season (genetic) color, at Landvik only. Based on the results from the SCANTURF trials in 2014–2016 and 2016–2018, the candidate varieties Fabian, Tetrastar, Annecy, and Monroe (*Lolium perenne*), Becca, Harmonie, Traction, and Markus (*Poa pratensis*) and Lystig, Greenmile, and Humboldt (*Festuca rubra* ssp. *commutata*) were recommended for lawns in the Nordic countries, while Eurocordus, Columbine, Monroe, and Annecy (*Lolium perenne*) and Harmonie (*Poa pratensis*) were recommended for sports grounds. More use of the recommended varieties will have a positive effect on quality of lawns and sport grounds in the Nordic countries. Less winter injury and increasing relative performance with increasing latitude of the tetraploid perennial ryegrass variety Fabian in the lawn trials may possibly lead to more use of perennial ryegrass in the northern and more continental parts of the region.

1 | INTRODUCTION

Testing of turfgrass varieties for lawns and sport grounds are carried out in North America (NTEP, 2020), UK (BSPB/STRI, 2020), France (GEVES, 2020), Germany (FBVO, 2020) and several other countries. However, there are several climatic and regulatory aspects that support the need of a specific variety testing programme for the Nordic countries. One consideration is the unique light conditions with photoperiods (including twilight) of 19–24 h in the middle of

TABLE 1 Estimated seed consumption[a] (tonnes) of various turfgrass species in the Nordic countries

	Denmark	Sweden	Norway	Finland	Iceland	Total
Lolium perenne (perennial ryegrass)	750	150	55	66	25	1046
Other *Lolium* spp.	-	-	<1	8	-	8
Poa pratensis (smooth stalked meadowgrass)	260	250	180	244	15	949
Other *Poa* spp.	9	15	<1	5	-	29
Festuca rubra (red fescue)	972	950	570	706	10	3208
Festuca ovina (sheep fecue)	-	4	9	2	-	15
Festuca brevipila (hard fescue)	30	23	4	10	-	67
Festuca arundinacea (tall fescue)	-	-	0	1	-	1
Agrostis canina (velvet bentgrass)	18[2]	-	<1	2	-	52[b]
Agrostis capillaris (common bentgrass)		4	11	3	-	
Agrostis stolonifera (creeping bentgrass)		4	2	8	-	
Deschampsia cespitosa (Tufted hairgrass)	-	-	<1	1	-	1
Total	2039	1400	831	1056	50	5376

[a]Estimations based on contact with seed companies / turfgrass specialists in the various countries.
[b]Total for all *Agrostis*-species.

the summer and low sun inclinations casting long shadows in autumn. Scandinavian winters may also cause severe winter injury, although these problems depend on latitude and coastal proximity. The Nordic countries also have a very restricted access to pesticides, emphasising the importance of varieties that are competitive with weeds and are resistant or tolerant to common pests.

In total, the annual demand for seed of turfgrass varieties in the five Nordic countries is estimated to be 5,000–6,000 tonnes. Of the various turfgrass species, the demand is greatest for *Festuca rubra* L., followed by *Lolium perenne and Poa pratensis* (Table 1). Based on the statistics in Table 1, trialling these species is most important.

Evaluation of new varieties for lawn and sports grounds has a long tradition in the Nordic countries. At its peak in the 1980s and early 1990s, a total of 21 different test sites were used for the national evaluation of turfgrass varieties in Finland, Sweden, Denmark and Norway (Aamlid et al., 2019). However, as governmental funding faded out in the late 1990s and early 2000s, the national testing programmes were discontinued. In response to this, an initiative was taken in 2005 by the turfgrass seed industry and researchers in Denmark, Sweden, Finland, Iceland and Norway for a new joint Scandinavian testing programme, called SCANTURF. With no government funding, the programme had to rely entirely on funding by the turfgrass seed industry, with revenue dependent on the annual number of varieties entered.

In the initial period from 2005 to 2011, the SCANTURF testing programme was divided into two climatic zones, one southern/coastal and one northern/inland zone, with two test sites in each zone as further described for variety testing on golf greens (SCANGREEN) by Aamlid et al. (2015) and

Aamlid et al. (2019). In addition to climatic and demographical considerations (e.g. Yan et al., 2011), the importance of having highly qualified personnel to carry out the assessments was emphasised when selecting test sites. However, in agreement with the seed industry on a cost reduction strategy, the programme was reduced from four to three test sites in 2013, now considering the five Nordic countries as one trial zone. When reducing test sites, the seed industry suggested to maintain two sites in the former southern/coastal zone, but only one test site in the former northern/inland zone because of lower seed sales. With the introduction of one common Nordic test zone, the importance for recommended varieties to perform well at all trial sites, regardless of climatic conditions, was emphasised.

Included in the SCANTURF programme is testing for short-mowed lawns (fairways, mowing height 15–20 mm; hereafter referred to as "lawn trials") and optional testing of turfgrasses exposed to football-type wear (mowing height of 25–30 mm; hereafter referred to as "wear trials"). The testing period is one seeding year plus three evaluation years, with new trials starting every second year (2017, 2019, 2021, etc.).

For each species/subspecies, all entered varieties are scored for several characters and ranked on the SCANTURF variety list (www.scanturf.org) according to their performance relative to a common control variety. The SCANTURF lists not only include varieties that have been tested since the programme started in 2005, but also varieties that are still on the market after being tested in the former national programmes. Each year the SCANTURF lists are updated both with rankings of new varieties and by removal of varieties that have been withdrawn or are no longer on the market. In addition,

updated information about the seed availability status for each variety is presented.

