Chapter 5

The Effect of Seeding Rate and Cultivar on the Establishment of Creeping Bentgrass Turf.

ABSTRACT

Wear stress tolerance of newly seeded turfgrass areas may depend on size of individual plants and on cultivar selection. These studies examined effects of four seeding rates, 250, 500, 750 and 1000 g 100 m^{-2}, on growth and turf development of three creeping bentgrass cultivars, 18th Green, Penncross and Putter. One field and one growth room experiment were conducted. Cores were taken at 4, 8, and 12 weeks after seeding (**WAS**) in the field and at 3, 6, and 9 **WAS** in the growth room. Seeding rate and cultivar effects were found for plants m^{-2}, tillers m^{-2}, tillers $plant^{-1}$, plant weight, tiller weight and biomass weight per m^{-2}. Seeding rate x cultivar interactions, including plants m^{-2}, tillers m^{-2}, dry weight $plant^{-1}$ and dry weight $tiller^{-1}$ were found, especially at 9 **WAS** in the growth room. Seeding rate of 250 g m^{-2} gave the largest plants for both tiller number and dry weight. Potential wear stress tolerance (logc) was not significantly different between seeding rates or cultivars by the end of the studies. Seeding rates should not exceed the 250 – 500 g m^{-2} recommended for creeping bentgrass.

Key words: creeping bentgrass, seeding rate, tillers, wear stress resistance, dry weight, cultivars

INTRODUCTION

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 1983). 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 after sowing.

Lower seedling densities in other grasses, 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) however, found that 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* (Ross and Harper 1972).

Creeping bentgrass cultivar availability has increased in recent years and cultivar may affect turf establishment rate. We have already reported that seedlings of creeping bentgrass cultivars tiller at different rates and at different times (Chapter 4), thus the onset of inter- and intra-plant competition may be cultivar specific.

The objective of this study was to investigate the effect of seeding rate on turf establishment in three creeping bentgrass cultivars.

MATERIALS AND METHODS

Experiment 1

On 16 June 1993, a field trial was established on a USGA specification sand based putting green at the University of Manitoba, Winnipeg, MB. Three cultivars, "Penncross" (standard entry), "Putter" and "18th Green" were seeded at four seeding rates, 250, 500, 750 and 1000 g 100 m^{-2}. Seeding rates for each cultivar were adjusted to equal Penncross, based on the 1000 seed weight and a 90% germination rate. A randomized complete block design with four replicates was used with all cultivar and seeding rate combinations. Plots were 1 m^2 in size and were raked before and after manual seeding. A 1 m x 1 m x 0.4 m seeding frame was used to keep seed within plots during broadcast seeding. Plots were immediately covered with a fiberglass filter material (Famcomat, American Air Filter, Kansas City, Mo.) and rolled prior to first irrigation to prevent seed movement between treatments. The covering was removed once emergence was clearly visible at 6 d after sowing. Plots were maintained as golf green turf with mowing 5 x weekly and a final mowing height of 4.5 mm. Plots received a total of 1350 g N 100 m^{-2} during the experiment. An application of 450 g N 100 m^{-2} was incorporated prior to seeding and the remainder applied in equal increments 20 d apart. Pre-establishment fertiliser carrier was a 19-26-5 product (O.M. Scotts, Marysville, OH). Initial mowing height was 12 mm at 4 weeks after seeding (WAS). Final mowing height was reached at 6 WAS. Wear stress was applied using a spiked roller (Cattani 1987), starting at 9 WAS, with three wear stress applications weekly until 12 WAS. Each wear stress treatment consisted of 6 passes across each plot.

Core samples (6.25 cm dia.) were taken at 4, 8 and 12 WAS. Tillers $core^{-1}$ were counted and above ground live dry matter (**AGLB**) determined by drying at 65 °C for 72 h. Plants $core^{-1}$ were counted at 4 WAS only.

Tillers m^{-2} and dry weight m^{-2} were used to calculate potential wear stress resistance (logc) as per Lush (1990):

$$\log c = \log 10\ b + \log 10\ (n*0.5),$$

where: b = dry weight m^{-2}, n = tillers m^{-2}.

One replicate was lost between 5 and 6 WAS due to a management error, therefore, the 8 and 12 **WAS** measurements were reduced to 3 replicates.

