POTENTIAL FOR

VELVET BENTGRASS

ON NORDIC GOLF GREENS

Fig. 1 *Leaves and a plant of velvet bentgrass. Photos: Agnar Kvalbein.*

VELVET BENTGRASS

BOTANICAL INFORMATION AND AREA OF USE

Velvet bentgrass (*Agrostis canina* L.) is a perennial grass species growing throughout Europe. On golf courses it is used primarily on greens because of its prostrate growth habit and extremely dense stand.

Other more commonly used *Agrostis*-species on greens are creeping bentgrass (*Agrostis stolonifera* L.) and colonial bentgrass (UK: browntop / common bent, *Agrostis capillaris* L.). All species belonging to the genus *Agrostis* have pointed leaves with longitudinal ribs, but velvet bentgrass has narrower leaves than the two other species.

Velvet bentgrass also has a ligula that is longer and more pointed then than the ligula in creeping and colonial bentgrass (Fig. 1 and 2). The development of stolons is much weaker in velvet than in creeping bentgrass, and at green mowing height it grows almost like a tufted grass.

Because of this and because of its growth rate which is lower than for other turfgrass species, it has a poor recuperative capacity with slow repair of ball marks and other injuries to the putting surface.

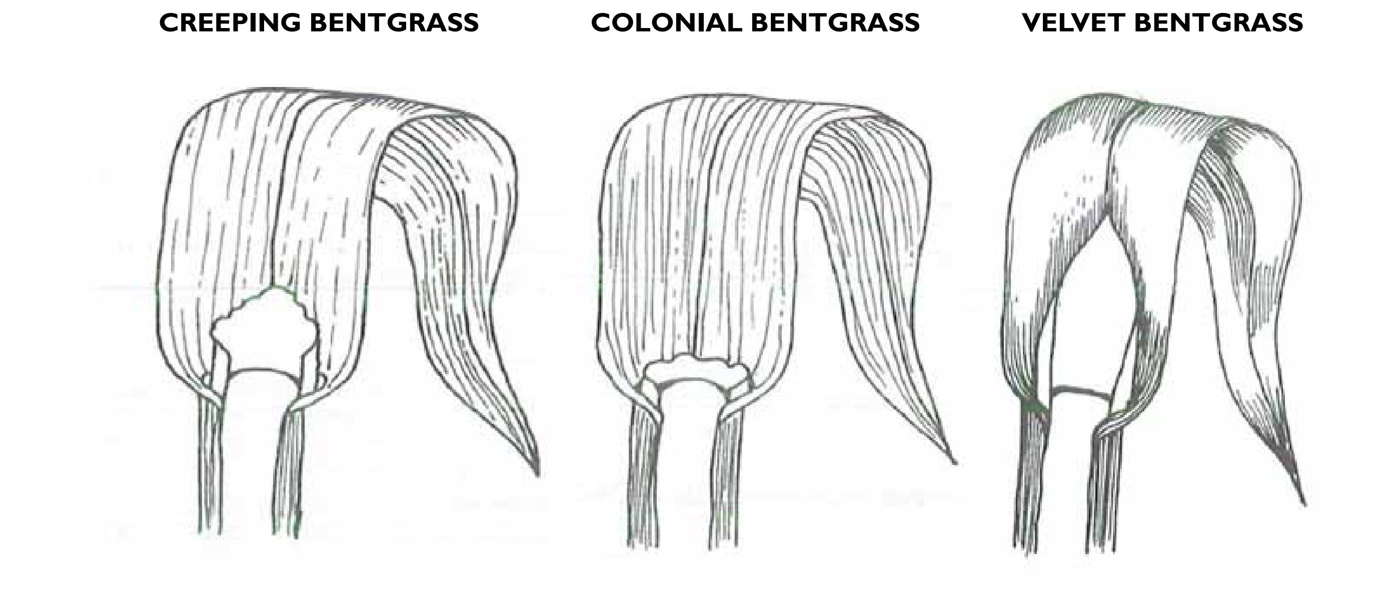

Fig.2 *Figure is from Christians, 2007.*

LIMITED USE DESPITE EXCELLENT PLAYABILITY

Velvet bentgrass putting greens are special, not only because of the fine texture and extremely dense and velvet-like putting surface, but also because of their characteristic intense and light-green color. The high tiller density and limited height growth often result in faster ball roll than for other turfgrass species. Velvet bentgrass tolerates mowing at 2.5-3 mm, and comparative stimpmeter readings on the day after mowing often show 0.5-1.0 foot better ball roll than in creeping bentgrass and red fescue (*Festuca rubra* L.).

Because of its low vertical growth rate, experienced greenkeepers often cut velvet bentgrass only 3-4 times per week.

The superior playing quality of velvet bentgrass in comparison with other bentgrass species was reported by professional golfers in Virginia, USA, as early as in the 1930s. At that time, the species had been introduced to the USA in a seed mixture referred to as 'South-German bent' and that consisted of 75 % colonial, 15 % velvet, and 10 % creeping bentgrass. Creeping bentgrass later became the predominant seeded on North-American putting greens. Nowadays only a few golf courses, mainly in the New England states, have putting greens seeded with velvet bentgrass.

The use of velvet bentgrass in the Nordic countries is rather limited, but 10-15 % of Finnish courses have greens seeded with this species. Finnish experiences with velvet bentgrass greens are both good and bad: On one course, greens were ranked as some of the best ones in Europe during the first two to three years after establishment, but then the greens collapsed due to diseases problems and winter injuries resulting from inadequate thatch control. Other Finnish courses have managed to maintain velvet bentgrass to a high standard over several years.

Less than 2% of the golf courses in Sweden, Denmark and Norway have velvet bentgrass greens. A couple of Danish courses have seeded velvet bentgrass in mixture with red fescue. This might be an alternative to the traditional colonial bentgrass/ red fescue mixture, but there is a great risk for velvet bentgrass to out-compete the fescues because of its much higher tiller density. The advantage of velvet bentgrass is, of course, that it will also out-compete annual bluegrass (*Poa annua* L.).

Imjelt Golf, Norway. Photo:Tatsiana Espevig

FEW CULTIVARS AND LIMITED KNOWLEDGE

Why is the use of velvet bentgrass so limited ? There are several reasons for that, the most important probably being little experience and knowledge about velvet bentgrass management. Secondly, turfgrass breeding and variety development has mostly focused on other species.

The first 'modern' velvet bentgrass variety, 'Kingstown', was released by Dr. C.R. Skogley and co-workers from the University of Rhode Island in 1962. During the past couple of decades, there has been a resurgence in the interest for velvet bentgrass with several new varieties being brought to the marked.

Presently, one of the most widely used varieties is 'SR 7200' (in Europe referred to as 'Avalon') which was developed as a collaborative effort between The University of Rhode Island and the company 'Seed Research of Oregon'.

Other varieties that have been released during the last 10-20 years and that all originate from the turfgrass breeding program at Rutgers University, New Jersey are 'Greenwich' 'Legendary', 'Vesper', 'Villa' and 'Venus'.