The present paper reports on results from SCANTURF variety testing after the five Nordic countries were considered as one trial zone, i.e. trials established in 2013 (evaluated in 2014–2016) and 2015 (evaluated in 2016–2018). Our objective was to clarify which varieties are best suited for use on lawn and sports grounds in the Nordic countries.

2 | MATERIALS AND METHODS

2.1 | Varieties included, test locations and climatic conditions

A total of 13 and 12 candidate varieties, representing five and four different species/subspecies, were entered by the variety owners into the SCANTURF lawn and wear testing programme and evaluated during 2014–2016 and 2016–2018, respectively (Table 2).

Testing of lawn characteristics were carried out at Tystofte, Denmark (55°15' N, 11°20' E), Landvik, Norway (58°21' N, 8°32' E) and Ylistaro, Finland (62°57' N, 22°31' E) (Figure 1) while testing for wear tolerance took place in separate trials at Landvik only.

The southernmost costal location, Tystofte, normally has higher temperatures during autumn and winter than Landvik and especially the northernmost inland location, Ylistaro. Of the three locations, Landvik normally receives more precipitation, especially during autumn, than Tystofte and Ylistaro (more than twice as much on a yearly basis) (Figure 2). During winter, snow cover varies from mostly absent at Tystofte, to unstable at Landvik and stable at Ylistaro.

FIGURE 1 Map showing the experimental locations at Landvik (Norway), Tystofte (Denmark) and Ylistaro (Finland)

2.2 | Sowing and management in establishment year

All varieties were established according to a randomised block design with three replications and a plot size of 1.7 to 2.3 m^2. Soil types were sand at Landvik and sandy loam at

TABLE 2 Candidate and control (c) varieties included in the lawn (all species) and wear (only *Lolium perenne* and *Poa pratensis*) trials during 2014–2016 and 2016–2018

Evaluation period	*Lolium perenne*	*Poa pratensis*	*Festuca rubra* ssp. *commutata*	*Festuca rubra* ssp. *littoralis*	*Festuca rubra* ssp. *rubra*
	Bargold (2x) (c)	Conni (c)	Musica (c)	Barcrown (c)	Rossinante (c)
	Vesuvius (2x) (c)	Limousine (c)	Calliope (c)	Cezanne (c)	Frigg (c)
2014–2016	Fabian (4x)	Harmonie	Greenmile	Tadorna	Barjessica
	Columbine (2x)	Sombrero	Humboldt		
	Jubilee EG (2x)	Baranello	Barpaul		
	Cordus (2x)	Markus			
2016–2018	Monroe (2x)	Harmonie	Joanna	Sprinkler	
	Annecy (2x)	Dakisha	Lystig		
	Tetrastar (4x)[a]	Becca	Rubicus		
		Traction	Aureline		

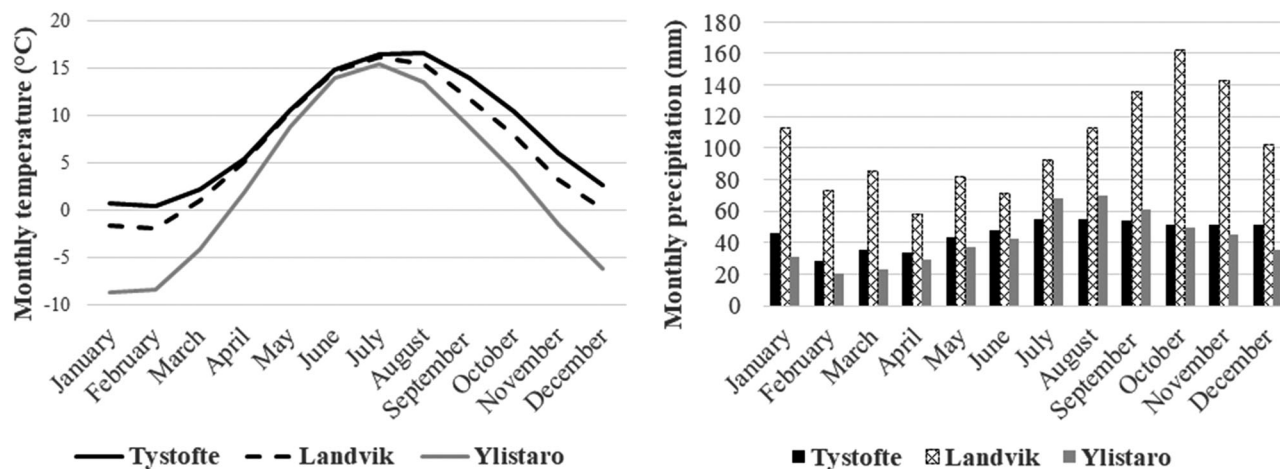[a]Tetrastar was not tested for wear.

FIGURE 2 Mean monthly temperature and precipitation (1961-1990) at the meteorological stations nearest the experimental sites in Denmark (Tystofte), Norway (Landvik) and Finland (Ylistaro).

Tystofte and Ylistaro. Sowing rates varied from 20 g m^{-2} in diploid *Lolium perenne*, *Poa pratensis* and *F. rubra* ssp. *commutata* and *littoralis* to 25 g m^{-2} in *F. rubra* ssp. *rubra* and 35 g m^{-2} in tetraploid *Lolium perenne*.

