



*Know-how for Horticulture™*

**Bentgrass maintenance for putting  
greens**

**TU202**

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Turfgrass Technology**

TU202

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## SUMMARY

The effect of mowing height (2, 3 and 4mm), rolling and wear on the green speed and agronomic characteristics of five bentgrass varieties (*Agrostis capillaris* var. Egmont, *A.stolonifera* var Cobra, Penncross and SR-1020 and Suttons a mix of Colonial and Creeping bentgrasses) was investigated. Green speed was fastest at lower mowing heights on all bentgrass varieties, however, with the stoloniferous bentgrasses the increased green speed due to low mowing was at the expense of turf quality. Rolling significantly increased green speed (0.3 to 0.5m) especially at the higher height of cut, while wear had little effect on green speed, though the spiking it caused resulted in ball deviation. In some instances, wear had a significant effect by increasing green speed, which was due to the compacting/rolling effect. When evaluating the change in green speed over an eight (8) hours period, all varieties increased in green speed over time with the stoloniferous types increasing the most. The effects of rolling lasted for the entire test period.

Egmont and Suttons had greater turf quality and density than the stoloniferous varieties with Egmont and Suttons providing a higher quality surface at the three mowing heights while the stoloniferous varieties performed best at a medium height of cut. Low turf density gave rise to increased moss and algae invasion. The stoloniferous varieties showed a greater level of spiking than the colonial and capillaris types with Penncross effected the most. The level of spiking increased on all varieties as the cutting height was raised.

Following renovation, the stoloniferous varieties returned to their pre-renovation green speed quicker than the other varieties, however, the stoloniferous varieties were slower to attain their pre-renovation turf quality and density.

## 1. INTRODUCTION

Putting greens are the main focal point of play on all golf courses with the golfer having to hit onto and then putt on the green. Two shots per hole are allocated to the putting green which constitutes 50 percent of the play on a Par 72 course, assuming that a par round is played. The greens on a golf course make up about two percent of the turf area but in many instances provides most of the discussion amongst golfers. There is little wonder that so much effort is put into improving the consistency, smoothness and speed of the putting surface.

There are a number of factors that affect the quality of the putting surface including uniformity, smoothness, firmness, resiliency, close mowing, spiking and absence of grain. Ball roll and speed are affected by management practices such as the height of cut, mowing frequency, rolling, fertility, dethatching, regular light topdressings and renovation practices. Practices used to increase green speed such as low mowing heights, reduced fertiliser applications, reduced watering etc are not always the best agronomic practices from a plant health perspective.

Since putting is a major factor in the game of golf, the speed and quality of the green is of great concern to the game. More than any other characteristic, mowing practices are the focus of attention when considering why a green putts well or poorly. Close and frequent mowing results in very high shoot density and vertical leaf orientation, resulting in a smooth and uniform surface. The extremely close mowing required on greens is a costly cultural practice that also places severe physiological stress on the turf. Rooting depth, carbohydrate reserves, recuperative potential and tolerance to environmental stresses are all adversely affected by low cutting heights. The optimum height of cut is generally specific to the particular turf variety. Rolling is sometimes used as a finishing technique to insure maximum surface smoothness for trueness of ball roll and to increase the speed of ball roll.

Bentgrass (*Agrostis* sp.) is the most desirable grass species on putting greens and over the past few years there have been a number of new varieties introduced to golf courses. Penncross creeping bentgrass (*A. Stolonifera* var. Penncross) has been the main variety for many years, however, there are several new creeping bentgrass varieties such as Cobra, SR-1020, Providence and Penlinks, as well as a non-creeping, browntop bentgrass *A. Capillaris* var. Egmont. With the introduction of these new grasses there has been a need to alter the management strategies to achieve a quality putting surface while also maintaining a turf cover of uniform density and health.

Green speed has become a key criteria for assessing putting green quality and in an endeavour to achieve faster greens, turf managers have often been forced to impose maintenance practices that, while providing faster greens, result in turf deterioration. At times maintenance practices that are satisfactory at other clubs are imposed elsewhere, with little consideration given to the grass type, levels of fertility and usage, again resulting in unsatisfactory turf quality.

A recent trial funded by the Victorian Golf Association and the Horticultural Research Development Corporation and carried out by Turfgrass Technology, specifically looked at several bentgrass varieties and the influence of mowing height, rolling and wear on surface quality and green speed.

## 2. METHODOLOGY

The trial was carried out on the practice putting green at Royal Melbourne Golf Club. The trial area was 30m x 23m and consisted of five bentgrass varieties; a colonial bentgrass (*Agrostis capallaris* var. Egmont); three Creeping bentgrasses (*Agrostis stolonifera* var. Cobra, Penncross & SR-1020) and Suttons mix which is a very old greens mix used on many of Melbourne's older golf courses consisting of Colonial and Creeping bentgrasses.

Creeping bentgrasses have vigorous creeping stolons that develop at the surface of the ground and initiate new roots and shoots from the nodes. When closely mown, it forms a fine textured turf of high shoot density, uniformity and quality. The finer textured cultivars tend to be compact and low growing with more upright stems, while the coarser textured varieties are usually more prostrate and forms a more open sward.

The Colonial bentgrasses form an upright, fine textured dense turf under close mowing. The stems are fine in texture and low growing which gives rise to a good tolerance to close mowing. The creeping tendency is minimal since the rhizome and stolon growth is either lacking or quite short.

The trial area was divided up into three sections maintained under different mowing heights; low: 2mm, medium: 3-3.5mm and high 4-5mm and was mown three times a week with a walk behind, Jacobsen cylinder mower. The green was rolled with a smooth roll polishing roller and a moderate level of wear was imposed prior to assessment. The plots were rolled from one end to the other and then back across the plot in the opposite direction. A motorised 80 kg roller with golf spikes was used to simulate wear and spiking caused by golfers. The level of wear imposed was equivalent to 135 rounds of golf. The 3 mowing heights, wear and rolling were applied to the trial site in such a way that the effect of each of these treatments and their interactions could be assessed.

Assessment of putting quality involved measurement of green speed and visual assessment of agronomic characteristics.

### 2.1 Green speed (ball roll distance)

Green speed was measured using a stimpmeter which is a universally accepted method of measuring green speed. The stimpmeter is an extruded aluminium bar with a V-shaped chute down its length. It is 0.9m long and has a milled ball-release notch 0.76m from the end that rests on the ground. It is designed so that a ball is released and starts to roll when it is raised to an angle of 20° from the horizontal insuring that the ball has a constant velocity. Three balls are released in two directions and their distances measured and averaged. The USGA have developed a green speed chart for regular membership play and for tournament conditions (table 1).

**Table 1: Green speed using the stimpmeter (United States Golf Association).**

Relative Green Speed	Regular Play (m)	Tournament Play (m)
Fast	2.59	3.20
Medium - Fast	2.29	2.90
Medium	1.98	2.59
Medium - Slow	1.68	2.29
Slow	1.37	1.98

Green speed measurements were taken within a few hours of mowing, rolling and the imposition of wear.

### 2.1 Turf quality

A visual assessment integrating colour, uniformity, texture, density, growth habit and smoothness using a 0 = poor to 9 = excellent scale.

### 2.2 Turf density

A visual estimate of the number of living plants per unit area (excluding damaged areas) using a 0 = very open to 9 = very dense scale.

### 2.3 Spiking

A visual estimate of the degree of surface disruption using a 0 = none to 5 = maximum scale.

Assessments commenced in December 1993 and were conducted on a regular basis until renovation in early March 1995.

In addition to assessing the effects of mowing height, rolling and wear on green speed, two subtrials were conducted to investigate the effect of nutritional level and the effect of renovation on green speed.

### 2.4 Effect of renovation

The trial area was hollow tyned (cored) and topdressed on 7<sup>th</sup> September 1994 and was not mown for two weeks following renovation. When mowing was resumed the cutting heights were 4, 5 and 6 mm. The plots were maintained at these heights for two weeks before being lowered to 3, 4 and 5 mm. The plots were maintained at this height for a further two weeks before being lowered to their normal cutting heights of 2, 3 and 4 mm.

Assessment of green speed and turf agronomic characteristics were undertaken for a 5 week period following renovation.

## 2.6 Effect of nutrition level

A "high" and "low" nitrogen level treatment was imposed and green speed and turf agronomic characteristics assessed. Greensmaster (20-0-20) a soluble fertiliser was applied on 10/11/94 and 11/1/95 using a diffuser. The two treatments were;

Low N:	0.125 kg N per 100m <sup>2</sup> 0.625 kg Greensmaster per 100m <sup>2</sup>
High N:	0.25 kg N per 100m <sup>2</sup> 1.25 kg Greensmaster per 100m <sup>2</sup>

Normal maintenance practices were carried out during the trial period and are summarised in table 2.

**Table 2: Trial maintenance practices**

DATE	MAINTENANCE SCHEDULE
29-11-93	Fertilise
31-1-94	Fertilise
8-2-94	Pennside (I)
25-3-94	Chloranil (F)
1-4-94	Argenstem (I)
14-4-94	Pennside (I)
25-4-94	Green renovated
10-5-94	Turf Starter
7-6-94	Soluble Iron
18-7-94	Fertilise
11-8-94	Endothal (H)
7-9-94	Topdressed
21-9-94	Fertilise
26-9-94	Argenstem (I)
28-9-94	Benlate & Chloranil (F)
4-10-94	Cultar (H)
17-10-94	Saturaid
9-11-94	Fertiliser
23-11-94	Argenstem (I)
27-2-95	Turfree

I=insecticide    F=fungicide    H=herbicide

### 3. RESULTS

#### 3.1 Effects of variety and cultural practices on green speed

**Table 3: Variety effect - green speed (m)**

Treatment	Avg	Dec-93	Feb-94	Jun-94	Aug-94	Sep-94	Oct-94
Egmont	2.73	2.91	3.03	2.58	2.74	2.84	2.27
Suttons	2.70	2.91	3.01	2.59	2.65	2.76	2.30
Cobra	2.77	3.01	3.03	2.58	2.67	2.90	2.41
Penncross	2.90	3.10	3.18	2.98	2.83	3.01	2.58
SR1020	2.94	3.12	3.16	2.92	2.79	2.98	2.71
LSD (p<0.05)	0.04	0.07	0.08	0.07	0.07	0.12	0.06

**Table 4: Mowing height effect - green speed (m)**

Treatment	Avg	Dec-93	Feb-94	Jun-94	Aug-94	Sep-94	Oct-94
Low	3.07	3.21	3.31	2.85	3.04	3.25	2.75
Medium	2.89	3.07	3.15	2.90	2.80	2.97	2.46
High	2.46	2.75	2.78	2.09	2.37	2.47	2.14
LSD (p<0.05)	0.03	0.06	0.06	0.06	0.05	0.10	0.05

**Table 5: Rolling effect - green speed (m)**

Treatment	Avg	Dec-93	Feb-94	Jun-94	Aug-94	Sep-94	Oct-94
Rolling	3.00	3.20	3.26	2.87	2.93	3.15	2.59
No rolling	2.61	2.82	2.90	2.42	2.54	2.64	2.31
LSD (p<0.05)	*	*	*	*	*	*	*

**Table 6: Wear effect - green speed (m)**

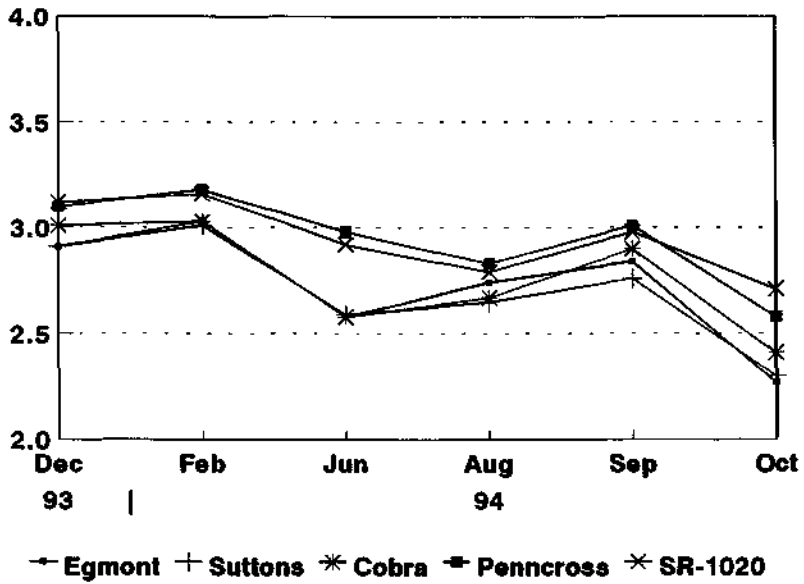
Treatment	Avg	Dec-93	Feb-94	Jun-94	Sep-94	Oct-94
Wear	2.83	3.01	3.07	2.70	2.89	2.54
No wear	2.81	3.01	3.08	2.64	2.90	2.45
LSD (p<0.05)	*	ns	ns	*	ns	*

**Table 7: Height x rolling - green speed (m)**

Treatment	Avg	Dec-93	Feb-94	Jun-94	Aug-94	Sep-94	Oct-94
Low	Roll	3.33	3.42	3.48	3.15	3.37	2.90
	No roll	2.81	3.01	3.13	2.56	2.70	2.85
Medium	Roll	3.08	3.24	3.34	3.15	2.96	2.61
	No roll	2.70	2.89	2.97	2.66	2.65	2.73
High	Roll	2.60	2.94	2.95	2.30	2.47	2.26
	No roll	2.32	2.57	2.60	2.05	2.27	2.36
LSD (p<0.05)	0.04	ns	ns	0.08	0.07	0.14	ns

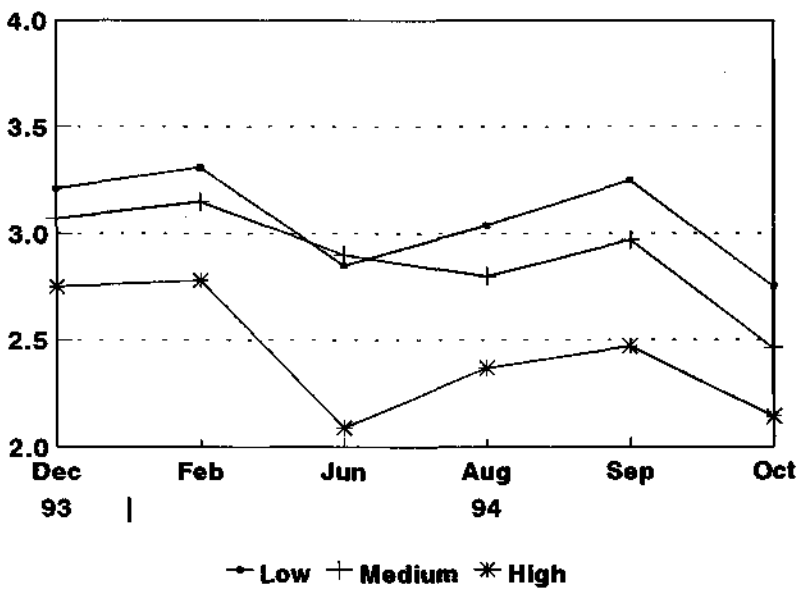
**Figure 1: Variety effect**

Green Speed (m)

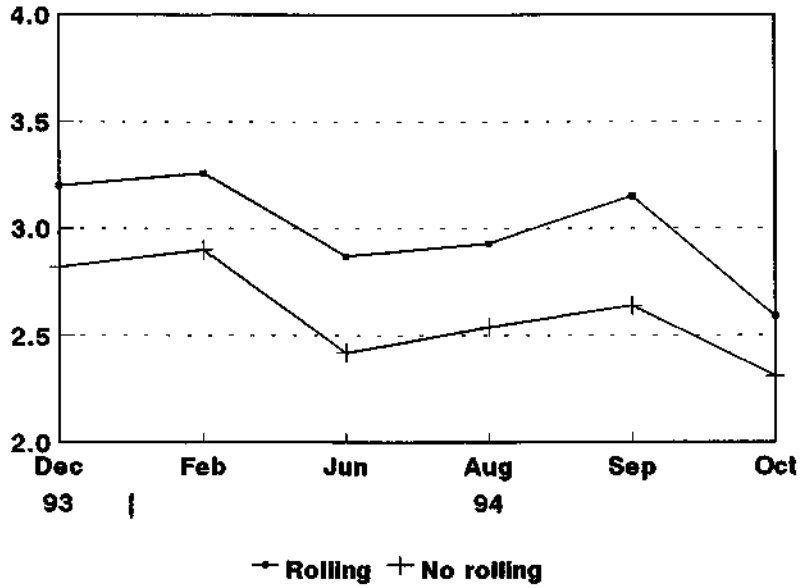


**Figure 2: Mowing height effect**

Green Speed (m)



**Figure 3: Rolling effect**  
Green Speed (m)



**Figure 4: Wear effect**  
Green Speed (m)

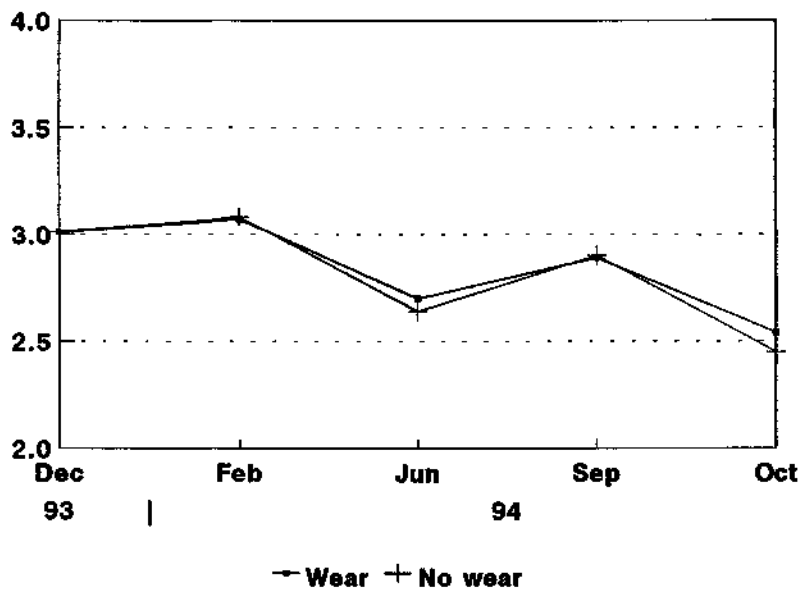


Table 8: Variety x height interaction - green speed (m)

Treatment		Avg	Dec-93	Feb-94	Jun-94	Aug-94	Sep-94	Oct-94
Egmont	low	3.04	3.16	3.28	2.79	3.20	3.23	2.63
	medium	2.79	2.99	3.12	2.76	2.67	2.93	2.27
	high	2.35	2.58	2.68	2.19	2.37	2.37	1.90
Suttons	low	2.97	3.12	3.17	2.94	2.89	3.06	2.63
	medium	2.79	3.00	3.15	2.78	2.69	2.80	2.30
	high	2.35	2.61	2.71	2.06	2.37	2.42	1.96
Cobra	low	3.00	3.17	3.28	2.76	2.90	3.23	2.71
	medium	2.90	3.07	3.05	2.95	2.81	3.02	2.47
	high	2.40	2.78	2.75	2.04	2.31	2.45	2.05
Pennncross	low	3.18	3.34	3.41	2.99	3.10	3.37	2.83
	medium	2.95	3.02	3.25	2.97	2.85	3.03	2.57
	high	2.58	2.94	2.87	2.32	2.53	2.64	2.34
SR1020	low	3.15	3.27	3.41	2.79	3.09	3.38	2.96
	medium	3.05	3.25	3.21	3.05	3.00	3.08	2.71
	high	2.63	2.85	2.87	2.26	2.28	2.49	2.45
LSD (p<0.05)		0.06	0.13	ns	0.13	0.11	ns	0.11

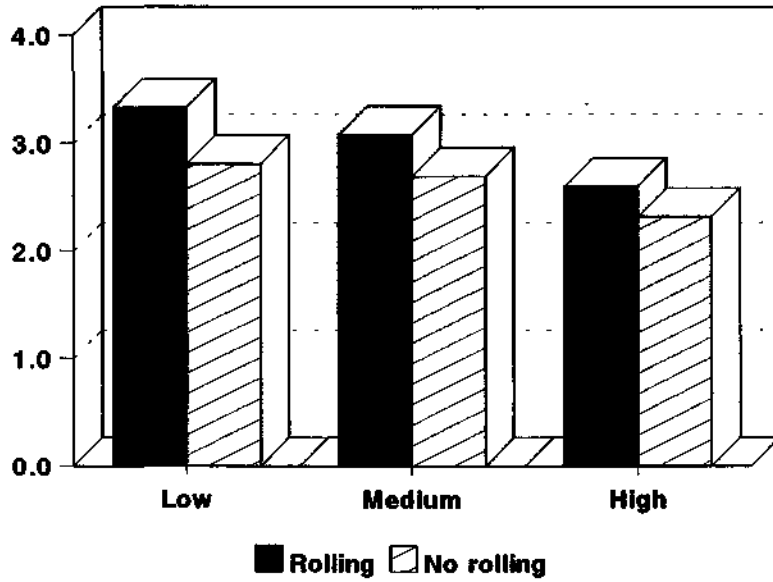
Table 9: Variety x rolling interaction - green speed (m)

Treatment		Avg	Dec-93	Feb-94	Jun-94	Aug-94	Sep-94	Oct-94
Egmont	Roll	2.94	3.09	3.18	2.78	2.98	3.16	2.44
	No roll	2.52	2.73	2.87	2.37	2.51	2.53	2.09
Suttons	Roll	2.91	3.09	3.25	2.81	2.84	3.02	2.43
	No roll	2.50	2.72	2.77	2.37	2.46	2.50	2.16
Cobra	Roll	2.99	3.26	3.23	2.85	2.95	3.15	2.52
	No roll	2.54	2.75	2.83	2.31	2.39	2.65	2.29
Pennncross	Roll	3.07	3.27	3.32	3.00	2.99	3.25	2.71
	No roll	2.73	2.93	3.04	2.52	2.67	2.78	2.45
SR1020	No roll	3.11	3.27	3.32	2.87	2.91	3.20	2.84
	Roll	2.77	2.97	3.00	2.53	2.67	2.76	2.57
LSD (p<0.05)		0.05	ns	ns	ns	0.09	ns	ns

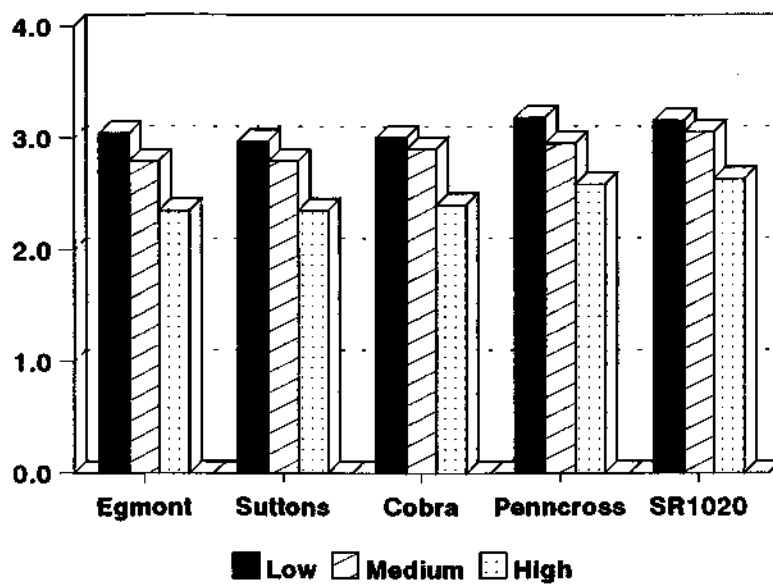
Table 10: Height x wear interaction - green speed (m)

Treatment	Avg	Dec-93	Feb-94	Jun-94	Sep-94	Oct-94
Low height of cut						
Wear	3.10	3.25	3.35	2.90	3.20	2.78
No wear	3.08	3.21	3.31	2.85	3.25	2.75
Medium height of cut						
Wear	2.92	3.04	3.13	2.93	2.95	2.55
No wear	2.91	3.07	3.15	2.90	2.97	2.46
High height of cut						
Wear	2.49	2.74	2.73	2.27	2.50	2.27
No wear	2.44	2.75	2.78	2.16	2.47	2.14
LSD (p<0.05)		ns	ns	ns	ns	0.05

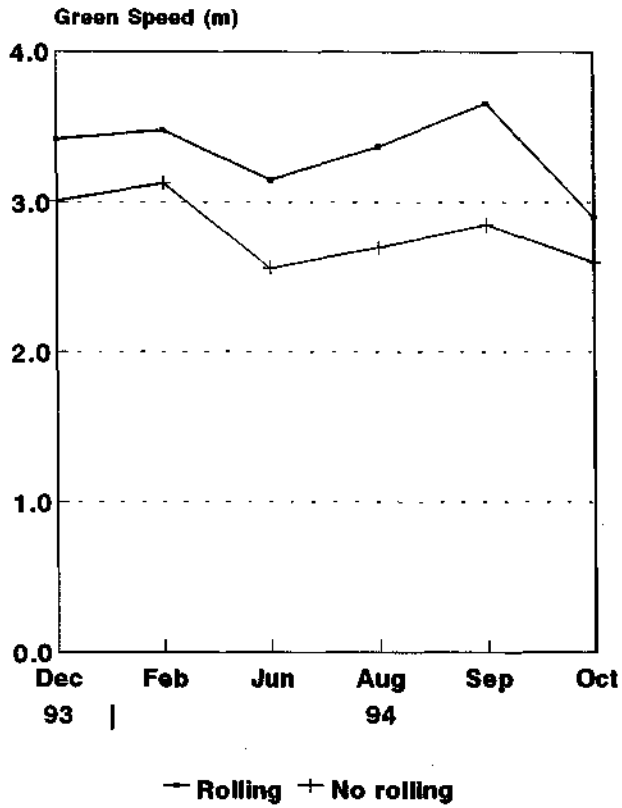
**Figure 5: Mowing height x rolling**  
Average green speed (m)