Development of velvet bentgrass at Rutgers University in New Jersey, USA

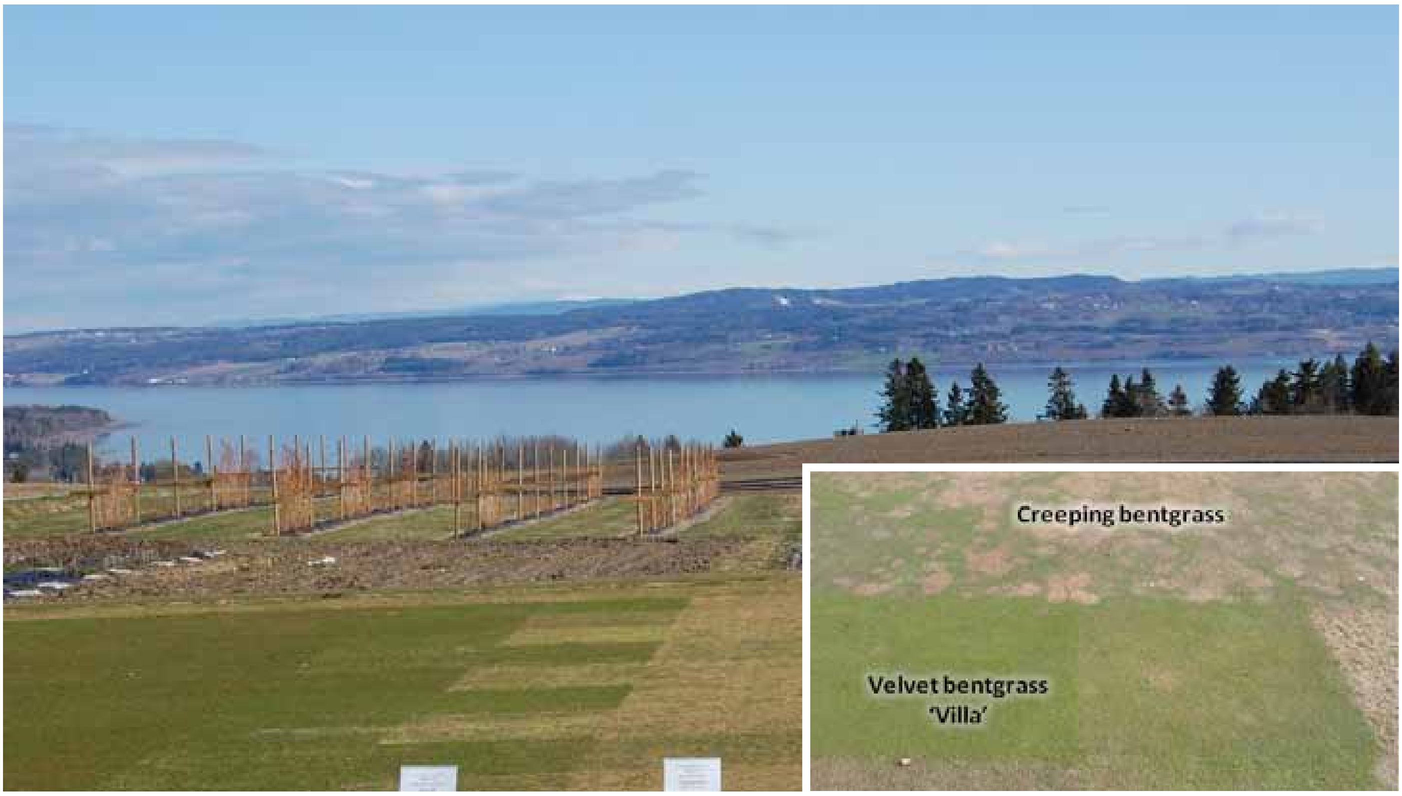

Fig. 3 *Winter survival of creeping and velvet bentgrass at Apelsvoll, April 2005. Photo: Frank Enger and Bjørn Molteberg.*

ADAPTATION AND OPTIMAL GROWING CONDITIONS

Excellent playability is but one of the advantages of velvet bentgrass compared with other bentgrass species. Most importantly, velvet bentgrass maintains its quality under dry conditions. It is shade-tolerant and has a low requirement for fertilizers and irrigation.

It also tolerates acidic soils and competes well with annual bluegrass. These characteristics make it a good alternative to creeping bentgrass when it comes to environment-friendly management of golf greens.

Winter hardiness is perhaps the important criterion when selecting turfgrasses for Nordic climate conditions. The winter hardiness of velvet bentgrass was evaluated at Bioforsk Landvik (coastal location, 58°N) and Bioforsk Apelsvoll (inland location, 61°N) during the first Scandinavian round of variety testing on golf greens, 2003-2006. It was the results from these tests that triggered the interest for velvet bentgrass among Scandinavian researchers and greenkeepers.

After the winter 2004/05, which had snow and ice cover from November till April at Apelsvoll, velvet bentgrass showed better winter survival than any other turfgrass species (Fig. 3). This fact, together with the very dense and attractive putting surface, resulted in a comprehensive research project funded by STERF.

Fig. 4 *The samples showing thickness of mat-layer were taken from an 1-yr old experimental putting green at Landvik. Photo:Trygve Aamlid.*

CHALLENGE: THATCH CONTROL

The biggest challenge with velvet bentgrass on putting greens is the accumulation of organic matter, which occurs faster than with other turfgrass species (Fig. 4). 'Thatch' is defined as the 'intermingled organic layer of dead and living shoots, stems, and roots that develops between the turf canopy of green vegetation and the soil surface', while 'mat' is used for the layer which is formed when thatch is intermixed with sand in the case of topdressing (definitions according to Beard, 2002).

On velvet bentgrass greens, the thickness of the mat-layer will often increase by more than 1 cm per year, but more importantly, there is also an increasing content of thatch within this layer. The most recognized measure for the content of thatch in the mat layer is the weight per cent of organic matter. This content should not exceed 4.5 %.

Thatch accumulation results in soft greens. Golf balls that are played onto the green will use their energy to create ball marks instead of rolling or bouncing a long distance on the green. Along with golfers' footprints and ruts from mowers and other machinery, such ball marks result in uneven putting surfaces.

The thatch also interferes with water infiltration and gas exchange to turfgrass roots, and increases the risk for turfgrass diseases because of the high water retention in the top layer. On the other hand, if the thatch/mat layer dries out, it may become very difficult to rewet and dry spots tend to develop.