Experiment 2

A controlled environment study was carried out using 12.5 cm dia. pots. USGA specification sand, similar to the field study, was used. Seeding rates and cultivars were similar to Experiment 1. Harvest dates were 3, 6 and 9 WAS, to coincide with the period of growth prior to wear stress treatment in the field. A randomized complete block design with four replicates was used. Harvest dates were blocked and pots rotated to lessen position effects. Seeds were broadcast on the surface then covered with 5 mm of media, then packed. Pots were clipped at 6 mm 3 times weekly, starting at 3 WAS. Destructive sampling was practised with 6.25 cm dia. cores being removed from the center of each pot. Plant number $core^{-1}$ and tillers $core^{-1}$ were counted and **AGLB** determined as noted above for all harvests.

Analysis of variance was performed using SAS (SAS Institute, Gary, NC).

RESULTS

Results of the statistical analysis for tiller density and Dry weight in Exp. 1 and for plants, tiller density and dry weight in Exp. 2 are found in Table 5.1.

Table 5.1. Source of variation, degrees of freedom, mean square, F value and probability of F for tillers m^{-2}, dry weight m^{-2} and plant number for the field and growth room studies.

		Field Study								
		Tillers								
		4 Weeks			**8 Weeks[z]**			**12 Weeks[z]**		
Source	**df**	**ms**	**F**	**P>F**	**ms**	**F**	**P>F**	**ms**	**F**	**P>F**
Seeding Rate	3	160923	17.1	.001	25841	10.5	.001	30540	13.0	.001
Cultivar	2	23343	2.49	.099	2650	1.08	.357	32752	13.9	.001
SR x Cv	6	11127	1.19	.338	2610	1.06	.413	3335	1.42	.252
		Dry Weight Tiller^{-1}								
Seeding Rate	3	.910	7.45	.001	1.256	18.2	.001	741	6.25	.003
Cultivar	2	.042	0.34	.712	.385	5.57	.011	349	2.95	.074
SR x Cv	6	.043	0.35	.902	.493	7.13	.001	117	0.99	.456
		Growth Room Study								
		Tillers								
		3 Weeks			**6 Weeks**			**9 Weeks**		
Seeding Rate	3	48684	58.8	.001	56436	20.7	.001	148049	24.4	.001
Cultivar	2	1424	1.72	.195	5658	5.74	.007	95289	15.7	.001
SR x Cv	6	939	1.13	.365	2649	0.97	.460	18664	3.08	.017
		Plant Number								
Seeding Rate	3	52421	65.0	.001	32177	31.5	.001	32554	51.3	.001
Cultivar	2	5478	6.79	.003	5954	8.75	.001	7403	11.7	.001
SR x Cv	6	1016	1.26	.303	2011	1.97	.099	3656	5.62	.001
		Dry Weight Tiller^{-1}								
Seeding Rate	3	0.498	15.2	.001	.104	17.5	.001	0.175	14.8	.001
Cultivar	2	0.073	2.22	.124	.011	1.81	.179	0.001	0.04	.957
SR x Cv	6	0.088	2.71	.030	.009	1.52	.203	0.028	2.32	.056

[z] Error term df for 8 and 12 weeks is reduced by 12 due to the loss of one replicate.

Table 5.2. Plants m^{-2}, tillers m^{-2}, and tillers plant^{-1} for the field experiment at 4, 8 and 12 weeks after seeding (WAS).

	Plants m^{-2}	Tillers m^{-2}			Tillers plant^{-1}
	(x 1000)				
Cultivar	4 WAS	4 WAS	8 WAS	12 WAS	4 WAS
Penncross	82.6 a[z]	91.5 a	89.3 a	106.6 b	1.25 c
18th Green	61.3 a	76.4 a	97.5 a	140.1 a	1.54 a
Putter	55.2 a	66.8 a	88.9 a	118.2 b	1.39 b
lsd (.05)	*23.9*	*22.7*	*13.7*	*13.4*	*0.12*
Seeding Rate (100 m^{-2})					
1000 g	110.3 a[z]	120.2 a	113.1 a	136.4 a	1.13 c
750 g	89.2 a	96.3 a	96.1 b	131.1 a	1.19 c
500 g	46.5 b	62.1 b	87.2 b	125.0 a	1.42 b
250 g	19.5 b	34.4 c	71.2 c	94.0 b	1.83 a
lsd (.05)	*27.6*	*26.2*	*15.8*	*15.4*	*0.14*

[z] Means followed by the same letter within columns are not significantly different using Fishers Protected LSD (P=.05).