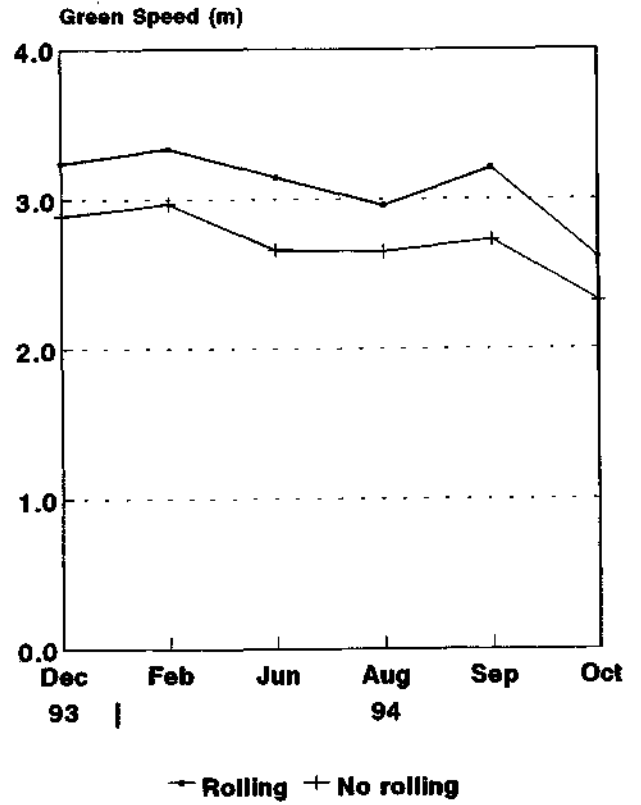
**Figure 6: Variety x mowing height**  
Average green speed (m)



### Low mowing height



### Medium mowing height



### High mowing height

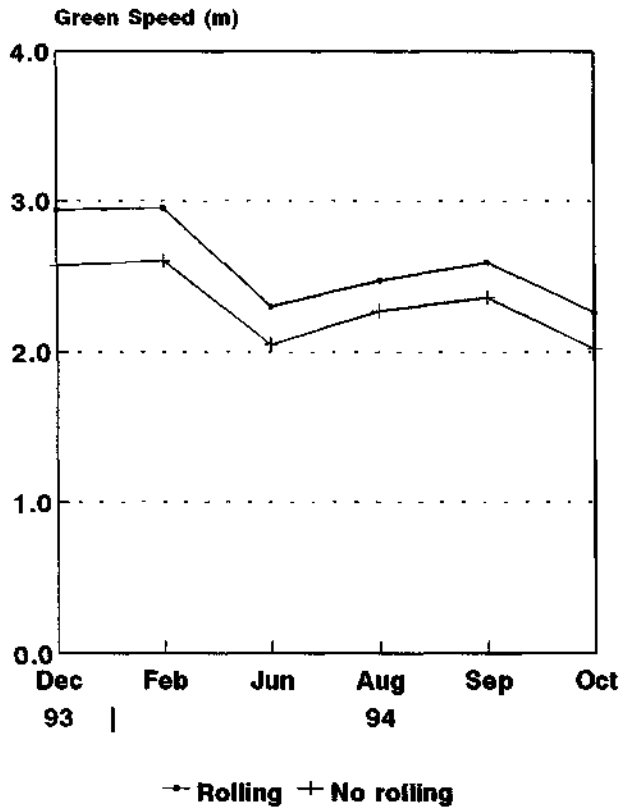
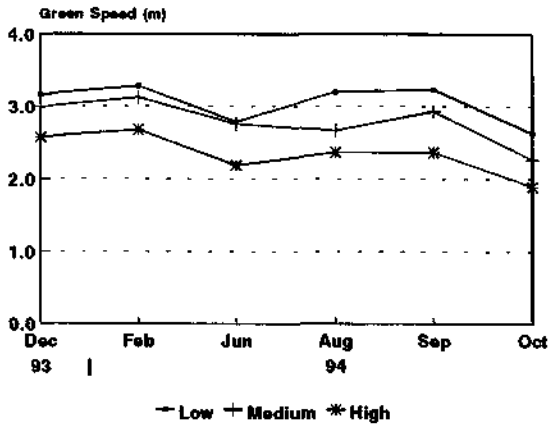
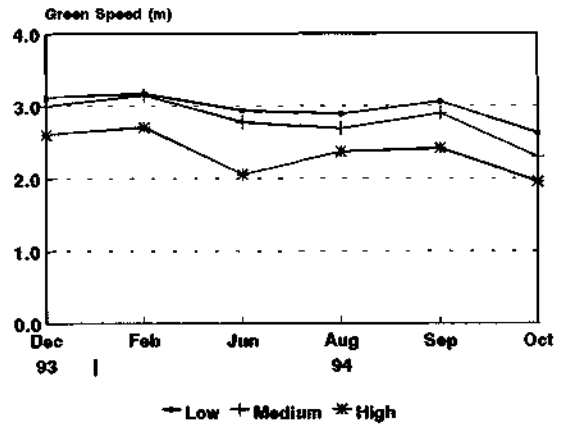


Figure 7: Mowing height x rolling interaction

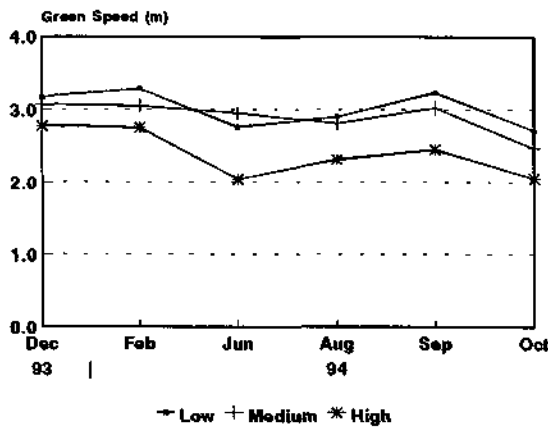
Egmont



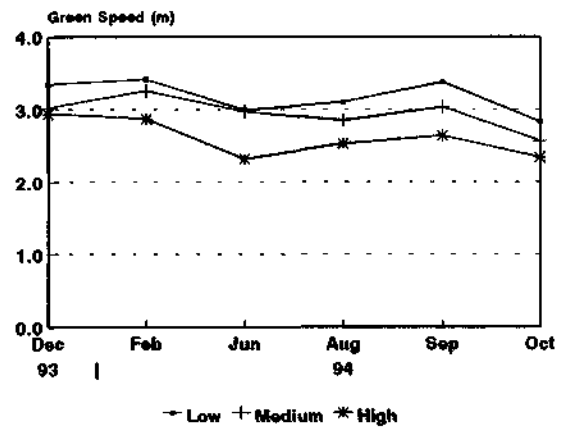
Suttons



Cobra



Penncross



SR 1020

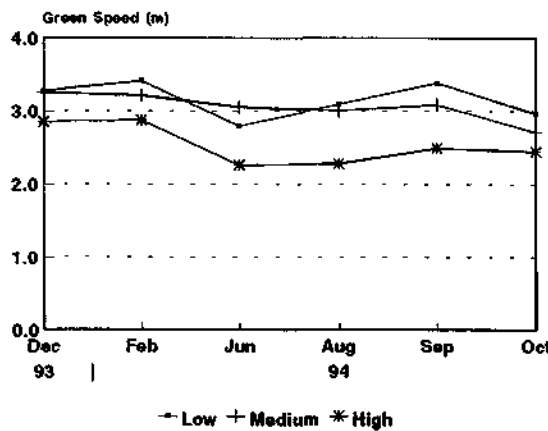


Figure 8: Variety x mowing height interaction

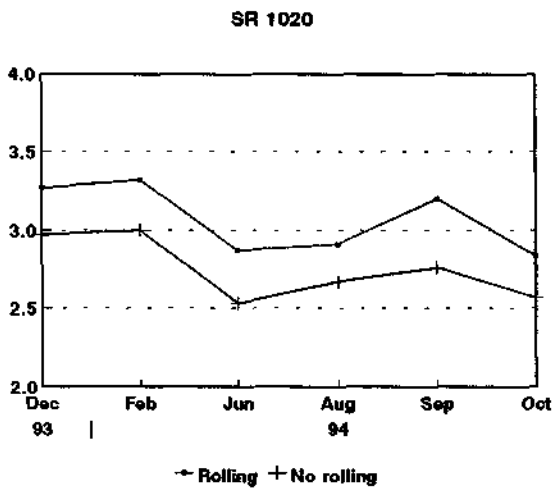
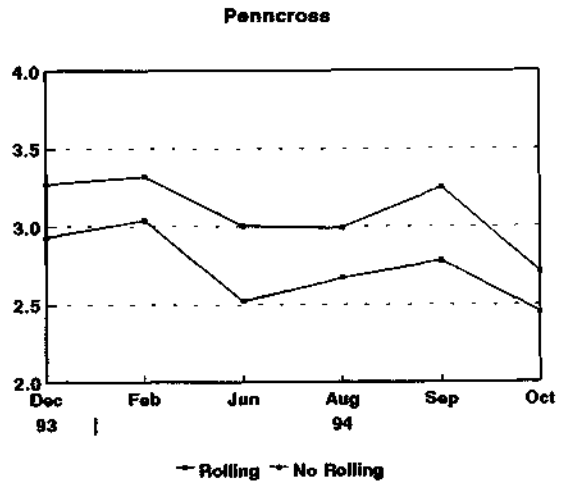
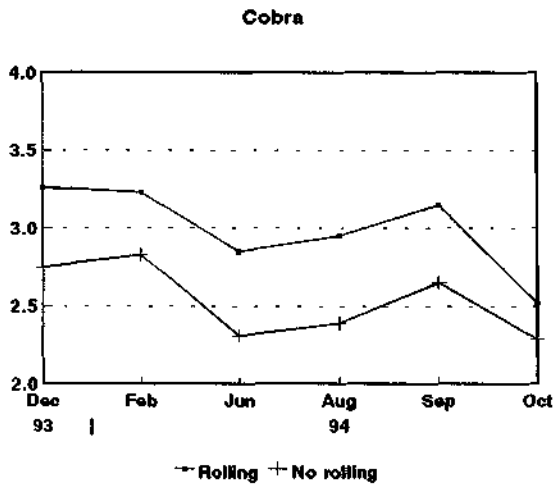
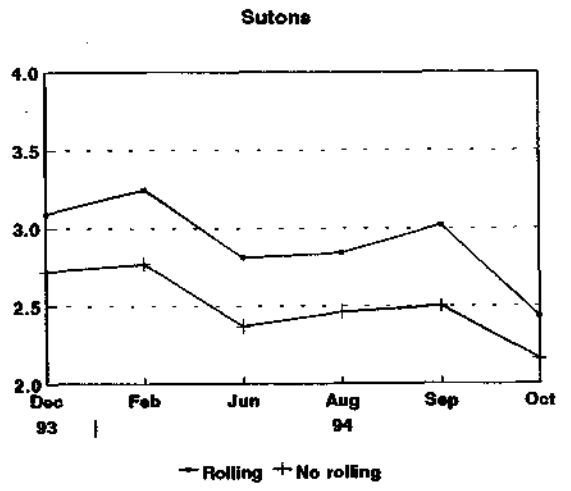
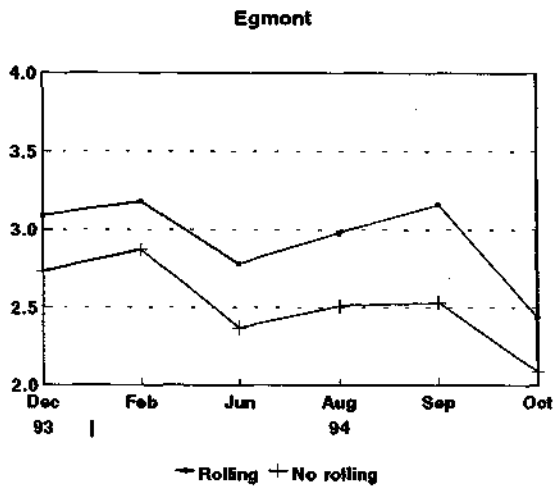


Figure 9: Variety x rolling interaction

**Table 11: Variety x wear interaction - green speed (m)**

Treatment		Avg	Dec-93	Feb-94	Jun-94	Sep-94	Oct-94
Egmont	Wear	2.76	2.97	2.98	2.56	2.87	2.41
	No wear	2.72	2.91	3.03	2.58	2.84	2.27
Suttons	Wear	2.79	2.93	3.10	2.73	2.82	2.39
	No wear	2.71	2.91	3.01	2.59	2.76	2.30
Cobra	Wear	2.84	2.99	3.13	2.75	2.84	2.46
	No wear	2.78	3.01	3.03	2.58	2.90	2.41
Pennncross	Wear	2.91	3.04	3.09	2.76	2.95	2.70
	No wear	2.89	3.10	3.18	2.75	3.01	2.58
SR1020	Wear	2.88	3.11	3.06	2.70	2.95	2.71
	No wear	2.92	3.12	3.16	2.69	2.98	2.71
LSD (p<0.05)		0.04	ns	0.08	0.08	ns	0.07

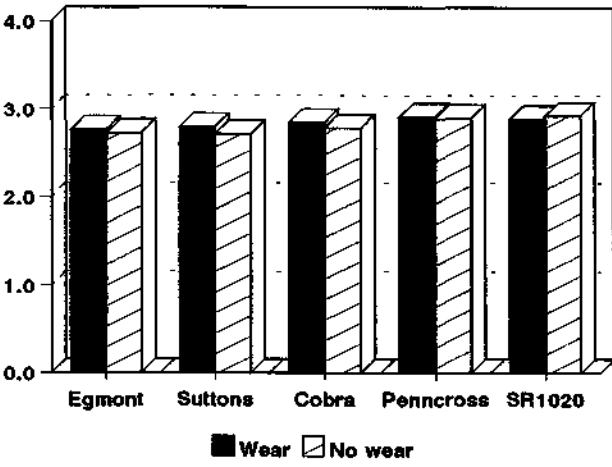
**Table 12: Rolling x wear interaction - green speed (m)**

Treatment		Avg	Dec-93	Feb-94	Jun-94	Sep-94	Oct-94
Rolling	Wear	2.96	3.16	3.19	2.81	3.09	2.63
	No wear	3.01	3.20	3.26	2.86	3.15	2.59
No rolling	Wear	2.70	2.85	2.95	2.60	2.68	2.45
	No wear	2.61	2.82	2.90	2.41	2.64	2.31
LSD (p<0.05)		0.03	0.05	0.05	0.05	ns	0.04

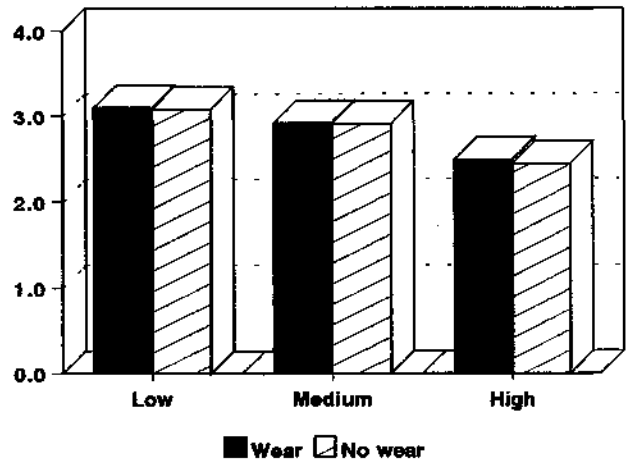
**Table 13: Wear x rolling x variety interaction - green speed (m)**

Treatment		Avg	Dec-93	Feb-94	Jun-94	Sep-94	Oct-94
Wear							
Rolling	Egmont	2.91	3.20	3.09	2.69	3.05	2.55
	Suttons	2.94	3.03	3.26	2.86	3.03	2.50
	Cobra	2.98	3.16	3.26	2.85	3.09	2.52
	Pennncro	3.04	3.21	3.21	2.85	3.14	2.76
	SR1020	2.98	3.20	3.14	2.79	3.12	2.80
No rolling	Egmont	2.60	2.73	2.87	2.44	2.68	2.28
	Suttons	2.65	2.82	2.94	2.60	2.60	2.29
	Cobra	2.69	2.82	3.00	2.66	2.60	2.39
	Pennncro	2.78	2.87	2.96	2.66	2.77	2.65
	SR1020	2.78	3.03	2.98	2.61	2.77	2.63
No wear							
Rolling	Egmont	2.93	3.09	3.18	2.78	3.16	2.44
	Suttons	2.92	3.09	3.25	2.81	3.02	2.43
	Cobra	3.00	3.26	3.23	2.85	3.15	2.52
	Pennncro	3.08	3.27	3.32	2.99	3.25	2.71
	SR1020	3.10	3.27	3.32	2.86	3.20	2.84
No rolling	Egmont	2.52	2.73	2.87	2.37	2.53	2.09
	Suttons	2.51	2.72	2.77	2.37	2.50	2.16
	Cobra	2.57	2.75	2.83	2.31	2.65	2.29
	Pennncro	2.71	2.93	3.04	2.50	2.78	2.45
	SR1020	2.75	2.97	3.00	2.51	2.76	2.57
LSD (p<0.05)		ns	0.1	ns	ns	ns	ns

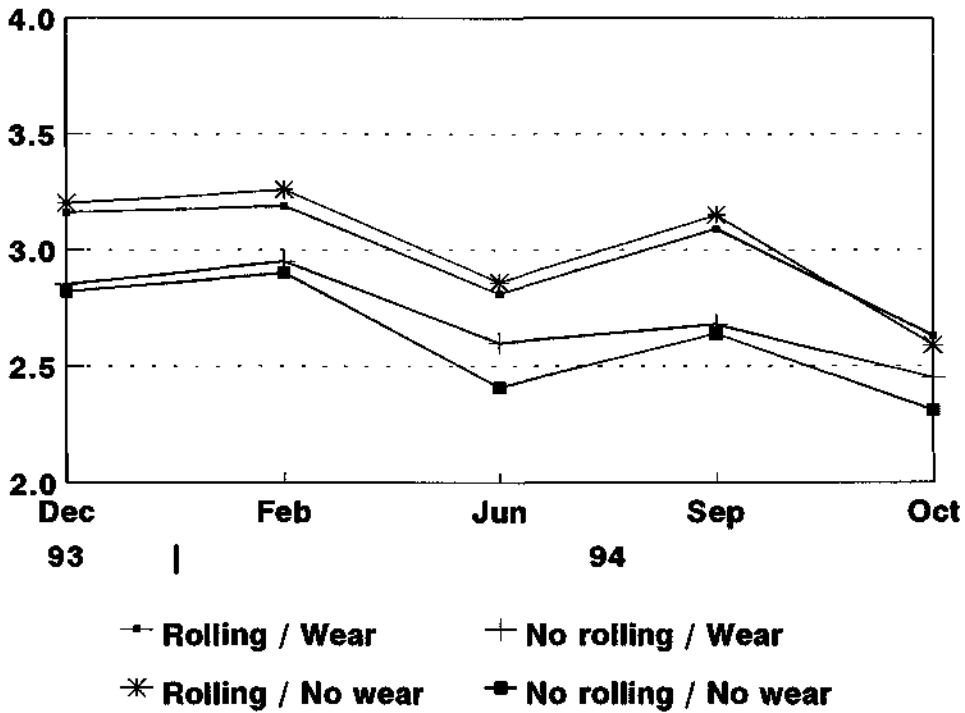
**Figure 10: Variety x wear**  
Average green speed (m)



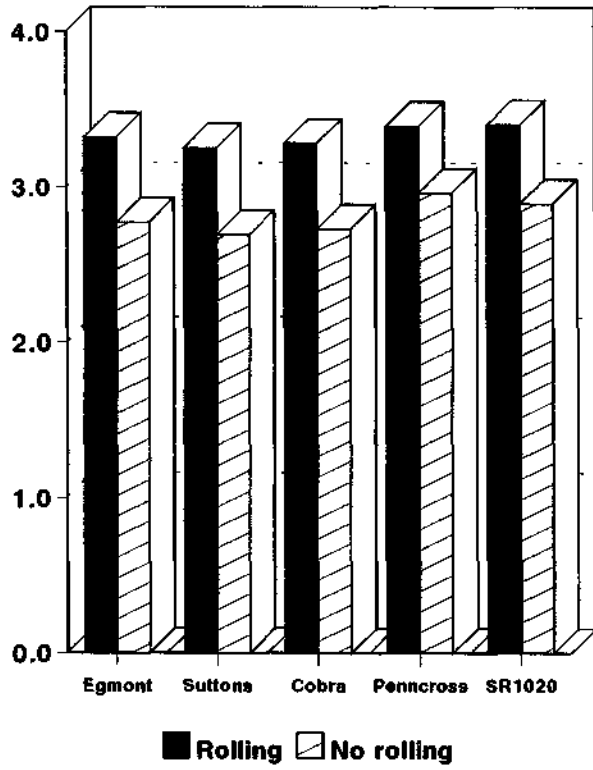
**Figure 11: Mowing height**  
Average green speed (m)



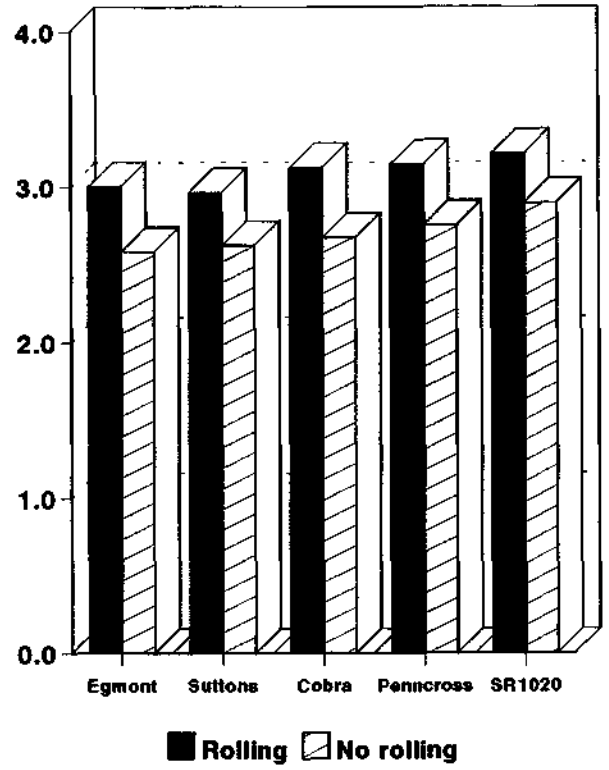
**Figure 12: Effect of wear x rolling**  
Green speed (m)



**Low height of cut**  
Average green speed (m)



**Medium height of cut**  
Average green speed (m)



**High height of cut**  
Average green speed (m)

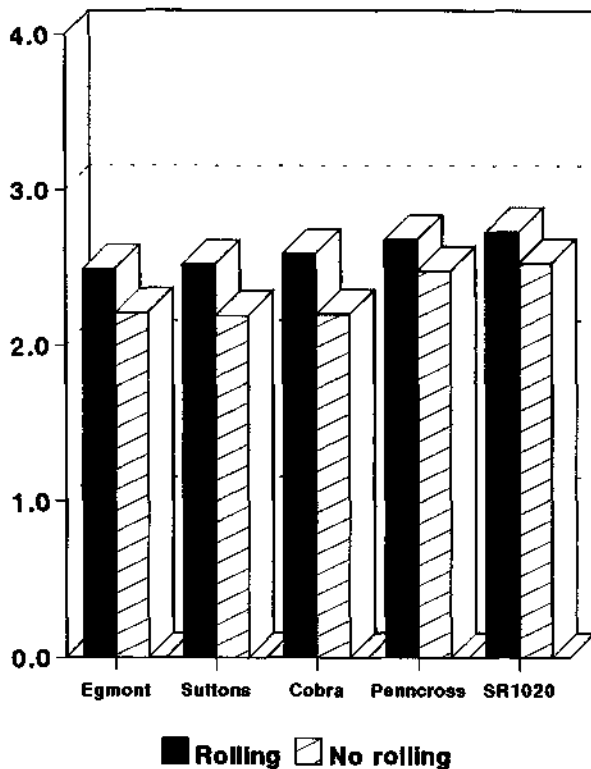


Figure 13: Variety x rolling x mowing height interaction

Table 14: Wear x rolling x height interaction - green speed (m)

Treatment	Avg	Dec-93	Feb-94	Jun-94	Sep-94	Oct-94
<b>Wear</b>						
Rolling	3.26	3.44	3.49	3.03	3.45	2.89
Low	3.05	3.17	3.25	3.01	3.20	2.61
Medium	2.60	2.88	2.83	2.38	2.61	2.38
High						
No Rolling	2.93	3.06	3.20	2.77	2.95	2.67
Low	2.79	2.90	3.01	2.86	2.71	2.49
Medium	2.37	2.60	2.63	2.16	2.40	2.17
High						
<b>No wear</b>						
Rolling	3.32	3.42	3.48	3.15	3.66	2.90
Low	3.11	3.24	3.34	3.15	3.21	2.61
Medium	2.59	2.94	2.95	2.29	2.59	2.26
High						
No Rolling	2.83	3.01	3.13	2.56	2.85	2.60
Low	2.71	2.89	2.97	2.66	2.73	2.32
Med	2.28	2.57	2.60	2.03	2.36	2.02
High						
LSD (p<0.05)	ns	ns	ns	0.09	0.13	ns

Table 15: Height x variety x rolling interaction - green speed (m)

