Vegetative tillering in creeping bentgrass

CATTANI, DOUGLAS JOHN

Doug Cattani

Propositions

1. A plant's biological yield potential is not indicative of suitability for turf grass use under intensive management conditions.
   (*this thesis*)

2. Rooting at stolon nodes alleviates the suppression of tillering rate in creeping bentgrass.
   (*this thesis*)

3. Early cessation of growth of creeping bentgrass in the fall reflects retarded spring growth initiation.
   (*this thesis*)

4. Resistance of turf to periods of wear stress and recovery of turf after wear stress are negatively correlated in creeping bentgrass.
   (*this thesis*)

5. Lower seeding rate provides better turf.

6. Genetic improvement of a perennial, obligate out-crossing species utilized for non-reproductive characteristics requires years of field testing.

7. To substantially change the genetic base of a creeping bentgrass turf community, severe stand disturbance is required.

Hunt *et al.* 1987. Growth and root-shoot partitioning in eighteen British grasses. OIKOS 50:53-59.

Kik *et al.* 1990. Life-history variation in ecologically contrasting populations of *Agrostis stolonifera*. J. Ecol. 78:962-973.

Jonsdottir 1991. Tiller demography in seashore populations of *Agrostis stolonifera*, *Festuca rubra* and *Poa irrigata*. J. Veg. Sci. 2:89-94.

Bullock *et al.* 1994. Tiller dynamics of two grasses - responses to grazing, density and weather. J. Ecology 82:331-340.

Sweeney and Danneburger, 1998. Introducing a new creeping bentgrass cultivar through interseeding: Does it work? USGA Greens Section Record, September/October 1998, p. 18-20.

8. Tillering patterns should, theoretically, follow a normal distribution with respect to tiller order; therefore tiller order distribution may be used as a selection criterion for tillering propensity and site usage.

   Neuteboom and Lantinga 1989. Tillering potential and relationship between leaf and tiller production in perennial ryegrass. Annals Bot. 63:265-270.

9. In order to be truly objective, you need to forget more than you have learned.

10. Man can never truly grasp the meaning of life without experiencing death.

Propostitions belonging to the thesis of D.J. Cattani, *Vegetative tillering in creeping bentgrass*. Wageningen, 9 February 2000.

Vegetative tillering in creeping bentgrass

Promotoren: dr. ir. P.C. Struik
hoogleraar in de gewasfysiologie

dr. J. Nowak
professor in plant physiology,
Nova Scotia Agricultural College, Truro, Nova Scotia, Canada

Co-promotor: dr. G.N. Atlin
associate professor in plant breeding,
Nova Scotia Agricultural College, Truro, Nova Scotia, Canada

Vegetative tillering in creeping bentgrass

D.J. Cattani

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ABSTRACT

Growth and development of creeping bentgrass (*Agrostis stolonifera* L.) under non-competitive and competitive conditions were studied.

Growth chamber experiments under non-competitive conditions with high and low tiller producing bentgrass populations produced plants with differing tiller appearance rates. However, the plants developed at a similar rate with respect to growth stage (using West's growth stages for stoloniferous plants). The populations produced similar above ground dry weights plant^{-1}. Dry weight partitioning patterns between tillers within the populations were different with the high tiller producing population demonstrating a more even dry matter distribution.

Tiller development patterns were similar under long and short days. Short days led to a reduced growth stage and tillering rate and retarded stolon development. The low tillering population had more coleoptilar tillers than the high tillering population. Coleoptilar tillers accounted for a large portion of the difference in tiller number between the short and long day environments for the low tillering population.

Increased tillering rate in seedlings led to higher turf tiller densities. Stolon internode length was negatively related to turf tiller density. A positive relationship was found between seedling stolon internode length and internode lengths found under turf conditions. Seedling selection may be used to reduce selection cycle duration where tillering characteristics are of interest.

Seeding rate was found to influence the rate of turf development. Lower seeding rates led to an increase in tillers plant^{-1}, larger plant weight and better wear stress resistance potential. Wear stress resistance potential of turf appeared to have equilibrated at 9-12 weeks after seeding.

Tiller density increased with turf age up to three years after seeding. Cultivar differences were consistent over time. Within year fluctuation in tiller density was found. Above ground biomass accumulation increased with time and tiller density.

Cultivars responded differently to ice and snow management in the spring with respect to their survival rate.