Experiment 1

No significant cultivar differences were found (Table 5.2) for plant m^{-2} at 4 WAS. The 1000 and 750 g 100 m^{-2} seeding rates (**SR4X** and **SR3X**, respectively) were highest for plants m^{-2} at 4 WAS.

18th Green was highest for tillers m^{-2} at 12 WAS, while no significant differences were found at the earlier dates. **SR4X** was highest for tillers m^{-2} on all dates, significantly higher at 8 WAS (Table 5.2). The 250 g 100 m^{-2} (**SR1X**) seeding rate was significantly lower than the other seeding rates on all dates (Table 5.2).

Significant differences were found between all cultivars for 250 g 100 m^{-2} tillers plant^{-1} at 4 WAS, with 18th Green having the highest values followed by Putter, then Penncross (Table 5.2). **SR1X** was significantly higher for tillers plant^{-1} at 4 WAS (Table 5.2). The 500 g 100 m^{-2} seeding rate (**SR2X**) was next highest followed by the two highest seeding rates.

Dry weight plant^{-1} (**DWP**) was highest for 18th Green at 4 WAS. Increasing seeding rates led to a decrease in **DWP** at 4 WAS (Table 5.3).

Dry weight tiller^{-1} (**DWT**) was higher for **SR1X** followed by the other seeding rates in order (Table 5.3) for 4 and 12 WAS respectively. A seeding rate x cultivar interaction was found at 8 WAS for **DWT** (Figure 5.1). Penncross and Putter both demonstrated a decrease in **DWT** as seeding rate increased, while 18th Green had a uniform **DWT** across all seeding rates (Figure 5.1).

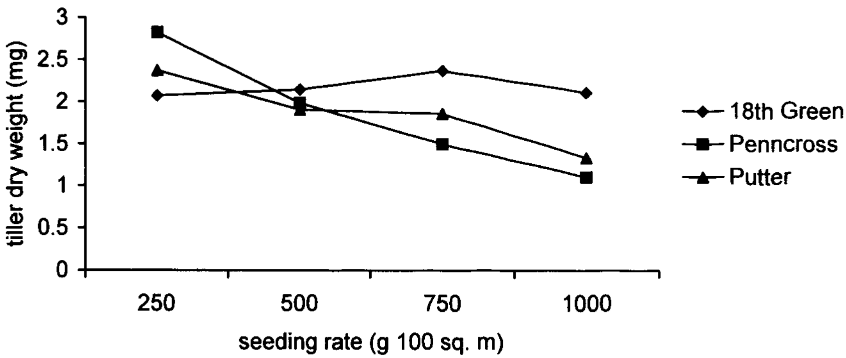

Figure 5.1. Dry weight tiller^{-1} interaction between cultivar and seeding rate at 8 weeks after seeding for the field study.

Higher seeding rates produced greater above ground live biomass (**AGLB**) at 4 WAS, which were taken prior to first clipping (Table 5.3). Mowing tended to equalize **AGLB** production under the canopy (Table 5.3). At 12 WAS, the two lowest seeding rates were maintaining or increasing for **AGLB** while the higher seeding rates were decreasing (Table 5.3).

Visual plot coverage and density ratings showed that 18th Green had the highest rating on all dates, and significantly was higher than Putter at 8 WAS and Penncross as well at 12 WAS (Table 5.4). Penncross showed the greatest decrease in plot density after wear stress was applied at 9 WAS.

Estimates of wear stress resistance (log *c*) were similar at all dates with the exception

Table 5.3. Dry weight plant^{-1} (DWP), dry weight tiller^{-1}, and dry weight of above ground live biomass accumulation for the 1993 field study at 4, 8 and 12 weeks after seeding (WAS).