Treatment	Avg	Dec-93	Feb-94	Jun-94	Aug-94	Sep-94	Oct-94
<b>Low height of cut</b>							
Rolling	3.32	3.32	3.42	3.04	3.63	3.73	2.81
Egmont	3.25	3.34	3.41	3.21	3.23	3.45	2.86
Suttons	3.28	3.53	3.47	3.07	3.18	3.66	2.76
Cobra	3.39	3.49	3.59	3.35	3.27	3.70	2.98
Pennecros	3.40	3.41	3.53	3.08	3.55	3.76	3.10
SR1020							
<b>No rolling</b>							
Egmont	2.77	3.00	3.14	2.53	2.77	2.72	2.44
Suttons	2.69	2.89	2.92	2.67	2.55	2.68	2.41
Cobra	2.73	2.81	3.09	2.45	2.62	2.79	2.65
Pennecros	2.96	3.20	3.24	2.64	2.94	3.05	2.69
SR1020	2.89	3.13	3.28	2.50	2.64	3.00	2.82
<b>Medium height of cut</b>							
Rolling	3.00	3.11	3.35	3.05	2.76	3.26	2.50
Egmont	2.96	3.19	3.37	3.07	2.83	2.93	2.35
Suttons	3.12	3.26	3.27	3.22	3.14	3.19	2.63
Cobra	3.14	3.20	3.35	3.20	3.04	3.30	2.74
Pennecros	3.21	3.43	3.37	3.21	3.01	3.39	2.84
SR1020							
<b>No rolling</b>							
Egmont	2.58	2.86	2.90	2.48	2.57	2.61	2.05
Suttons	2.62	2.82	2.93	2.50	2.55	2.66	2.25
Cobra	2.67	2.89	2.83	2.69	2.49	2.85	2.31
Pennecros	2.75	2.84	3.14	2.74	2.66	2.76	2.39
SR1020	2.89	3.07	3.05	2.89	2.99	2.77	2.57
<b>High height of cut</b>							
Rolling	2.49	2.85	2.79	2.26	2.56	2.47	2.01
Egmont	2.52	2.75	2.97	2.16	2.46	2.68	2.08
Suttons	2.59	2.99	2.94	2.28	2.54	2.60	2.18
Cobra	2.68	3.12	3.01	2.46	2.65	2.74	2.43
Pennecros	2.73	2.98	3.07	2.32	2.17	2.46	2.58
SR1020							
<b>No rolling</b>							
Egmont	2.21	2.32	2.57	2.12	2.18	2.28	1.79
Suttons	2.19	2.46	2.45	1.95	2.27	2.16	1.83
Cobra	2.20	2.57	2.57	1.79	2.08	2.31	1.92
Pennecros	2.48	2.76	2.74	2.18	2.42	2.53	2.26
SR1020	2.53	2.71	2.67	2.19	2.39	2.52	2.33
LSD (p<0.05)	ns	ns	ns	ns	0.16	ns	0.16

Table 16: Height x wear x variety interaction - green speed (m)

	Avg	Dec-93	Feb-94	Jun-94	Sep-94	Oct-94
<b>Low height of cut</b>						
Wear						
Egmont	3.02	3.14	3.22	2.80	3.22	2.72
Suttons	3.10	3.17	3.39	2.90	3.28	2.74
Cobra	3.10	3.34	3.43	2.93	3.17	2.66
Penncro	3.14	3.34	3.32	3.00	3.13	2.91
SR1020	3.11	3.26	3.37	2.87	3.20	2.87
No wear						
Egmont	3.01	3.16	3.28	2.79	3.23	2.63
Suttons	2.98	3.12	3.17	2.94	3.06	2.63
Cobra	3.03	3.17	3.28	2.76	3.23	2.71
Penncro	3.19	3.30	3.39	2.99	3.40	2.90
SR1020	3.16	3.27	3.41	2.79	3.38	2.96
<b>Medium height of cut</b>						
Wear						
Egmont	2.84	3.03	3.02	2.77	2.88	2.51
Suttons	2.84	2.92	3.17	3.00	2.80	2.33
Cobra	2.91	2.94	3.20	3.01	2.89	2.52
Penncro	3.03	3.08	3.23	2.94	3.15	2.73
SR1020	2.99	3.22	3.06	2.95	3.04	2.67
No wear						
Egmont	2.81	2.99	3.12	2.76	2.93	2.27
Suttons	2.81	3.00	3.15	2.78	2.80	2.30
Cobra	2.91	3.07	3.05	2.95	3.02	2.47
Penncro	2.97	3.02	3.25	2.97	3.03	2.57
SR1020	3.06	3.25	3.21	3.05	3.08	2.71
<b>High height of cut</b>						
Wear						
Egmont	2.41	2.73	2.70	2.12	2.51	2.01
Suttons	2.44	2.69	2.73	2.29	2.37	2.10
Cobra	2.49	2.71	2.76	2.33	2.47	2.20
Penncro	2.56	2.70	2.71	2.34	2.58	2.46
SR1020	2.53	2.87	2.75	2.28	2.60	2.60
No wear						
Egmont	2.34	2.58	2.68	2.19	2.37	1.90
Suttons	2.35	2.61	2.71	2.06	2.42	1.96
Cobra	2.41	2.78	2.75	2.04	2.45	2.05
Penncro	2.52	2.94	2.87	2.27	2.64	2.34
SR1020	2.55	2.85	2.87	2.22	2.49	2.45
LSD (p<0.05)	ns	0.12	ns	0.11	ns	ns

### 3.2 Changes in green speed over a day

Table 17: Variety effect - green speed (m)

Treatment	28-Jan 1994				24-Mar 1994				28-Jul 1994			
	8:45	11:00	1:15	3:15	8:15	10:30	1:00	3:00	8:45	10:30	1:00	3:00
Egmont	2.92	2.95	3.08	2.91	3.05	3.02	3.00	3.02	2.45	2.51	2.58	2.57
Suttons	3.14	3.06	3.07	2.96	3.11	3.10	3.19	3.08	2.54	2.52	2.60	2.57
Cobra	3.07	3.00	3.06	3.10	3.08	3.06	3.17	3.07	2.63	2.52	2.68	2.69
Pennncross	3.22	3.15	3.29	3.24	3.27	3.27	3.40	3.43	2.73	2.72	2.87	2.85
SR1020	3.24	3.29	3.23	3.31	3.19	3.21	3.38	3.35	2.64	2.84	2.78	2.70
LSD (p<0.05)	0.11	0.12	0.09	0.14	0.08	0.07	0.10	0.08	0.07	0.09	0.08	0.08

Table 18: Mowing height effect - green speed (m)

Treatment	28-Jan 1994				24-Mar 1994				28-Jul 1994			
	8:45	11:00	1:15	3:15	8:15	10:30	1:00	3:00	8:45	10:30	1:00	3:00
Low	3.37	3.28	3.40	3.34	3.47	3.44	3.59	3.54	2.86	2.87	3.01	3.00
Medium	3.10	3.09	3.15	3.18	3.21	3.17	3.24	3.21	2.76	2.78	2.84	2.85
High	2.89	2.90	2.88	2.79	2.74	2.78	2.86	2.83	2.18	2.22	2.25	2.18
LSD (p<0.05)	0.09	0.09	0.07	0.11	0.06	0.06	0.08	0.07	0.05	0.07	0.06	0.06

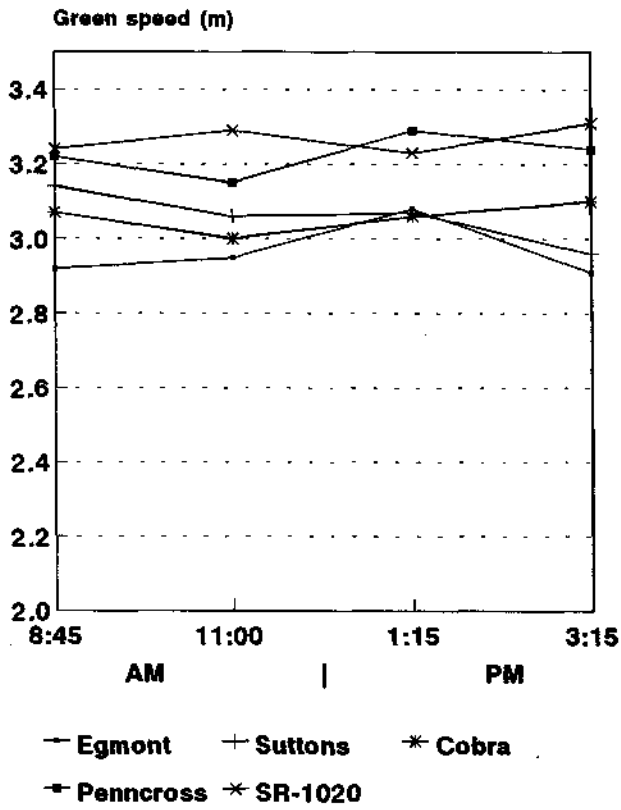
Table 19: Rolling effect - green speed (m)

Treatment	28-Jan 1994				24-Mar 1994				28-Jul 1994			
	8:45	11:00	1:15	3:15	8:15	10:30	1:00	3:00	8:45	10:30	1:00	3:00
Rolling	3.28	3.24	3.26	3.23	3.33	3.34	3.39	3.34	2.82	2.87	2.90	2.84
No rolling	2.96	2.94	3.03	2.98	2.95	2.91	3.06	3.04	2.38	2.37	2.50	2.51
LSD (p<0.05)	*	*	*	*	*	*	*	*	*	*	*	*

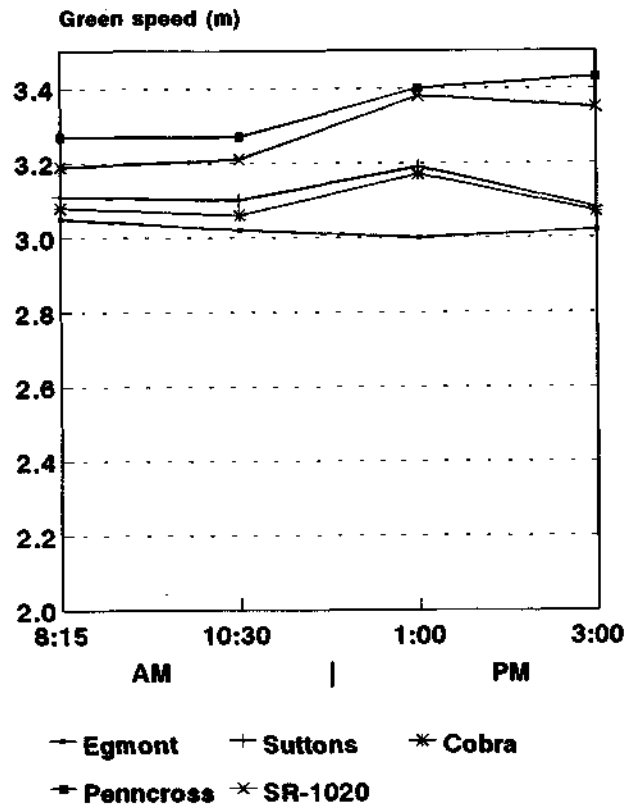
Table 20: Variety x roll interaction - green speed (m)

Treatment	28-Jan 1994				24-Mar 1994				28-Jul 1994			
	8:45	11:00	1:15	3:15	8:15	10:30	1:00	3:00	8:45	10:30	1:00	3:00
Rolling												
Egmont	3.10	3.12	3.30	3.06	3.22	3.21	3.12	3.20	2.67	2.75	2.80	2.77
Suttons	3.34	3.19	3.17	3.10	3.35	3.37	3.39	3.26	2.79	2.75	2.83	2.76
Cobra	3.23	3.18	3.15	3.26	3.26	3.23	3.33	3.20	2.90	2.76	2.89	2.82
Pennncross	3.43	3.32	3.36	3.29	3.46	3.45	3.58	3.47	2.96	2.97	3.05	3.04
SR1020	3.29	3.37	3.32	3.42	3.36	3.47	3.55	3.54	2.80	3.13	2.93	2.82
No rolling												
Egmont	2.75	2.78	2.87	2.77	2.87	2.82	2.88	2.84	2.24	2.28	2.35	2.38
Suttons	2.94	2.92	2.96	2.83	2.87	2.83	3.00	2.89	2.28	2.29	2.38	2.37
Cobra	2.91	2.82	2.98	2.94	2.91	2.88	3.02	2.94	2.37	2.28	2.47	2.57
Pennncross	3.01	2.98	3.22	3.19	3.07	3.10	3.22	3.39	2.51	2.47	2.69	2.65
SR1020	3.20	3.21	3.14	3.20	3.02	2.94	3.21	3.17	2.49	2.54	2.62	2.58
LSD (p<0.05)	0.16	ns	0.12	ns	ns	0.10	ns	0.12	0.10	ns	ns	ns

### Summer



### Autumn



### Winter

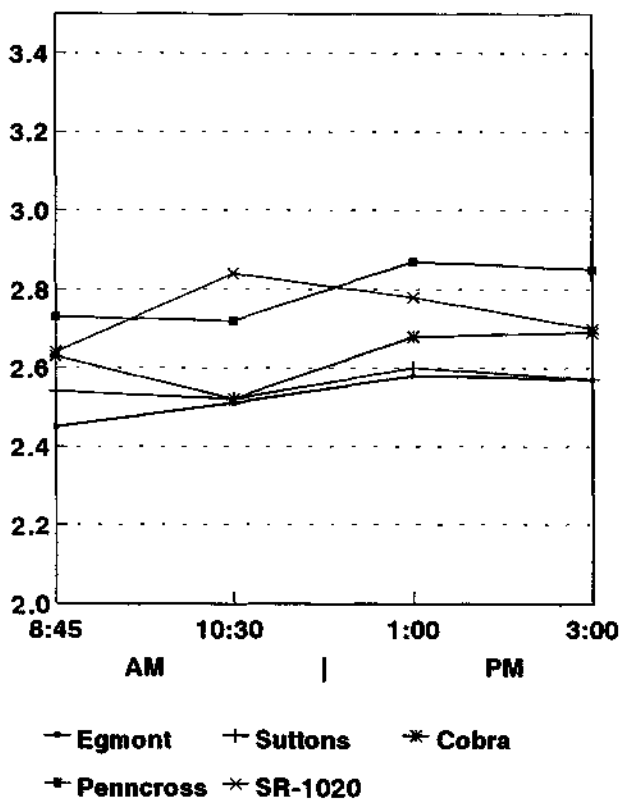
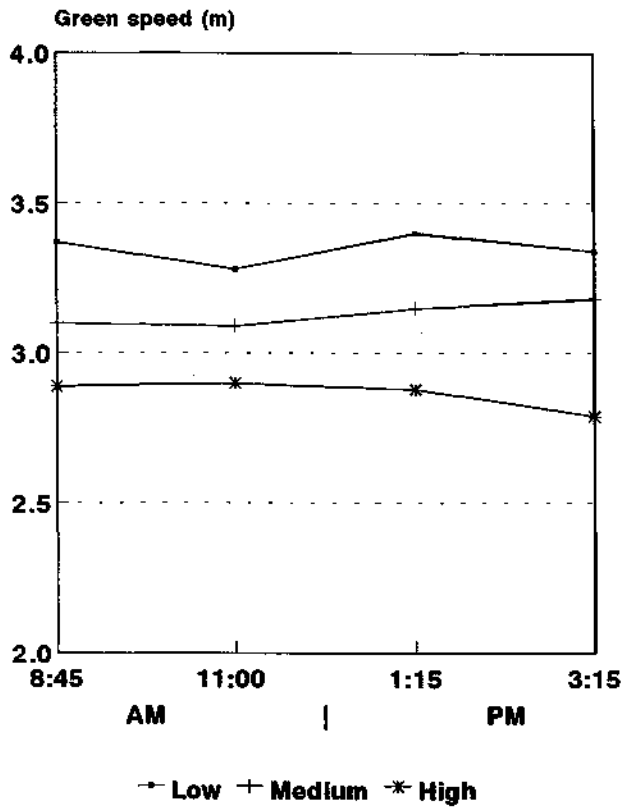
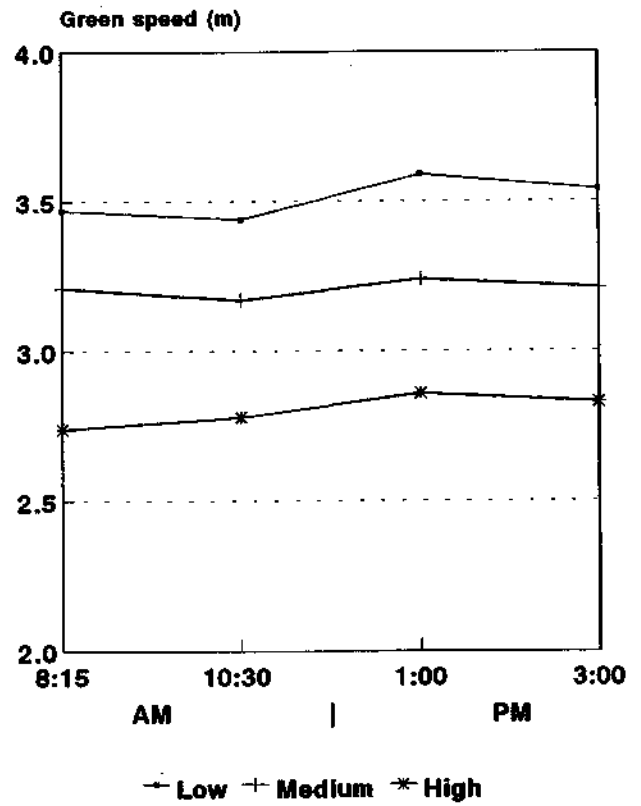


Figure 14: Change in green speed over a day - variety effect

### Summer



### Autumn



### Winter

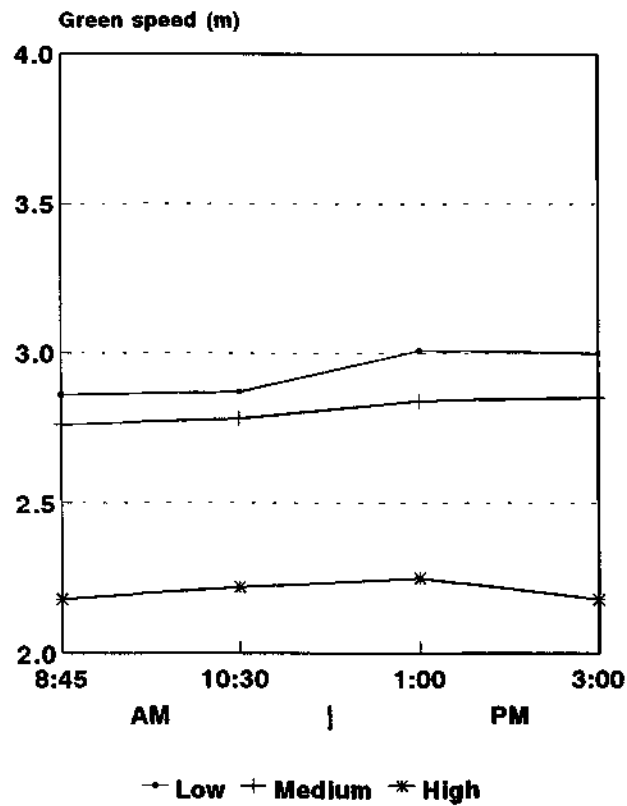
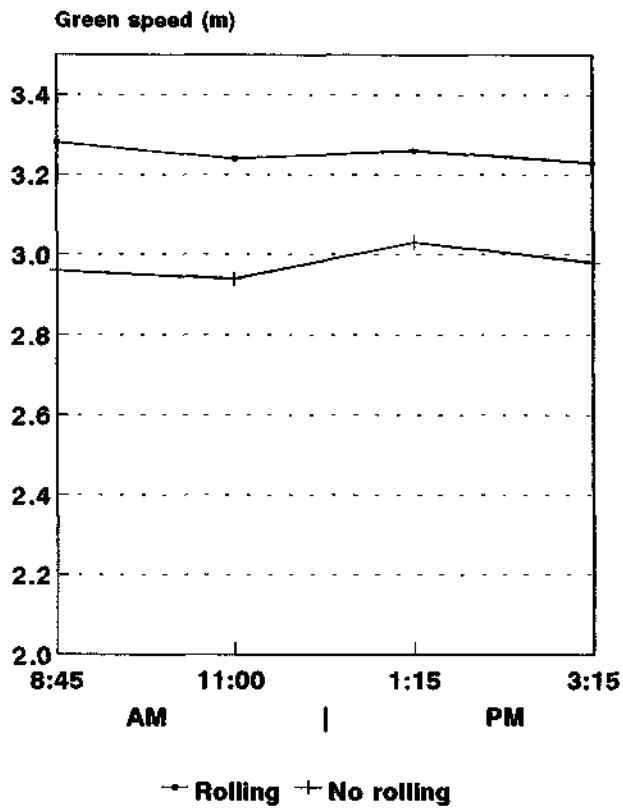
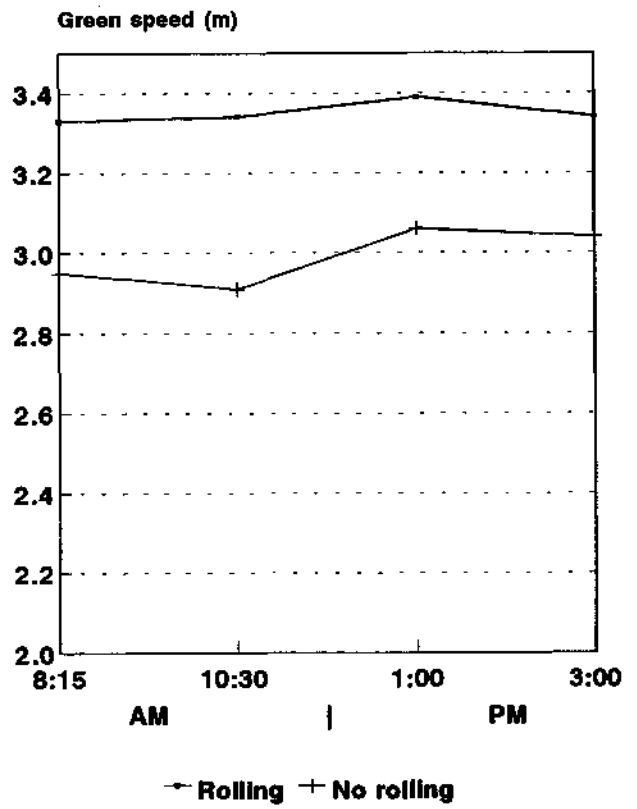


Figure 15: Change in green speed over a day - mowing height effect

### Summer



### Autumn



### Winter

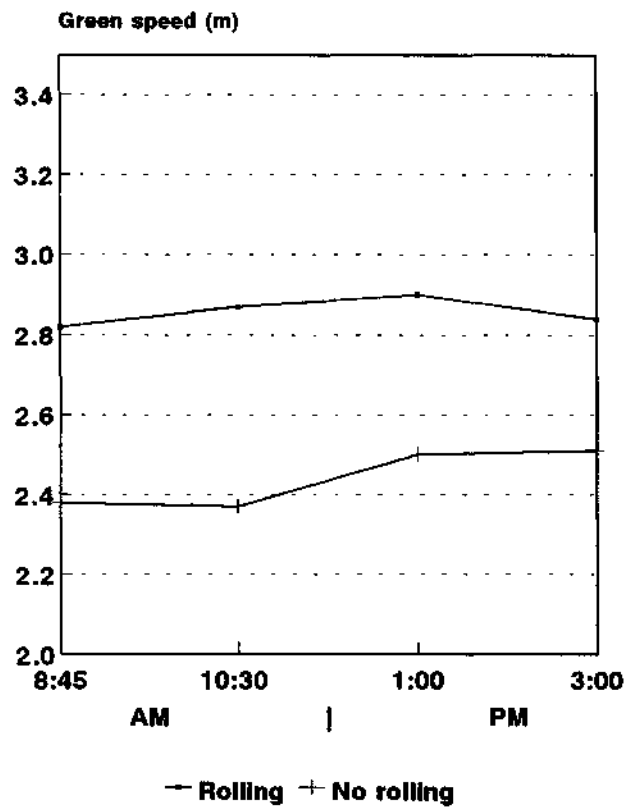
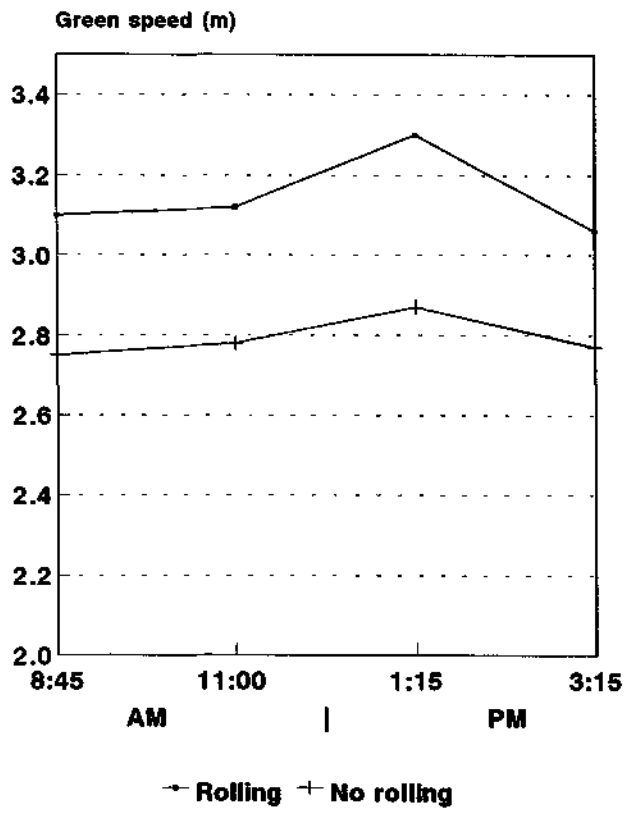
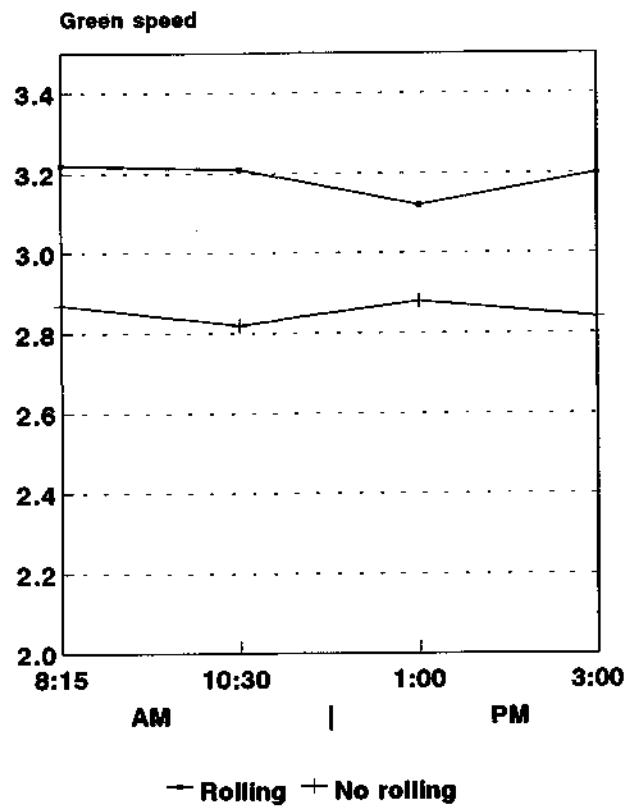