After grow-in, trials were mowed 2–3 times per week at 15–20 mm (lawn trials) or 30 mm (wear trial) until late autumn. Weeds were controlled either by hand or chemically, when needed. The fertilization rate was 10–20 kg N ha^{-1} per growing month in all trials. No wear treatments were carried out in the establishment year.

2.3 | Management in evaluation years

The lawn trials were mowed to a height of 15–20 mm, 2–3 times per week, usually with a reel mower that returned the mowed material. The wear trials were mowed to 30 mm 1–2 times per week with a rotary mower that collected the mowed material. Fertilizer, 10–20 or 30–40 kg N ha^{-1} per growing month in the lawn trials and the wear trial, respectively, were applied during the growing season to ensure a dense sward. No pesticides or growth regulators were applied in the evaluation years.

In the wear trial, wear treatments started in late April/early May (after all varieties were out of winter dormancy) and continued until 1 November. There were 2–3 wear treatments per week, corresponding to around 300 hours of play per year. A trailer with two rollers (diameters of 40 cm and a width of 145 cm), both with football-shoe studs at a spacing of 8 cm by 8 cm and mounted to a John Deere Gator vehicle, was used to simulate football (soccer) wear (Figure 3). Calculations of hour of play was based on football-shoe stud density (302 studs per 1 m^2 for one rotation of the two rollers), step length (0.762 m), running distance per match (11.5 km) (Ollestad, 2017), pitch area (68 m by 105 m) and the wear inten-

sity (number of wear rounds during the experimental period) (modified after Rossi, personal communication, 2008).

2.4 | Assessments in evaluation years

In the evaluation years, visual merit, overall winter damage, disease severity, turfgrass growth rate, and winter color were assessed at all three test sites, always by the same person at each site. Visual merit was assessed on a scale from 1 to 9 where 9 is the best merit. The character described overall turfgrass quality based on a combination of live ground cover, greenness, fineness/coarseness of leaves, disease attacks and shoot density. The character was assessed at the beginning of each month from April to November. Overall winter damage was assessed 1–2 weeks after green-up as per cent of plot area damaged by all types of abiotic and biotic winter stresses. Disease severity was assessed as per cent of plot area infected by disease at the start of each month throughout the growing season or whenever observed. Only observations of red thread (*Laetisaria fuciformis*) and microdochium patch (*Microdochium nivale*) are shown in this paper. Winter color, i.e. the intensity of green color outside the growing season, scale 1–9 (1-completely brown/withered, 5-pale green, 7-green and 9-intensely green) was observed on 1 December / shortly before expected snow fall or on 1 March / shortly after the period of snow cover. Turfgrass growth rate was observed three times per year (15 May, 15 July and 15 September.) as daily height increment calculated from mowing height (bench setting) and three measurements per plot of plant height taken minimum three days after mowing. Plant height was measured using a ruler at Ylistaro and at Tystofte in 2014–2016 and using a Turf Check Prism device (Check Signature Inc., Shoreview, MN, USA) at Landvik and a BSM Prism device (BRIT Manufacturing Solutions LTD, Bedfordshire, UK) at

FIGURE 3 Trailer with two rollers, both with football-shoe studs fixed on the surface (close-up, right), and mounted to a John Deere Gator vehicle, used for wear treatments in the trials at Landvik. Photo credit: Lars T. Havstad.

Tystofte in 2017–2018. Minimum three measurements were taken per plot and the mean value calculated.

For economic reasons, shoot density (scale 1–9, 9 is the highest density), fineness of leaves, (scale 1–9, 9 is the finest leaves), and genetic green color (scale 1–9, 9 is the darkest green) was assessed at Landvik only. The assessments were conducted in early May, July and September. The reason for limiting these observations to one trial site was our experience from the former Nordic variety evaluation programmes showing less climatic influence on these characters than on those described above.

Wear tolerance (1-9, 9 is best tolerance) was assessed in the separate wear trial at Landvik on 1 June, 1 July, 1 August, 1 September, 1 October and 1 November This character was based on coverage of sown variety after wear exposure, but plot uniformity was included as well.

2.5 | Statistical analyses and presentation of results

For each species/subspecies in the lawn trials, analyses of variance (PROC ANOVA; SAS Institute, 2015) for the various characters were either performed individually for each of the three sites or collectively for all trials. In the collective analyses, trial site was always regarded as a random variable. In Tables 3, 5, 7, 8 and 9, results are shown for each test site (visual merit only) and as mean values across the three sites (all characters). In the wear trials with *Lolium perenne* and *Poa pratensis* at Landvik, analyses were per-

formed for each experiment and across experimental years (Tables 4 and 6). Each replication or each year was regarded as a random variable in the annual and the overall analyses, respectively. Significant differences were separated by Least Significant Difference (LSD) ($P \leq .05$). Within each species/subspecies, varieties were ranked depending on their average visual merit score for the whole experimental period. In case two or more varieties had identical scores, they were further ranked depending on tiller density, and, if necessary, also depending on winter damage. In the wear trials, varieties were ranked according to their overall wear tolerance score.

