# MAXIMISING THE PERFORMANCE OF SPORTS TURF

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# ABSTRACT

## P. M. CANAWAY. MAXIMISING THE PERFORMANCE OF SPORTS TURF

Research was carried out on four main subject areas: playing quality of natural turf; establishment; nitrogen nutrition and stabilisation of sand rootzones.

Apparatus and test methods for determining playing quality are described and procedures for the development of standards for playing quality measures are given. A theoretical analysis of the factors governing playing quality was undertaken which showed that natural turf must be considered in terms of the plant and soil constituents and the manner in which these interact, especially in response to wear. The soil factor grouping is shown to be the most important influence on playing quality, primarily through its effect on moisture retention and throughput. A large-scale field experiment was carried out in order to investigate the effect of five different constructional techniques on playing quality and other aspects of turf performance. Constructional types included: pipe-drainage, slit-drainage, slit-drainage with a 25mm sand layer, a sand carpet and a sand profile construction. The results showed that the sand-based constructions provided the best playing quality but that potential numbers of days lost due to the presence of standing water decreased with increasing constructional sophistication. A review of playing quality of fine turf was carried out and an experiment on ball roll characteristics of five turfgrass species was undertaken which showed significant differences among species.

Two experiments on the establishment of turf using different types of seed and sod were carried out, whose objective was to determine the effects of these experimental treatments on the playing quality, ground cover and water infiltration rate of playing surfaces for both football and golf. Experimental treatments included grades of mature turf, juvenile turf and seed. The most notable finding was the dramatic reduction in water infiltration rate where mature turf was used for establishment. This was ascribed to a combination of organic and mineral matter imported along with the turf causing blockage of soil macropores and hence reducing water infiltration rate.

The effect of fertiliser nitrogen on the response of *Lolium perenne* turf grown on a Prunty-Mulqueen sand carpet rootzone was studied a field experiment which was subjected to football-type artificial wear treatments during two playing seasons. Measures included ground cover under wear and playing quality. In the case of ground cover and player traction responses to nitrogen showed distinct optima particularly during wear. Ball rebound resilience and hardness showed no such response.

Finally an experiment on the stabilisation of sand rootzones for sport was carried out the objective of which was to study the effect of artificially strengthening a sand rootzone using randomly oriented tensile inclusions (Netlon mesh elements). Three different rates of mesh elements, two different sizes and establishment using two types of turf were studied in a field experiment. Mesh element inclusion was found to increase water infiltration rate, traction and hardness. Turf treated by washing to remove adhering soil prior to laying also gave higher infiltration rates and, in addition, affected playing quality.

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Chapter 3 Establishment

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# CHAPTER 1
## GENERAL INTRODUCTION

## HISTORICAL BACKGROUND

> "Then God said 'Let the earth bring forth grass, the herb that yields seed .....'. And the earth brought forth grass, the herb that yields seed according to its kind." (Genesis 1,11-12.)

The fact that grass is the first plant mentioned in the Bible illustrates man's close relationship and dependence on *Gramineae* from time immemorial, first for food and grazing, and as civilisation developed, to provide aesthetic and functional areas for relaxation and recreation. The use of grass for lawns and gardens is documented in Asia from ancient times, spreading through the Middle East into Europe in medieval times (Roberts *et al.* 1992). The use of short grass or turf for sports in Britain is also of ancient origin, although documented examples are hard to find before 1500 AD. Evans (1992) refers to a bowling green at Hereford which has been in continuous use since 1484. He also refers to an even more ancient green dating back to just after the Norman Conquest, which is situated at Lewes in Sussex and was originally constructed as a jousting ground by William de Warenne. The development of the lawn mower by Edwin Budding in 1830 revolutionised the production of playing surfaces for sports, golf and football, in particular developing greatly during the nineteenth century and early twentieth century. For example, there were only 43 golf courses in Scotland prior to 1880, but 266 by 1910 (Price 1989). A similar upsurge in the number of golf courses occurred in the USA (Beard 1982). The development of the research on matters connected with upkeep of turf paralleled the growth of sports and recreation, the earliest research being conducted at the Olcott Turf Gardens in Connecticut in 1885 (Roberts *et al.* 1992). In 1916 the United States Department of Agriculture (USDA) established the Arlington Turf Gardens on the site where the Pentagon now stands. The USDA, together with the United States Golf Association (USGA) Green Section which was established in 1920, carried out co-operative research and advisory work mainly directed at golf. In 1929 the world's first turf research station was established at Bingley, then known as the Board of Greenkeeping Research and later becoming the Sports Turf Research Institute or STRI at which the research in this thesis was conducted.