Figure 16: Change in green speed over a day - rolling effect

### Summer



### Autumn



### Winter

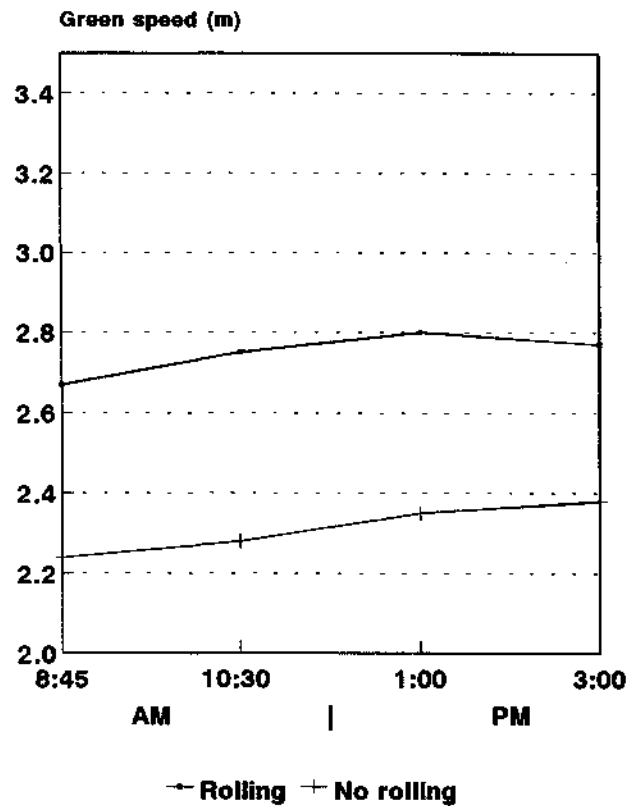
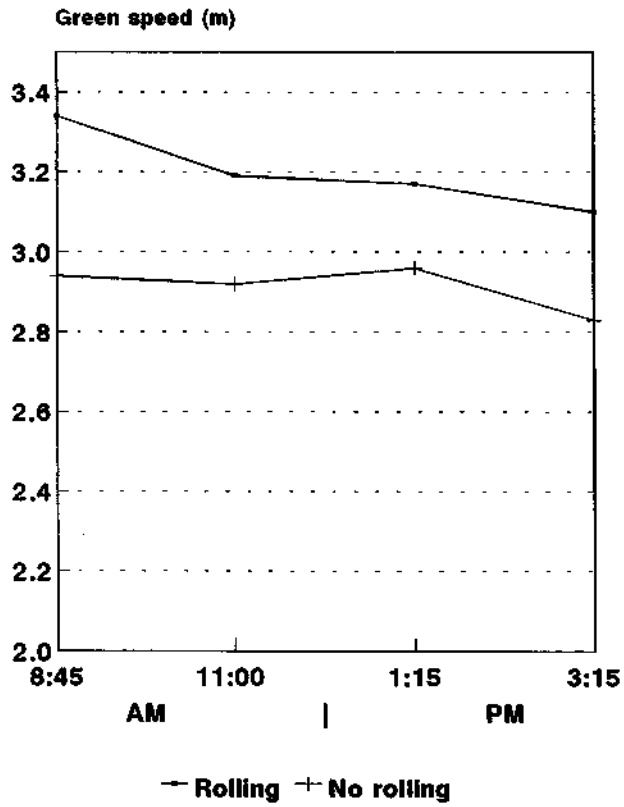
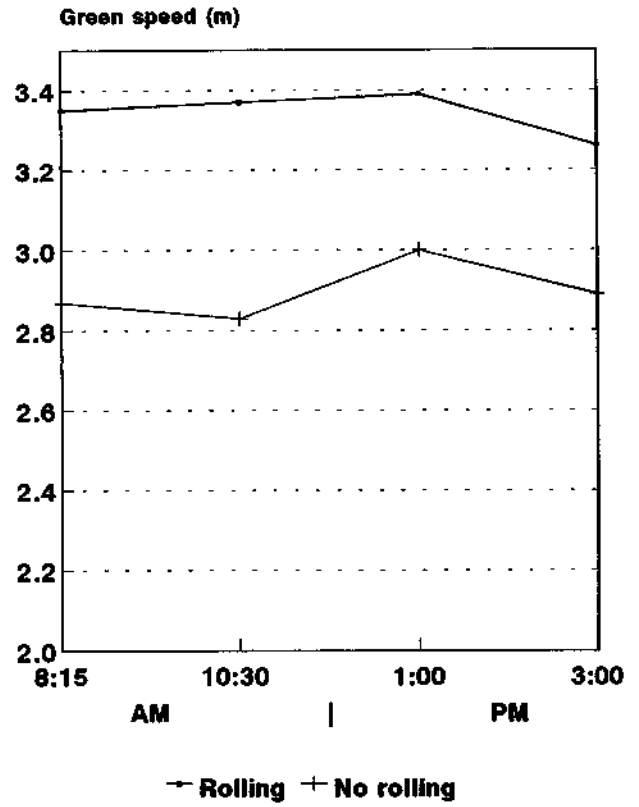


Figure 17: Effect of rolling over a day - Egmont

### Summer



### Autumn



### Winter

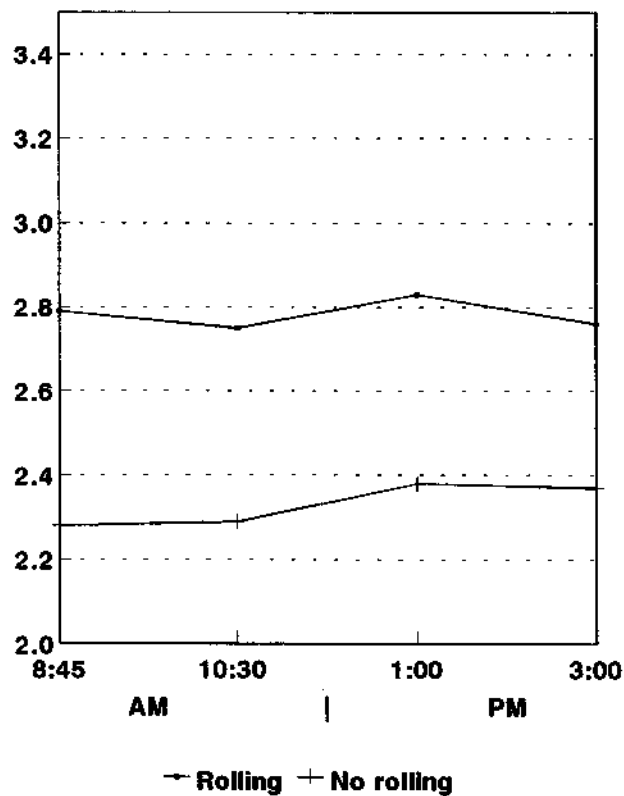
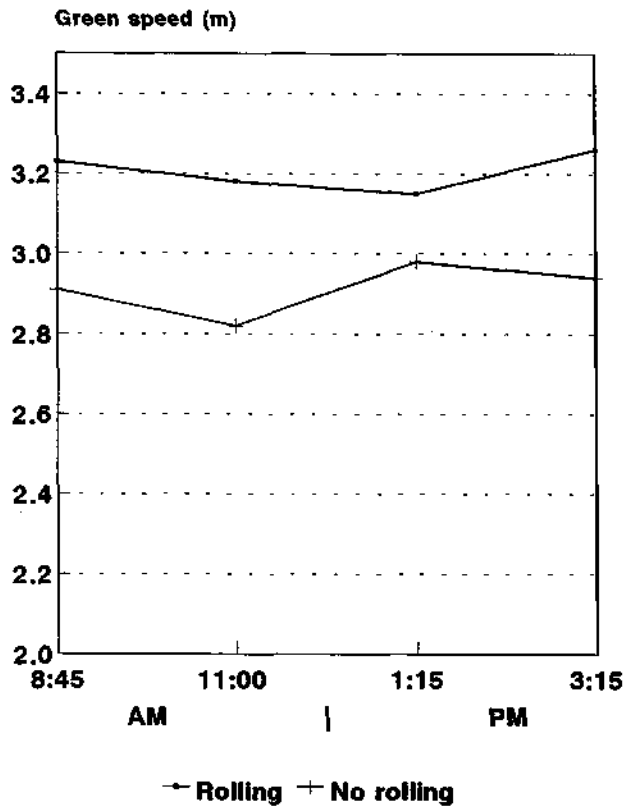
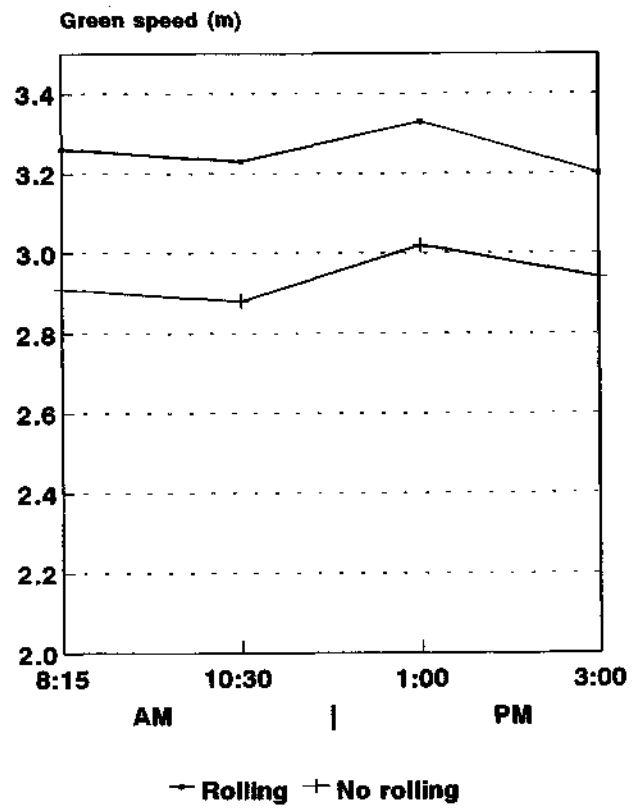


Figure 18: Effect of rolling over a day - Suttons

### Summer



### Autumn



### Winter

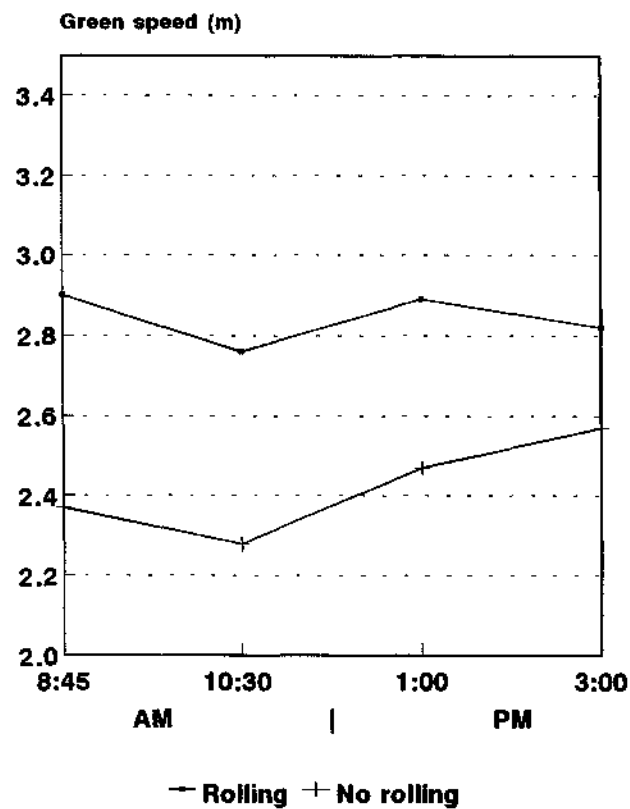
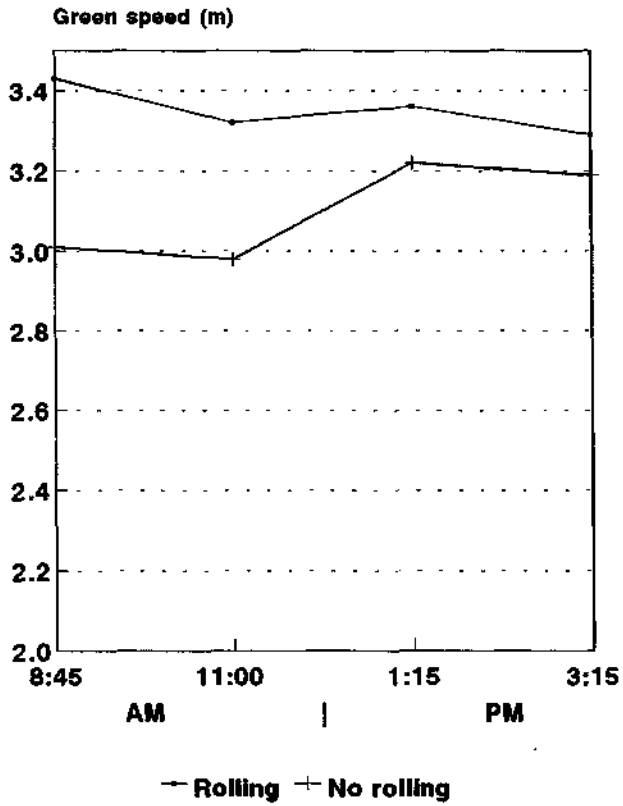
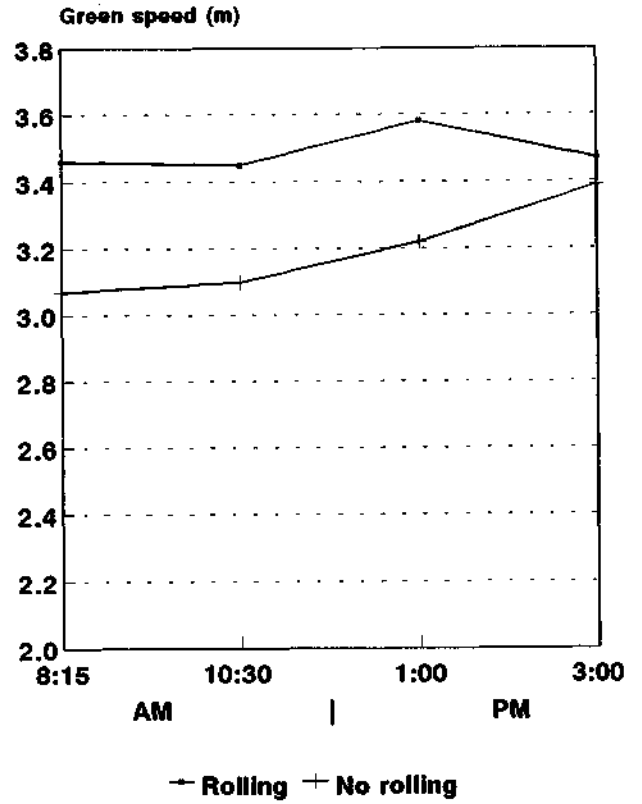


Figure 19: Effect of rolling over a day - Cobra

### Summer



### Autumn



### Winter

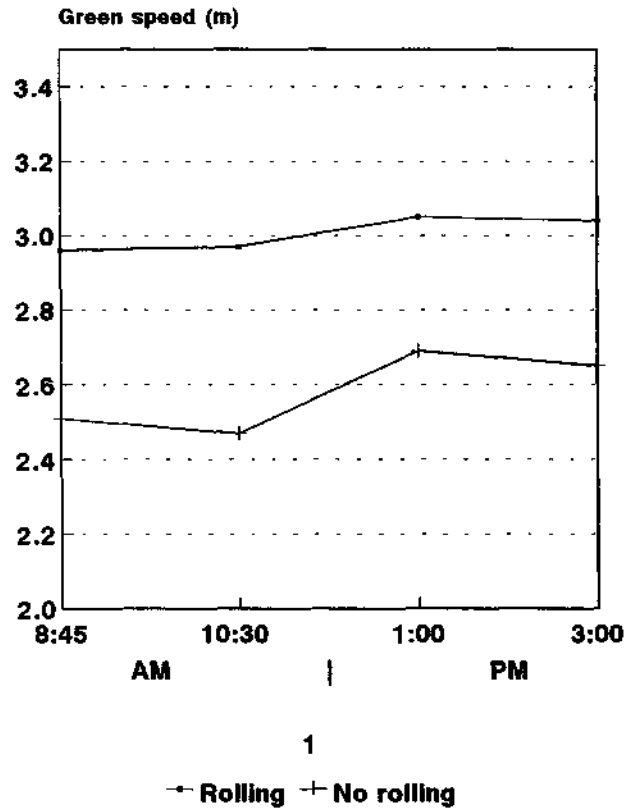
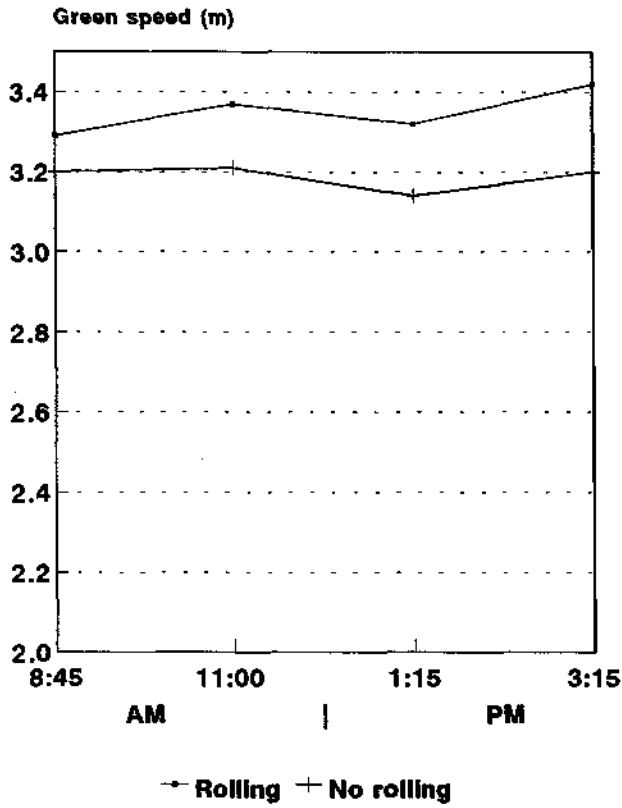
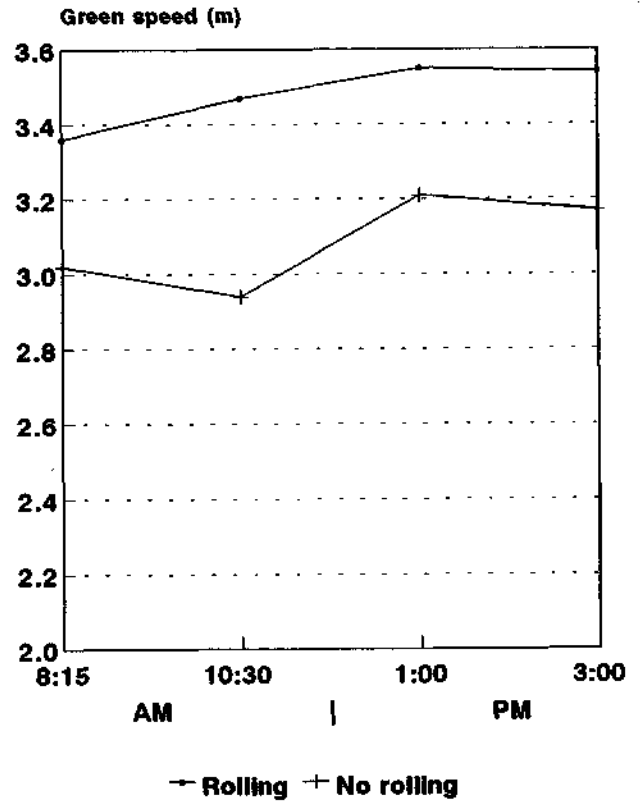


Figure 20: Effect of rolling over a day - Penncross

### Summer



### Winter



### Winter

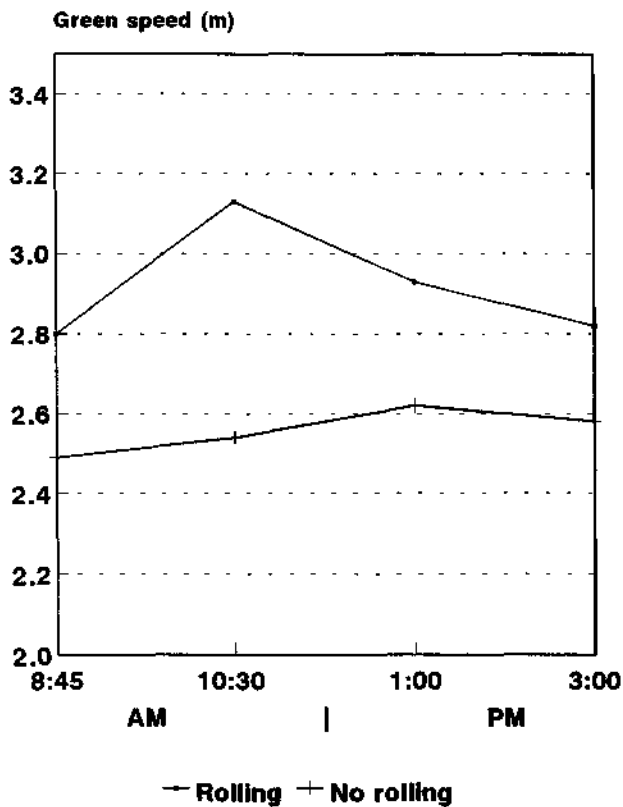


Figure 21: Effect of rolling over a day - SR 1020

Table 21: Height x variety interaction - green speed (m)

Treatment	28-Jan 1994				24-Mar 1994				28-Jul 1994			
	8:45	11:00	1:15	3:15	8:15	10:30	1:00	3:00	8:45	10:30	1:00	3:00
Low height of cut												
Egmont	3.10	3.21	3.44	3.21	3.40	3.34	3.29	3.42	2.74	2.94	2.94	3.01
Suttons	3.48	3.29	3.45	3.35	3.48	3.36	3.60	3.33	2.83	2.72	2.92	2.80
Cobra	3.38	3.23	3.40	3.39	3.46	3.46	3.52	3.37	2.89	2.71	2.96	2.99
Pennncross	3.48	3.34	3.37	3.38	3.56	3.55	3.68	3.82	2.96	2.90	3.22	3.19
SR1020	3.39	3.32	3.35	3.40	3.44	3.50	3.84	3.75	2.88	3.10	3.01	3.01
Medium height of cut												
Egmont	3.04	2.88	2.99	2.89	3.11	3.12	3.05	3.09	2.59	2.65	2.72	2.69
Suttons	3.11	3.01	2.98	2.92	3.11	3.15	3.22	3.15	2.73	2.75	2.81	2.83
Cobra	2.99	3.01	3.10	3.10	3.19	3.03	3.14	3.08	2.77	2.73	2.79	2.82
Pennncross	3.15	3.13	3.49	3.44	3.37	3.34	3.45	3.39	2.83	2.86	2.94	2.97
SR1020	3.21	3.43	3.21	3.54	3.25	3.19	3.35	3.33	2.88	2.91	2.96	2.94
High height of cut												
Egmont	2.63	2.76	2.82	2.65	2.63	2.59	2.66	2.55	2.03	1.95	2.07	2.02
Suttons	2.83	2.86	2.77	2.63	2.73	2.79	2.75	2.76	2.05	2.10	2.08	2.06
Cobra	2.85	2.76	2.68	2.81	2.60	2.68	2.86	2.77	2.25	2.13	2.29	2.27
Pennncross	3.03	2.98	3.02	2.89	2.87	2.93	3.07	3.09	2.41	2.41	2.45	2.38
SR1020	3.12	3.12	3.12	2.99	2.87	2.93	2.95	2.98	2.17	2.51	2.35	2.14
LSD (p<0.05)	ns	ns	0.15	0.24	ns	0.13	ns	0.15	0.12	0.15	ns	0.13

Table 22: Height x roll interaction - green speed (m)

Treatment	28-Jan 1994				24-Mar 1994				28-Jul 1994			
	8:45	11:00	1:15	3:15	8:15	10:30	1:00	3:00	8:45	10:30	1:00	3:00
Rolling												
Low	3.52	3.43	3.50	3.47	3.70	3.69	3.72	3.64	3.16	3.20	3.29	3.22
Medium	3.30	3.21	3.24	3.33	3.40	3.39	3.44	3.37	3.01	3.04	3.06	3.02
High	3.01	3.08	3.04	2.88	2.89	2.96	3.02	3.01	2.30	2.38	2.35	2.29
No rolling												
Low	3.21	3.13	3.31	3.22	3.23	3.20	3.45	3.44	2.56	2.54	2.73	2.78
Medium	2.89	2.98	3.07	3.02	3.02	2.94	3.04	3.05	2.51	2.52	2.62	2.68
High	2.78	2.71	2.72	2.71	2.59	2.61	2.70	2.65	2.06	2.06	2.15	2.06
LSD (p<0.05)	ns	ns	ns	ns	ns	0.08	ns	0.09	0.07	0.09	0.09	0.08

Table 23: Height x rolling x variety interactions - green speed (m)