3 | RESULTS AND DISCUSSION

3.1 | Perennial ryegrass (*Lolium perenne*)

3.1.1 | Lawn trials

Perennial ryegrass varieties suffered winter damage at Ylistaro in most years and at Landvik in 2017–2018, mainly due to lack of snow cover combined with periods with frost and ice encasement. On average for all evaluation years and three experimental sites, the tetraploid variety Fabian had 50% less winter damage than the diploid varieties during the 2013–2016 test period, while the tetraploid variety Tetrastar was more winter-hardy than all diploid varieties except Annecy during 2015–2018 (Table 3). The two tetraploid varieties also had a darker in-season color at Landvik and a better winter color on average for three sites. At Landvik, the tiller

TABLE 3 Comparison of candidate and control (c) varieties of perennial ryegrass (*Lolium perenne*) in lawn trials during the evaluation periods 2014–2016 and 2016–2018

	Visual merit				Tiller density[a]	Leaf fineness[a]	In-season color[a]	Winter color[b]	Winter damage[b]	Red thread[b]	Micro-dochium patch[b]	Daily height growth[b]
	Landvik	Tystofte	Ylistaro	Mean of 3 sites								
	scale 1-9									% of plot area		mm
2014-2016:												
Bargold (c)	4.4	7.4	5.3	5.7	6.2	6.4	5.8	6.2	14.0	2.1	0.4	6.3
Fabian (4x)	4.4	7.1	5.6	5.7	5.6	5.6	6.8	6.7	8.2	2.1	0.2	6.3
Eurocordus	4.1	7.1	5.0	5.5	5.7	6.1	5.7	5.8	16.0	3.8	0.3	6.6
Columbine	4.1	6.8	5.4	5.3	5.8	6.1	5.8	6.1	15.9	2.2	0.3	6.4
Vesuvius (c)	3.9	6.8	5.1	5.2	5.3	5.9	5.8	5.9	15.3	2.8	0.5	6.5
Jubilee EG	3.7	6.8	4.5	5.0	5.7	5.9	6.3	5.9	18.2	2.5	0.9	6.3
P-value	<.001	<.01	<.01	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	.03	.29	.73
LSD (*P* ≤ 0.05)	0.3	0.4	0.4	0.2	0.3	0.2	0.2	0.3	3.6	1.1	-	-
2016-2018:												
Tetrastar (4x)	4.9	6.9	6.6	6.2	5.6	5.3	7.8	6.5	45	3.8	1.1	4.4
Monroe	4.7	6.7	6.7	6.0	5.5	5.9	6.3	5.7	48	3.8	2.9	4.0
Annecy	4.5	6.8	6.8	6.0	5.3	6.1	5.7	5.1	46	3.8	1.9	3.8
Bargold (c)	4.6	6.5	6.7	5.9	5.3	6.1	5.7	5.2	48	4.8	2.5	4.0
Vesuvius (c)	4.6	6.4	6.3	5.7	5.6	5.6	5.5	5.2	47	4.3	2.6	4.2
P-value	.73	<.001	.10	<.01	<.001	<.0001	<.0001	<.0001	.01	.83	.10	.07
LSD (*P* ≤.05)	-	0.2	-	0.2	0.2	0.2	0.2	0.2	2	-	-	-

[a] Assessments at Landvik only.
[b] Mean of three sites.

TABLE 4 Wear tolerance (1 to 9 scale, 9 = best) of candidate and control (c) varieties of perennial ryegrass (*Lolium perenne*) in wear trials at Landvik, Norway, during 2014–2015[a] and 2016–2018

| Variety (2014–2015[a]) | Wear tolerance | | | Variety (2016–2018) | Wear tolerance | | | |
	2014 (first year)	2015 (second year)	Mean 2014–2015		2016 (first year)	2017 (second year)	2018[b]	Mean 2016–2018
	scale 1-9				scale 1-9			
Vesuvius (c)	5.8	5.4	5.6	Annecy	8.0	8.1	7.7	7.9
Eurocordus	5.8	5.1	5.4	Monroe	7.7	8.1	7.4	7.7
Columbine	5.6	4.8	5.2	Vesuvius (c)	7.8	7.6	7.2	7.5
Bargold (c)	4.9	4.1	4.5	Bargold (c)	7.4	7.3	6.3	7.0
Jubilee EG	5.1	3.8	4.5					
Fabian	4.6	3.8	4.2					
P-value	<.0001	<.0001	<.0001	*P*-value	.15	<.01	.01	<.0001
LSD (*P* ≤ .05)	0.2	0.3	0.2	LSD (*P* ≤ .05)	-	0.4	0.8	0.3

[a]Wear was not performed in the third lawn year (2016).

[b]Due to winter kill, plots were resown in spring 2018 and wear performed after green-up in the establishing year during August–October.