## BENEFITS OF TURFGRASS TO SOCIETY

Because, especially in Britain, we are surrounded by areas of turf and amenity grassland their benefits can easily be overlooked. For example lawns around homes provide areas for leisure and relaxation, together with their aesthetic value in traditional garden design. Roadside verges provide sight lines and emergency run-off areas for vehicles, thus contributing to road safety. In airports, grassed areas between runways and taxiways provide low cost soil stabilisation, aid noise and dust abatement and reduced fire hazard.

Many of our sports are played on natural turf surfaces, e.g. bowls, cricket, football, golf, hockey, horse racing, lawn tennis, polo and rugby to name some of the most important. These provide much benefit in terms of physical and mental health, together with relaxation and recreation for the spectators whether at home or at the sporting venue. Beard & Green (1994) in a review of the role of turfgrasses in society list the main benefits in terms of functional, recreational and aesthetic benefits. These are given in Table 1.

TABLE 1
Main benefits of turfgrasses (from Beard & Green 1994)

| Functional benefits | Recreational benefits | Aesthetic benefits |
|---|---|---|
| Soil erosion | Low cost surfaces | Beauty |
| Dust prevention | Physical health | Quality of life |
| Heat dissipation | Mental health | Mental health |
| Noise abatement | Safety | Social harmony |
| Glare reduction | Spectator entertainment | Community pride |
| Air pollution control | | Increased property values |
| Nuisance animal reduction | | Complements trees and shrubs in landscape |

In the UK it is estimated that between 1.5 million and 2 million hectares can be classified as amenity grassland (National Turfgrass Council 1993) of which about 110,000 ha are intensively managed mainly comprising football, cricket, rugby and hockey pitches which amount to about 90,000 ha (National Turfgrass Council 1993). In employment terms it is estimated that some 88,000 persons are employed in landscaping and grounds maintenance (National Turfgrass Council 1993). Thus natural turf is an important component of our society, worthy of research and investigation in order to bring about improvements in the quality of recreational provision.

## AIMS OF THE RESEARCH

In contrast to some parts of agricultural and horticultural research, turfgrass science has always received limited, or negligible, support from government and therefore the pace of research has been slow. Consequently, for the researcher turfgrass science presents a rich field for conducting original investigations into questions which are of fundamental importance to the subject as a whole.

In 1977 a major review of the needs for research on amenity grass was published (NERC 1977) which identified a number of major areas where research was needed, some of which are addressed in this thesis. For example it identified the need for work on measurement standards and construction and drainage as 'priority topics'. These are addressed in Chapter 2. It identified the need for research on establishment (Chapter 3) and fertilisation (Chapter 4). However, on re-reading the review by NERC (1977) it is apparent how much has changed since that time, particularly in relation to the fundamental scientific processes of observation, data collection and interpretation. With hindsight, one could argue that before the 1980's we were not measuring the most important properties of playing surfaces, now collectively referred to as "playing quality". The work described in this thesis was intimately connected with the development of the concepts of playing quality which is now becoming an established part of turfgrass science. In Chapter 2, Part 1 the aim is to review the apparatus and test methods developed for this purpose, including work on standards for different aspects of playing quality which were subsequently used to determine the success or otherwise of experimental treatments. In Chapter 2, Part 2 the theme of playing quality is further developed with a theoretical analysis of the mechanisms by which playing quality is determined. In Chapter 3, Part 3 the key issue of sports field construction and its influence on playing quality and other aspects of turf performance, is addressed in a large-scale field experiment. Chapter 2, Parts 4 and 5 are concerned with playing quality of fine turf.

Having developed the concept of playing quality, the aim of the research was to logically investigate important areas of research in each of the stages involved in the production of playing surfaces: construction (Chapter 2), establishment (Chapter 3), maintenance - in this case one important aspect of maintenance - fertiliser nutrition (Chapter 4) and lastly, a topic which has implications for both construction and maintenance - soil stabilisation (Chapter 5).