Treatment	28-Jan 1994		24-Mar 1994		28-Jul 1994							
	8:45	11:00	1:15	3:15	8:45	10:50	1:00	3:00				
<b>Low height of cut</b>												
Rolling												
Egmont	3.25	3.42	3.60	3.35	3.62	3.53	3.36	3.58	2.98	3.32	3.22	3.23
Suttons	3.65	3.44	3.59	3.52	3.85	3.69	3.76	3.46	3.16	3.06	3.28	3.03
Cobra	3.52	3.44	3.50	3.57	3.67	3.69	3.71	3.50	3.17	2.94	3.23	3.22
Penncross	3.67	3.44	3.37	3.48	3.70	3.72	3.81	3.78	3.29	3.23	3.38	3.40
SR1020	3.53	3.39	3.45	3.44	3.67	3.79	3.96	3.85	3.21	3.47	3.34	3.21
No rolling												
Egmont	2.96	2.99	3.29	3.06	3.18	3.15	3.21	3.26	2.50	2.56	2.65	2.78
Suttons	3.31	3.15	3.31	3.17	3.11	3.03	3.45	3.19	2.50	2.38	2.57	2.58
Cobra	3.23	3.03	3.31	3.21	3.24	3.22	3.34	3.23	2.61	2.48	2.69	2.75
Penncross	3.29	3.23	3.37	3.28	3.43	3.37	3.54	3.85	2.64	2.37	3.07	2.98
SR1020	3.25	3.25	3.26	3.36	3.21	3.21	3.73	3.65	2.54	2.72	2.68	2.82
<b>Medium height of cut</b>												
Rolling												
Egmont	3.28	2.91	3.27	2.96	3.24	3.37	3.28	3.22	2.75	2.88	2.91	2.89
Suttons	3.44	3.18	3.07	3.15	3.30	3.40	3.42	3.34	3.02	3.00	2.98	2.98
Cobra	3.12	3.17	3.17	3.33	3.39	3.16	3.28	3.24	3.06	2.99	3.02	2.97
Penncross	3.38	3.28	3.47	3.51	3.63	3.53	3.62	3.51	3.06	3.13	3.17	3.18
SR1020	3.30	3.49	3.22	3.71	3.42	3.49	3.60	3.53	3.14	3.20	3.25	3.11
No rolling												
Egmont	2.79	2.86	2.70	2.83	2.97	2.86	2.82	2.96	2.43	2.43	2.54	2.50
Suttons	2.78	2.85	2.89	2.68	2.93	2.91	3.01	2.96	2.43	2.51	2.64	2.68
Cobra	2.85	2.85	3.04	2.88	2.99	2.91	3.00	2.92	2.47	2.47	2.57	2.68
Penncross	2.92	2.97	3.50	3.36	3.12	3.15	3.28	3.27	2.61	2.58	2.70	2.77
SR1020	3.13	3.38	3.21	3.37	3.08	2.88	3.10	3.14	2.62	2.62	2.67	2.77
<b>High height of cut</b>												
Rolling												
Egmont	2.78	3.03	3.02	2.87	2.81	2.73	2.71	2.81	2.27	2.06	2.28	2.18
Suttons	2.93	2.96	2.84	2.64	2.90	3.01	2.98	3.00	2.18	2.21	2.22	2.28
Cobra	3.05	2.94	2.78	2.90	2.72	2.84	3.00	2.87	2.48	2.36	2.44	2.28
Penncross	3.25	3.23	3.25	2.87	3.06	3.09	3.31	3.12	2.53	2.55	2.60	2.55
SR1020	3.03	3.24	3.31	3.12	2.98	3.12	3.11	3.24	2.05	2.75	2.19	2.14
No rolling												
Egmont	2.49	2.50	2.61	2.42	2.46	2.46	2.61	2.29	1.79	1.85	1.86	1.86
Suttons	2.74	2.77	2.69	2.62	2.57	2.56	2.52	2.52	1.92	1.99	1.94	1.85
Cobra	2.66	2.59	2.59	2.73	2.48	2.52	2.72	2.68	2.01	1.90	2.14	2.26
Penncross	2.81	2.72	2.79	2.91	2.67	2.76	2.84	3.06	2.28	2.26	2.30	2.21
SR1020	3.21	3.00	2.94	2.87	2.76	2.74	2.80	2.71	2.30	2.28	2.52	2.14
LSD (p<0.05)												
	ns	ns	0.21	ns	ns	ns	ns	ns	0.19	ns	0.19	ns

### 3.3 Turf agronomic characteristics

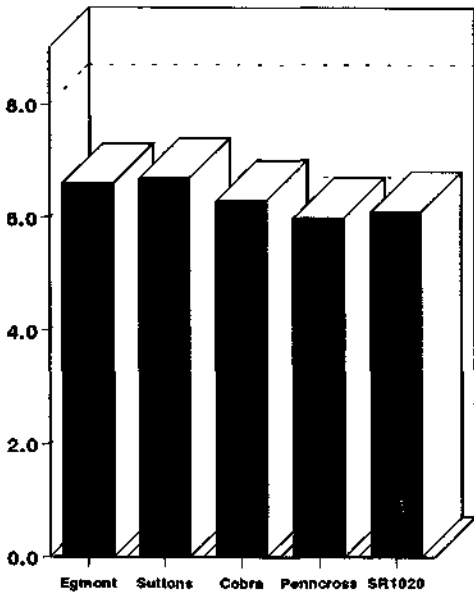
Table 24: Turf quality

VARIETY	AVG	Dec-93	Jan-94	Feb-94	Mar-94	Jun-94	Jul-94	Aug-94	Sep-94	Nov-94	Jan-95	Feb-95
<b>Low height of cut</b>												
Egmont	6.5	7.0	6.5	6.5	6.5	6.5	6.5	6.0	6.0	7.0	6.5	6.5
Suttons	6.5	6.5	6.5	7.0	6.5	6.0	6.5	6.0	6.5	6.5	7.0	7.0
Cobra	6.0	6.0	6.0	6.0	5.5	5.5	6.0	6.0	6.0	6.5	6.0	6.0
Pennncross	5.7	6.0	5.5	5.0	4.5	5.5	6.0	6.0	5.5	6.5	6.0	6.0
SR1020	5.7	5.0	5.0	4.5	4.0	6.0	6.5	6.5	6.0	6.0	6.5	6.5
<b>Medium height of cut</b>												
Egmont	6.7	6.0	6.5	7.0	7.0	7.0	6.5	6.0	7.0	7.0	7.0	6.5
Suttons	6.9	7.0	7.0	7.5	7.5	6.5	6.0	6.0	6.5	6.5	7.0	8.0
Cobra	6.4	6.0	6.5	7.0	6.0	6.0	6.5	6.5	6.5	6.5	6.5	6.0
Pennncross	6.1	6.0	6.0	6.0	5.5	5.5	6.0	6.5	5.5	7.0	7.0	6.0
SR1020	6.4	6.5	6.0	6.0	6.0	6.0	6.0	6.5	6.5	7.0	7.0	6.5
<b>High height of cut</b>												
Egmont	6.6	6.5	6.5	7.0	7.0	6.0	6.5	7.0	7.0	6.0	6.5	7.0
Suttons	6.6	7.0	7.0	7.5	7.0	6.0	6.0	6.0	6.5	6.0	7.0	7.0
Cobra	6.5	6.5	6.5	7.0	6.5	5.5	5.5	6.5	7.0	6.5	7.0	6.5
Pennncross	6.1	6.5	6.0	6.0	6.0	6.0	5.5	6.0	6.0	6.5	6.0	6.5
SR1020	6.3	7.0	6.5	7.0	7.0	6.5	5.5	5.5	5.5	6.5	6.5	6.0
<b>Variety effect</b>												
Egmont	6.6	6.5	6.5	6.8	6.8	6.5	6.5	6.3	6.7	6.7	6.7	6.7
Suttons	6.7	6.8	6.8	7.3	7.0	6.2	6.2	6.0	6.5	6.3	7.0	7.3
Cobra	6.3	6.2	6.3	6.7	6.0	5.7	6.0	6.3	6.5	6.5	6.5	6.2
Pennncross	6.0	6.2	5.8	5.7	5.3	5.7	5.8	6.2	5.7	6.7	6.3	6.2
SR1020	6.1	6.2	5.8	5.8	5.7	6.2	6.0	6.2	6.0	6.5	6.7	6.3
<b>Height of cut effect</b>												
Low	6.1	6.1	5.9	5.8	5.4	5.9	6.3	6.1	6.0	6.5	6.4	6.4
Medium	6.5	6.3	6.4	6.7	6.4	6.2	6.2	6.3	6.4	6.8	6.9	6.6
High	6.4	6.7	6.5	6.9	6.7	6.0	5.8	6.2	6.4	6.3	6.6	6.6

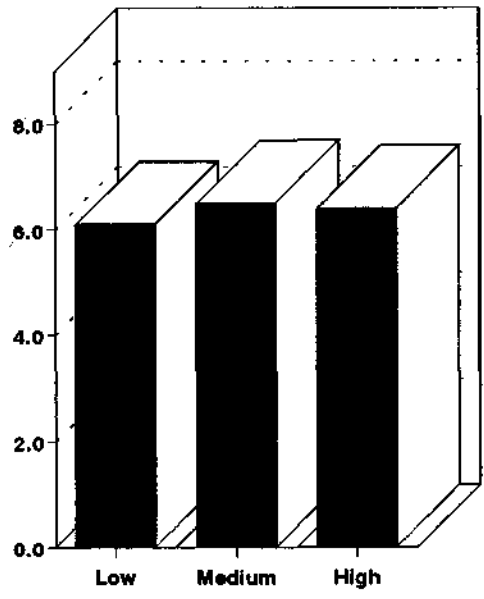
Table 25: Turf density

VARIETY	AVG	Dec-93	Jan-94	Feb-94	Mar-94	Jun-94	Jul-94	Aug-94	Sep-94	Nov-94	Jan-95	Feb-95
<b>Low height of cut</b>												
Egmont	6.4	6.5	6.5	6.5	6.5	6.5	6.5	5.0	6.5	6.5	6.5	7.0
Suttons	6.8	6.5	7.0	7.5	7.0	6.5	7.0	6.0	7.0	6.5	6.5	7.5
Cobra	6.1	6.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.5	6.0	6.5
Pennncross	5.8	6.0	5.5	5.5	5.0	6.0	6.0	5.5	5.5	6.5	6.0	6.5
SR1020	6.0	6.0	5.0	5.5	5.0	6.0	6.0	6.5	6.5	6.5	6.0	6.5
<b>Medium height of cut</b>												
Egmont	6.7	6.5	6.5	7.0	7.0	6.5	7.0	5.5	6.5	7.5	7.0	6.5
Suttons	7.3	7.5	8.0	8.0	7.5	7.0	7.0	6.0	7.0	7.0	7.0	8.0
Cobra	6.5	6.5	6.5	7.0	6.0	6.0	6.5	6.5	6.0	7.0	6.5	6.5
Pennncross	6.1	6.0	6.0	6.0	6.0	5.5	6.0	6.0	6.0	6.5	6.5	6.5
SR1020	6.4	6.5	6.0	6.5	6.0	6.0	6.5	6.0	7.0	7.0	6.5	6.5
<b>High height of cut</b>												
Egmont	7.0	7.0	7.0	7.0	7.0	6.5	7.0	7.0	7.5	6.5	7.0	7.0
Suttons	7.3	7.5	8.0	7.5	7.5	6.5	7.0	7.0	7.0	7.0	7.0	8.0
Cobra	6.6	6.5	7.0	7.0	6.5	6.0	6.0	6.5	6.5	7.0	7.0	6.5
Pennncross	6.3	6.5	6.5	6.5	6.5	6.0	6.0	6.0	6.0	6.5	6.0	6.5
SR1020	6.5	7.0	7.0	7.5	7.5	6.5	5.5	6.0	6.0	6.5	6.0	6.5
<b>Variety effect</b>												
Egmont	6.7	6.7	6.7	6.8	6.8	6.5	6.8	5.8	6.8	6.8	6.8	6.8
Suttons	7.1	7.2	7.7	7.7	7.3	6.7	7.0	6.3	7.0	6.8	6.8	7.8
Cobra	6.4	6.5	6.5	6.7	6.2	6.0	6.2	6.3	6.2	6.8	6.5	6.5
Pennncross	6.1	6.2	6.0	6.0	5.8	5.8	6.0	5.8	5.8	6.5	6.2	6.5
SR1020	6.3	6.5	6.0	6.5	6.2	6.2	6.0	6.2	6.5	6.7	6.2	6.5
<b>Cutting height effect</b>												
Low	6.2	6.3	6.0	6.2	5.9	6.2	6.3	5.8	6.3	6.5	6.2	6.8
Medium	6.6	6.6	6.6	6.9	6.5	6.2	6.6	6.0	6.5	7.0	6.7	6.8
High	6.7	6.9	7.1	7.1	7.0	6.3	6.3	6.5	6.6	6.7	6.6	6.9

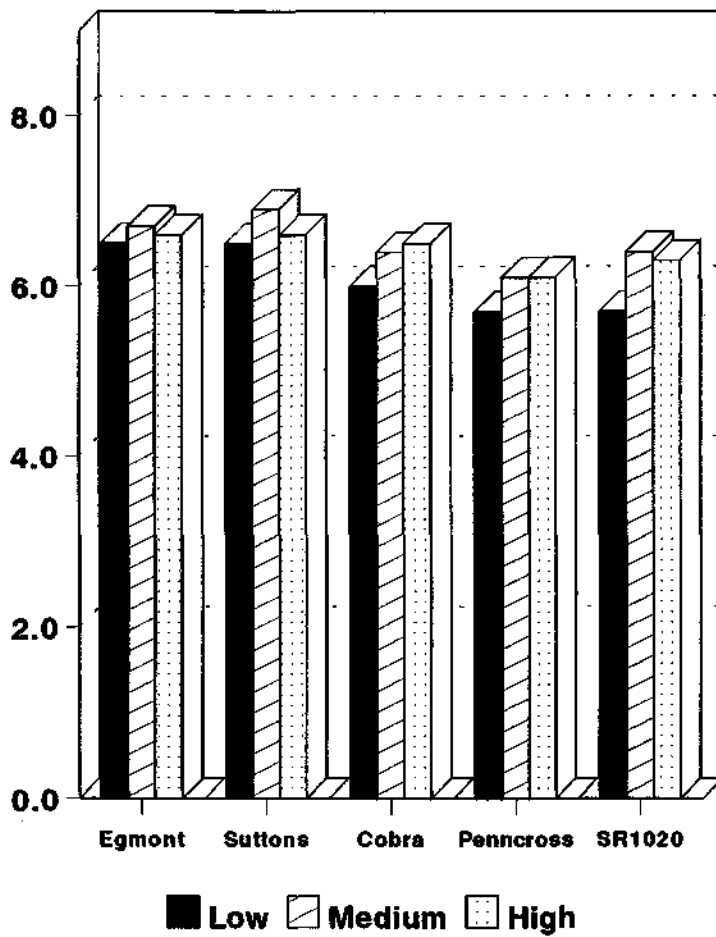
**Figure 22: Average turf quality**  
Variety effect



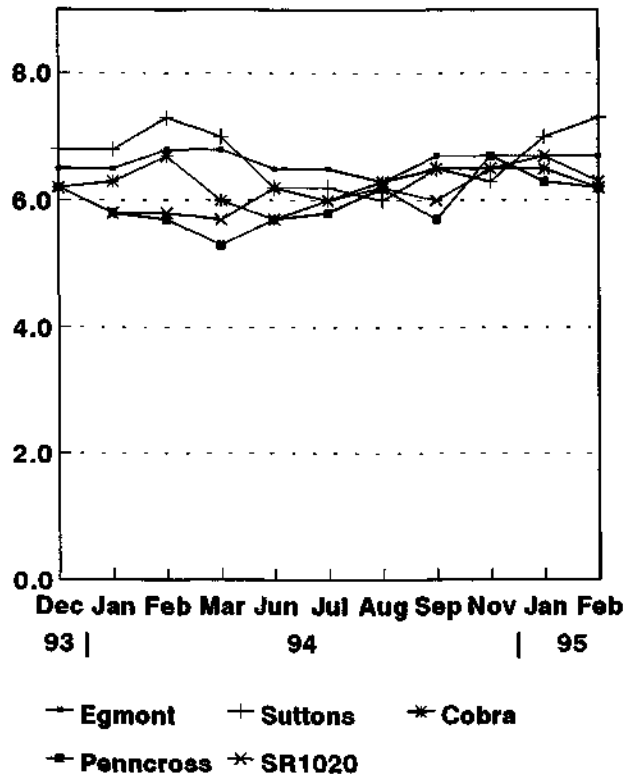
**Figure 23: Average turf quality**  
Mowing height effect



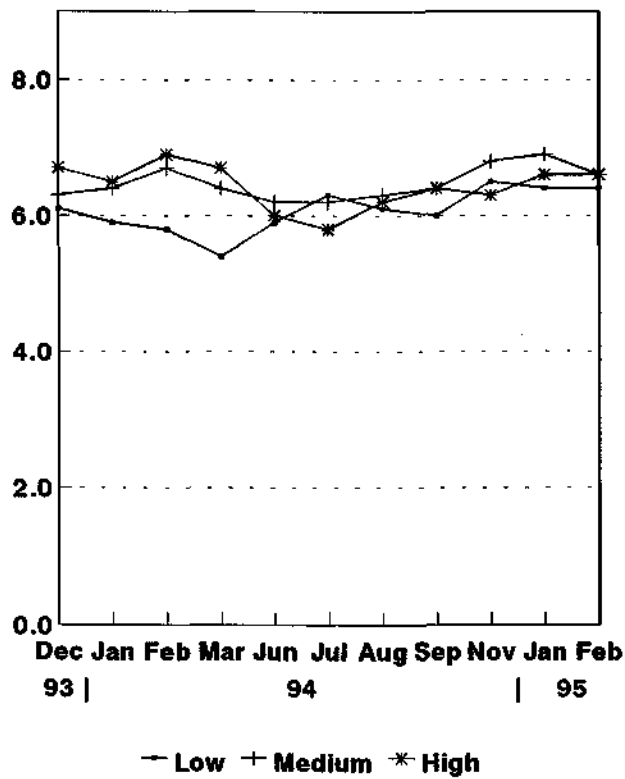
**Figure 24: Average turf quality**  
Variety x mowing height interaction



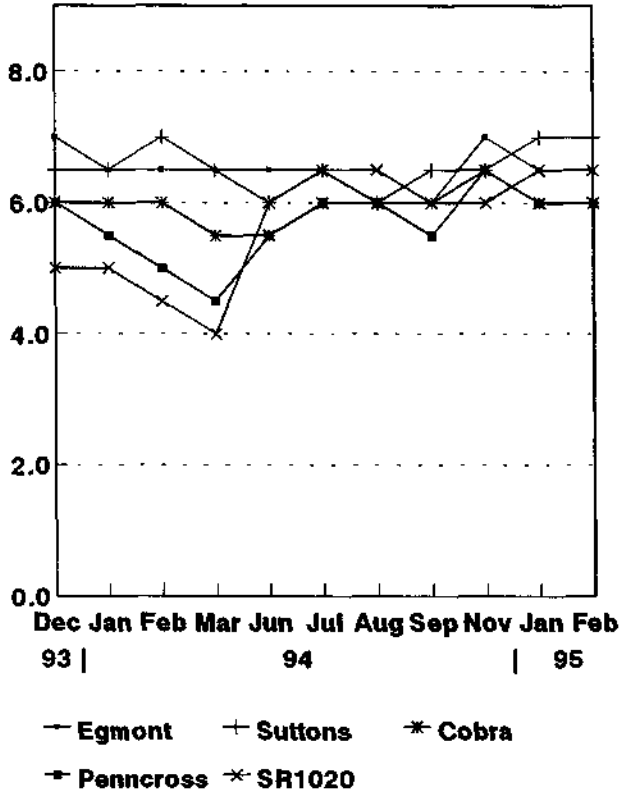
**Figure 25: Turf quality**  
Variety effect



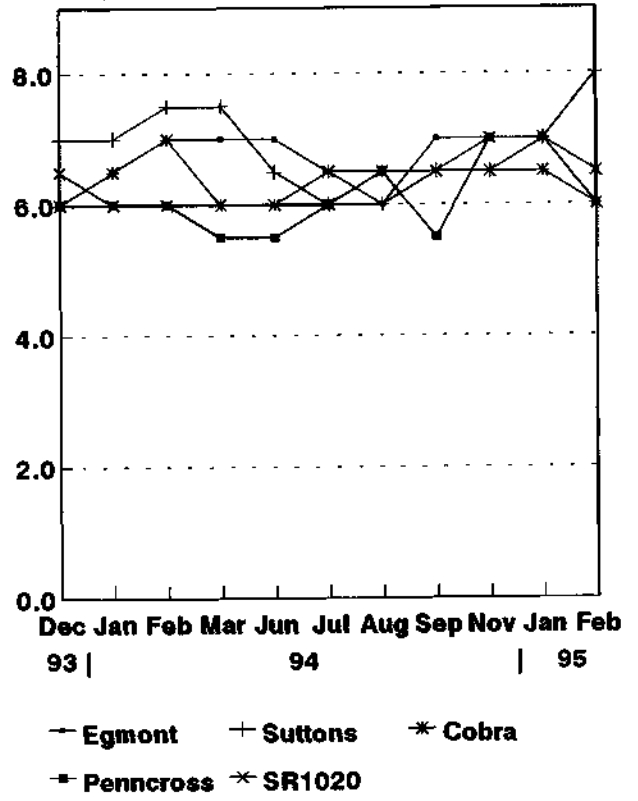
**Figure 26: Turf quality**  
Mowing height effect



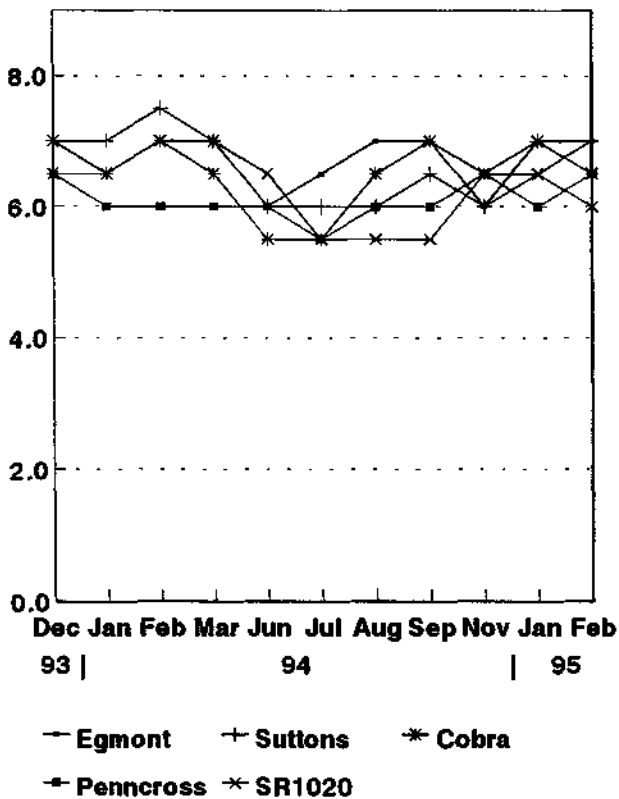
**Low mowing height**



**Medium mowing height**

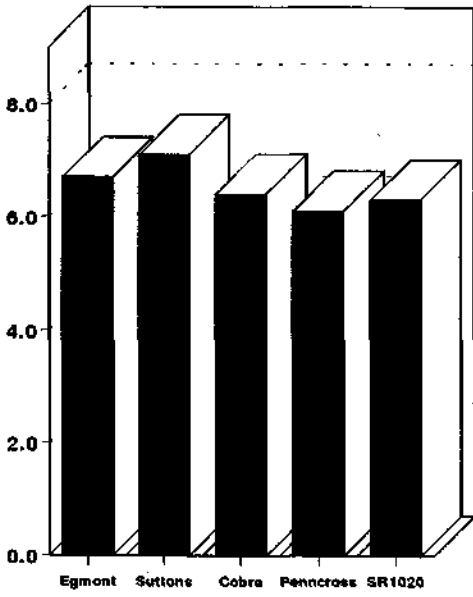


**High mowing height**

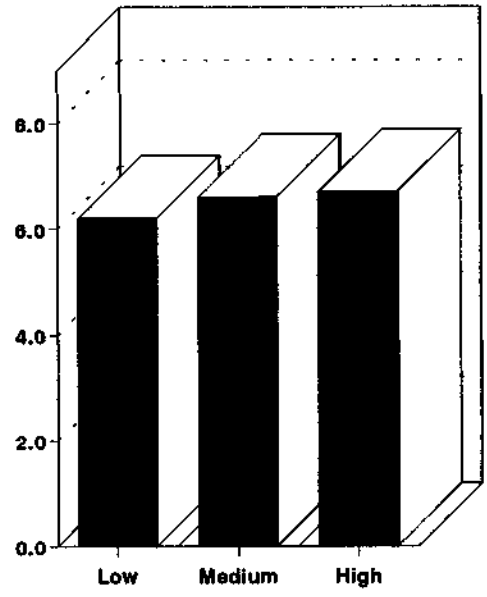


**Figure 27: Effect of variety & mowing height on turf quality**

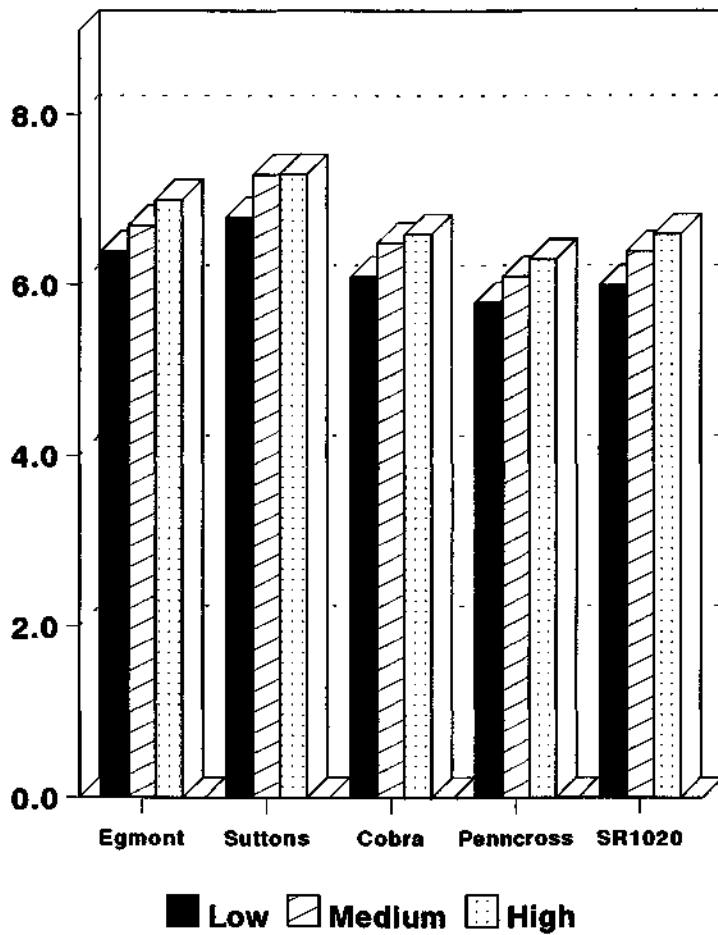
**Figure 28: Average turf density**  
Variety effect