density of Fabian was behind the control variety Bargold but better than the control variety Vesuvius in 2014–2016, while Tetrastar was on level with or better than both control varieties in 2015–2018. As reflected by the visual merit scores for each site and across sites, these results suggest that tetraploid perennial ryegrass varieties have a potential in seed mixtures for lawns in the Nordic countries. Furthermore, the benefit of replacing diploid varieties with Fabian also increased with increasing latitude towards the margin of perennial ryegrass adaptation. These are important findings because up to present, perennial ryegrass has only been recommend in seed mixtures for lawns in the former southern zone of the Nordic counties, i.e. Denmark, Southern Sweden and coastal areas of Southern Norway (Kvalbein & Aamlid, 2015). An analysis of genetic gain in diploid perennial ryegrass varieties entered into variety testing in the Nordic counties during 1986–2007 also show less improvement in winter stress tolerance than in tiller density, leaf fineness, height growth and disease resistance (Aamlid & Gensollen, 2014). Improved stress tolerance in tetraploid perennial ryegrass has earlier been reported by Leyland (2016) who also found that the darker in-season color and better winter color in tetraploid varieties was associated with increased chlorophyll content. In agreement with BSPB/STRI (2020) and GEVES (2020), our evaluation showed Fabian and Tetrastar to have coarser leaves than the diploid varieties; apparently this is a character that will have to be sacrificed, or it may provide a target for future breeding efforts, shall the area of perennial ryegrass use be extended further north in the Nordic countries. Of the two tetraploid varieties, Tetrastar, scored higher than Fabian on the final ranking (SCANTURF, 2020), which is opposite to the results from GEVES (2020) and BSPB/STRI (2020)

but in agreement with turf quality testing in New Jersey, USA (Vines et al., 2018).

Of the diploid varieties, averaged for all three sites, Annecy and Monroe were both on level with the highest ranked control variety Bargold for visual merit during 2016–2018. Especially Annecy performed well for visual merit at the southern location Tystofte, compared to control varieties (Table 3).

3.1.2 | Wear trials

None of the candidate varieties had better wear tolerance than the control variety Vesuvius in the 2014–2016 test round at Landvik. Variety Eurocordus came closest, followed by Columbine, which both had higher wear tolerance than the lowest ranked control variety Bargold. At the lower end of the scale, the wear tolerance of Jubilee EG, and especially Fabian, showed no improvement compared with Bargold (Table 4). While BSPB/STRI (2020) also reported Fabian to have less wear tolerance than diploid varieties in unshaded field trials, this may perhaps be different on shaded stadiums because tetraploid varieties contain twice as many chloroplasts as diploids and therefore are able to keep up photosynthesis at lower flux densities than diploids (Leyland, 2016).

In the 2016–2018 test round, the candidate varieties were highly tolerant against wear and ranked either higher (Annecy) or on level (Monroe) with the best control variety Vesuvius (Table 4). In agreement with these findings, Monroe and Annecy obtained good scores for wear tolerance on the sports uses variety list in the UK (BSPB/STRI, 2020) and a high "sport index" in variety testing in France (GEVES, 2020).

TABLE 5 Comparison of candidate and control (c) varieties of smooth stalked meadow grass (*Poa pratensis*) in lawn trials during the evaluation periods 2014–2016 and 2016–2018

	Visual merit (1 to 9)				Tiller density[a]	Leaf fineness[a]	In-season color[a]	Winter color[b]	Winter damage[b]	Red thread[b]	Micro-dochium patch[b]	Daily height growth[b]
	Landvik	Tystofte	Ylistaro	Mean of 3 sites								
					scale 1-9					% of plot area		mm
2014-2016:												
Limousine (c)	4.5	6.4	6.4	5.8	5.4	5.0	6.6	4.2	8.2	0.5	0.5	3.4
Markus	5.0	6.3	5.9	5.7	4.9	4.4	6.6	5.4	8.7	0.1	0.7	4.0
Conni (c)	4.6	6.1	5.8	5.5	4.2	4.6	7.3	4.8	14.9	0.1	0.5	3.7
Sombrero	4.2	6.2	6.1	5.5	4.5	4.7	6.7	4.4	11.5	0.4	0.5	3.4
Baranello	3.9	6.6	5.7	5.4	4.4	4.2	7.7	5.8	10.4	0.2	0.5	3.7
P-value	<.0001	.07	<.01	<.0001	<.0001	<.0001	<.0001	<.0001	.07	<.01	.69	<.0001
LSD (P ≤ 0.05)	.3	-	0.4	0.2	0.3	0.2	0.3	0.3	-	0.2	-	0.2
2016-2018:												
Becca	4.7	6.3	6.1	5.7	5.0	4.4	7.1	5.9	12	0.5	0.0	2.4
Harmonie	4.3	6.4	6.4	5.7	4.8	4.1	7.2	5.7	10	0.9	0.2	2.5
Traction	4.3	6.3	6.3	5.6	4.7	4.4	7.1	5.8	14	0.5	0.0	2.5
Limousine (c)	4.3	6.3	6.3	5.6	4.7	4.1	7.1	5.7	13	1.1	0.3	2.5
Conni (c)	3.9	6.5	6.2	5.5	4.2	3.9	7.2	5.5	16	0.4	0.0	2.6
Dakisha	4.0	6.5	6.0	5.5	4.2	3.7	7.2	5.6	17	0.7	0.3	2.6
P-value	<.01	.12	.31	.18	<.0001	<.001	.68	<.01	.10	.39	.43	.52
LSD (P ≤ .05)	0.4	-	-	-	0.3	0.2	-	0.2	-	-	-	-

[a] Assessments at Landvik only.
[b] Mean of three sites.