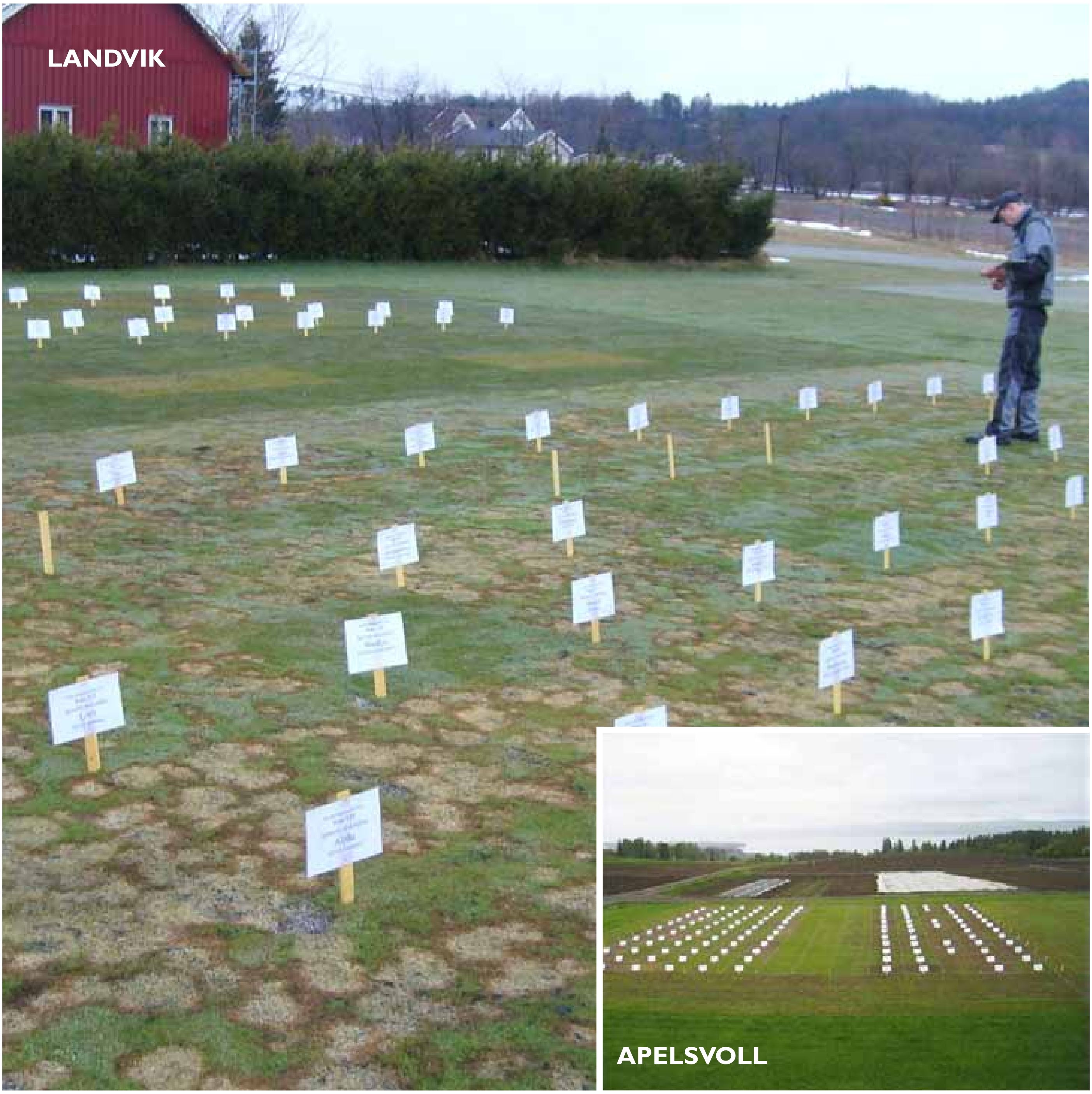

Fig. 5 *Winter hardiness of various turfgrass species is tested on experimental golf greens at the Bioforsk research centers Landvik (left) and Apelsvoll (right).*

VELVET BENTGRASS WINTER HARDINESS

Winter damage is a common problem on golf courses. About 70 % of the approximately 900 courses in the Nordic countries suffer economic losses from winter damage every year. The losses can be reduced by using more winter-hardy species and varieties. Testing of turfgrass varieties under realistic green conditions started in the Nordic countries in 2003 (Fig. 5). The results from these trials have usually shown that velvet bentgrass is more winter-hardy than creeping bentgrass (Table 1).

Winter hardiness is, however, a complex character. The turf is exposed to various types of stresses and combinations among them. Most detrimental are long-lasting ice covers causing suffocation from oxygen deficiency and accumulation of toxic gases. Another type of damage is caused by snow on unfrozen ground, which increases the risk for snow mold damage. On the other hand, if not protected by snow, the turf may die from low freezing temperatures, especially if the low temperatures are combined with strong winds that dry out plants unable to absorb water from the frozen soil. It is the ability of the turf to withstand these stresses, both separately and in combination, that is referred to as 'winter hardiness'.

It is all determined by the genetic make-up of the grasses, and considerable differences exist, both among species and among varieties within species. Among the species found on golf greens, bentgrasses and red fescues are usually much more winter hardy than annual bluegrass.

The ability of turfgrasses to tolerate winter stresses will normally increase upon exposure to low temperatures and altered light conditions in autumn. This process is referred to as 'hardening'. Temperatures in the range 2-5°C for two or more weeks in autumn result in more winter-hardy plants. Optimal hardening is also favored by high light intensity, i.e. bright days and non-shaded areas. During this the hardening period, turfgrass growth is limited by low temperature, but photosynthesis and the production of sugars continue. While most of the sugars are allocated to growth of new leaves during the growing season, the drop in temperature in autumn causes sugars to be converted to storage carbohydrates (fructans), mainly in turfgrass crowns, rhizomes and tiller bases. These reserves are necessary to sustain the turf during the winter months, and they are critical for the turf's regrowth capacity in spring.

TABLE 1 - Per cent winter damage within each species

	Apelsvoll 2003-06	Apelsvoll 2007-10	Landvik 2007-10
Velvet Bentgrass	25	48	15
Creeping Bentgrass	54	64	17
Red Fescue	30	40	4

Table 1. *Per cent winter damage in variety trials at Apelsvoll (inland) and Landvik (coast) during various testing periods. Mean of varieties within each species.*

The allocation of sugars from photosynthesis into storage carbohydrates is, however, only the first step in the hardening process leading to better winter survival. To obtain maximal hardiness, the turf must also be exposed to subfreezing temperatures in the range -2 to -5 °C. A few days with gentle frosts render cell membranes more permeable so that water can penetrate and freeze to ice in the intercellular spaces instead of inside the cell. Intracellular frost is lethal, but extracellular frost is no problem for well-hardened turf.

To improve turfgrass hardening conditions, greenkeepers are advised to remove trees and shrubs throwing long shades in autumn. Apart from that, there is little you can do to improve the climate for optimal turfgrass hardening. Inevitably, the extent and type for winter damages varies from year to year depending on weather conditions.

There are, however, other factors that have an impact on winter survival. One of them is turfgrass nutrition during the growing season and especially in the fall. Greenkeepers have usually been taught that nitrogen inputs should be reduced to lower the risk for snow mold during winter. This is, however, a delicate balance, as nitrogen deficiency will also reduce chances for optimal winter survival. In our project, a one year old velvet bentgrass green had less snow mold damage and better overall winter survival at an annual input of 1.50 kg N/100 m^2 than at 0.75 kg N/100 m^2. In this case, the lower rate was clearly not sufficient to ensure optimal winter survival and spring growth on the young green.

The use of mature (stable) compost as soil amendment may also reduce snow mold damage on sand-based putting greens (Fig. 6). The exact reason for this is still a matter of debate, but one explanation is that microorganisms in the compost suppress *Microdochium nivale* - the causal fungus for pink snow mould. At the same time, the compost-amended rootzones usually contain more plant-available nitrogen that peat-amended or pure sand rootzones. Additional nitrogen on newly-seeded golf greens result in stronger plants and faster recovery in spring. A third explanation may be that compost-amended sand contains less air-filled macropores than straight sand, thus causing better oxygen availability for the aerobic pathogen *Microdochium nivale*.

But compost amendment is not always conducive to winter survival: If winter damage is caused by physical conditions such as frost or freeze/thaw cycles, survival may in fact be better on pure sand than on compost-amended rootzones. Unfortunately, we have no specific data on this from velvet bentgrass, but we have experiences from other turfgrasses (Fig. 7). In this case the most likely reason for better survival on straight sand plots was better drainage and drier conditions around turfgrass apices.