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# CHAPTER 2

## PLAYING QUALITY OF NATURAL TURF

### INTRODUCTION

For the agriculturist the objective of his work is to produce some form of crop yield. By contrast, the sports turf manager aims to produce a playing surface for sport. His "yield" cannot be measured in terms of plant biomass or digestibility, but rather in terms of the level of use and quality of the playing surface produced. Until recently, much research on turfgrass systems almost entirely used scientific methods derived from agriculture or ecology, partly because turfgrass scientists have been trained in these disciplines and partly because of the lack of suitable techniques for quantifying the playing properties of sports turf. These properties can be encompassed by the term "playing quality". The aim of this chapter is to develop the concept of playing quality through a combination of review, theoretical analysis and experimental work.

The greater part of this thesis concerns the performance of heavy duty turf for football. The first three parts of this chapter therefore, form the foundation for much of the work which follows. In Part 1 the idea of playing quality of turf for Association Football is introduced and apparatus and test methods for measuring playing quality are reviewed. These methods are later used throughout the thesis. In order to make the values of the various playing quality tests meaningful, work on the development of standards for the components of playing quality, through a combination of field testing and player evaluation work, is described. This work has been used in the drafting of European standards for playing quality of turf. The standards referred to are subsequently used as a bench mark throughout the thesis for comparing the effects of different experimental treatments on playing quality.

In Part 2 a theoretical analysis of the factors affecting playing quality is carried out, drawing partly on my own work and work at the STRI where a large proportion of playing quality work has taken place and partly on other published papers on the subject. Part 2 shows that for heavy duty turf for football the soil component, especially rootzone construction and its influence on soil moisture content and water movement, is shown to be the most important factor grouping in determining playing quality. Wear is shown to regulate the effects of construction on playing quality.

In Part 3 a large-scale field experiment on rootzone construction and its effects on playing quality is described.

Although, as stated, the greater part of the thesis concerns heavy duty turf, two experiments are reported on fine turf, one in Chapter 3 and the other in Part 5 of this chapter. Therefore, the review presented in Part 4 sets the scene for the reader, who will not necessarily be familiar with the rather different requirements for golf. The review is not confined to playing quality alone, giving a historical introduction and outlining possible directions for research which are not explored elsewhere in this thesis. Part 5 describes an experiment on one specific aspect of playing quality for fine turf, namely ball roll and also takes in bowls. General requirements in terms of construction, choice of species and maintenance are very similar for golf and bowling greens and it therefore seemed sensible to carry out the tests in a manner relevant to both sports. The theme of playing quality for fine turf recurs in Chapter 3, Part 3 where the effects of different methods of establishment on golf green ground cover and playing quality are described.

# PART 1

## A REVIEW OF METHODS FOR MEASURING THE PLAYING QUALITY OF NATURAL TURF FOR ASSOCIATION FOOTBALL

### SUMMARY

Natural turf is the preferred playing surface for many sports. The nature of that playing surface is clearly important to the quality of play and yet it is often neglected as an area for scientific study and low in priority for improvement. Apparatus and test methods are described for quantifying playing quality of natural turf for Association Football in terms of: ball rebound resilience, ball roll, player traction and hardness. Standards for these components of playing quality were developed using a combination of field testing and player evaluation work. Standards are given in terms of 'preferred' limits and less stringent 'acceptable' limits for components of playing quality, for example, players preferred playing surfaces to have ball rebound values between 20% and 50%, the acceptable range being between 15% and 55%. The apparatus and standards described are referred to in subsequent parts of this chapter and in subsequent chapters.

### INTRODUCTION

Many sports have their origins on natural turf playing surfaces, for example, Association Football, Rugby, golf, tennis, hockey, cricket and bowls to name but a few. Some of these have predominantly moved to man-made surfaces subsequently, e.g. hockey and tennis, but for many sports participants natural turf is still the preferred surface. Since the main function of sports turf is to provide a playing surface for sport, then it follows that the attributes of the turf which make it a good playing surface (i.e. playing quality factors) for the sport in question should be first priority for research, other attributes being of secondary importance. However, up until the 1980's the literature on wear and durability of sports turf was dominated by measurements other than playing quality factors. (The earlier literature on turfgrass wear was reviewed by Canaway 1975a, 1980.) This situation is believed to have arisen because of a combination of historical and methodological reasons (Canaway 1984). These are: [1] much of sports turf research at the time involved methods originally derived from agricultural or ecological research where such measures as biomass, ground cover and botanical composition etc. are of primary importance. [2] Whereas in agricultural research there is usually a clearly defined measure such as yield which can be readily quantified, in sports turf research it is more difficult to do so and it is only in recent years that progress towards quantifying playing quality has been achieved. [3] Even where quantitative playing quality data were collected there were no suitable standards by which to judge a given result and interpret its significance.