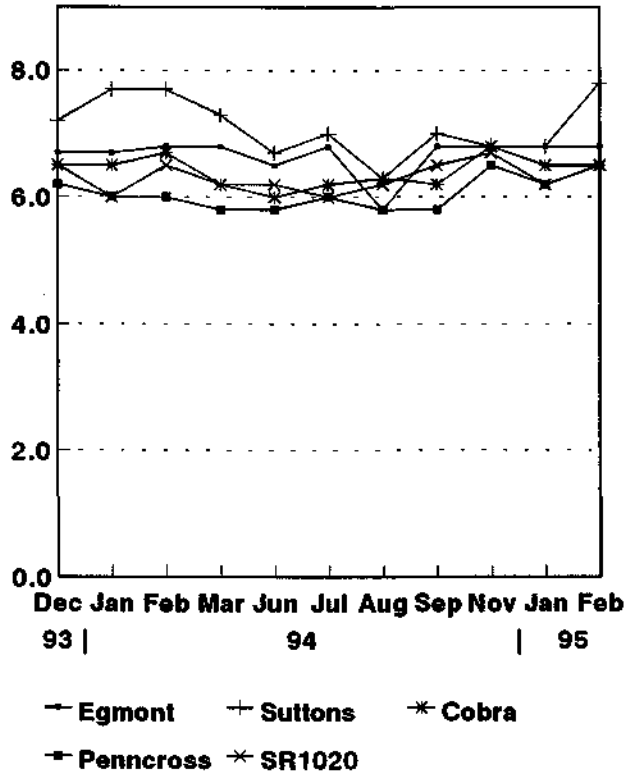
**Figure 29: Average turf density**  
Mowing height effect



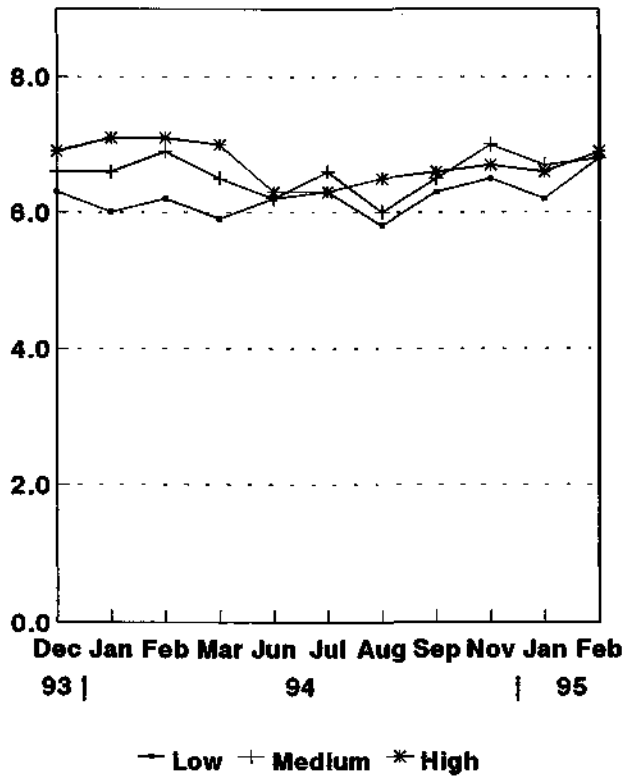
**Figure 30: Average turf density**  
Variety x mowing height interaction



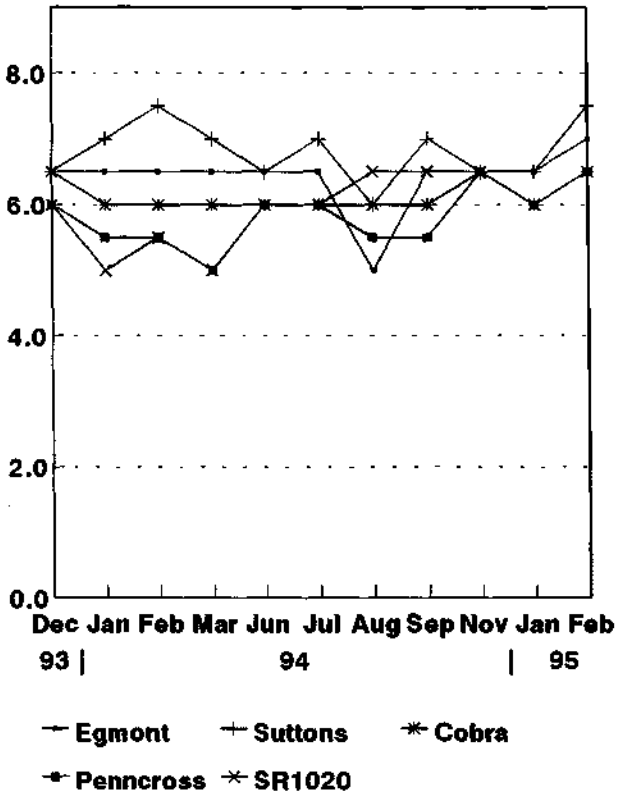
**Figure 31: Turf density**  
Variety effect



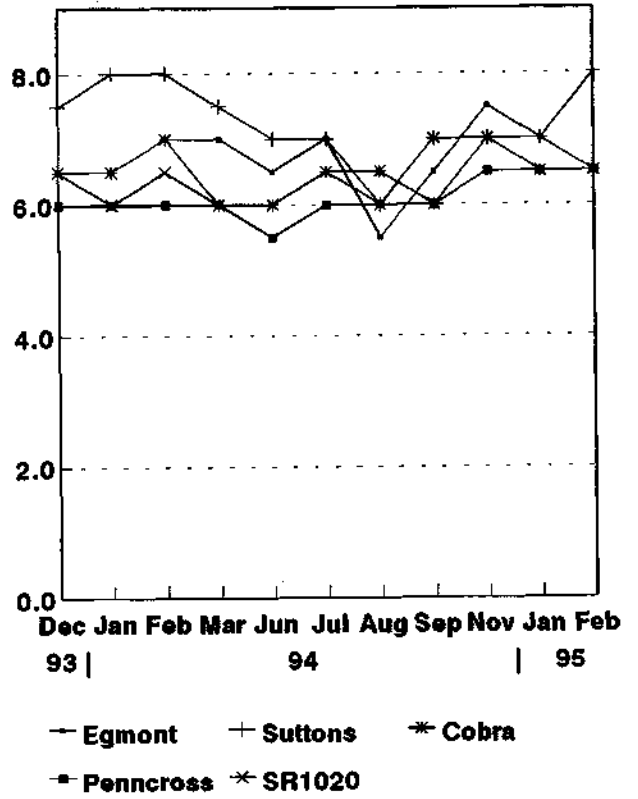
**Figure 32: Turf density**  
Mowing height effect



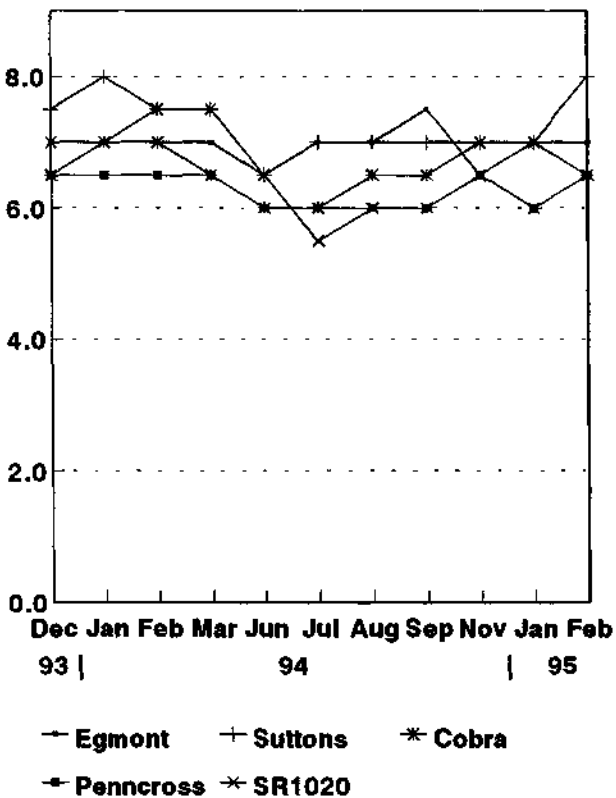
**Low mowing height**



**Medium mowing height**



**High mowing height**

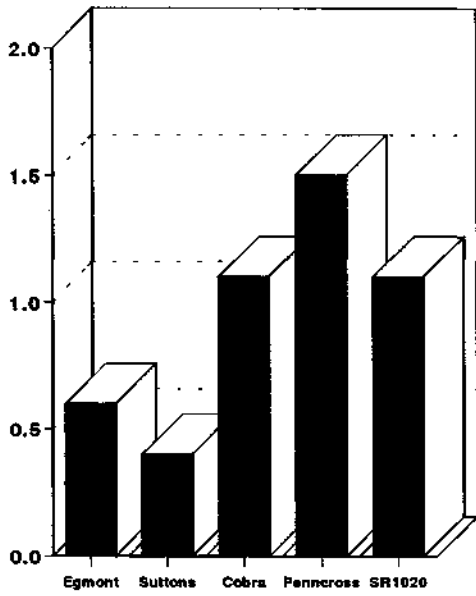


**Figure 33: Effect of variety & mowing height on turf density**

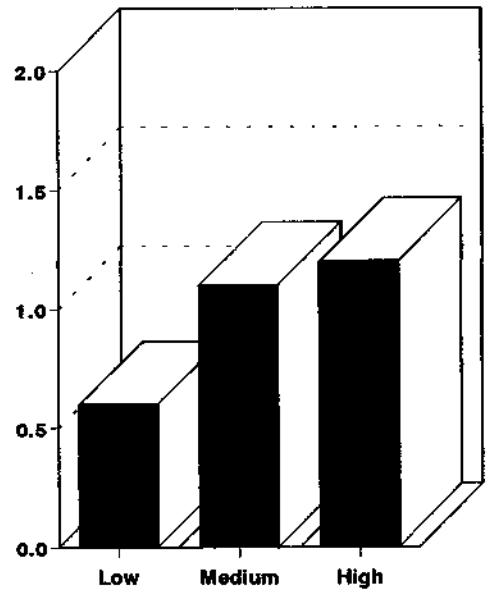
**Table 26: Spiking**

Variety	AVG	Feb-94	Sep-94	Oct-94	Nov-94	Feb-95	Moss Feb-95
<b>Low height of cut</b>							
Egmont	0.3	1.0	0.5	0.0	0.0	0.0	4.5
Suttons	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Cobra	0.7	1.0	1.5	0.5	0.5	0.0	3.5
Pennncross	1.2	2.0	1.0	1.0	1.0	1.0	3.5
SR1020	0.6	1.0	0.5	0.5	0.0	1.0	3.0
<b>Medium height of cut</b>							
Egmont	0.6	1.0	0.5	0.5	0.0	1.0	0.0
Suttons	0.6	1.0	0.5	1.0	0.5	0.0	0.5
Cobra	1.3	1.0	2.0	1.5	1.0	1.0	0.0
Pennncross	1.7	2.0	2.0	1.5	1.0	2.0	0.0
SR1020	1.2	1.0	1.5	1.0	1.5	1.0	1.5
<b>High height of cut</b>							
Egmont	0.8	1.0	0.0	1.0	1.0	1.0	0.0
Suttons	0.7	1.0	1.0	1.0	0.5	0.0	1.0
Cobra	1.2	2.0	1.0	2.0	1.0	0.0	0.0
Pennncross	1.7	2.0	1.5	2.0	1.0	2.0	2.3
SR1020	1.4	1.0	2.0	2.0	1.0	1.0	0.0
<b>Variety effect</b>							
Egmont	0.6	1.0	0.3	0.5	0.3	0.7	1.5
Suttons	0.4	0.7	0.5	0.7	0.3	0.0	1.5
Cobra	1.1	1.3	1.5	1.3	0.8	0.3	1.2
Pennncross	1.5	2.0	1.5	1.5	1.0	1.7	2.0
SR1020	1.1	1.0	1.3	1.2	0.8	1.0	1.5
<b>Cutting height effect</b>							
Low	0.6	1.0	0.7	0.4	0.3	0.4	3.5
Medium	1.1	1.2	1.3	1.1	0.8	1.0	0.4
High	1.2	1.4	1.1	1.6	0.9	0.4	0.7

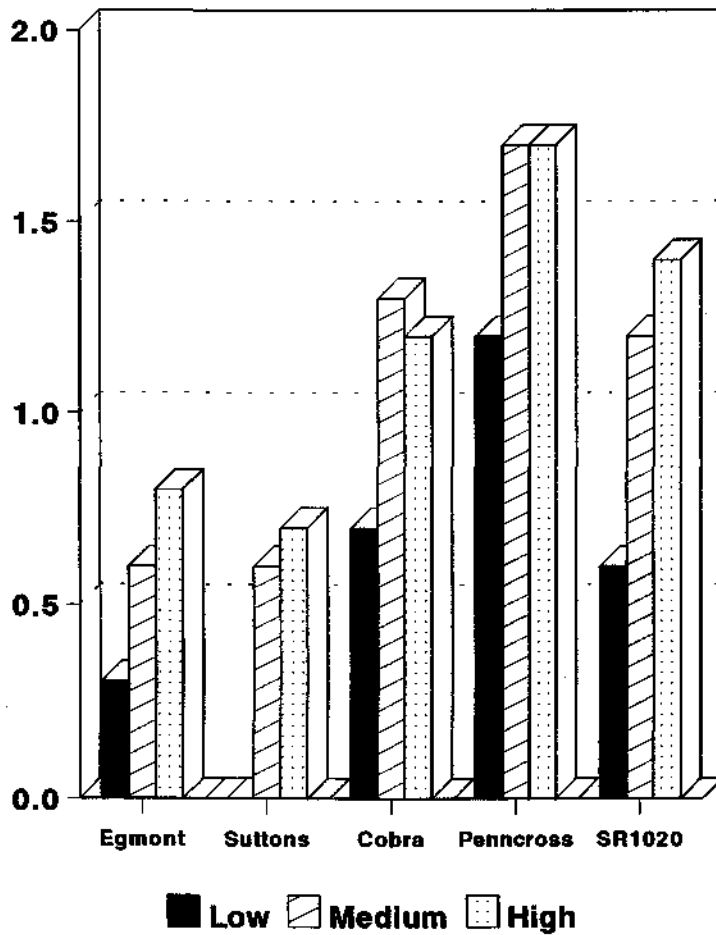
**Figure 34: Average spiking**  
Variety effect



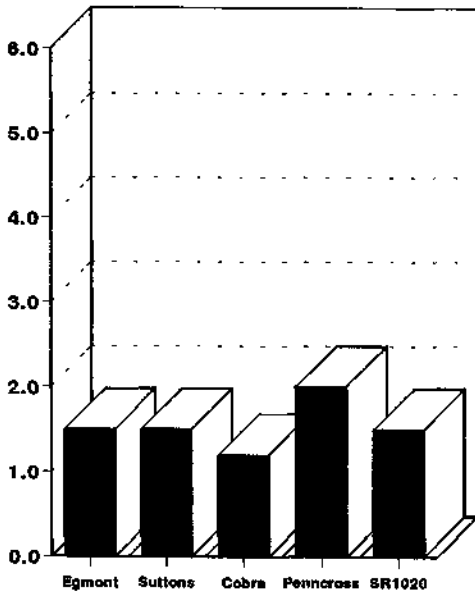
**Figure 35: Average spiking**  
Mowing height effect



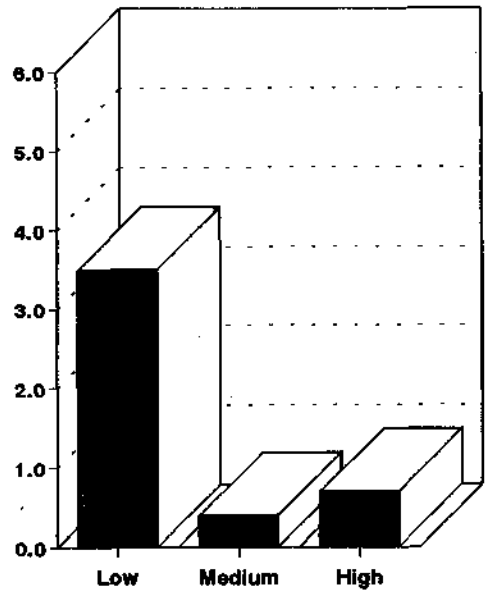
**Figure 36: Average spiking**  
Variety x mowing height



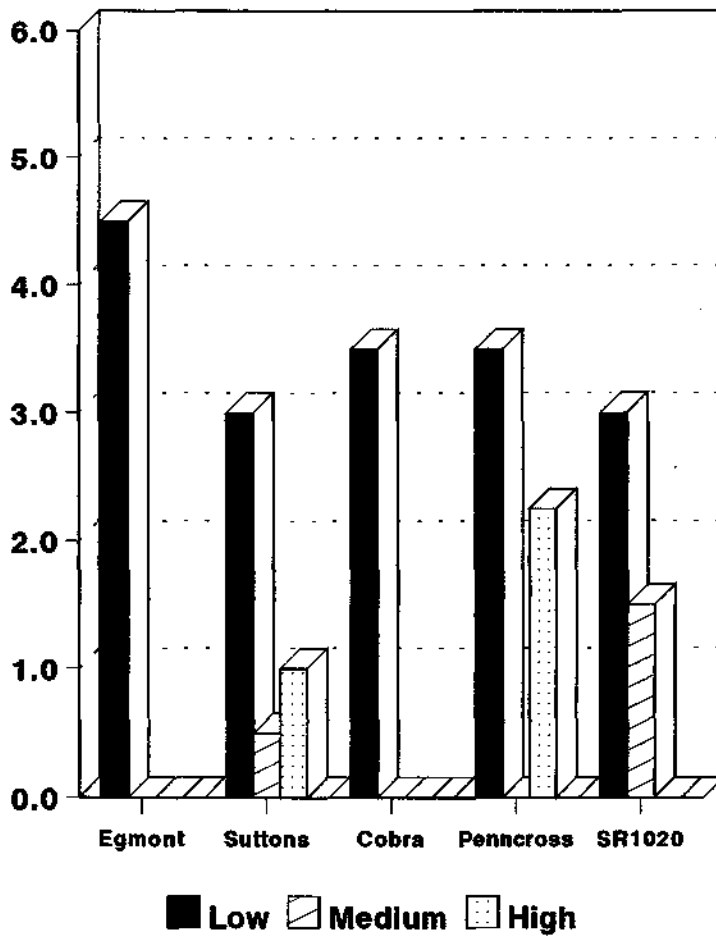
**Figure 37: Moss invasion**  
Variety effect



**Figure 38: Moss invasion**  
Mowing height effect



**Figure 39: Moss invasion**  
Variety x mowing height



### 3.4 Effects of renovation on green speed and turf agronomic characteristics

**Table 27: Variety effect - green speed (m)**

Variety	25-Aug	02-Sep	23-Sep	30-Sep	07-Oct	14-Oct
Egmont	2.51	2.53	2.22	2.01	2.05	2.09
Suttons	2.46	2.50	2.01	1.99	2.09	2.16
Cobra	2.39	2.65	2.16	2.07	2.22	2.29
Pennncross	2.69	2.78	2.25	2.11	2.36	2.45
SR1020	2.67	2.76	2.11	2.15	2.46	2.57
LSD (p<0.05)	0.09	0.10	0.11	0.13	0.07	0.09

\* Renovation: 07-Sep

**Table 28: Mowing height effect - green speed (m)**

Variety	25-Aug	02-Sep	23-Sep	30-Sep	07-Oct	14-Oct
Low	2.70	2.85	2.39	2.37	2.39	2.60
Medium	2.67	2.73	2.15	1.99	2.24	2.32
High	2.27	2.36	1.91	1.84	2.07	2.02
LSD (p<0.05)	0.07	0.08	0.08	0.10	0.05	0.07

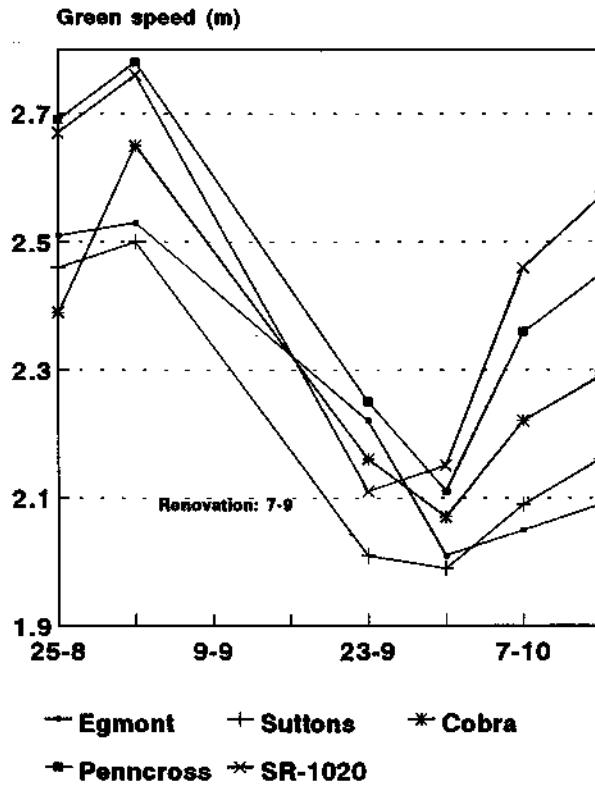
\* Renovation: 07-Sep

**Table 29: Variety x Height interaction - green speed (m)**

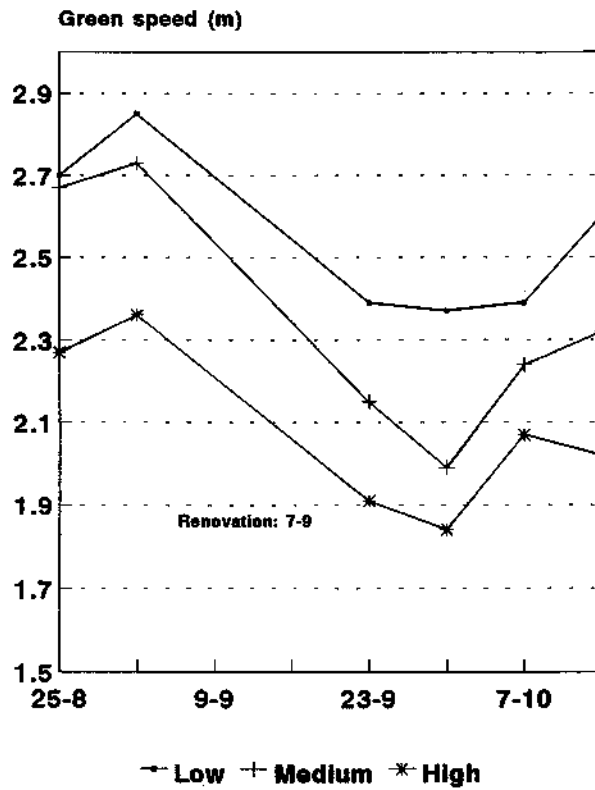
Variety	25-Aug	02-Sep	23-Sep	30-Sep	07-Oct	14-Oct
Low height of cut						
Egmont	2.77	2.72	2.45	2.25	2.25	2.44
Suttons	2.55	2.68	2.12	2.29	2.37	2.41
Cobra	2.62	2.79	2.39	2.40	2.34	2.65
Pennncross	2.94	3.05	2.41	2.43	2.44	2.69
SR1020	2.64	3.00	2.58	2.47	2.57	2.82
Medium height of cut						
Egmont	2.57	2.61	2.43	2.05	2.06	2.05
Suttons	2.55	2.66	2.09	1.96	1.97	2.25
Cobra	2.49	2.85	2.16	1.95	2.30	2.31
Pennncross	2.73	2.76	2.13	1.99	2.40	2.39
SR1020	2.99	2.77	1.96	2.02	2.50	2.57
High height of cut						
Egmont	2.18	2.28	1.77	1.72	1.86	1.79
Suttons	2.27	2.16	1.82	1.72	1.94	1.83
Cobra	2.08	2.31	1.94	1.85	2.02	1.92
Pennncross	2.42	2.53	2.21	1.93	2.23	2.26
SR1020	2.39	2.52	1.80	1.97	2.31	2.33
LSD (p<0.05)	0.15	ns	0.19	ns	0.12	0.15

\* Renovation: 07-Sep

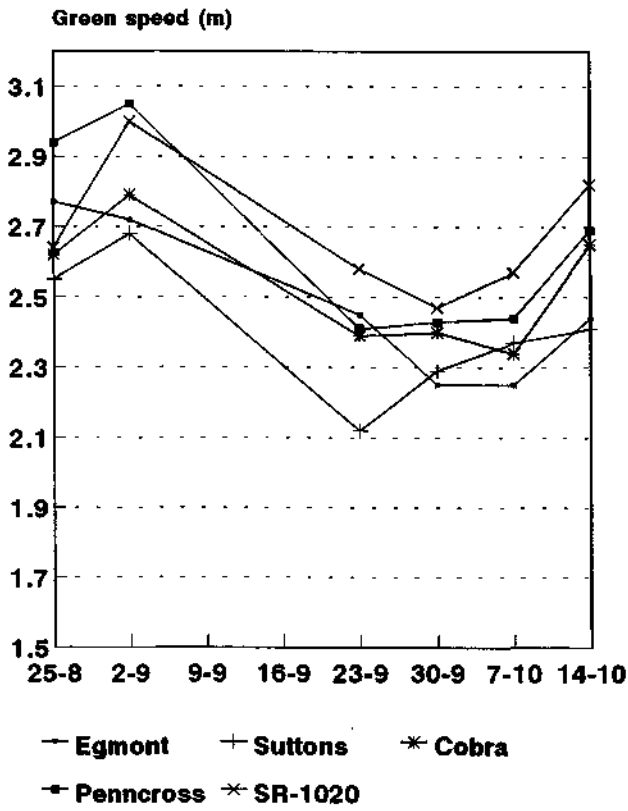
**Figure 40: Effect of renovation**  
Variety