When considering compost as organic amendment to sand-based growth media, it is always important to keep in mind that there are huge variations in the original material as well as in the composting process. To be on the safe side, always use a compost that is mature and well documented by chemical analyses.

Field studies on compost mixes in velvet greens.

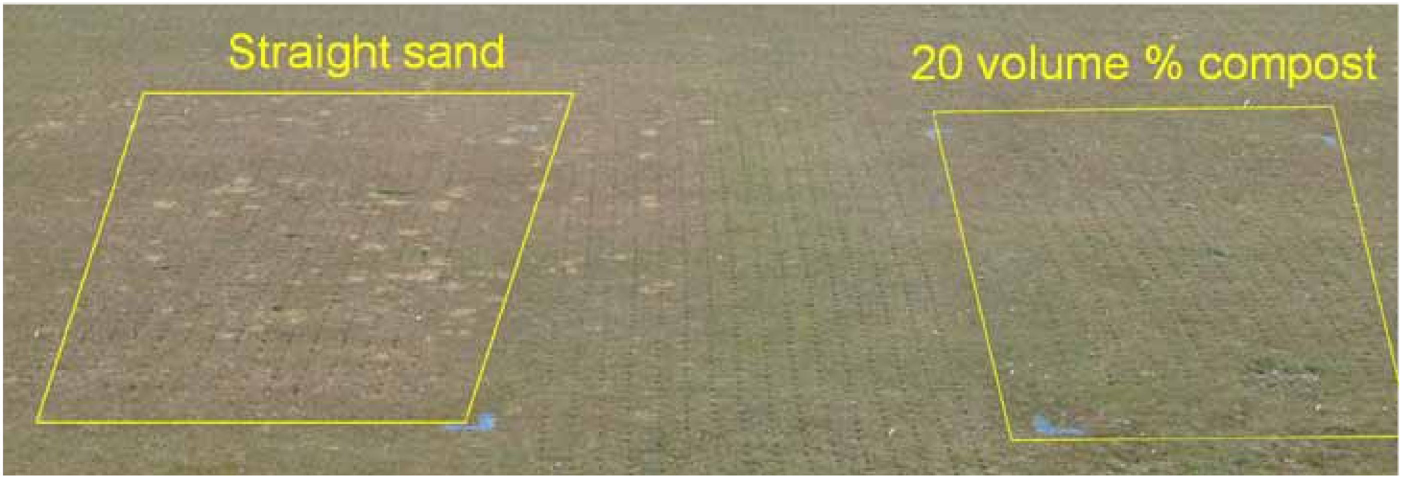

Fig. 6 *Effect of compost amendment on snow mold injury on a young velvet bentgrass green in spring 2008. Photo:Trygve S. Aamlid.*

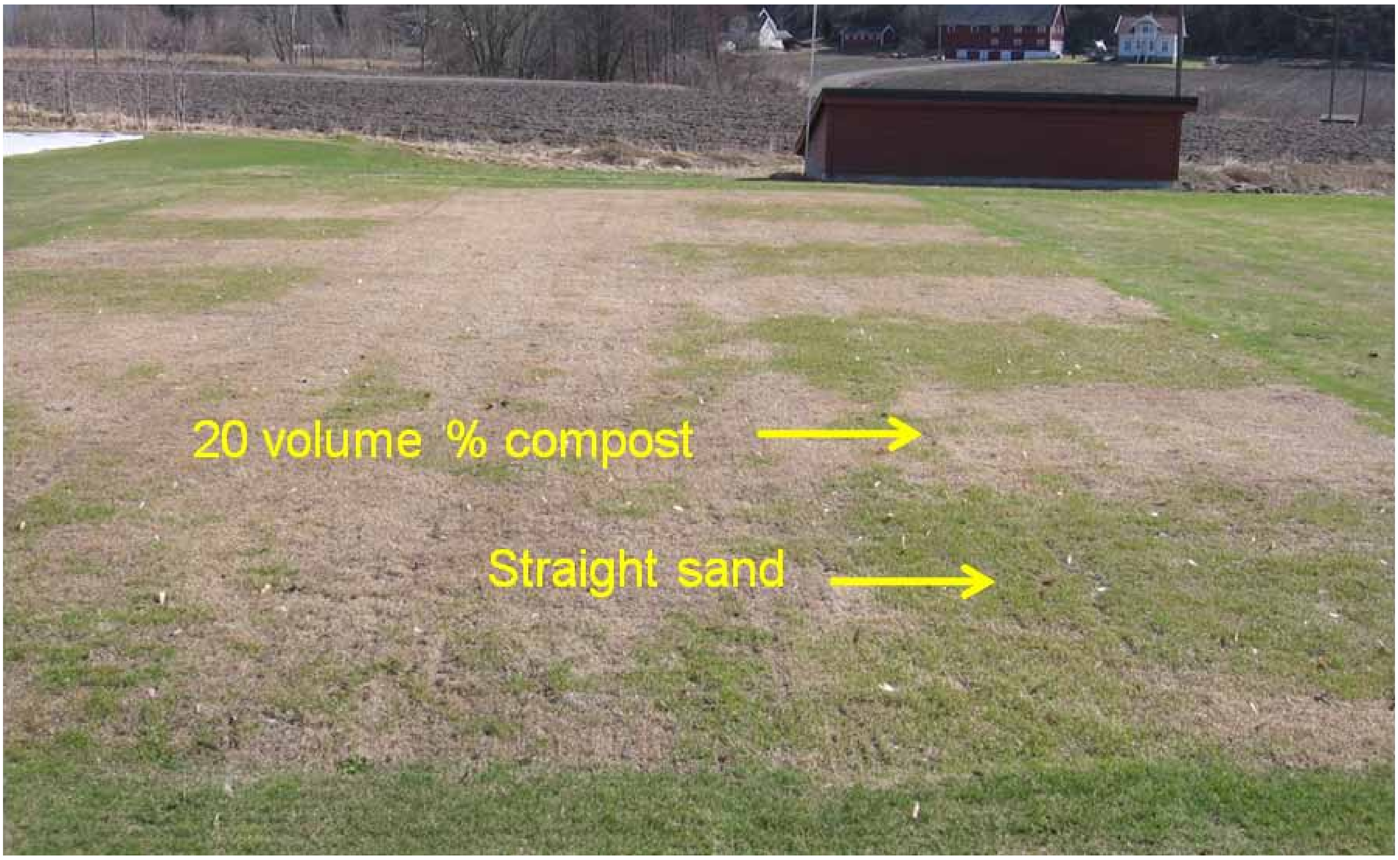

Fig. 7 *Winter survival of perennial ryegrass (Lolium perenne L.) fairway on rootzones with and without compost. Photo:Tanja Espevig*