The growth in research on playing quality and the development of standards for playing quality arose, somewhat paradoxically, from developments in synthetic turf. During the

1970's and early 1980's synthetic turf manufacturers produced surfaces which, in general, players did not like and commentators ridiculed with comments such as "ping-pong football". These surfaces were characterised by high bounce, excessive ball roll and excessive hardness and because of commercial pressures, there was a need to make synthetic surfaces behave more like natural turf in terms of their playing quality. Consequently, there was a need for objective measures of playing quality, in order to relate artificial turf performance to that of natural turf. The Sports Council for England and Wales commissioned a programme of research with the Rubber and Plastics Research Association (RAPRA) to undertake this work and RAPRA duly produced standards and specifications for artificial turf which were published by the Sports Council (Sports Council 1984a, b). Thus, early in the 1980's more was known about playing quality of artificial turf than natural turf which the former was supposed to emulate.

Playing quality, like aesthetic quality, is essentially an abstract concept based on human perception. It is "how it plays". However, just as aesthetic quality of turf is comprised of variables which can at least in part be quantified, such as colour, density, uniformity and so forth, playing quality is also comprised of identifiable components. For football we can categorise these into ball/surface characters and player/surface characters. Ball/surface characters include:

[a] ball rebound resilience (ball bounce);
[b] ball roll or rolling resistance.

Player/surface characters include:

[a] player traction - how much "grip" or "purchase" the player can obtain from the surface for twisting, turning, stopping and starting - the essential movements involved in sporting activity. If traction becomes too great there is a greater risk of injury to knee and ankle ligaments, but if it is too little then the player is continually slipping and falling;
[b] surface hardness - strictly speaking the subjective experience of hardness comprises "stiffness" (deformation in response to applied load) and "resilience" (the amount of energy returned to the player expressed as a proportion of that expended) (Bell *et al.* 1985). If the surface is too had it becomes jarring to the limbs to play on and may cause injury in the event of a fall or dive. Conversely if the surface becomes too soft it becomes excessively tiring to run on.

Prior to the 1980's studies on playing quality had developed in a sporadic or piecemeal fashion. The first study on ball rebound resilience was done by Langvad in the 1960's (Langvad 1968), but there was no further work done on it until the 1980's. Player traction on the other hand had long been studied, partly because of agronomists' interest in turf strength. If turf is to be harvested, as in commercial turf production, it is important that turf strength is sufficient to hold it together. Stuurman & Koenigs (1968) and Stuurman (1969) were among the first to measure tearing strength of turf and the interpretation of their term "Scherfestigkeit" in the German, as "shear strength" remaining in use for many years, the term "traction" (analogous to friction but applicable to studded or cleated footwear, whereas the term "friction" would only be applicable to non-studded footwear) is of relatively recent origin (Canaway & Bell 1986). The author was the first to develop an apparatus, now currently accepted as the standard method for measurement of traction in the 1970's (Canaway 1975b). Liesecke & Schmidt (1978) used a similar apparatus, together with a shear vane and cone penetrometer, in order to determine the minimum requirements for surface strength, but were unable to do so. The currently used apparatus was first published by Canaway & Bell (1986) as a modification of the original (Canaway 1975b) apparatus (see below). Before the 1980's there were no studies on hardness of natural turf football pitches using objective tests and only a single example of a study on ball roll (Langvad 1968).

Following the work on artificial turf by RAPRA (Sports Council 1984a, b), the Sports Council commissioned a four year programme of research at the Sports Turf Research Institute. This led to the development of apparatus and test methods for measuring playing quality and to the production of standards for the components of playing quality. The objective of this Part is to describe the apparatus produced and to briefly outline the standards work and the limits set for different components of playing quality. Both apparatus and standards are referred to throughout the thesis and therefore the apparatus is fully described here with more brief descriptions being given in later chapters or parts of chapters.

