Environmental and Experimental Botany xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Environmental and Experimental Botany

journal homepage: www.elsevier.com/locate/envexpbot

Dehardening resistance of six turfgrasses used on golf greens

Tatsiana Espevig[a,*], Mats Höglind[b], Trygve S. Aamlid[a]

[a] *Bioforsk – Norwegian Institute for Agricultural and Environmental Research, Landvik, 4886 Grimstad, Norway*
[b] *Bioforsk – Norwegian Institute for Agricultural and Environmental Research Særheim, 4353 Klepp, Norway*

ARTICLE INFO

Article history:
Received 1 November 2013
Received in revised form 22 January 2014
Accepted 5 February 2014

Keywords:
De-acclimation
Re-acclimation
Freezing tolerance
LT$_{50}$
Perennial grasses
Daily height increment

ABSTRACT

Winter injuries on golf greens cause big economic losses in Scandinavia. Dehardening resistance and rehardening capacity are important traits for survival of low freezing temperatures following warm spells during winter and early spring. Our objective was to determine plant hardiness at the start of winter and dehardening resistance of six cool-season turfgrass species/subspecies commonly used on golf greens. Plant material was collected on an experimental green at Bioforsk Landvik, SE Norway in late November 2011 and 2012 and subjected to six or twelve days of dehardening at 10 °C in a growth chamber. The ranking order for freezing tolerance (measured as lethal temperature for 50% plants (LT$_{50}$)) of turfgrasses taken from the field in late November was: annual bluegrass (*Poa annua* L.) (−13 to −14 °C) < colonial bentgrass (*Agrostis capillaris* L.) (−18 to −20 °C) ≤ slender creeping fescue (*Festuca rubra trichophylla* L.) (−19 °C) ≤ chewings fescue (*Festuca rubra commutate* L.) (−21 °C) < velvet bentgrass (*Agrostis canina* L.) (−23 to −27 °C) ≤ creeping bentgrass (*Agrostis stolonifera* L.) (<−30 °C). The main dehardening occurred during the first 6 days at 10 °C and dehardening rates increased in the order: slender creeping fescue < chewings fescue < colonial bentgrass < annual bluegrass < creeping bentgrass. The dehardening rate of velvet bentgrass was inconsistent in the two years. An additional rehardening treatment at 2 °C for 23 days was included in 2012. None of the species were able to reharden to their original freezing tolerance after 12-d dehardening at 10 °C. Low overall freezing resistance and less capacity to reharden in annual bluegrass than in the other species was associated with more leaf growth during both hardening and dehardening. The results indicate that hardening ability and dehardening resistance are not necessarily positively correlated and that the turfgrasses studied have developed different strategies to survive the winter.

1. Introduction

Winter damage is a major problem on Scandinavian sport fields. Reseeding in spring is time consuming, labour intensive, and leads to a delay of the playing season and to economic losses. Winter injuries can be caused by low freezing temperatures, frost heave, ice, flooding, photoinhibition (abiotic factors) and/or snow molds (biotic factors) alone or in combination (Kvalbein et al., 2013). The extent and origin of winter injuries vary from year to year depending on the interaction between turfgrass genotype, turf management and the environmental conditions during fall and winter.

Freezing tolerance – the ability of the plant to withstand low temperatures – has been shown to be a major component of winter hardiness of perennial grasses (Larsen, 1994; Hulke et al., 2008; Gusta and Wisniewski, 2012). Cold hardening, also known as cold acclimation, refers to an increase in freezing tolerance over time in response to inductive conditions. Hardening is a long process starting in late summer and peaking in January (White and Smithberg, 1980). Two alternate stages of cold hardening have been suggested in winter cereals and temperate grass species (Tumanov, 1940). The first hardening stage occurs at temperatures above freezing and is characterized by several changes including accumulation of osmolytes (e.g. carbohydrates, proline and other amino acids), antifreeze proteins, and reserve carbohydrates, increases in antioxidant production, and alterations in phospholipids and fatty acids (Anchordoguy et al., 1987; Livingston, 1991; Espevig et al., 2011, 2012). The second stage is referred to as sub-zero hardening and leads to acquisition of additional freezing tolerance (Tumanov, 1940; Livingston, 1996; Tronsmo et al., 2013). The second hardening stage is commonly associated with induced ice formation in

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Abbreviations: LT50, lethal temperature for 50% plants; PPFD, photosynthetic photon flux density.