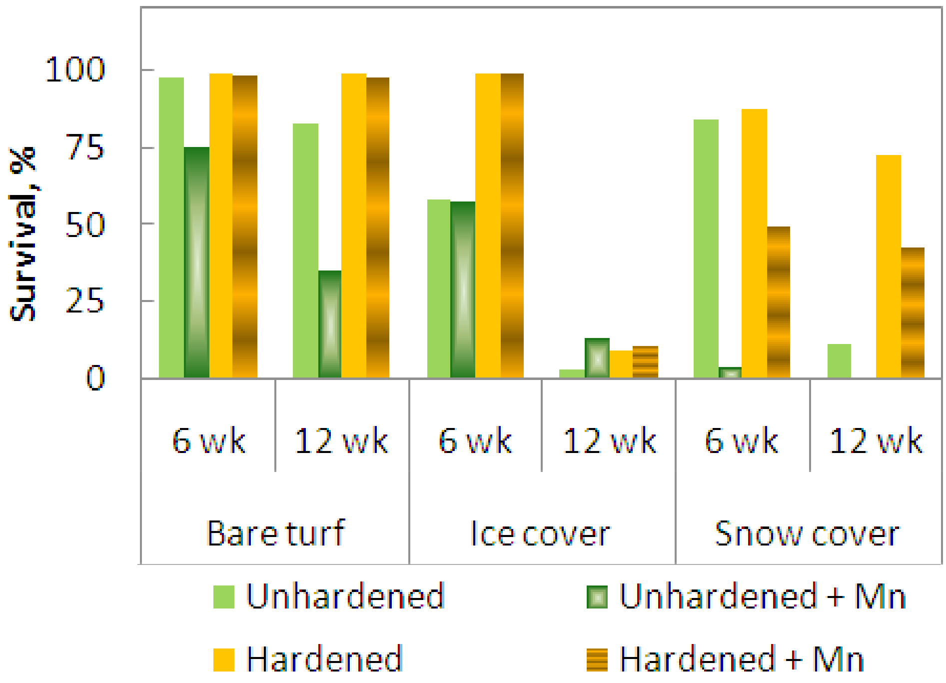

Fig. 8. *The susceptibility to Microdochium nivale depends on winter conditions. Figure shows survival after different treatments under controlled conditions. Mn: turf inoculated with Microdochium nivale.*

As part of our velvet bentgrass project, we tested winter survival under controlled environmental conditions. The experiments were conducted by Bioforsk and the Norwegian University of Life Science in collaboration with Rutgers University and University of Massachusetts, USA. Our focus was freezing tolerance and resistance to *Microdocium nivale* causing both pink snow mold during winter and Microdochium patch during the growing season. The experiments showed that the freezing tolerance of velvet bentgrass was on the same level as for creeping bentgrass 'Penn A-4'. Optimally hardened plants of creeping bentgrass have earlier been reported to tolerate temperatures as low as -35 °C.

The damage from *Microdochium nivale* in our trials varied depending on hardening and whether or not the turf was covered by simulated snow or ice cover (Fig. 8). Not unexpectedly, turfgrass that was hardened and not inoculated with *Microdochium nivale* (yellow columns) showed the best survival. The combination of *Microdochium nivale* and simulated snow cover reduced the survival of hardened plants to 40-50% depending on the duration of the snow cover.

Under most conditions, we found no differences in *Microdochium nivale* resistance between velvet bentgrass and creeping bentgrass. There was, however an exception for unhardened plants that were not covered by ice or snow. Under these conditions, creeping bentgrass 'Penn A-4' was virtually unaffected by *Microdochium nivale* whilst all varieties of velvet bentgrass were severely damaged. (Fig. 9, left). This suggests that unhardened velvet bentgrass is susceptible to *Microdochium* patch and that a conversion from creeping to velvet bentgrass may, in fact, increase the need for fungicide applications during the growing season. As for snow mold, we recommend prophylactic application of an approved fungicide in areas with snow cover (Fig. 10).

The most severe winter damage in our experiment was recorded for after 12 weeks of simulated ice cover (Fig. 8). In this case, inoculation with *Microdochium nivale* made no difference. Most likely, both the turf and the fungus died from oxygen deficiency. Other trials have shown that velvet bentgrass may survive up to 100 days under a 5 cm layer of black, impermeable ice (Fig. 11).

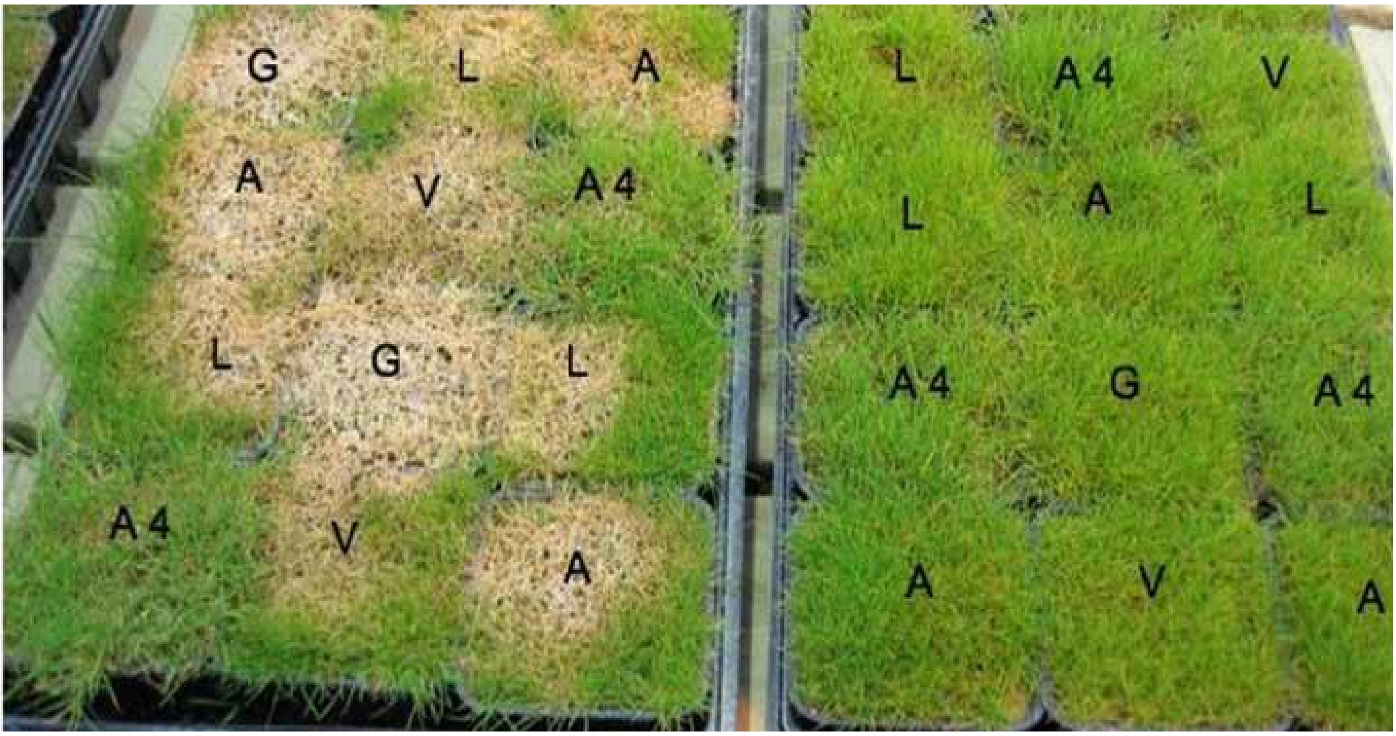

Fig. 9 *Resistance to Microdochium nivale of unhardened (left) and hardened (right) plants of creeping bentgrass 'Penn A-4' and four varieties of velvet bentgrass. Pots were inoculated with Microdochium nivale and kept at 1°C for 12 weeks, but not covered by ice or snow. Varieties: A = Avalon V = Villa G = Greenwich L = Legendary A4 = Penn A-4. Photo: Katarina Gundsø Jensen.*