Creeping bentgrass growth and development is predictable. Tiller number and growth stage may be utilized to ascertain the relative developmental status of plants under experimental conditions. Controlled environment growth studies are a useful tool in the selection for tiller related traits.

Preface

I would first off like to thank my promotor, dr. Paul C. Struik for the opportunity to pursue this degree. I would also like to thank him for the effort, patience and advice he provided throughout the process. To Dr. Jerzy Nowak, my other promotor, I thank for his encouragement, help and, as importantly, his friendship over these last three years. To Dr. Gary Atlin, co-promotor, I thank you for your help over the last year in the preparation of this document. I am greatly indebted to Wageningen University for the opportunity to qualify for this programme.

The experiments that are reported within took place over a number of years, primarily in Manitoba, Canada. I remember thinking about my lack of common sense as the watering hose was frozen to my glove and my feet soaking wet on many December mornings while conducting the experiment in Chapter 7. My sanity, or at least my ability to discern the difference between dedication and obsession, was definitely questioned. My arthritis will continue to remind me of this time in my life.

There are many people who have been professionally involved in the work reported herein. I wish to thank them all for their assistance. To Dr. S. Ray Smith Jr., Department of Plant Science, University of Manitoba, for allowing me to pursue experimentation related to turf production in creeping bentgrass, I am particularly indebted.

To the summer assistants, Anh Phan, Anthony Mintenko and Alex Avecilla for their hard work in maintaining plots. I am indebted to Mr. Keith Bamford, for his patience. He allowed me to drone on while discussing many of the early experiments described within.

My family has been supportive throughout the time period of the work reported herein. I thank them for allowing me to pursue my desire to understand the processes of what I was observing. (My children still cringe at the sight of a grass plant.)

The final two people that I wish to thank have been very important in my personal and professional development. Dr. Anna K. Storgaard, I owe more than I can repay. I thank you for your instilling in me that I must understand how a perennial grass develops in order for it to be properly managed. Secondly, I thank you for your encouragement over the last 18 years. To Pat, my wife, whose patience, support and love have allowed me to put, and hopefully keep, things in perspective. Your love and encouragement have been invaluable. Thank you dear. Love you all.

ACCOUNT

Parts of this research have been included in the following publications.

Chapter 2	Cattani, D.J. (1999) Early plant development in "Emerald" and "UM67-10" creeping bentgrass. Crop Sci. 39:754-762.
Chapter 3	Cattani, D.J. and P.C. Struik (xx) Tillering, stolon development and dry matter partitioning in creeping bentgrass (*Agrostis stolonifera* L.). (submitted).
Chapter 4	Cattani, D.J., P.R. Miller and S.R. Smith Jr. (1996) Relationship of shoot morphology between seedlings and established turf in creeping bentgrass. Can. J. Plant Sci. 76:283-289.
Chapter 5	Cattani, D.J. and S.R. Smith Jr. (xx) The effect of seeding rate and cultivar on the establishment of creeping bentgrass turf. (submitted).
Chapter 6	Cattani, D.J., M.H. Entz and K.C. Bamford (1991) Tiller production and dry matter accumulation in six creeping bentgrass entries grown in Manitoba. Can. J. Plant Sci. 71:591-595.
Chapter 7	Cattani, D.J., P.R. Miller and S.R. Miller Jr. (2000) The effect of ice encasement and early snow removal on the survival of creeping bentgrass. Can. J. Plant Sci. (in press).

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Chapter 1

Introduction

Creeping bentgrass is a cool season, perennial grass that spreads vegetatively via stolons. Stolons are specialized stems, or tillers, that grow in a prostrate fashion along the soil surface. The ability to root at the nodes (zone of leaf sheath attachment to the stem) allows for the formation of a dense sod. The tolerance to frequent cutting at heights of less than 3 mm has led to its use for golf course putting greens.

Creeping bentgrass has been shown to possess excellent cold temperature tolerance (Gusta *et al.* 1980) and ice-encasement tolerance of up to 60 days (Beard 1964). Creeping bentgrass is an efficient user of nutrients due to the rapid root proliferation in areas of high nutrient concentration (Crick and Grime 1987). In general, however, creeping bentgrass is noted for its preference for high disturbance and low stress habitats (Hunt *et al.* 1987).