TABLE 6   Wear tolerance (1 to 9, 9 = best) of candidate and control (c) varieties of smoot stalked meadow grass (*Poa pratensis*) tested in wear trials at Landvik, Norway, during 2014–2015[a] and 2016–2018

	Wear tolerance				Wear tolerance			
Variety (2014–2015[a])	2014 (first year)	2015 (second year)	Mean 2014–2015	Variety (2016–2018)	2016 (first year)	2017 (second year)	2018 (third year)	Mean 2016–2018
	———scale 1-9———				———scale 1-9———			
Limousine (c)	3.4	1.9	2.7	Harmonie	5.9	5.8	4.8	5.5
Sombrero	3.4	2.1	2.7	Limousine (c)	5.2	4.8	4.1	4.7
Markus	3.1	2.0	2.6	Dakisha	5.0	5.5	3.1	4.6
Baranello	2.8	1.7	2.2	Traction	4.9	4.6	3.5	4.3
Conni (c)	2.6	1.0	1.8	Becca	4.8	4.1	2.9	4.0
				Conni (c)	4.3	3.0	2.0	3.1
P-value	.10	.02	<.001	*P*-value	.01	<.001	.01	<.0001
LSD (*P* ≤ .05)	-	0.5	0.4	LSD (*P* ≤ .05)	0.7	1	1.3	0.5

[a]Wear was not performed in the third lawn year (2016).

3.2 | Smooth stalked meadow grass (*Poa pratensis*)

3.2.1 | Lawn trials

On average for all sites, none of the candidate varieties were ranked higher for visual merit than Limousine (control) in the 2014–2016 test round. In the trial at Landvik, Limousine was in a class of its own with regard to tiller density and leaf fineness. Despite this, Markus had the highest score for visual merit at Landvik and could not be separated statistically from Limousine in the ranking across sites (Table 5). While Markus also maintained a greener color than the control varieties during the winter months, it was not as green as Baranello which also had the darkest in-season color. The tendency for Baranello to have the highest visual merit score at the southernmost location Tystofte but the lowest score at Landvik and Ylistaro might reflect that this variety is more adapted to the southernmost parts of the Nordic counties which normally has no snow cover. Another reason for Baranello's low score in the rather wet climate at Landvik was probably the emergence of light-green annual bluegrass (*Poa annua* L.) which created an unsightly contrast to the dark-green variety. Unlike at BSPB/STRI (2020), Sombrero was also behind Limousine at Landvik and Ylistaro (Table 5).

In 2016–2018, on average for all sites, there was no difference in visual merit among varieties. Becca, Harmonie, and Traction received scores similar to or higher than Limousine, which implies that these varieties are well suited for the Nordic market, with high tiller density and fine leaves (Table 5). Especially at Landvik, Becca stood out in a positive way, with the highest score for visual merit among all varieties (Table 5). In line with these results, although not fully tested in the UK, Becca was ranked as the best newcomer in BSPB/STRI (2020), with the second highest ranking of all varieties.

3.2.2 | Wear trials

In the two test rounds, only Harmonie showed better wear tolerance than Limousine (control) (Table 6), which is in line with the BSPB/STRI (2020) ranking. However, in contrast to the BSPB/STRI (2020) ranking, our results showed Becca to be less wear tolerant than Limousine under Nordic conditions.

3.3 | Chewings fescue (*Festuca rubra* ssp. *commutata*)

Visual merit of Greenmile and Humboldt were on level with the best control variety Musica at all sites in the 2014–2016 test round (Table 7), indicating that they should be well suited for the Nordic lawn market. This recommendation is consistent with recommendations in the UK where Humboldt was ranked on level with Musica and Greenmile slightly behind Musica for visual merit (BSPB/STRI, 2020).

Only Lystig was ranked on level with Musica (control) for visual merit in 2016–2018. The good performance of Lystig was evident at all test sites; although, it was behind Musica for both in-season color and winter color (Table 7). In this test round, Musica also showed better resistance to red thread disease than any other variety.

TABLE 7 Comparison of candidate and control (c) varieties of chewings fescue (*Festuca rubra* ssp. *commutata*) in lawn trials during the evaluation periods 2014–2016 and 2016–2018

	Visual merit				Tiller density[a]	Leaf fineness[a]	In-season color[a]	Winter color[b]	Winter damage[b]	Red thread[b]	Micro-dochium patch[b]	Daily height growth[b]
	Landvik	Tystofte	Ylistaro	Mean of 3 sites								
	scale 1-9								% of plot area			mm
2014–2016:												
Musica (c)	6.4	6.7	7.2	6.8	7.5	8.1	6.1	5.1	2.9	1.3	0.3	5.3
Greenmile	6.4	6.7	7.2	6.7	7.6	7.9	6.1	5.3	3.1	2.2	0.3	5.4
Humboldt	6.4	6.7	7.1	6.7	7.6	8.0	6.1	5.1	4.3	0.5	1.2	5.0
Calliope (c)	6.2	6.5	6.9	6.5	7.5	7.9	5.8	4.4	4.9	4.9	0.4	5.4
Barpaul	5.7	6.7	7.1	6.5	7.3	7.7	6.6	4.7	5.0	1.6	1.1	5.5
P-value	<.01	.26	.45	<.01	.39	<.01	<.001	<.0001	.01	<.0001	.01	.11
LSD (*P* ≤ .05)	0.4	-	-	0.2	-	0.2	0.3	0.4	1.5	1.0	0.7	-
2016–2018:												
Lystig	7.0	6.8	6.8	6.9	7.5	8.4	5.7	5.3	13	15.6	0.2	3.0
Musica (c)	7.0	6.8	6.6	6.8	7.6	8.5	6.0	6.1	17	5.1	0.1	3.1
Rubicus	6.1	6.4	6.3	6.3	7.2	8.0	7.0	5.8	17	14.9	0.5	3.0
Aureline	6.2	6.3	6.1	6.2	7.2	8.3	6.6	5.7	20	16.7	0.0	3.1
Joanna	6.3	6.3	6.0	6.2	7.2	8.1	6.8	5.7	18	12.9	0.0	3.0
Calliope (c)	6.2	6.1	6.1	6.1	7.1	8.4	5.7	5.2	20	18.4	0.3	3.1
P-value	<.001	<.0001	<.01	<.0001	.001	<.0001	<.0001	<.0001	.28	<.0001	.15	.75
LSD (*P* ≤ .05)	0.5	0.2	0.4	0.2	0.2	0.1	0.3	0.2	-	2.8	-	-