Fig. 10 *Preventive application of fungicides against pink snow mould is a good investment in areas with snow cover. The plot in the foreground had been left by the greenkeeper as an unsprayed control. Photo: Ole Albert Kjøsnes.*

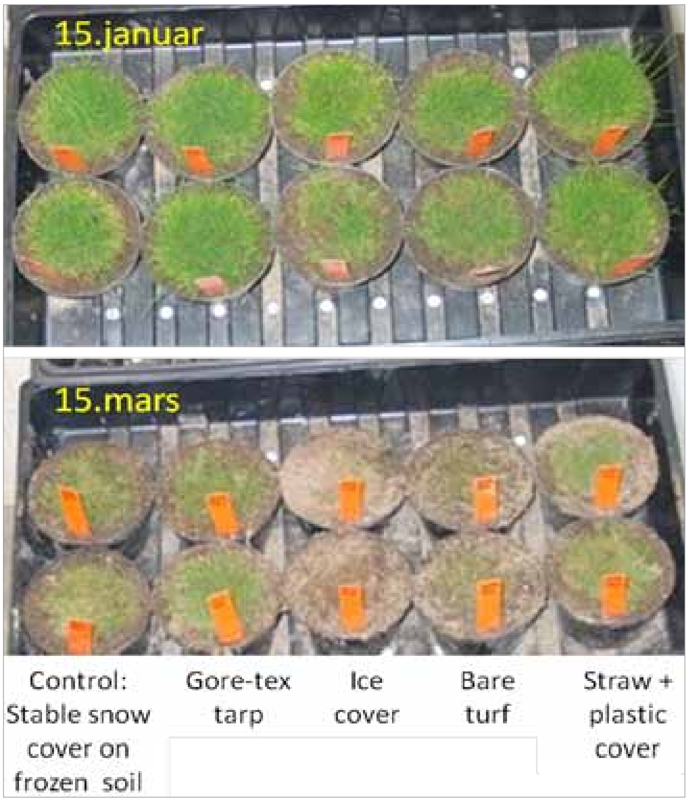

Fig. 11 *Survival of velvet bentgrass 'Legendary' on an experimental green at Apelsvoll, Norway, during the winter 2010-2011. Samples were taken to the greenhouse on 15 Jan. and 15 March from plots that had been exposed to various covers / winter treatments since 6 Nov. The photos were taken after two weeks of recovery in the greenhouse. Photo: Frank Enger.*

Kytäjä GK, Finland. Photo: Agnar Kvalbein.

ESTABLISHMENT OF VELVET GREENS

GROWING MEDIUM

According to USGA recommendations, putting greens can be constructed with or without organic amendment to the sand-based rootzone. Velvet bentgrass greens will benefit from a growing medium with a relatively high water retention capacity enabling it to withdraw water from the thatch/mat layer.

Compared with straight sand greens, the inclusion of 1.5-2 % (w/w) of organic matter in the rootzone will reduce the risk the development of a separate thatch/ may layer very distint from the rootzone underneath. When choosing organic material, one of the advantages of a well-defined and homogenous compost is that it contributes to a higher activity of thatch-degrading microorganisms than a traditional amendment with peat. On the other hand, composts usually have high pH values which increase the risk for take-all disease (*Gaeumannomyces graminis*) during the first years after establishment.

Don't forget regular thatch control. Foto: Agnar Kvalbein

SEEDING AND GROW-IN

Seeds of velvet bentgrass are very small and about the same size as seeds of creeping bentgrass. The recommended seeding rate is 0.6 kg per 100 m^2. The tiny seed must not be covered by more than 5 mm of soil or sand. The irrigation system must be set at frequent intervals (1-2 mm every 2-3 hours) so that the surface never dries out during the germination and early seedling stages. After seeding, the green should be covered with a white permeable tarp that increases soil temperature and reduces soil evaporation. The cover has to be removed after 5-8 days, when the seedlings are 5-10 mm high and start to grown into the tarp. Another reason for timely removal of the cover is the risk for development of *Pythium* disease if the tarp maintains a continuous water film on the leaves of the seedlings.

Once the cover is removed, the newly seeded green should receive fertilizer at weekly intervals until turf cover is 90-100%. The fertilizer requirement in the grow-in year is 1.8-2.2 kg N per 100m^2, i.e. much higher than on established greens. The surface should be rolled gently soon after removal of the tarp, and the first mowing accomplished at 8-9 mm when seedlings are 10-15 mm high.

When establishing velvet bentgrass greens, it is never too early to start thinking about thatch control. The immature surface does not tolerate mechanical treatments, but gentle topdressing should start not later than one month after germination. Because of the fine texture and high density of mature velvet bentgrass greens, it is important to select a fine to medium sand that has a chance of being absorbed. Sand with a with grain size in the range 0.2-0.7 is a good choice. Angular sand is preferable to round sand because it improves green firmness, but unfortunately, angular sand with the optimal grain size distribution is not easy to get hold of in the Nordic countries.

Fig. 12. *Three fertilizer levels but the same amount of sand resulted in various amounts of thatch, both when measured as thickness and as per cent organic matter in the mat. Fertilizer rates from left to right were 0.9, 1.3, and 2.2 kg N per 100m² per year over two growing seasons. Photo: Agnar Kvalbein.*

MAINTENANCE

FOCUS ON THATCH

The accumulation of thatch on a green is the net result of two processes, namely thatch formation and thatch degradation. If formation is faster than degradation, thatch will accumulate in thickness, density or both. A moderate thatch/mat layer is useful as it contributes to a stronger putting surface.

Problems arise when thatch/mat thickness increases beyond 1 cm (Fig. 12). The green becomes soft and playing quality deteriorates. Ball marks, footprints and ruts from mowers and other machinery contribute to uneven putting surfaces.

More importantly, the thatch will also reduce infiltration and gas exchange to turfgrass roots, interfere with germination after overseeding, and increase the risk for turfgrass diseases and winter damage. To be successful with velvet bentgrass greens, it is therefore critical to control thatch.

The amount of thatch can be quantified in various ways. If the layer is clearly separate from the soil (sand) underneath, thatch/mat thickness is an easy and descriptive measure. If the layer is less distinct, ignition loss gives a good indication of percent organic matter and thus any potential problem. Mat ignition losses below 3.5 - 4.5 % are usually acceptable.

METHODS FOR THATCH CONTROL

Principally, there are four different ways to control the organic matter content in the mat layer:

- Limiting turfgrass growth by less irrigation and fertilizer inputs
- Stimulation of thatch-degrading microorganisms
- Dilution of the thatch with sand
- Mechanical removal of organic matter.

Combinations of the methods are usually necessary for successful management of velvet bentgrass greens. Furthermore, there are often interactions between two or more methods. This means that the response to one treatment depends on the level of one or more of the other treatments. Typical examples are the two-way interactions 'nitrogen x topdressing' and 'mechanical removal x topdressing'.