Taxonomic Classification

Agrostis stolonifera L. and *A. palustris* Huds. are the two most common species names used for creeping bentgrass. Jones (1953) determined the normal chromosome compliment to be 2n=28. The species is an allotetraploid, therefore behaving as a functional diploid during meiosis (Jones 1953). Funk and Ahmed (1973) cite this work on *A. stolonifera* in describing *A. palustris*. Hitchcock (1935) differentiates between *A. stolonifera* and *A. palustris* by using stolon length, with the latter having longer stolons. Hubbard (1968) suggests that *A. stolonifera* should be broken into two subspecies, namely, *A. s. stolonifera* and *A. s. palustris*, again utilising stolon length as a similar criterion as Hitchcock.

Other cytogenetic studies have found varying chromosome numbers for *A. stolonifera*. Bjorkman (1954) and Kik *et al.* (1992) both reported tetra-, penta- and hexa-ploid *A. stolonifera* plants. Bradshaw (1958) reported naturally occurring hybrids of *A. stolonifera* and *A. tenuis* Sibth. While this is possible, these apparent hybrids could be naturally occurring somaclonal mutants of *A. stolonifera* L.

The above information appears to support that *A. stolonifera* L. should be used to describe creeping bentgrass.

Tillering

Neuteboom and Lantinga (1989) described the potential tiller appearance order for grass plants and the frequency of tiller appearance (site usage). Skinner and Nelson (1992, 1994) with tall fescue and van Loo (1992) working with perennial ryegrass have shown tillering to follow, in general, the predicted sequence. The potential for tillering follows an exponential curve with a high level of synchronisation between tillers on a plant (Nelson and Skinner 1992). Neuteboom and Lantinga (1989) suggested that a single phyllochron separated the appearance of a tiller and its first daughter tiller. Low leaf elongation rate is related to high tillering in tall fescue and is initially due to high coleoptile tiller production (Skinner and Nelson 1994). Many grass species possess specialised plant growth appendages, e.g. rhizomes and stolons, which allow for the vegetative spread of the plant. However, these specialised stems may have an impact on tillering via intra-plant competition for resources.

Robson (1973) described an exponential phase, a linear phase and a static or decreasing phase of tiller appearance in grasses. Jonsdottir (1990) monitored tiller birth and death in a naturally occurring stand of creeping bentgrass and found that they were offsetting.

Tiller development in plants is related to leaf appearance (Davies and Thomas 1983). Leaf length and leaf width (Bos 1999) and leaf density will all impact the level of competition for light (Wilson and Cooper 1969). Red:far red light ratio has been shown to be important in tillering (Casal et al. 1990). Vine (1983) reported that leaf appearance rates are reduced drastically in late-September to late-October in perennial ryegrass, thus reducing tillering potential.

Madison (1960) reported a period of leaf elongation followed by new leaf appearance after mowing in creeping bentgrass. Duff and Beard (1974) reported stolon development to be apparent one week after mowing of leaf blades on a tiller. Tillering in creeping bentgrass is affected by temperature (Duff and Beard 1974; Hawes and Decker 1977), and therefore the performance of cultivars in a cold, dry prairie climate may be different from performance in less severe environments (Hunt *et al.* 1987). At least one new cultivar of creeping bentgrass has been selected for survival under severe Manitoba conditions (Cattani *et al.* 1992). As a creeping bentgrass turf develops, stolons provide surface structure and cushion the surface to help resist tearing.

The development of a turfgrass area will depend upon plant density, the development of individual plants within the turf, and their interaction. The rate and sequence of tiller appearance will influence plant development and may ultimately dictate the rate of turf development. Seeding rate has been shown to influence stand density and number of leaves $tiller^{-1}$ in *Poa pratensis* L. and influenced the developmental rate of individual plants within the turf (Brede and Duich 1982). Germinability, vigour and competition for resources will also greatly influence emergence and establishment of seedlings. Parr (1982) found higher mortality rates at higher seeding rates for *Lolium perenne* and *Poa pratensis*. Above ground biomass was found to be independent of seeding rate after turf establishment with lower seeding rates producing larger plants (Parr 1982).

Once a creeping bentgrass stand is established, very little subsequent growth of new seedlings occurs within a stand (Jonsdottir 1990, Bullock et al. 1994), even where regular overseeding is practised (Sweeney and Danneberger 1998). Therefore, due to this lack of the establishment of new individuals, the genetic make-up of a stand is established in the initial period of growth.

Vegetative growth of creeping bentgrass predominates in areas where growing conditions are favourable (Kik *et al.* 1990) and the environment is undisturbed (Hunt *et al.* 1987). High tiller density provides a dense surface that allows for smooth ball roll and resistance to ingress by other, less desirable plants species.