	DWP	Dry Weight Tiller^{-1}		Above Ground Live Biomass (Dry Weight)		
	mg			g m^{-2}		
Cultivar	**4 WAS**	**4 WAS**	**12 WAS**	**4 WAS**	**8 WAS**	**12 WAS**
18th Green	1.77 a[z]	1.09 a	1.33 b	216 a	216 a	173 a
Putter	1.59 ab	1.09 a	1.46 ab	201 a	186 a	166 a
Penncross	1.30 b	1.00 a	1.73 a	230 a	200 a	185 a
lsd (.05)	*0.45*	*0.25*	*0.33*	*36*	*37*	*37*
Seeding Rate (g 100 m^{-2})						
250	2.59 a	1.42 a	1.83 a	147 c	169 a	173 a
500	1.64 b	1.11 b	1.52 ab	194 b	171 a	190 a
750	1.10 c	0.93 bc	1.24 b	255 a	183 a	160 a
1000	0.89 c	0.78 c	1.43 c	268 a	192 a	175 a
lsd (.05)	*0.51*	*0.29*	*0.38*	*42*	*44*	*44*

[z] Means followed by the same letter are not significantly different using Fishers Protected LSD (P=.05).

Table 5.4. Plot coverage and visual density ratings and estimates of wear stress resistance (log c) for cultivars and seeding rates of creeping bentgrass at 4, 8, and 12 weeks after seeding (WAS) for the field study.

	Field Study, 1993			Growth room Study, 1994		
	Plot Coverage[z] (%)	Visual Density Ratings (9 - best, 1 - no turf)		Log *c*		
Cultivar	**4 WAS**	**8 WAS**	**12 WAS**	**4 WAS**	**8 WAS**	**12 WAS**
18th Green	98 a[y]	7.75 a	7.42 b	4.28 a[z]	5.64 b	5.74 a
Putter	98 a	7.06 b	6.67 b	4.24 a	5.80 a	5.77 a
Penncross	97 a	7.88 a	6.50 a	4.18 a	5.66 b	5.73 a
lsd (.05)	*1.5*	*0.5*	*0.54*	*0.12*	*0.08*	*0.1*
Seeding Rate g 100m^{-2}						
1000	99 a	8.42 a	7.44 a	4.46 a	5.73 ab	5.74 a
750	99 a	7.92 ab	7.11 ab	4.38 a	5.74 a	5.74 a
500	97 b	7.50 b	6.78 b	4.16 b	5.69 ab	5.81 a
250	95 c	6.42 c	6.11 c	3.92 c	5.64 b	5.70 a
lsd (.05)	*1.7*	*0.57*	*0.63*	*0.14*	*0.09*	*0.12*

[Z] Percentage of plot covered by turf (visually estimated).
[Y] Means followed by the same letter are not significantly different using Fishers Protected LSD (P=.05)

Table 5.5. Plants m^{-2}, tillers m^{-2}, and tillers plant^{-1} for the growth room experiment at 3, 6 and 9 weeks after seeding (WAS).

	Plants m^{-2}		Tillers m^{-2}		Tillers plant^{-1}		
	3 WAS	6 WAS	3 WAS	6 WAS	3 WAS	6 WAS	9 WAS
Cultivar	-----------------------*(x 1000)*	-------------------					
Putter	50.3 a^{z}	47.5 b	53.1 a	117.1 b	1.07 b	2.67 a	5.71 b
Penncross	48.6 a	55.2 a	50.5 a	128.2 ab	1.06 b	2.58 b	5.62 b
18th Green	39.1 b	39.7 c	46.9 a	137.5 a	1.28 a	3.56 a	8.23 a
lsd (.05)	*6.6*	*7.5*	*6.7*	*14.1*	*0.07*	*0.27*	*0.86*
Seeding Rate (100 m^{-2})							
1000 g	67.6 a^{z}	64.8 a	71.1 a	146.8 a	1.06 b	2.39 c	4.89 c
750 g	59.7 b	52.0 b	62.9 b	136.0 ab	1.07 b	2.73 b	5.47 c
500 g	35.9 c	48.5 b	46.9 c	132.3 b	1.18 a	2.88 b	6.57 b
250 g	20.8 d	24.4 c	25.4 d	94.5 c	1.25 a	4.73 a	9.15 a
lsd (.05)	*7.7*	*8.7*	*7.8*	*14.1*	*0.08*	*0.31*	*0.99*

^{z} Means followed by the same letter are not significantly different using Fishers Protected LSD (P=.05).

of 18th Green and Penncross having a higher value at 8 WAS (Table 5.4).