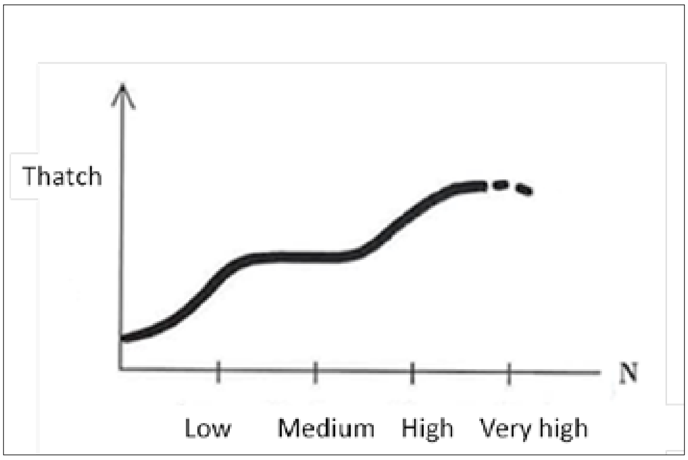

Fig. 13 *Net thatch production as a function of nitrogen level. (After Carrow et al., 2001).*

Fig. 14 *Take-all patch on a one year old velvet bentgrass green receiving moderate fertilizer inputs. Photo: Agnar Kvalbein..*

FERTILIZATION AND IRRIGATION

These factors are of utmost importance for turfgrass growth and thus for the production of thatch. However, fertilizers, especially nitrogen, do not only affect thatch production, but also degradation, as the thatch-eating microbes (mostly fungi) need nitrogen. Thus, the net production of thatch as a function of nitrogen level can be depicted as in Fig. 13.

At low and high nitrogen fertility, thatch production will normally exceed degradation leading to more accumulation of thatch with increasing nitrogen rates. When the nitrogen fertility level is low, there are usually not enough thatch-degrading fungi to cope with the increasing production of organic matter caused by moderate nitrogen increments. At the opposite end of the scale, i.e. at high nitrogen fertility levels, additional nitrogen increments will also have a stronger impact on production than on degradation, thus resulting in thatch build-up. There is, however, an intermediate fertility level where production and degradation are at balance and little influenced by moderate adjustments in nitrogen rate, and this is also the level that will, in the long run, give the best compromise between visual quality and playing quality on the green.

As already mentioned, velvet bentgrass requires relative high amounts of nitrogen during the first year after seeding. However, when the green is established, it is important to reduce fertilizer inputs to a level that is sustainable in the long run. From our experimental data, we recommend an annual input of c. 0.9 kg N / 100m2 to mature velvet bentgrass greens. Since there is no indication that the requirements for other nutrients is different in velvet bentgrass compared to other turfgrass species, we recommend that a complete fertilizer with all essential nutrients at a balanced ratio of is applied at no more than two week intervals throughout the growing season.

As already mentioned, take-all is a common disease on young velvet bentgrass greens. The patches often become very visible at low to moderate nitrogen and irrigation levels (Fig. 14). If the soil pH (measured in H2O) is higher than 5.7, the use of a strongly acidifying fertilizer, e.g. ammonium sulfate, is likely to reduce the problem. Since the take-all fungus makes turfgrass roots less capable of absorbing water and nutrients, an increase in irrigation frequency may also be considered.

When take-all is not present, irrigation on velvet bentgrass green should not be redundant as it will only increase thatch formation. Moreover, the thatch should neither be too moist nor too dry. In other turfgrass species we are currently doing research with deficit irrigation trying to keep the soil water content at a low, but fairly constant level. Until we have the results from this project, we recommended that velvet bentgrass greens are irrigated to field capacity at 2-3 day intervals on straight sand greens and 5-7 day intervals on greens with 15-20 % (v/v) organic amendment to the rootzone. Such a deep and infrequent irrigation strategy is likely to result in deeper roots enabling the turf to tolerate drought periods. But please keep in mind that the thatch must never be allowed to dry out completely as this will make it water repellent and lead to localized dry spots.

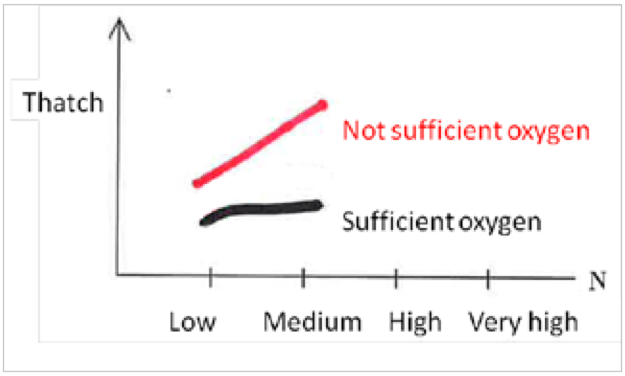

Fig. 15 *Interaction between topdressing and nitrogen fertilization on thatch accumulation.*

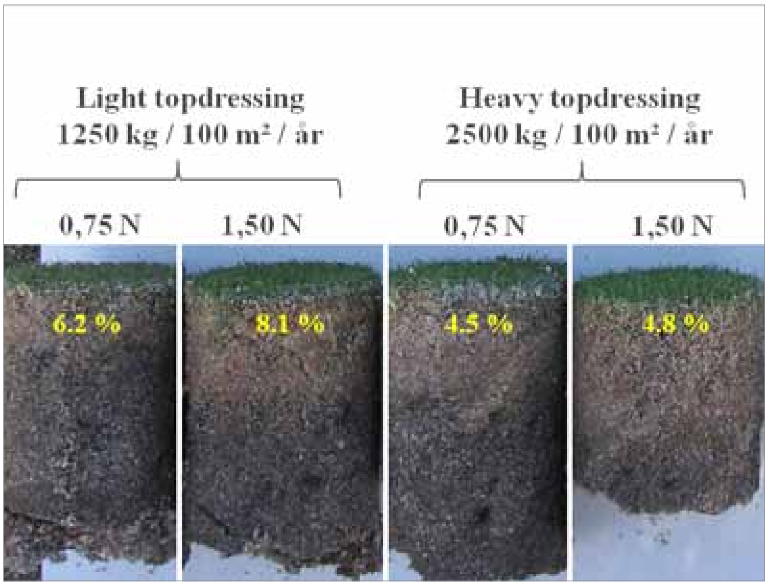

Fig. 16 *Thatch formation resulting from the interaction between topdressing level and nitrogen rate. Doubling the N rate resulted in a significantly higher content of organic matter in the mat layer at the low topdressing level, but had only marginal effect at the high level. Nitrogen rates are given as kg per 100 m^2 per year.*

THATCH DEGRADATION

Soils usually contain huge populations of microorganisms such as protozoa (single-celled animals), fungi and bacteria. These microorganisms all contribute to the degradation of plant debris, but to various extents. Of special importance are fungi because they are the only organisms that can decompose both cellulose and lignin efficiently. These fungi depend on water, oxygen, temperature and other environmental factors to do a good job. Wet and swampy thatch will usually increase rapidly in size and volume because the beneficial microorganisms do not thrive under such conditions.

Topdressing is important not only because it dilutes the thatch (see later) but also because it creates air-filled macropores supplying oxygen for the beneficial microorganisms. The fact that a moderate increment in nitrogen rate will not result in more thatch at intermediate fertility levels (Fig. 13) is only correct if there is sufficient oxygen to sustain the microbial activity in the mat layer. If gas diffusion is impeded, more nitrogen will result in more thatch irrespective of initial fertility level (Figs. 15 and 16).