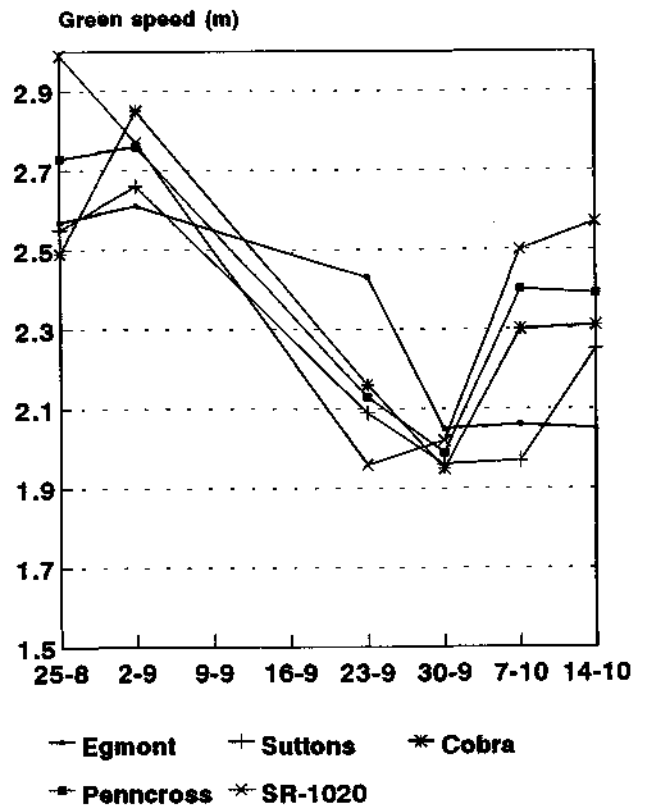
**Figure 41: Effect of renovation**  
Mowing Height



**Low mowing height**



**Medium mowing height**



**High mowing height**

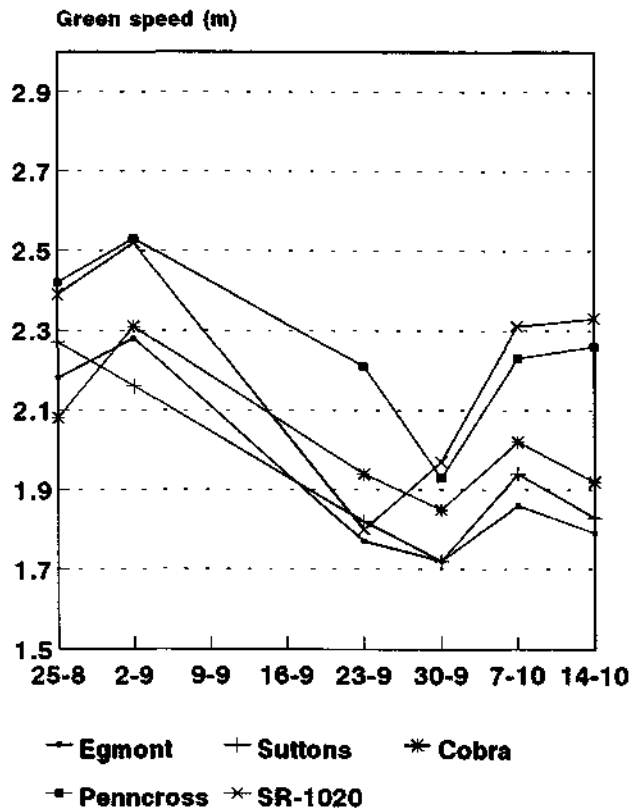


Figure 42: Effect of renovation on green speed - variety x mowing height

Renovation: 7-9-94

**Table 30: Effect of renovation on turf quality**

VARIETY	25-Aug	02-Sep	23-Sep	30-Sep	07-Oct	14-Oct
<b>Low height of cut</b>						
Egmont	6.0	6.0	4.5	6.0	6.5	6.5
Suttons	6.0	6.5	5.0	6.5	7.0	6.5
Cobra	6.0	6.0	4.5	6.0	6.0	6.5
Pennncross	6.0	5.5	4.5	6.0	6.0	6.5
SR1020	6.5	6.0	4.5	5.5	6.5	6.0
<b>Medium height of cut</b>						
Egmont	6.0	7.0	6.0	7.0	6.5	7.0
Suttons	6.0	6.5	6.0	7.5	6.5	6.5
Cobra	6.5	6.5	5.5	6.0	6.5	6.5
Pennncross	6.5	5.5	5.5	6.0	6.5	6.5
SR1020	6.5	6.5	5.5	6.0	7.0	7.0
<b>High height of cut</b>						
Egmont	7.0	7.0	6.5	7.0	7.0	6.5
Suttons	6.0	6.5	6.0	6.0	6.5	6.0
Cobra	6.5	7.0	6.5	6.0	6.0	6.5
Pennncross	6.0	6.0	5.5	5.0	5.0	6.0
SR1020	5.5	5.5	5.0	4.5	5.0	5.5
<b>Variety effect</b>						
Egmont	6.3	6.7	5.7	6.7	6.7	6.7
Suttons	6.0	6.5	5.7	6.7	6.7	6.3
Cobra	6.3	6.5	5.5	6.0	6.2	6.5
Pennncross	6.2	5.7	5.2	5.7	5.8	6.3
SR1020	6.2	6.0	5.0	5.3	6.2	6.2
<b>Cutting height effect</b>						
Low	6.1	6.0	4.6	6.0	6.4	6.4
Medium	6.3	6.4	5.7	6.5	6.6	6.7
High	6.2	6.4	5.9	5.7	5.9	6.1

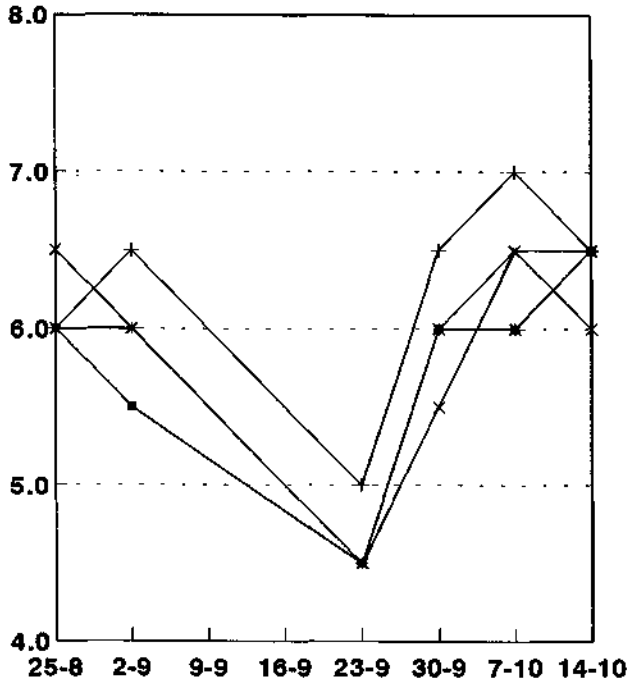
\* Renovation: 07-Sep

**Table 31: Effect of renovation on turf density**

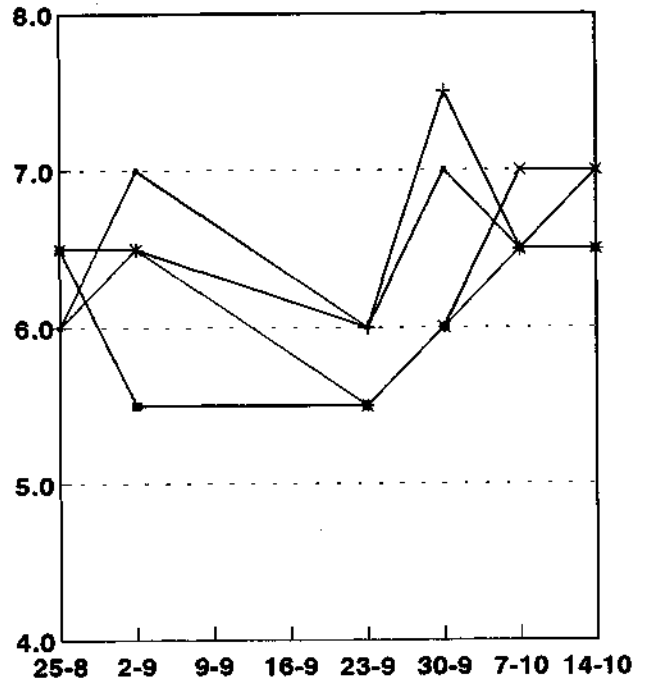
VARIETY	25-Aug	02-Sep	23-Sep	30-Sep	07-Oct	14-Oct
<b>Low height of cut</b>						
Egmont	5.0	6.5	4.5	5.5	6.5	6.5
Suttons	6.0	7.0	4.5	6.5	7.0	6.5
Cobra	6.0	6.0	4.5	6.0	6.0	6.0
Pennncross	5.5	5.5	4.5	5.5	6.0	6.5
SR1020	6.5	6.5	4.5	5.5	6.0	6.5
<b>Medium height of cut</b>						
Egmont	5.5	6.5	5.5	7.0	6.5	7.0
Suttons	6.0	7.0	5.5	7.5	7.0	7.0
Cobra	6.5	6.0	5.0	6.0	6.5	7.0
Pennncross	6.0	6.0	5.0	6.0	6.5	6.5
SR1020	6.0	7.0	5.5	6.0	7.0	7.0
<b>High height of cut</b>						
Egmont	7.0	7.5	6.0	7.0	7.5	7.0
Suttons	7.0	7.0	5.5	6.5	7.5	7.0
Cobra	6.5	6.5	6.0	6.0	7.0	7.0
Pennncross	6.0	6.0	5.0	5.0	6.0	6.5
SR1020	6.0	6.0	5.5	5.0	5.5	6.0
<b>Variety effect</b>						
Egmont	5.8	6.8	5.3	6.5	6.8	6.8
Suttons	6.3	7.0	5.2	6.8	7.2	6.8
Cobra	6.3	6.2	5.2	6.0	6.5	6.7
Pennncross	5.8	5.8	4.8	5.5	6.2	6.5
SR1020	6.2	6.5	5.2	5.5	6.2	6.5
<b>Cutting height effect</b>						
Low	5.8	6.3	4.5	5.8	6.3	6.4
Medium	6.0	6.5	5.3	6.5	6.7	6.9
High	6.5	6.6	5.6	5.9	6.7	6.7

\* Renovation: 07-Sep

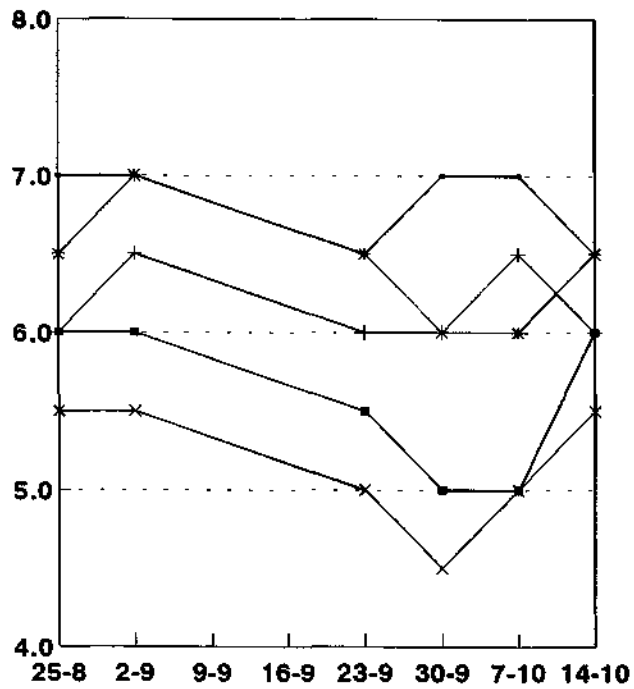
**Low mowing height**



**Medium mowing height**



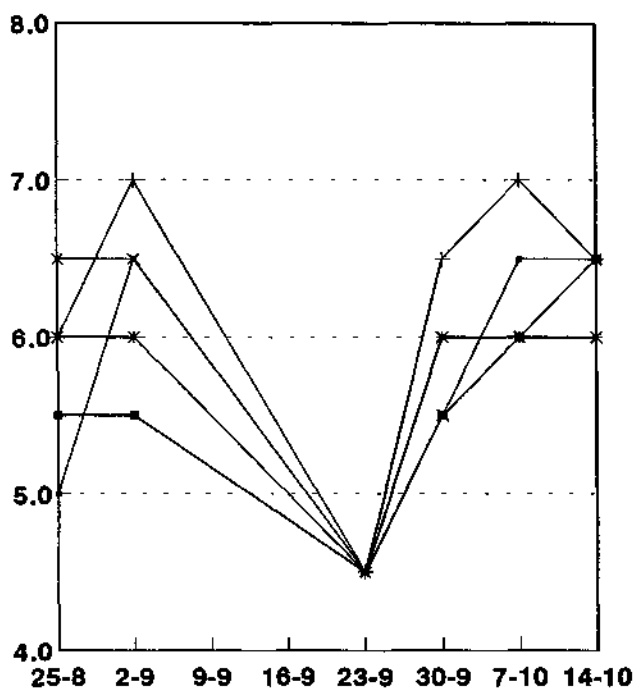
**High mowing height**



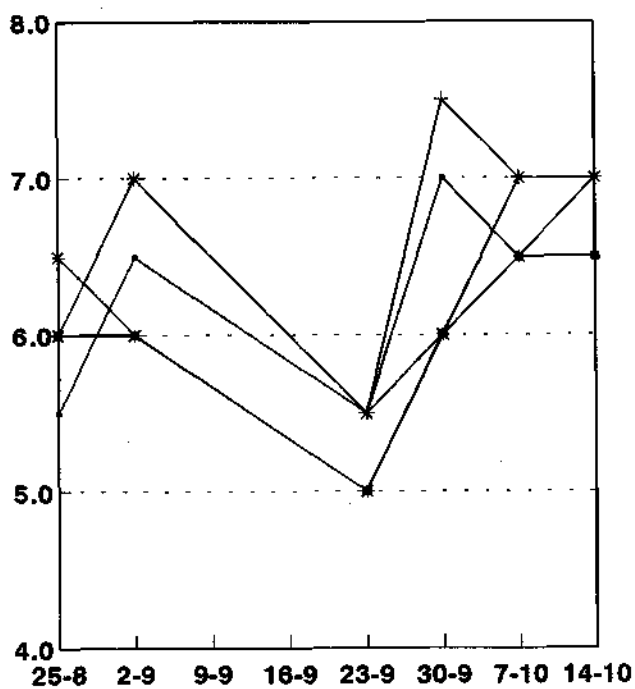
**Figure 43: Effect of renovation on turf quality - variety x mowing height**

**Renovation: 7-9-94**

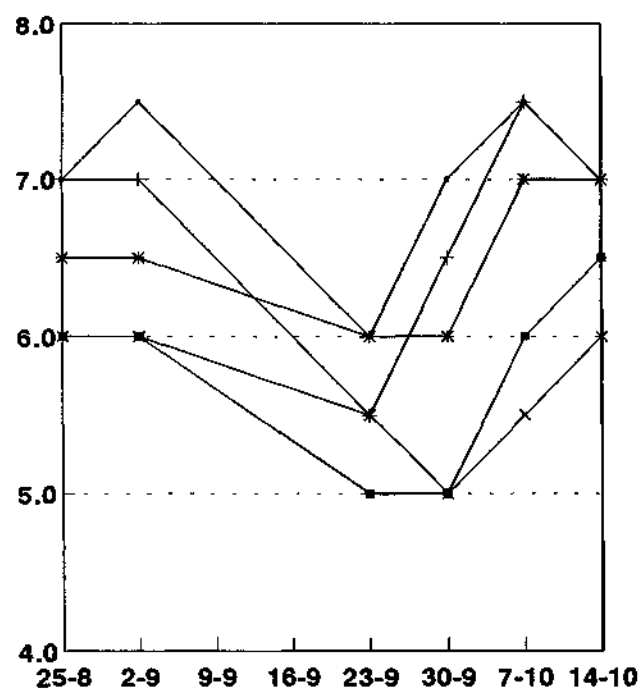
**Low mowing height**



**Medium mowing height**



**High mowing height**



**Figure 44: Effect of renovation on turf density - variety x mowing height**

**Renovation: 7-9-94**

### 3.5 Effects of nutrition level on green speed and turf agronomic characteristics

**Table 32: Nutritional effect - green speed (m)**

Treatment	Avg	Nov-94	Feb-95
Low N	2.50	2.45	2.54
High N	2.52	2.48	2.55
LSD (p<0.05)	ns	ns	ns

**Table 33: Height x nutritional level interaction - green speed (m)**

Treatment	Avg	Nov-94	Feb-95	
Low	Low N	2.65	2.59	2.71
	High N	2.68	2.60	2.76
Medium	Low N	2.58	2.55	2.61
	High N	2.56	2.55	2.56
High	Low N	2.24	2.20	2.29
	High N	2.31	2.30	2.32
LSD (p<0.05)	ns	ns	0.06	

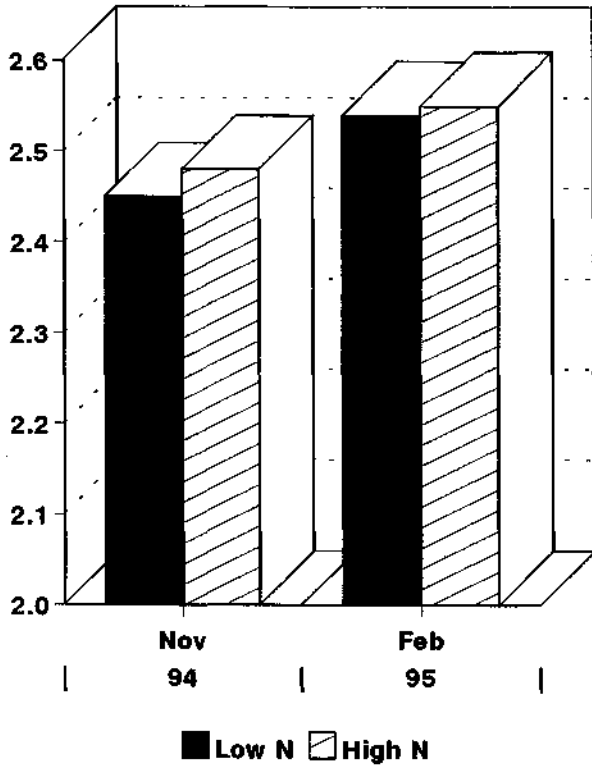
**Table 34: Variety x nutritional level interaction - green speed (m)**

Treatment	Avg	Nov-94	Feb-95	
Egmont	Low N	2.38	2.32	2.44
	High N	2.41	2.42	2.40
Suttons	Low N	2.39	2.31	2.47
	High N	2.43	2.38	2.48
Cobra	Low N	2.48	2.45	2.50
	High N	2.49	2.44	2.54
Penncross	Low N	2.55	2.52	2.59
	High N	2.59	2.55	2.64
SR1020	Low N	2.66	2.64	2.68
	High N	2.65	2.63	2.67
LSD (p<0.05)	ns	ns	ns	

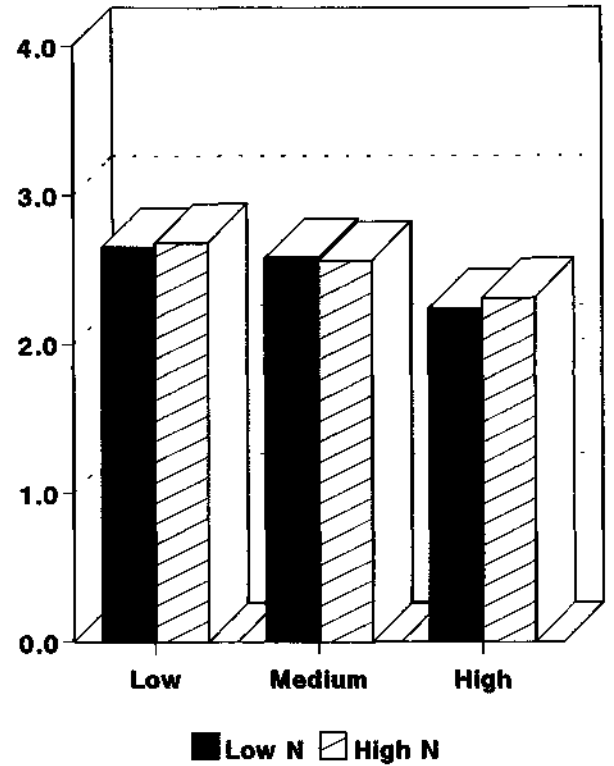
**Table 35: Wear x nutritional level - green speed (m)**

Treatment	Avg	Nov-94	Feb-95	
Low N	Wear	2.53	2.48	2.58
	No wear	2.45	2.41	2.49
High N	Wear	2.57	2.52	2.60
	No wear	2.47	2.44	2.49
LSD (p<0.05)	ns	ns	ns	

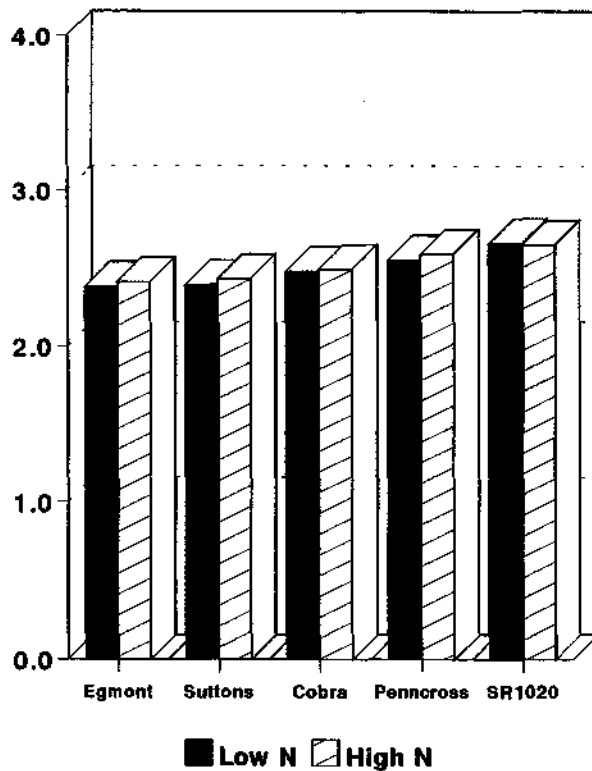
**Figure 45: Nitrogen level effect**  
Green speed (m)



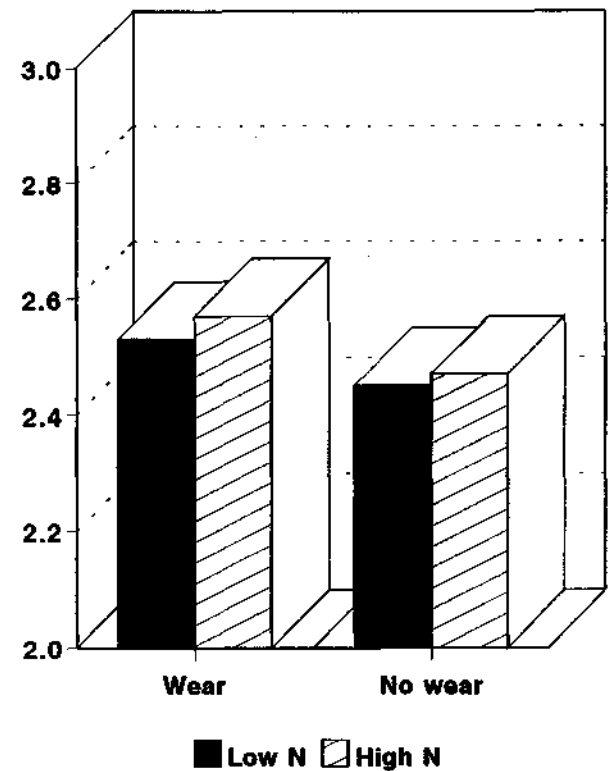
**Figure 46: Nitrogen level x mowing height**  
Average green speed (m)



**Figure 47: Variety x nitrogen level**  
Average green speed (m)



**Figure 48: Wear x nitrogen level**  
Average Green speed (m)



**Table 36: Height x variety x nutritional level interactions - green speed (m)**

Treatment		Avg	Nov-94	Feb-95
Low height of cut				
Low N	Egmont	2.56	2.49	2.62
	Suttons	2.53	2.42	2.64
	Cobra	2.63	2.57	2.68
	Penncross	2.73	2.68	2.78
	SR1020	2.79	2.77	2.82
High N	Egmont	2.52	2.53	2.51
	Suttons	2.62	2.47	2.76
	Cobra	2.64	2.52	2.77
	Penncross	2.78	2.68	2.87
	SR1020	2.84	2.79	2.90
Medium height of cut				
Low N	Egmont	2.44	2.34	2.55
	Suttons	2.45	2.47	2.43
	Cobra	2.57	2.57	2.56
	Penncross	2.65	2.63	2.67
	SR1020	2.78	2.74	2.83
High N	Egmont	2.49	2.52	2.47
	Suttons	2.46	2.47	2.46
	Cobra	2.50	2.45	2.54
	Penncross	2.67	2.66	2.68
	SR1020	2.65	2.65	2.66
High height of cut				
Low N	Egmont	2.13	2.12	2.15
	Suttons	2.19	2.02	2.35
	Cobra	2.24	2.22	2.27
	Penncross	2.26	2.25	2.30
	SR1020	2.40	2.41	2.39
High N	Egmont	2.21	2.20	2.22
	Suttons	2.20	2.19	2.22
	Cobra	2.33	2.36	2.30
	Penncross	2.32	2.30	2.38
	SR1020	2.46	2.46	2.46
LSD (p<0.05)		ns	ns	0.13