Experiment 2

Significant differences were found among cultivars and seeding rates at 3 and 6 WAS for plants m^{-2} (Table 5.5). 18th Green had significantly fewer plants m^{-2} at both dates. **SR1X** was lowest at both dates and 500 g 100 m^{-2} (**SR2X**) and 750 g 100 m^{-2} (**SR3X**) were similar at 6 WAS (Table 5.5). A seeding rate x cultivar interaction was found at 9 WAS for plants m^{-2}. 18th Green had similar levels of plants m^{-2} at **SR3X** and **SR4X** while plants m^{-2} increased with increasing seeding rate for Penncross and Putter (Figure 5.2).

Significant differences were found at 6 WAS between cultivars for tillers m^{-2} with 18th Green being higher than Putter. Significant differences between seeding rates for tillers m^{-2} were found at 3 and 6 WAS (Table 5.5). Tillers m^{-2} increased with increasing seeding rate. A significant seeding rate x cultivar interaction was found at 9 WAS for tiller m^{-2} (Table 5.1). Putter and 18th Green showed a leveling off or a decrease at **SR4X** as compared to **SR3X** while Penncross increased with seeding rate (Figure 5.3).

18th Green was significantly higher than Penncross at 3, 6 and 9 WAS and Putter at 6 and 9 WAS for tillers plant^{-1} (Table 5.5). **SR1X** was in the highest grouping on all dates and

SR4X was in the lowest grouping on all dates (Table 5.5).

18th Green had a higher dry weight plant^{-1} (**DWP**) at 6 WAS (Table 5.6). Lower **DWP** was found as seeding rate increased for 3 and 6 WAS (Table 5.6). A significant seeding rate x cultivar interaction was found at 9 WAS for **DWP**. **DWP** increased at **SR4X** as compared to

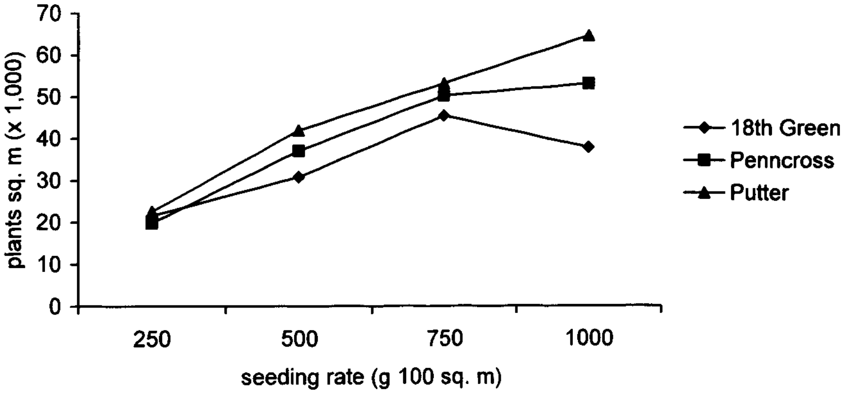

Figure 5.2. Plant m^{-2} interaction between cultivar and seeding rate at 9 weeks after seeding for the growth room study.

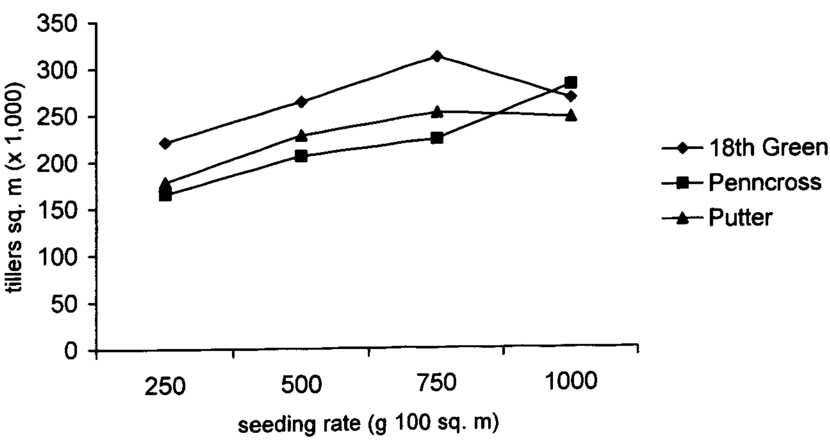

Figure 5.3. Tillers m^{-2} interaction between cultivar and seeding rate at 9 weeks after seeding for the growth room study.