Ong (1978) found tiller weight to be the important factor in tiller survival under whole plant stress. Dry matter partitioning within the plant will be important for turf plant development and persistence. Stolon development would increase tiller dry weight by increasing tiller length (internode elongation) and the accumulation of cellulose and lignin (Esau 1977). Shearman and Beard (1975) reported that total cell wall content (mg dm^{-2}) accounted for almost all of the variation in wear tolerance differences between turfgrass species.

Dry matter accumulation $tiller^{-1}$ is important for wear stress resistance in *Poa pratensis* L. (Shildrick and Peel 1984). However, it appears that tiller density and dry weight $tiller^{-1}$ are negatively correlated in creeping bentgrass (Cattani 1987). Lush (1990) used tiller density and dry weight per unit area to estimate potential wear stress resistance. Trenholm *et al.* (1999) reported that higher tiller densities resulted in greater wear resistance for seaside paspalum (*Paspalum vaginatum* Swartz).

Tiller density is, therefore, an important morphological characteristic in creeping bentgrass. It is positively related to wear stress recovery (Hawes and Decker 1977) and potential wear stress resistance in turf (Lush 1990). Other research has indicated that tiller density and leaf density were positively associated ($r = 0.97$) and both with visual turf density ratings in creeping bentgrass turf (Cattani and Clark 1991). Lehman and Engelke (1991) found narrow-sense heritabilities for tiller number of 0.31 to 0.41 with creeping bentgrass.

Hunt *et al.* (1987) reported a reduction in the relative growth rate under low light intensity conditions (80% shade) of approximately 50% in creeping bentgrass. High shoot stress was also measured under the low light conditions (Hunt *et al.* 1987). Seeding time may therefore affect the plant development and turf development with a late summer/early fall seeding under shortening days leading to reduced plant development and growth when compared to a late spring seeding.

Wear Stress Resistance

A turfgrass surface is a collection of plants. Inter- and intra-plant competition, both within and between species, dictates the stress performance of the stand. Lush (1990) proposed the use of the power rule (rule of self-thinning (Lonsdale and Watkinson 1982)) to predict potential wear stress resistance of turfgrasses:

$$\log_{10} B = \log_{10} C - 0.5 \log_{10} N.$$

where, B is the population biomass m^{-2}, N is the density (individuals m^{-2}) and $\log_{10} C$ is the estimate of the biomass of a single individual.

Limitations of the power rule are that input and management changes or enhancing performance through genetic advances lead to a shift in the $\log_{10} C$. This will increase or decrease potential wear stress resistance (Lush 1990). At a given $\log_{10} C$, increasing tiller density will be at the expense of tiller size. Implications of this rule are that the potential wear stress resistance within a given turf may be manipulated to enhance tiller size and therefore wear resistance. Within cultivars, the $\log_{10} C$ estimate may therefore provide a measure for determining site-specific management practices to enhance wear stress resistance.

Therefore, an important characteristic among creeping bentgrass cultivars is tiller density (TD). Tiller density is positively related to wear stress recovery in bentgrasses (Hawes and Decker 1977), and wear stress resistance in Kentucky bluegrass (*Poa pratensis* L.)

(Shildrick and Peel 1984), tall fescue (*Festuca arundinacea* Schrib.) (Shildrick and Peel 1983), seaside paspalum (Trenholm *et al.* 1999) and, theoretically all turfgrasses (Lush 1990). However, tiller number and dry weight tiller^{-1} are negatively correlated in creeping bentgrass (Cattani 1987). We previously found visual stand density of turf subjected to wear stress, a measure of wear stress resistance, to be correlated with tiller density (Cattani and Clark 1991).

Greater wear stress resistance among turfgrass is often attributed to higher levels of aboveground biomass (AGB) or thatch (i.e., living and dead material above the soil surface) (Shildrick and Peel 1984). The mathematical relationship between TD and live AGB has been proposed as a method for predicting potential wear stress resistance among bentgrass cultivars (Lush 1990). However, while high levels of AGB may be desirable for turfgrasses (Shildrick and Peel 1983; Lush 1990), higher levels of fertilization and cultural management may be required to maintain the integrity of the green (Shildrick 1985).

Lower mowing heights have been shown to increase tiller populations in creeping bentgrass (Madison 1962). Salaiz *et al.* (1995) reported greater root production and turfgrass quality at 4.8 mm height of cut compared to 3.2 mm.