* Corresponding author at: Bioforsk – Norwegian Institute for Agricultural and Environmental Research, Reddalsveien 215, 4886 Grimstad, Norway.
Tel.: +47 406 23 778; fax: +47 370 44 278.
E-mail address: tanja.espevig@bioforsk.no (T. Espevig).

http://dx.doi.org/10.1016/j.envexpbot.2014.02.006
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Please cite this article in press as: Espevig, T., et al., Dehardening resistance of six turfgrasses used on golf greens. Environ. Exp. Bot. (2014), http://dx.doi.org/10.1016/j.envexpbot.2014.02.006

the apoplast and dehydration of plant cells (Steponkus and Lynch, 1989; Herman et al., 2006).

Dehardening, or deacclimation, refers to a loss of freezing tolerance (Kalberer et al., 2006) and occurs much faster than hardening (Gay and Eagles, 1991). Research on dehardening of winter cereals and forage grasses shows that temperature is the main factor which triggers loss of freezing tolerance and that the rate of dehardening increases both with the temperature *per se* and with the duration of the mild period (Gusta and Fowler, 1976b; Jørgensen et al., 2010; Hoffman et al., 2014). The rate of dehardening may also vary from year to year and among plant species and cultivars. Jørgensen et al. (2010) showed that dehardening of timothy (*Phleum pratense* L.) 'Engmo' under controlled conditions varied significantly in spite of the same freezing tolerance gained in January in two experimental years in the field. Jørgensen et al. (2010) also documented that a hardier cultivar of timothy dehardened faster than a less hardy one. Similarly, Hoffmann et al. (2014) recently showed that at higher temperature (8 °C and 12 °C) the more winter hardy creeping bentgrass (*Agrostis stolonifera* L.) dehardened more than the less hardy annual bluegrass (*Poa annua* L.). However, at the lower temperature of 4 °C annual bluegrass exhibited a greater loss in freezing tolerance than creeping bentgrass, indicating a *genotype* × *temperature* interaction on dehardening resistance.

Dehardening can be completely reversible, partly reversible or completely irreversible depending on the temperature and duration of the dehardening period (Pomeroy et al., 1975; Gusta and Fowler, 1976a and 1976b; Rapacz, 2002). Rehardening capability refers to the plants' ability to increase its freezing tolerance after a mild spell. Mechanisms for dehardening and rehardening are not completely understood, and reversibility has been shown to depend on water content and distribution, carbohydrate metabolism, photosynthesis, antioxidants, proteins and gene expression (Kalberer et al., 2006). Only few studies have been conducted on dehardening of cool season turfgrasses in the field (Hoffman et al., 2014) or under controlled environmental conditions (Tompkins et al., 2000) and these studies seem to be limited to creeping bentgrass and annual bluegrass and except for Tompkins et al. (2000) we are not aware whether there is no literature on rehardening capacities of turfgrasses.

Dehardening in response to spells of mild temperature conditions in winter and spring followed by rapid temperature drop leading to freezing injury, is claimed to be a major reason for winter kill in perennial plants including turf grasses. Due to coastal climate in the south and west of Norway, warm spells may occur any time in the winter, also in mid-winter. According to scenarios for climate change in Norway, mild spells may appear more frequently and for longer periods of time (Hansen-Bauer et al., 2009), and plants may be more exposed to temperature fluctuations due to reduced snow cover and snow duration (Thorsen and Höglind, 2010). Moreover, the global warming would lead to a warmer fall and, thus, to an incomplete hardening (Jørgensen et al., 2010; Thorsen and Höglind, 2010). Thus, our primary objective was to study over two years the resistance to dehardening of six turfgrass species/subspecies (in the following referred to as 'species') commonly used of golf greens during mild periods in winter. In the second year, the species' capacity to reharden after such dehardening was also studied.