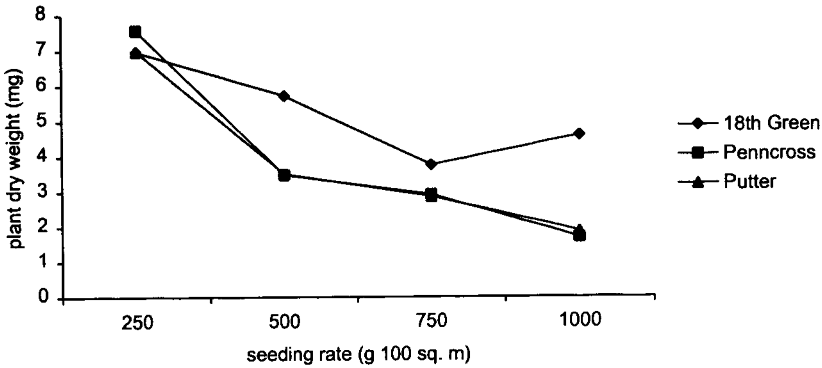

Figure 5.4. Dry weight plant^{-1} interaction between cultivar and seeding rate at 9 weeks after seeding for the growth room study .

Table 5.6. Plant height (cm), plant weight (g), tiller weight (g), above ground live biomass (g m^{-2}) and visual density ratings for the growth room study.

	Plant Height	Dry Weight Plant^{-1}		Dry Weight Tiller^{-1}		Above Ground Live Biomass (Dry Weight)		
	3 WAS	3 WAS	6 WAS	6 WAS	9 WAS	3 WAS	6 WAS	9 WAS
Cultivar		*mg*				*g m^{-2}*		
Penncross	7.0 a[z]	0.96 a	1.65 b	0.62 a	0.64 a	126 a	233 b	413 b
Putter	6.5 b	0.93 a	1.68 b	0.62 a	0.63 a	122 ab	252 ab	425 b
18th Green	4.6 c	0.98 a	2.48 a	0.62 a	0.63 a	106 b	273 a	510 a
lsd (.05)	*0.4*	*0.17*	*0.24*	*0.06*	*0.08*	*18*	*22*	*53*
Seeding Rate (g 100 m^{-2})								
250	6.2 a[z]	1.37 a	3.00 a	0.76 a	0.80 a	86 c	226 b	459 a
500	6.2 a	1.00 b	1.82 b	0.63 b	0.64 b	109 b	252 a	452 a
750	6.0 ab	0.75 c	1.62 b	0.61 bc	0.57 bc	136 a	251 a	453 a
1000	5.8 b	0.71 c	1.30 c	0.54 c	0.53 c	142 a	240 ab	432 a
lsd (.05)	*0.4*	*0.19*	*0.28*	*0.07*	*0.09*	*21*	*25*	*62*

[z] Means followed by the same letter are not significantly different using Fishers Protected LSD (P=.05).

SR3X for 18th Green while the other cultivars continued to decrease as seeding rate increased (Figure 5.4). This mirrors tillers m^{-2} (Figure 5.3).

DWT showed no cultivar differences once clipping was implemented (Table 5.6). A significant seeding rate x cultivar interaction was found at 3 WAS (Table 5.1). 18th Green exhibited little difference for **DWT** across seeding rates while Penncross and Putter showed a decrease in **DWT** (Figure 5.5) as seeding rate increased similar to 8 WAS in the field (Figure 5.1). **AGLB** increased throughout the study (Table 5.6). Cultivar differences changed as clipping was implemented (Table 5.6). Prior to clipping at 3 WAS, Penncross was significantly higher than 18th Green. However at 9 WAS 18th Green was significantly higher than Penncross and Putter (Table 5.6). Seeding rate differences were not seen by 9 WAS.

Cultivar differences for visual density ratings changed as clipping began with 18th Green being higher at 6 and 9 WAS (Table 5.7). Visual density ratings were higher for higher seeding rates throughout the study (Table 5.7).

Cultivar differences for log *c* values were variable at 6 and 9 WAS (Table 5.7). Log *c* values increased throughout the study with initial seeding rate differences disappearing by 9 WAS (Table 5.7).