A greater knowledge of tiller dynamics in turfgrass is also important since TD is becoming an increasingly useful characteristic in turfgrass breeding and management programs (Lush 1990). Information on AGB production among turfgrass cultivars is important, especially for determining the level and type of management required to maintain a good-quality playing surface.

Seeding Rate and Development

Madison (1962, 1966) determined seeding rates and looked at tiller density at different mowing heights. This work is still the basis for seeding rate. Golf course superintendents in Canada are often faced with the demand for a quick establishment of a golf putting green, often within three months. Superintendents have reported using up to 2.5 kg 100 m^{-2}. Recommended seeding rates are between 250-500 g 100 m^{-2} (Beard 1982). Madison (1966) found that a 450 g m^{-2} seeding rate for creeping bentgrass was sufficient to establish a playable turf within a three month period. As creeping bentgrass cultivar availability has increased in recent years, cultivar may affect turf establishment rate.

Lower seedling densities in perennial ryegrass and timothy result in a greater wear stress tolerance due to larger plant and tiller size (Parr 1982). The same author also reported that plant number did not decrease over time under mowing stress. Rossi and Mallett (1996) found self-thinning took place in creeping bentgrass at high seeding rates primarily due to disease. Seedling competitiveness was influenced by early emergence in *Dactylis glomerata* L. (Ross and Harper 1972).

Cultivar Development

Creeping bentgrass has long been cultivated for golf course use, primarily for putting greens (Duich 1985). The practice of vegetative propagation, which was the primary propagation method until the release of "Penncross" in the 1950s, resulted in little interest in plant development and establishment. Penncross has long dominated the industry and is only now in the late 1990s losing its sizable market share. The latest listing from NTEP (National Turfgrass Evaluation Program) lists at least 28 cultivars commercially available in 1997 (NTEP 1999).

Modern cultivars of creeping bentgrass are the result of synthetic development (Brauen *et al.* 1993, Engelke *et al.* 1995a,b). The uniformity of a cultivar is therefore dependent upon the number of parental germplasms making up the synthetic and the genetic uniformity of and between the parentals. Golembiewski *et al.* (1997), using RAPD markers, found repeatable differences between most creeping bentgrass cultivars tested, however, they reported some difficulty in distinguishing between two cultivars, due to seed lot effects. Warnke *et al.* (1997) utilizing isozyme polymorphisms, reported relationships between creeping bentgrass cultivars. "Emerald" and "18th Green" were found to be closest with respect to genetic distance and are therefore thought to be from a similar base population ("Seaside") (Warnke *et al.*, 1997). 18th Green was selected out of UM67-10 (Cattani *et al.* 1992).

Progress in turfgrass breeding has been limited as each cycle of selection requires the establishment and maintenance of turfgrass plots. The ability to relate shoot morphological characteristics of seedlings to established turf would be useful for plant breeders. Important shoot morphological characteristics would include higher tiller densities for improved golf putting green wear-stress tolerance and increased stolon length for quicker colonisation of bare spots in golf greens, fairway and tee-box turfs. Selecting desirable creeping bentgrass plants in the seedling stage would provide an improved methodology for generation advance. This would allow selection of plants with desired shoot morphological attributes at an early stage, enabling earlier transplanting of seedlings to field or greenhouse crossing blocks. If selection for one characteristic can be achieved at an early growth stage and selection for another characteristic at a later stage (e.g., disease tolerance), advancement for both characteristics may be possible without extending the time for generation advancement.

Objectives and Outline of this Thesis

The objectives of this thesis are: 1) to characterize creeping bentgrass growth patterns; 2) to evaluate creeping bentgrass cultivars and germplasms for plant development and turf characteristics; 3) to assess the utility of early plant selection for turf tiller density; 4) to investigate the effect of seeding rate and cultivar on early turf development; 5) to determine the effect of stand age on turf tiller density and; 6) investigate the effect of cultivar selection on ice encasement and snow cover survival.

Chapters 2 and 3 investigate the effect of population and daylength on tillering and stolon development in creeping bentgrass. Chapter 4 contains a study of the relationship between early plant growth and the turf tiller density in creeping bentgrass cultivars. Chapter 5 looks at the effect of seeding rate and cultivar on creeping bentgrass turf establishment. Chapter 6 is a study of turf tiller density over a three year period. Chapter 7 looks at ice encasement and snow management on the survival of creeping bentgrass.

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Part I

Effect of day length on creeping bentgrass plant growth and development