2. Materials and methods

2.1. Site and weather data

Plant material was collected from an experimental green at the Bioforsk Turfgrass Research Centre Landvik (south coast of Norway, 58° N latitude, 12 m above sea level). Weather data from the local weather station are shown in Figs. 1 and 2 (http://lmt.bioforsk.no/). The fall 2012 was colder than the fall 2011. The average daily air temperatures in September, October, and November (until samplings dates) were 12.9 °C, 8.9 °C, 6.3 °C in 2011 and 11.6 °C, 6.8 °C, and 5.8 °C in 2012, while 30-yr normal temperatures for the corresponding months are 11.8 °C, 7.9 °C, and 3.2 °C. Monthly precipitation in September, October and November were, in turn, 103 mm lower, 144 mm higher and 173 mm higher in 2012 than in 2011. In spite of more rainfall the light conditions almost did not differ between the two years. The average photosynthetic photon flux density (PPFD) for the light hours in September (13.5 h), October (11 h) and November (until samplings dates) (9 h) amounted to 399, 256, and 102 μmol m^{-2} s^{-1} in 2011 and to 437, 268, and 107 μmol m^{-2} s^{-1} in 2012, respectively.

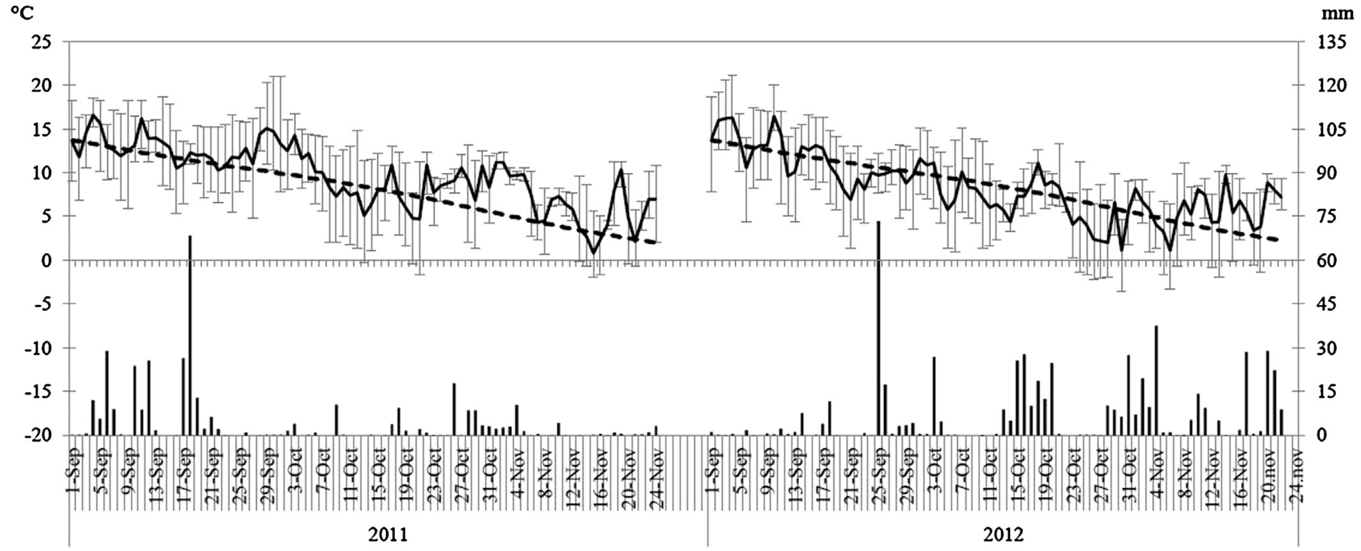

Fig. 1. Daily air temperature and precipitation during the fall 2011 and 2012 at Landvik prior to dehardening treatments. Dotted lines show normal temperature for the reference period 1961–90. Bars following the daily air temperature show maximal and minimal air temperatures.

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