The visual quality of the velvet bentgrass greens in our project was better when the annual fertilizer rate was doubled from 0.75 to 1.5 kg N / 100 m^2. As shown in Fig. 14, the higher N rate did not cause any increase in the organic matter content of the mat layer at the high topdressing level, but greens became very soft. Therefore, we do not recommend more than 0.9 kg N / 100 m^2 /yr on established velvet bentgrass greens.

Garden compost usually contains fungi which are able to decompose the lignin in the thatch/mat layer. Lignin is the component of the dead plant material that is most resistant to degradation. Degradation of lignin is usually advantageous, but in some cases the fungi may become too efficient, thus resulting in soft and sunken spots on the green (Fig. 17).

There are on the marked several commercial products containing microorganisms that are supposed to enhance thatch degradation. We tested ”Thatch-less™” and found that the surface became firmer after two years' regular application to a young velvet bentgrass green. On the other hand, the product had no impact on per cent organic matter in the mat layer.

Fig. 17 *Left photo: Samples from a velvet bentgrass green with (left) and without (right) degraded lignin in the thatch/mat layer. Right photo:The decomposing fungi caused soft indents with darker turf due to mineralization of nitrogen. Photo:Trygve Aamlid.*

THATCH DILUTION

Besides the indirect effect on microbial decomposition, topdressing will also have a direct effect through dilution of the organic matter. Thatch dilution is very important for green firmness. As mentioned earlier, it is important that sand has an optimal grain size distribution and preferably an angular shape .

The dressing frequency must be sufficient to prevent layers of organic matter from building up between each dressing event. Established greens with velvet bentgrass should receive 2000 to 2500 kg sand per $100m^2$ per year regardless of green age.

Because of the fine texture and high density it can often be a challenge to get the sand incorporated properly into velvet bentgrass greens. At least part of the solution to this is to dress shortly after the stand has been opened by verticutting or aeration. Finnish greenkeepers have good experiences with vertical mowers intended for fairway use (double spacing between knives) at weekly intervals prior to dressing.

THATCH REMOVAL

The fourth way to control thatch is to remove it mechanically by verticutting or hollow tine coring. These operations reduce mat thickness, but they do reduce per cent organic matter in the mat layer unless accompanied by topdressing.

Although mechanical treatments may contribute to more oxygen in the rootzone, their effect on microbial degradation is usually small compared to that of topdressing. Other disadvantages are that mechanical removal of thatch disrupts the putting surface, and that velvet bentgrass will use a long time to recover because of its low recuperative capacity.

We therefore recommend that thatch control on velvet bentgrass greens is based primarily on reduced production, microbial degradation and dilution with sand, so that the need for mechanical removal is minimized.

KEY FACTORS TO SUCCEED WITH VELVET BENTGRASS GREENS

Velvet bentgrass maintenance is a delicate balance. In order to promote faster repair of ball marks, winter damages, mechanical injuries and spots from oil spill or fungi, greenkeepers will always be tempted to apply more nitrogen and irrigation water. This may, however, increase turfgrass growth to such an extent that thatch accumulation gets out of control.

We therefore recommend greenkeepers with velvet bentgrass to establish a nursery green from which they can replace damaged areas on the greens in ordinary play. Ideally, the nursery green should be maintained as the greens in play, and the sod should not be allowed to become more than two years old at the time of replacement.

If winter damages are severe, greenkeepers with velvet bentgrass should generally be less hesitant that their colleagues with creeping bentgrass to deturf damaged greens and start over again. Extra holes and/or large nursery greens are good investments on golf courses aiming for velvet bentgrass.

We do not recommend velvet bentgrass as an alternative for golf courses with poor economy or inexperienced greenkeepers. In our opinion, velvet bentgrass is primarily an alternative for highly profiled courses aiming at spectacular greens with extraordinary playing quality. While it is true that velvet bentgrass requires less water and nitrogen than creeping bentgrass, it is clearly not a low-input species with regard to topdressing, fungicides or greenkeepers' competence.

Managing velvet bentgrass is challenge, but for the right course and the right greenkeeper, it may also be rewarding.

ADVANTAGES AND DISADVANTAGES

ADVANTAGES	**DISADVANTAGES**
Good ball roll (green speed)	Heavy thatch production resulting in soft greens
Winter hardy	Equally susceptible to turfgrass diseases, especially *Microdochium nivale*, as other bentgrass species.
Intense and attractive color	Poor recuperative capacity. Slow repair of ball marks
Drought tolerant	
Low fertilizer requirements	
Competitive to annual bluegrass	
More tolerant to shade than other turfgrass species	

VELVET BENTGRASS GREENS: RECOMMENDATIONS TO GREENKEEPERS

	SOWING (BEFORE MID-SUMMER) AND GROW-IN
Rootzone	USGA sand with 1.5-2 % (w/w) organic matter
Preplant fertillizers	Organic fertilizer, 0.5-0.7 kg N / 100 m^2 raked into the seedbed
Varieties / sowing rate / cover	Avalon, Greenwich, Legendary, Venus, Vesper or Villa. Villa is the most highly ranked variety in Scandinavia. Sowing rate: 0.6 kg per 100 m^2. Cover newly seeded greens with a white permeable tarp for the first 5-8 days after sowing.
Irrigation	Light and frequent during the first 2-3 weeks after sowing: 1-2 mm every 2-4 hours
	LATER IN THE SOWING YEAR
Fertilizers	First application of NPK about two weeks after sowing. Then regular inputs every 1-2 wk, totaling 1.8-2.2 kg N /100m2 in establishment year. N:P:K ratio approx. 100:12:65. Reduce fertilizer rate with falling light and temperature in autumn, but continue with small inputs until October-November depending on location. Irrigate 3-4 mm after each application.
Irrigation	Well-established, sand-based greens (2% OM) should be irrigated twice per week during good summer periods with daily reference evapotranspiration (ET0) rates of 4-5 mm.
Mowing	First cut at 8-9 mm when the newly seeded turf is 10-15 mm high. Then 1-2 mm reduction in mowing height per week until a standard mowing height of 3 mm. Cut 3-6 times per week, preferably when the turf is dry. Remove of dew and guttation water, at least on days without mowing. Keep the mowing height at 3 mm even in autumn.
Topdressing	0.3-0.5 mm sand every second week or half rate every week. Particle size 0.2 - 0.7 mm. Total dressing in the first season: 630-1260 kg per 100 m2 depending on sowing time
Mechanical treatments	Avoid mechanical thatch control in the sowing year.
	ESTABLISHED GREENS
Mowing / rolling	Mow at 3 mm 3-6 days a week. Rolling on alternate days.
Fertilizer applications	Light and frequent fertilizer inputs, at least every second week. Total N input about 0.9 kg per 100 m^2 per year. Irrigate 3-4 mm after each application.
Irrigation	Deep and infrequent: Irrigate to field capacity at 5-7 day intervals on sand-based greens with 1.5-2 % (w/w) organic matter.
Topdressing	Every second week, after vertical cutting, total annual rate 2500 kg per 100 m^2
Mechanical treatments	Light vertical mowing every second week, e.g. with 5 cm distance between knives as used for fairways. Aerify 6-8 times per season with needles / pins to ensure infiltration and air permeability. Avoid deep vertical mowing (scarification) except on greens with excessive thatch accumulation.
Plant protection	Preventive application of approved fungicide against snow mold in areas with regular and long-lasting snow cover. Replace turf that has been damaged by fungi or ballmarks with new turf from nursery green to prevent *Poa annua* invasion. *Poa annua* is not a problem on dense and healthy greens.

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