[a] Assessments at Landvik only.
[b] Mean of three sites.

TABLE 8 Comparison of candidate and control (c) varieties of slender creeping red fescue (*Festuca rubra* ssp. *littoralis*) in lawn trials during the evaluation periods 2014–2016 and 2016–2018

	Visual merit				Tiller density[a]	Leaf fineness[a]	In-season color[a]	Winter color[b]	Winter damage[b]	Red thread[b]	Micro-dochium patch[b]	Daily height growth[b]
	Landvik	Tystofte	Ylistaro	Mean of 3 sites								
					scale 1-9					% of plot area		mm
2014-2016:												
Cezanne (c)	6.9	6.8	6.3	6.7	7.7	7.8	6.3	6.5	7.3	0.7	4.0	4.9
Barcrown (c)	5.9	6.8	6.4	6.4	7.3	8.0	6.2	6.4	8.5	0.4	2.5	5.1
Tadorna	5.8	6.6	6.3	6.3	7.0	7.7	7.0	6.3	13.9	0.3	1.7	4.8
P-value	<.01	.04	.90	<.001	.05	.01	<.0001	.30	.10	.45	.58	.39
LSD (*P* ≤ .05)	0.6	0.2	-	0.2	0.5	0.2	0.2	-	-	-	-	-
2016-2018:												
Cezanne (c)	6.2	6.9	6.1	6.4	7.2	8.1	5.6	6.3	20	6.8	0.4	2.7
Barcrown (c)	5.5	7.1	6.3	6.3	6.7	8.1	5.6	6.0	26	9.1	1.1	2.9
Sprinkler	5.6	6.3	6.2	6.1	6.7	7.9	6.0	5.7	21	15.9	0.6	3.2
P-value	<.01	<.0001	.30	<.0001	.12	.79	.06	<.001	.09	.001	.64	<.001
LSD (*P* ≤ .05)	0.4	0.2	-	0.2	-	-	-	0.3	-	4.5	-	0.2

[a] Assessments at Landvik only.
[b] Mean of three sites.

TABLE 9 Comparison of candidate and control (c) varieties of strong creeping red fescue (*Festuca rubra* ssp. *rubra*) in lawn trials during the evaluation period 2014–2016

	Visual merit				Tiller density[a]	Leaf fineness[a]	In-season color[a]	Winter color[b]	Winter damage[b]	Red thread[b]	Micro-dochium patch[b]	Daily height growth[b]
	Landvik	Tystofte	Ylistaro	Mean of 3 sites								
					scale 1-9				% of plot area			mm
2014–2016:												
Frigg (c)	5.5	6.2	6.3	6.0	6.3	7.4	6.5	2.6	2.3	2.9	0.2	6.4
Rossinante (c)	5.1	6.6	6.1	5.9	6.7	7.4	6.2	5.7	8.3	8	0.5	5.7
Barjessica	4.9	6.5	5.8	5.7	6.6	7.2	6.6	5.5	11.0	5.6	0.2	5.7
P-value	<.001	.25	<.01	.01	.07	.29	.01	<.0001	.14	<.01	.47	<.001
LSD (P ≤ .05)	0.3	-	0.3	0.2	-	-	0.3	0.3	-	2.8	-	0.4

[a]Assessments at Landvik only.
[b]Mean of three sites.

3.4 | Slender creeping red fescue (*Festuca rubra* ssp. *littoralis*)

On average for all test sites, the candidate varieties Tadorna (2014–2016) and Sprinkler (2016–2018) scored lower for visual merit than the highest ranked control variety Cezanne. They also showed no improvement compared to the other control variety, Barcrown at any site (Table 8). Due to the lack of genetic improvement compared to control varieties at any location, neither Tadorna nor Sprinkler can be recommended for the Nordic market. Among the negative aspects of these varieties were a tendency for poor winter survival of Tadorna and a high susceptibility to red thread in Spinkler. In SCANTURF (2020) lists, Finesto and Valdora are the highest ranked varieties, followed by Cezanne and Barcrown at 4th and 6th place, respectively.

3.5 | Strong creeping red fescue (*Festuca rubra* ssp. *rubra*)

On average for all sites, the only candidate variety, Barjessica, tested in 2014–2016, scored lower for visual merit than the highest ranked control variety Frigg (Table 9). Since it also showed no improvement compared to the other control variety Rossinante, Barjessica cannot be recommended in seed mixtures for lawns in the Nordic countries. Provisional results from BSPB/STRI (2020) also ranked Barjessica behind Rossinate for visual merit. The highest ranked varieties on the SCANTURF list (2020) are Heidrun, Rossinante, and Frigg. Frigg is in a class of its own with regard to winter hardiness, but it also has a very poor winter color that makes it a preferred variety only in northern areas with snow cover.