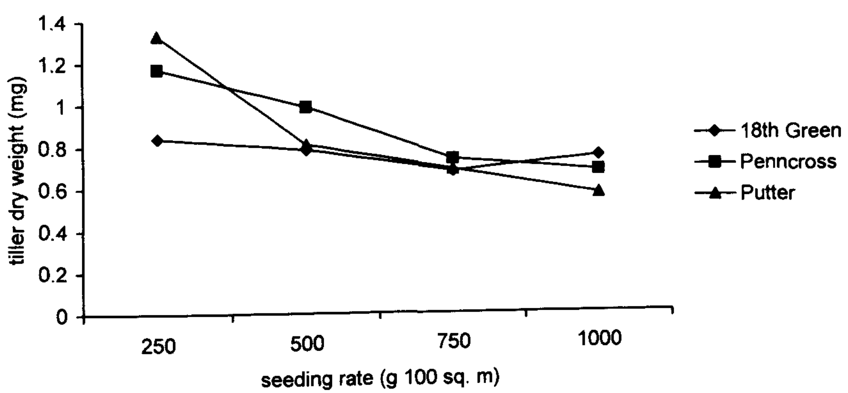

Figure 5.5. Dry weight tiller^{-1} interaction between cultivar and seeding rate at 3 weeks after seeding for the growth room study (prior to first clipping).

Table 5.7. Turfgrass visual density ratings and estimates of wear stress resistance (log c) for cultivars and seeding rates of creeping bentgrass at 3, 6, and 9 WAS in the growth room.

	Visual Density Ratings (9 - best, 1 - no turf)			Log c		
Cultivar	**3 WAS**	**6 WAS**	**9 WAS**	**3 WAS**	**6 WAS**	**9 WAS**
Penncross	5.04 a[z]	5.50 b	6.25 b	6.93 a	7.42 b	7.79 b
Putter	4.88 a	5.13 b	6.13 b	6.92 a	7.38 b	7.93 a
18th Green	3.50 b	6.06 a	6.75 a	6.83 a	7.50 a	7.81 b
lsd (.05)	*0.4*	*0.27*	*0.37*	*0.09*	*0.05*	*0.06*
Seeding Rate (g 100 m^{-2})						
1000	6.47 a[z]	7.08 a	7.42 a	7.08 a	7.46 a	7.85 a
750	5.56 b	6.13 b	7.33 a	7.03 a	7.47 a	7.87 a
500	4.06 c	5.21 c	5.83 b	6.84 b	7.47 a	7.84 a
250	1.81 d	3.83 d	4.92 c	6.63 c	7.34 b	7.81 a
lsd (.05)	*0.47*	*0.31*	*0.42*	*0.1*	*0.06*	*0.07*

[z] Means followed by the same letter are not significantly different using Fishers Protected LSD (P=.05).

DISCUSSION

SR1X produced fewer, heavier plants, a lower tiller density and heavier tillers. Larger plant and tiller size for **SR1X** account for the comparable log*c* values obtained by the end of the studies. Larger plants withstand wear stress better than smaller plants (dry weight and tiller number) (Parr 1982). Tallowin *et al.* (1989) reported that tiller order was influenced by severe grazing stress, promoting only primary tiller production in *Lolium perenne*. This could account for the relatively equal tiller weights found for 18th Green at 8 WAS (Figure 5.1) and 3 WAS (Figure 5.5). A similar trend was found for primary tillers in UM67-10 (Chapter 2), the parental population of 18th Green (Cattani *et al.* 1992). Results of Kays and Harper (1974) would suggest that as the turf develops, **DWT** would eventually converge between seeding rates. Lower **DWT** values found in the growth room are most likely the result of lower light intensity (Kays and Harper 1974).

Our results suggest that **SR1X** and **SR2X** are better for establishment of creeping bentgrass, regardless of cultivar used, as found by Madison (1966). Cultivar did affect **DWP** in the growth room study and **DWT** at 8 WAS in the field and 9 WAS in the growth room. Wear stress was applied at 9 WAS in the field and lower seeding rates appeared to perform better as evidenced by increasing log *c*'s. Higher seeding rates remained relatively stable for log *c*, however there was a decrease in **AGLB** between 8 and 12 WAS.

Higher plant densities for the seeding rates were found in the field study than in the growth room study. Covering to prevent seed movement during establishment appeared to have provided a more favorable environment for germination and emergence. Seed was raked into the soil surface while in the growth room, seed was placed at a 5 mm depth. Madison (1966) reported that creeping bentgrass had higher plant populations when seeded at the soil surfaces compared to seeding into the soil.