**Table 37: Height x wear x nutritional level interactions - green speed (m)**

Treatment		Avg	Nov-94	Feb-95
Low height of cut				
Wear	Low N	2.69	2.62	2.77
	High N	2.73	2.62	2.85
No wear	Low N	2.60	2.55	2.65
	High N	2.63	2.58	2.68
Medium height of cut				
Wear	Low N	2.60	2.57	2.62
	High N	2.57	2.57	2.58
No wear	Low N	2.56	2.53	2.59
	High N	2.54	2.53	2.54
High height of cut				
Wear	Low N	2.30	2.27	2.35
	High N	2.38	2.38	2.38
No wear	Low N	2.19	2.14	2.24
	High N	2.24	2.22	2.25
LSD (p<0.05)		ns	ns	ns

**Table 38: Variety x wear x nutritional level interactions - green speed (m)**

Treatment		Avg	Nov-94	Feb-95
<b>Wear</b>				
Low N	Egmont	2.43	2.42	2.44
	Suttons	2.40	2.29	2.52
	Cobra	2.57	2.55	2.59
	Pennncross	2.57	2.52	2.63
	SR1020	2.69	2.65	2.73
High N	Egmont	2.45	2.47	2.43
	Suttons	2.51	2.48	2.54
	Cobra	2.54	2.45	2.64
	Pennncross	2.63	2.55	2.72
	SR1020	2.67	2.66	2.69
<b>No Wear</b>				
Low N	Egmont	2.33	2.21	2.44
	Suttons	2.38	2.33	2.43
	Cobra	2.39	2.36	2.42
	Pennncross	2.53	2.52	2.54
	SR1020	2.63	2.62	2.63
High N	Egmont	2.37	2.36	2.37
	Suttons	2.34	2.27	2.42
	Cobra	2.43	2.43	2.44
	Pennncross	2.55	2.54	2.57
	SR1020	2.63	2.61	2.65
LSD (p<0.05)		ns	0.13	ns

**Table 39: Nutritional level effect - agronomic characteristics**

Treatment	-----Turf quality-----				-----Turf density-----				-----Spiking-----		
	AVG	Nov-94	Jan-95	Feb-95	AVG	Nov-94	Jan-95	Feb-95	AVG	Nov-94	Feb-95
High N	6.6	6.5	6.7	6.7	6.7	6.8	6.5	7.0	1.0	1.1	0.9
Low N	6.6	6.5	6.6	6.5	6.7	6.7	6.5	6.8	0.7	0.7	0.7

**Table 40: Nutritional x Variety interaction - agronomic characteristics**

Treatment	-----Turf quality-----				-----Turf density-----				-----Spiking-----		
	AVG	Nov-94	Jan-95	Feb-95	AVG	Nov-94	Jan-95	Feb-95	AVG	Nov-94	Feb-95
<b>High nutrition</b>											
Egmont	6.7	6.5	6.7	6.8	6.9	6.8	6.8	7.0	0.6	0.8	0.3
Suttons	6.9	6.3	7.0	7.5	7.2	7.0	6.8	7.8	0.8	0.7	0.8
Cobra	6.5	6.5	6.7	6.3	6.7	6.7	6.5	6.8	1.0	1.3	0.7
Pennncross	6.4	6.5	6.3	6.3	6.4	6.5	6.2	6.5	1.6	1.7	1.5
SR1020	6.6	6.7	6.7	6.3	6.6	6.8	6.2	6.7	1.1	1.2	1.0
<b>Low nutrition</b>											
Egmont	6.7	6.7	6.7	6.7	6.8	6.8	6.8	6.8	0.5	0.3	0.7
Suttons	6.9	6.3	7.0	7.3	7.2	6.8	6.8	7.8	0.2	0.3	0.0
Cobra	6.4	6.5	6.5	6.2	6.6	6.8	6.5	6.5	0.6	0.8	0.3
Pennncross	6.4	6.7	6.3	6.2	6.4	6.5	6.2	6.5	1.3	1.0	1.7
SR1020	6.5	6.5	6.7	6.3	6.4	6.7	6.2	6.5	0.8	0.8	0.7

**Table 41: Nutritional level x Mowing Height interaction - agronomic characteristics**

Treatment	-----Turf quality-----				-----Turf density-----				-----Spiking-----		
	AVG	Nov-94	Jan-95	Feb-95	AVG	Nov-94	Jan-95	Feb-95	AVG	Nov-94	Feb-95
<b>High nutrition</b>											
Low	6.6	6.6	6.5	6.6	6.6	6.7	6.2	6.8	0.9	0.7	1.0
Medium	6.8	6.7	6.9	6.9	6.9	6.8	6.7	7.1	1.0	0.8	1.2
High	6.4	6.2	6.6	6.5	6.8	6.8	6.6	7.0	1.2	1.9	0.4
<b>Low nutrition</b>											
Low	6.4	6.5	6.4	6.4	6.5	6.5	6.2	6.8	0.6	0.3	0.8
Medium	6.8	6.8	6.9	6.6	6.8	7.0	6.7	6.8	0.8	0.8	0.8
High	6.5	6.3	6.6	6.6	6.7	6.7	6.6	6.9	0.7	0.9	0.4

**Table 42: Nutrition level x Mowing Height x Variety interactions - agronomic characteristics**

Treatment	-----Turf quality-----				-----Turf density-----				-----Spiking-----		
	AVG	Nov-94	Jan-95	Feb-95	AVG	Nov-94	Jan-95	Feb-95	AVG	Nov-94	Feb-95
<b>High N</b>											
<b>Low Height of cut</b>											
Egmont	6.5	6.5	6.5	6.5	6.7	6.5	6.5	7.0	0.5	0.0	1.0
Suttons	7.0	6.5	7.0	7.5	7.0	7.0	6.5	7.5	0.8	0.5	1.0
Cobra	6.3	6.5	6.5	6.0	6.3	6.5	6.0	6.5	1.0	1.0	1.0
Penncross	6.5	7.0	6.0	6.5	6.3	6.5	6.0	6.5	1.0	1.0	1.0
SR1020	6.5	6.5	6.5	6.5	6.5	7.0	6.0	6.5	1.0	1.0	1.0
<b>Medium height of cut</b>											
Egmont	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	0.3	0.5	0.0
Suttons	7.2	6.5	7.0	8.0	7.3	7.0	7.0	8.0	1.0	0.5	1.5
Cobra	6.5	6.5	6.5	6.5	6.7	6.5	6.5	7.0	1.0	1.0	1.0
Penncross	6.7	6.5	7.0	6.5	6.5	6.5	6.5	6.5	1.8	1.0	2.5
SR1020	6.8	7.0	7.0	6.5	6.8	7.0	6.5	7.0	1.0	1.0	1.0
<b>High height of cut</b>											
Egmont	6.5	6.0	6.5	7.0	7.0	7.0	7.0	7.0	1.0	2.0	0.0
Suttons	6.7	6.0	7.0	7.0	7.3	7.0	7.0	8.0	0.5	1.0	0.0
Cobra	6.7	6.5	7.0	6.5	7.0	7.0	7.0	7.0	1.0	2.0	0.0
Penncross	6.0	6.0	6.0	6.0	6.3	6.5	6.0	6.5	2.0	3.0	1.0
SR1020	6.3	6.5	6.5	6.0	6.3	6.5	6.0	6.5	1.3	1.5	1.0
<b>Low N</b>											
<b>Low height of cut</b>											
Egmont	6.7	7.0	6.5	6.5	6.7	6.5	6.5	7.0	0.5	0.0	1.0
Suttons	6.8	6.5	7.0	7.0	6.8	6.5	6.5	7.5	0.0	0.0	0.0
Cobra	6.2	6.5	6.0	6.0	6.3	6.5	6.0	6.5	0.3	0.5	0.0
Penncross	6.2	6.5	6.0	6.0	6.3	6.5	6.0	6.5	1.5	1.0	2.0
SR1020	6.3	6.0	6.5	6.5	6.3	6.5	6.0	6.5	0.5	0.0	1.0
<b>Medium height of cut</b>											
Egmont	6.8	7.0	7.0	6.5	7.0	7.5	7.0	6.5	0.5	0.0	1.0
Suttons	7.2	6.5	7.0	8.0	7.3	7.0	7.0	8.0	0.3	0.5	0.0
Cobra	6.3	6.5	6.5	6.0	6.7	7.0	6.5	6.5	1.0	1.0	1.0
Penncross	6.7	7.0	7.0	6.0	6.5	6.5	6.5	6.5	1.5	1.0	2.0
SR1020	6.8	7.0	7.0	6.5	6.7	7.0	6.5	6.5	0.8	1.5	0.0
<b>High height of cut</b>											
Egmont	6.5	6.0	6.5	7.0	6.8	6.5	7.0	7.0	0.5	1.0	0.0
Suttons	6.7	6.0	7.0	7.0	7.3	7.0	7.0	8.0	0.3	0.5	0.0
Cobra	6.7	6.5	7.0	6.5	6.8	7.0	7.0	6.5	0.5	1.0	0.0
Penncross	6.3	6.5	6.0	6.5	6.3	6.5	6.0	6.5	1.0	1.0	1.0
SR1020	6.3	6.5	6.5	6.0	6.3	6.5	6.0	6.5	1.0	1.0	1.0

## **4. DISCUSSION**

### **4.1. Effects of variety and cultural practices on green speed**

#### **4.1.1 Variety**

SR1020 and Penncross had the greatest green speed compared to all other varieties while Cobra had greater green speed than Suttons and Egmont (table 3, figure 1). There was no difference in green speed between Suttons and Egmont. These trends were consistent over the long term average and at each test period.

In general, the stoloniferous varieties had greater green speed than the capillaris types. This is most probably due to the greater amount of vertical growth which increases the amount of friction on ball roll

#### **4.1.2 Mowing height**

As mowing height is lowered there is an increase in green speed (table 4, figure 2). There was approximately a 0.5m increase in green speed from a high to medium cutting height and a 0.3m increase from a medium to low cutting height. These trends were consistent over the long term average and at each test period.

By lowering the mowing height there is a reduction in turf biomass which results in less resistance to ball roll. At higher mowing heights the surface is less firm (i.e., softer) and there is greater surface deformation as the ball rolls through the grass rather than on top of it.

#### **4.1.3 Rolling**

Rolling increased green speed by approximately 0.4m (range 0.36 to 0.51m) (table 5, figure 3). This increase was consistent over the long term average and at all test periods. Rolling causes a compaction of the surface and a flattening of the leaf blade resulting in less friction to ball roll.

Rolling has been used extensively on lawn bowling greens to increase green speed and provide a smooth uniform surface. It is also used on cricket pitches to provide a firm flat surface. The use of rollers on putting greens has increased in recent years (particularly for tournaments) and continues to gain acceptance as a useful maintenance tool especially for providing consistency between greens.

Potentially, rolling can also increase soil compaction thereby inhibiting root growth, increase turf injury from wear and impede air and water movement through the soil profile. Sand based greens are less likely to compact than the older style greens constructed on finer soil types.

Recent research at North Carolina State University (DiPaola et al, 1994) showed that light weight rolling at moderate levels (< 3 times/week) resulted in no additional increase in soil compaction on USGA constructed profiles, increased green speeds and no change in turf quality. However, higher rolling frequencies (> 3 times/week) resulted in lower turf quality. Similar research at Penn State University (Hamilton et al, 1994) found that bulk density in the surface 25mm of soil and saturated infiltration were not affected by rolling

The amount of thatch present may have an effect on how much an increase in green speed is achieved, how long the effect lasts, and how much compaction is caused by the rolling. On greens with excessive thatch, rolling will have very little effect on green speed as the thatch will spring back very quickly to its original size, but rolling will improve surface smoothness.

#### 4.1.4 Wear

The effect of imposing artificial wear was to cause spiking of the turf and in general it did not overly affect green speed. On some occasions wear had a significant effect on increasing green speed (table 6, figure 4), however, this was probably due to the compacting / rolling affect of the wear machine (i.e., similar to rolling) with the greatest increase being no more than 10cm.

Recent research at Ohio State University Turfgrass Research Centre (Morrow et al, 1995) confirmed this. They found that metal spiked turf, despite the spike marks, allowed the ball to roll further than the plots which recieved no traffic.

#### 4.1.5 Interactions

##### 4.1.5.1 Height x rolling

On several occasions there were significant interactions between the height of cut and rolling on green speed (table 7, figure 5 & 7) with the combined effect increasing green speed compared to the individual treatments. There was also a significant interaction on the long term average.

By raising the height of cut and rolling a green speed similar to that obtained at a lower height of cut can be achieved. For example, at a medium cutting height with rolling, produced as good or better green speed than the low height of cut with no rolling. By increasing the cutting height there is less stress placed on the turf, the turf density will be improved and moss and alge invasion will be lessened while maintaining an acceptable green speed. This is an important consideration during the winter months when turf recovery is slow, particularly on small or heavily trafficked greens.

##### 4.1.5.2 Variety x height

At several assessments and over the long term average there was a significant variety x cutting height interaction (table 8, figure 6 & 8) in that the combined effect of cutting height and variety provided a significant difference in green speed.

For each variety, there was an increase in green speed as the cutting height was lowered. For all varieties, over all assessment periods, the greatest change in green speed was going from a high to a medium height of cut (average increase of 0.2m) while there was a much smaller increase (average increase of 0.7m) when reducing the mowing height from a medium to low height of cut.

At some assessments, there were no significant difference in green speed when the mowing height was reduced from a medium to low height of cut. Therefore, from this data it appears that a medium height of cut (3 - 3.5mm) is the optimum height of cut for all varieties particularly when considering other turf agronomic factors (e.g. density). In terms of agronomic characteristics, some varieties responded better than others to lower heights of cut (see 4.3 Agronomic Characteristics).

#### 4.1.5.3 Variety x rolling

Even though there was a significant difference in the variety x rolling interaction for the long term average there was only one assessment period where a significant interaction occurred (August 1994) (table 9, figure 9). This indicates that there is very little difference in how the varieties react to rolling. That is, there is a consistent varietal response to rolling.

It was also apparent that rolling reduced the varietal influence on green speed. That is, the varietal difference in green speed is less compared to non rolling.

#### 4.1.5.4 Mowing height x wear

There was only one assessment where the mowing height x wear interaction was significant. On this occasion (October 1994) both the medium and high cutting heights subjected to the wear treatment had greater green speed than with no wear (table 10, figure 11). However, at the lower cutting height there was no significant interaction. Again, this reinforces the rolling effect of the wear treatment which is more pronounced at higher heights of cut.

#### 4.1.5.5 Variety x wear

On the long term average, Cobra and Suttons exhibited a significant interaction in that wear had a greater effect in increasing green speed compared to the other varieties (table 11, figure 10).

There were several other occasions where there was a significant interaction with a varietal increase in green speed under wear. However, in February 1994 there was a decrease in green speed under wear with Penncross and SR1020 and this was due to the spiking effect. The long term averages for Penncross and SR1020 reinforce this observation.

#### 4.1.5.6 Rolling x wear

On the long term average and on most assessments there was a significant Rolling x wear interaction (table 12, figure 12). Under rolling, wear had a minimal effect on green speed, however, on one occasion there was a significant interaction with the effect being that the wear plus rolling treatments reduced green speed.

Under no rolling, the wear treatment increased green speed due to compaction while under the rolling treatment, green speed was reduced due to the spiking effect of the wear treatment.

#### 4.1.5.7 Height x variety x rolling

At two assessments there was a significant interaction between height of cut, variety and rolling. However, this interaction was not consistent and generally all varieties exhibit an increase in green speed at a lower height of cut and with rolling.

#### 4.1.5.8 Height x wear x variety

There was no significant long term interaction and there were only two assessments that were significant (table 10).

#### 4.1.5.9 Wear x rolling x variety

There was no significant long term interaction and there was only one assessment that was significant (table 14).

#### 4.1.5.10 Wear x rolling x height

There was no significant long term interaction and there were only two assessments that were significant.

## 4.2 Change in green speed over a day

### 4.2.1 Variety effect

Penncross and SR1020 had the highest green speed over a day with Cobra having a similar to marginally greater green speed than Suttons, with Egmont the slowest (table 17, figure 14).

Throughout the day, Egmont and Suttons were at their fastest in the middle of the day though Suttons, in January, was at its fastest early in the morning. Cobra was generally inconsistent in terms of its maximum green speed but tended to be at its fastest in the mid-late part of the day. Penncross and SR1020 exhibited their greatest green speed in the mid to later part of the day.

In general, the stoloniferous varieties exhibit their greatest green speed mid to late in the day with the capillaris varieties having their greatest green speed in the middle of the day and show no further increase in their green speed as they progress.

The increase in green speed during the course of the day is most probably related to the surface becoming drier with the turf having a lower moisture content and the leaf less turgid and offering less surface resistance.

In summer and autumn, the green speed was greater than for the winter assessment though the change in green speed over a day remained much the same.

### 4.2.2 Mowing Height

At the low height of cut the green speed increased to its maximum by the middle of the day (an increase of around 0.12m) whereas at the medium height of cut maximum green speed was achieved from mid to late in the day (an increase of around 0.09m) (table 18, figure 15), while at the highest cutting height any increase in green speed was minimal.

At the lowest height of cut, green speed will increase more quickly due to a lower turf density, there is less turf biomass to dry out which is required for the green speed to increase.

### 4.2.3 Rolling Effect

There was little change in green speed over the day due to rolling, i.e., the effects of rolling persisted throughout the day. This suggests that rolling does not have a temporary effect on ball roll (table 19, figure 16).

The difference between the rolled and unrolled treatments decreased over time due to the effects from rolling wearing off late in the day. However, the difference between the rolled and unrolled treatments was still significant late in the day.

Research at Penn State University (Hamilton et al, 1994) found that light weight rolling increased green speed by an average of 0.38m and this increase lasted less than 48 hours.

#### 4.2.4 Interactions

##### 4.2.4.1 Variety x rolling

During the summer and autumn assessments there was some significant variety x rolling interaction, however, this was not consistent over all measurements during the day. That is, some varieties responded differently to rolling than others during the course of the day (table 20, figures 17-21).

It would appear that in the summer assessment, Penncross and SR1020 exhibited a significant interaction under the non-rolling treatment compared to the other varieties, whereas, Egmont exhibited a significant interaction compared to Suttons and Cobra.

In the Autumn assessment, Penncross and SR1020 exhibited a greater increase in green speed due to the interaction compared to the other varieties under both rolling and non-rolling.

In the Winter, green speeds were considerably slower and any interactions were less pronounced though Penncross and SR1020 showed a significant interaction under the non-rolling treatment compared to Cobra, Suttons and Egmont.

##### 4.2.4.2 Height x rolling

There was a greater interaction between rolling and the height of cut on green speed during winter than in the summer and autumn assessments (table 22).

In winter, green speeds are at their slowest and the treatments exert a greater influence on green speed. Whereas in summer, green speeds are already fast and any treatment effect is less pronounced. In autumn there is some significant interactions but they are intermediate between the winter and summer extremes and inconsistent.

##### 4.2.4.3 Height x variety

There were significant interactions due to the combined effects of height of cut and variety interaction (table 21).

In summer there was a greater difference between the treatments late in the afternoon, while in winter there was a significant interaction throughout the day. During autumn the effect of height and variety was variable.

##### 4.2.4.4 Height x rolling x variety

There was little or no significant interaction between height x rolling x variety in summer and autumn (table 23). When conditions are less conducive to high green speed, each small advantage of each treatment combines to give a significant improvement in green speed.

## **4.3 Turf agronomic characteristics**

### **4.3.1 Turf quality**

Turf quality was assessed both as putting surface as well as on agronomic characteristics and the minimum acceptable turf quality was a rating of six. Based on the long term averages, Egmont and Suttons generally had a greater turf quality than the stoloniferous varieties (table 24, figures 22-26). For most of the year all varieties had an acceptable turf quality, however, in the summer months, Penncross and SR1020 had less than acceptable turf quality. For Penncross, this poor turf quality extended into June, July and September.

Based on the overall average, the best turf quality was achieved with the medium and high heights of cut. However, in the summer months the highest height of cut produced the best turf quality due to there being less stress on the turf (figure 27).

Egmont and Suttons provided a high quality surface at the three mowing heights while Penncross and SR1020 had an unacceptable turf quality at the low height of cut. Under the low height of cut, Penncross and SR1020 suffered severe thinning of the turf sward with Cobra being of intermediate turf quality. On this basis, Penncross and SR1020 should be kept at a medium height of cut (ie. 3-3.5mm) to achieve a good quality surface.

### **4.3.2 Turf density**

Overall, Egmont and Suttons had greater turf density than the stoloniferous varieties (table 25, figures 28-32). There was a dramatic increase in turf density as the height of cut is raised from low to medium and only a moderate increase in density from the medium to high cutting height.

Penncross and SR1020 had unacceptable turf density at the low height of cut while all other varieties maintained an acceptable turf density (figure 33). Excessively low turf density results in poor ball roll with the ball deviating and not holding a true line when putted.

Penncross was the variety that was most affected by the low height of cut and tended to have the lowest density and even at the medium height of cut, Penncross exhibited marginal turf density compared to the other varieties.

In addition , a dense turf reduces the incidence of moss/algae and weed invasion.

### **4.3.3 Spiking**

Spiking is a problem on heavily trafficked greens and reduces the smoothness and uniformity of the turf. As a result of spiking, the roll of the ball is interrupted and can cause the ball to move off line.

The stoloniferous varieties showed the greatest level of spiking with Penncross the highest. Both Egmont and Suttons had considerably less spiking with Suttons exhibiting the least spiking (table 26, figures 34 -36).

As the cutting height was increased the level of spiking increased and this is due to there being more leaf material that was softer and more easily disrupted by spiking. However, there is very little difference in the level of spiking between the medium and high cutting heights. This trend was also reflected in the variety x cutting height interaction, that is, as cutting height increased the level of spiking increased.

#### 4.3.4 Moss invasion

Penncross had the greatest level of moss invasion with Cobra the least (table 26, figures 37-39) and Egmont, Suttons and SR1020 exhibiting an intermediate level of moss invasion. Turf density was the main determining factor in that the lower the density the greatest the moss invasion. Penncross, due to its low density was most susceptible to moss invasion.

The greatest incidence of moss invasion was at the lowest cutting height. There was very little difference in moss levels between the medium and high cutting heights.

#### **4.4 Effects of renovation on green speed and turf agronomic characteristics**

Green speed was reduced by renovation (coring and topdressing) for about 25 days over which time the mowing heights were raised and were only reduced to their original heights six weeks after renovation. At 25 days after renovation the green speed increased dramatically for the stoloniferous varieties but remained slow for Egmont and Suttons (tables 27-29, figures 40-42).

Renovation decreased green speed, the extent to which this reduction persisted depended on the severity of renovation, extent of topdressing, height of cut after renovation and weather conditions.

Renovation caused a reduction in turf quality (table 30, figure 43) and the effect was greatest at the lowest height of cut.

The effects of renovation were also related to turf density in that, as turf density was reduced due to renovation, green speed was also reduced and the effect was greatest at the lowest mowing height (table 31, figure 44).

The stoloniferous varieties were slower than Egmont and Suttons to return to their pre-renovation turf quality and density. The downside to this is that Egmont and Suttons were slower to return to pre-renovation green speed due to a denser and lush growth.

## **4.5 Effects of nutrition level on green speed and agronomic characteristics**

### **4.5.1 Nitrogen level**

There was no significant effect of nitrogen level on green speed (table 32, figure 45) and this may be due to this subtrial not running long enough.

It is generally accepted that faster green speeds can be achieved by low nitrogen application rates that avoid overstimulation of shoot growth. Excessive nitrogen applications lead to objectional surface quality, thatch accumulation, increased disease problems, reduced tolerance to environmental stresses, decreased wear tolerance, a restricted root system and low recuperative potential caused by a lack of carbohydrate reserves.

### **4.5.2 Cutting height x nitrogen level**

There was no significant interaction between cutting height and nitrogen levels except for February 1995. Under each height of cut there was no effect on green speed due to nitrogen level with the height of cut having the primary influence on green speed (table 33, figure 46).

### **4.5.3 Variety x nitrogen level**

There was no significant difference on any occasion, that is, there was no varietal response to nitrogen level (table 34, figure 47).

### **4.5.4 Wear x nitrogen level**

There was no significant difference on any occasion, that is, there was no wear response to nitrogen level (table 35, figure 48).

### **4.5.5 Three way interaction**

There was no significant interaction between cutting height x wear x nitrogen level on green speed (table 37). Of the height x variety x nitrogen level the only significant interaction was in February 1995 (table 36). There was also a significant interaction between variety x wear x nitrogen level in November 1994 (table 38).

### **4.5.6 Agronomic characteristics**

Turf quality and density were unaffected by the level of nutrition (tables 38-42) and any differences in turf quality and density were primarily varietal or due to the cutting height.

There appeared to be slightly greater spiking with the higher level of nutrition which is due to lusher growth at the higher level of nutrition.

## 5. CONCLUSION

The results of this project indicate that green speed was faster at lower mowing heights on all bentgrass varieties. However, with the stoloniferous bentgrasses the increased speed due to low mowing was at the expense of turf quality and density. The use of greens rollers can significantly increase the green speed while maintaining a higher height of cut. On greens subject to heavy traffic or under poor growing conditions, the use of a roller can ensure a good putting performance without reducing turf density and quality.

Wear had little effect on green speed, though the spiking it caused resulted in the deviation of the ball. When evaluating the changes in green speed over a day, all varieties increased in green speed with the stoloniferous types increasing the most. The effects of rolling lasted for the entire day.

Based on the long term averages, Egmont and Suttons had greater turf quality and density than the stoloniferous bentgrasses. Egmont and Suttons provided a high quality surface at the three mowing heights while the stoloniferous varieties performed best at a medium height of cut. Low turf density gave rise to increased moss and algae invasion. The stoloniferous varieties showed the greatest level of spiking with Penncross the highest and the level of spiking increased for all varieties as the cutting height was raised.

Following renovation, the stoloniferous varieties returned to their pre-renovation green speed quicker than the other varieties. However, the stoloniferous varieties were slower to attain their pre-renovation turf quality and density.

These findings are indicative and provide a general guide to the performance of these grasses under mowing and rolling. There will always be exceptions to the rule, however, to maintain grasses unnaturally at a low height of cut will require a more intensive level of management in order to maintain an acceptable turf quality. If a Club is looking to increase green speed, all factors of traffic, grass type, maintenance budget etc. must be assessed before placing the turf under any additional stress.

## **6. ACKNOWLEDGMENTS**

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