4 | CONCLUSION

Based on the results from the SCANTURF trials in 2014–2016 and 2016–2018, the candidate varieties Fabian, Tetrastar, Annecy and Monroe (perennial ryegrass), Becca, Harmonie, Traction, and Markus (smooth stalked meadowgrass) and Lystig, Greenmile, and Humboldt (Chewings fescue) can be recommended for lawns in the joint Nordic test zone. By the same token, Eurocordus, Columbine, Monroe, and Annecy (perennial ryegrass) and Harmonie (smooth stalked meadowgrass) can be recommended for use on sports grounds. The fact that the ranking of varieties for visual merit in the lawn trials differed among the three test sites for all species and subspecies except Chewings fescue shows that that present practice of regarding the five Nordic countries as one common test zone is not an ideal solution, but rather a compromise to reduce variety testing costs in this large and

relatively sparsely populated region. Although not encouraged by the seed industry, it may therefore well be that variety by site interactions should be included in future analyses to further refine recommendations for the different climates represented by the three sites. Most importantly, the finding that the winter survival and visual merit of the tetraploid variety Fabian relative to diploid control varieties increased with increasing latitude ought to be followed up in new trials to explore if the present recommendation for inclusion of perennial ryegrass in seed mixtures for lawns can be extended further north.

For each species/subspecies, the final ranking of varieties for lawns and sports grounds in the Nordic countries are updated annually on the SCANTURF web site (www. scanturf.org).

REFERENCES

Aamlid, T.S., & Gensollen, V. (2014). Recent achievements in breeding for turf quality under biotic and abiotic stress. In: D. Sokolovic, C. Huyghe & J. Radovic, (Eds.), *Quantitative traits breeding for multifunctional grasslands and turf* (pp. 189–196). Dordrecht, Germany: Springer Science and Business Media.

Aamlid, T.S., Heltoft, P., Thorvaldsson, G., Jensen, A.M.D., Espevig, T., Hesselsøe, K.J., Waalen, W., Petersen, T.K., Pettersen, T., Tangsveen, J., Sørensen, P., Gneist, T., & Hannesson, B. (2019). SCANGREEN 2015–2018: Turfgrass species, varieties, seed mixtures and seed blends for Scandinavian putting greens. *NIBIO Report*, 5(154), 1–100.

Aamlid, T.S., Waalen, W. Thorvaldsson, G. Jensen, A.M.D. Espevig, T., Pettersen, T. Tangsveen, J., Steensohn, A. A. Sørensen, P., & Hannesson, B. (2015). SCANGREEN 2011–2014: Turfgrass species and varieties for Integrated Pest Management of Scandinavian putting greens. *Bioforsk Report*, 10(65), 1–91

BSPB/STRI. (2020). *Turfgrass seed 2020. The buyers guide to quality amenity turfgrasses*. Cambridgeshire: British Society of Plant Breeders (BSPB), Ltd. Retrieved from http://www.plantbreedingmatters.com/sg_userfiles/BSPB_Turfgrass_2020_LRes.pdf

FBVO. (2020). Notes on Federal Plant Variety Office turf testing. *Federal Plant Variety Office (Bundessortenamt)*. Retrieved from

https://www.bundessortenamt.de/bsa/en/for-applicants/suitability-test-for-turf-grasses

GEVES. (2020). *Your online database of turfgrass varieties*. Beaucouzé, France: GEVES. Retrieved from https://www.turfgrass-list.org

Kvalbein, A., & Aamlid, T.S. (2015). *The Grass Guide 2015: Amenity turf grass species for the Nordic countries*. Stockholm, Sweden: Scandinavian Turfgrass and Environment Research Foundation. Retrieved from http://www.sterf.org

Leyland, J. (2016). What is a tetraploid?: We look at the technology of tetraploid perennial ryegrasses, which are highly valued for their fast establishment, cool temperature recovery, high root mass and greater stress tolerance. *The Groundsman*, Sept. 2016, 24–25, 27.

NTEP. (2020). National Turfgrass Evaluation Program. Retrieved from https://www.ntep.org

Ollestad, B.S. (2017). *En analyse av løpsresultater under kamp i et norsk eliteserielag i fotball. [An analysis of running distances during football matches for a team in the Norwegian top league (Eliteserien)]*. Master's thesis. Kongsberg, Norway: University of South-Eastern Norway. In Norwegian.

SAS Institute. (2015). *Base SAS 9.4 Procedures guide*. Fifth ed. Cary, NC: SAS Institute Inc.

SCANTURF. (2020). *Scanturf variety list 2020*. Grimstad, Norway: ScanTurf. Retrieved from: http://www.scanturf.org

Vines, P L, R.F. Bara, D A Smith, Y. Qu, R M Daddio, S A Bonos, and W.A. Meyer. (2018) *Performance of perennial ryegrass cultivars and selections in New Jersey turf trials, 2018*. New Brunswick, NJ: Rutgers The State University of New Jersey. Retrieved from https://turf.rutgers.edu/research/reports/2018/125.pdf

Yan, W., Pageau, D., Frégeau-Reid, J., & Durand, J. (2011). Assessing the representativeness and repeatability of test sites for genotype evaluation. *Crop Science*, 51(4): 1603–1610.