Putter and 18th Green showed evidence of interplant competition at 9 WAS. 18th Green had fewer plants at **SR4X** than **SR3X** while Putter had similar tiller densities at these rates. Inter-plant competition could be a negative factor with respect to early upright growth of turfgrass. Increased disease incidence has been noted for higher seeding rates in creeping bentgrass possibly due to smaller plant size (Rossi and Mallett 1996). Cultivars that possess longer leaves may be subject to greater tissue removal during mowing. As distal portions of blades are more physiologically mature (Bregard and Allard 1999), greater removal may mean a greater reduction in photosynthetic capacity.

Plant growth rate will also impact occupation of biological space within a population. Earlier emergence of a seedling confers a competitive advantage to that seedling within the developing plant community (Ross and Harper 1972). 18th Green produced more tillers plant^{-1} in the present studies. 18th Green has been shown to have a high tillering rate relative to other creeping bentgrass cultivars (Chapter 4). This higher tillering rate may be exerting greater inter-plant stress, thus reducing plant numbers, especially at higher seeding rates (Figure 5.2). Higher plant densities have been reported to lead to stand thinning in creeping bentgrass turf (Rossi and Mallett (1996), however the seeding rated in the present studies are in the low to mid range of their study.

AGLB had equilibrated between seeding rates by 8 and 9 WAS for the field and growth room studies respectively. This would appear to indicate that the respective mowing heights had restricted **AGLB** accumulation. Kays and Harper (1974) found a similar trend with *L. perenne* between seeding rates.

Lower seeding rates may be more desirable as they should allow for greater horizontal growth via stolons due to less crowding. Duff and Beard (1974) reported that tillers began stolon growth one week after experiencing mowing. Once mowing is initiated, stolonization should quickly follow. Leaf blade orientation may be more horizontal at lower plant densities allowing for less removal during mowing events. Stolon internode elongation may be controlled by light competition (Casal *et al.* 1990). Higher tiller densities with upright growth of tillers may encourage stolon development through greater shading of tiller bases (Casal *et al.* 1985). Without adequate space for horizontal expansion, growth may continue in a vertical direction leading to removal during mowing. Lower seeding rates should allow for horizontal stolon growth and thus higher tiller weights (Chapter 3), increasing wear stress tolerance (Lush 1990). Lower seeding rates should also provide greater turf strength, if root formation at stolon nodes takes place.

Stolon production did not take place until at least 3 weeks after transplanting in non-competitive environments (Chapter 3). This may be a factor of light competition. Stolon length differs between cultivars (Chapter 4) and this may have ramifications on potential wear stress resistance as the turf matures. In the present studies, tiller initiation was somewhat delayed as compared to non-competitive plants (Chapter 2). Stolon growth was only seen in a single creeping bentgrass plant prior to tillering, and only under a short daylength (Chapter 3).

Rossi and Mallett (1996) found that self-thinning took place at high seeding rates, similar to **SR4X** and higher. This was only seen for 18th Green at the highest seeding rate (Table 5.2, Figure 5.1). Increasing tiller densities as the study progressed also suggest that tiller density had not reached its maximum. We found that tiller density increased over a three year period in creeping bentgrass grown as golf green turf seeded at a single rate (**SR2X**) (Chapter 6). Brede and Duich (1982) found that a five-year period was required in *Poa pratensis* L. for tiller densities of turf seeded at four rates to converge. Therefore turfgrass development takes place over an extended period.

Expectations are that a turf will persist for a number of years. Turf health (Rossi and Mallett 1996) and stress resistance will impact the longevity of the stand. Seeding rates used in these studies are well within rates used by the turf industry. Higher seeding rates will lead to turf comprised of more immature plants. Ability of a turfgrass to withstand and recover from stress, especially wear and diseases, will also be important with respect to weed competition, especially *Poa annua* L., which readily invades creeping bentgrass turf.

CONCLUSIONS

Turfgrass areas established with increased seeding rates appeared better suited for early initiation of play. However, turfgrass areas seeded at high rates were comprised of less developed plants than those seeded at lower rates. Mature plant development appears to enhance wear stress resistance. Cultivar selection did not appear to affect turf development at the end of the studies. Seeding rate differences were found with respect to turf wear stress resistance (log *c*) development. Newer cultivars were often different from the standard cultivar.

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