## APPARATUS AND TEST METHODS

### Ball bounce or rebound resilience

Ball rebound resilience is measured by releasing the ball from a standard height. For football this height is 3.0 m ± 5 mm from the bottom of the ball to the playing surface. The apparatus must release the ball without impulse or spin and a vertical scale must be provided so that rebound height can be measured. It is usual to graduate the vertical scale in terms of % rebound and to arrange the graduations so as to record rebound height, as the maximum rebound height of the top of the ball for ease of recording. The ball must be of a standard size and inflation pressure (FIFA size 5 inflated to 70 kPa) and it should have a rebound resilience of between 56% and 59% when tested on concrete. In practice a number of drops are performed on each test area and the apparatus is moved between drops to avoid successive impacts on the same location. The apparatus is shown in Plate 1.

PLATE 1. Apparatus for measuring ball rebound resilience in use on a reinforced rootzone as described in Chapter 5.

### Ball roll or rolling resistance

For ball roll the simplest approach is measurement of distance rolled by a ball released from a standard ramp. For measurement of distance rolled an inclined ramp apparatus is used, which consists of two parallel bars mounted on a rigid frame to produce a release 'ramp' inclined at an angle of 45°. The foot of the ramp is constructed to a radius of 500 mm to prevent the ball abruptly changing direction and bouncing off the surface. The apparatus is placed so that the ball is released from a height of 1.0 m and allowed to be rolled down the ramp and along the playing surface. The distance rolled by the ball from the end of the ramp to the resting place of the ball is measured. Three observations should be made in two opposing directions on each test area. The greater is the distance rolled by the ball, the lower is the rolling resistance and *vice versa*. The main drawback of the method is that it is easily influenced by wind and it is not recommended to use the technique if the wind speed exceeds Beaufort Scale 4 (moderate breeze, 5.6-8.1 m $s^{-1}$). Results are expressed in terms of the mean distance rolled in metres. The apparatus is shown in Plate 2.

PLATE 2. Ball roll testing at Anfield Road, Liverpool.

An alternative method to distance rolled as a measure of rolling resistance is to measure ball deceleration as it rolls across the surface. This method is particularly appropriate to measurements on experimental plots where space is restricted and the ball would roll off the experimental area.

For assessment of ball deceleration, an apparatus was constructed comprising two sets of timing gates operated by infra-red sensors. Each timing gate comprised two pairs of infra-red emitters and detectors on opposing sides of the apparatus. When the ball passes between each pair a signal is sent to a timer unit. The detectors in each pair are 30 cm apart. The time taken for the ball to roll between the first pair of detectors is used to calculate is 'initial' velocity $u$, the ball is allowed to roll a further 2.0 m (distance $s = 2.0$ m) before it reaches the second pair of detectors where its 'final' velocity ($v$) is determined. The ball deceleration ($a$) is determined from one of the standard equations of motion:

$v^2 = u^2 + 2as$

The standard 1 m high ramp described above is used to provide standardised initial conditions. The arrangement of apparatus in shown in Plate 3.

PLATE 3. The Author measuring ball deceleration on the experimental plots described in Section 3 of this chapter using the timing gate apparatus. The timing gates are at each end of the apparatus and the ball roll ramp is used to provide a standard initial velocity.

### Traction

An apparatus for measuring traction and friction on natural and artificial playing surfaces was described by Canaway & Bell (1986). The apparatus (Fig. 1) consists of a mild steel test disc "foot" 145 mm in diameter, centre drilled with 6 football studs arranged in a radially symmetrical manner 46 mm from the centre of the disc. A shaft is screwed in the centre of the disc. The shaft incorporates lifting handles and passes through a set of weights to provide a load of 46 kg including the mass of the other components. The weights are supported on a roller bearing to permit free rotation of the disc, whilst the weights remain still. To make the measurements a two-handled torque wrench with a scale up to 80 N m, is attached to the top of the shaft, the apparatus is lifted and allowed to fall on to the turf from a height of 60 mm to ensure the studs penetrate the surface. The torque wrench is then turned without placing any additional vertical force on the handles and torque required to tear the turf is measured. The higher is the value the greater is the traction available to the player. Low values would indicate a surface on which falls are likely and very high values could predispose knee and ankle injuries. After each reading the disc and studs are cleaned of any mud or turf and the measurement repeated on undamaged turf until sufficient data have been collected.

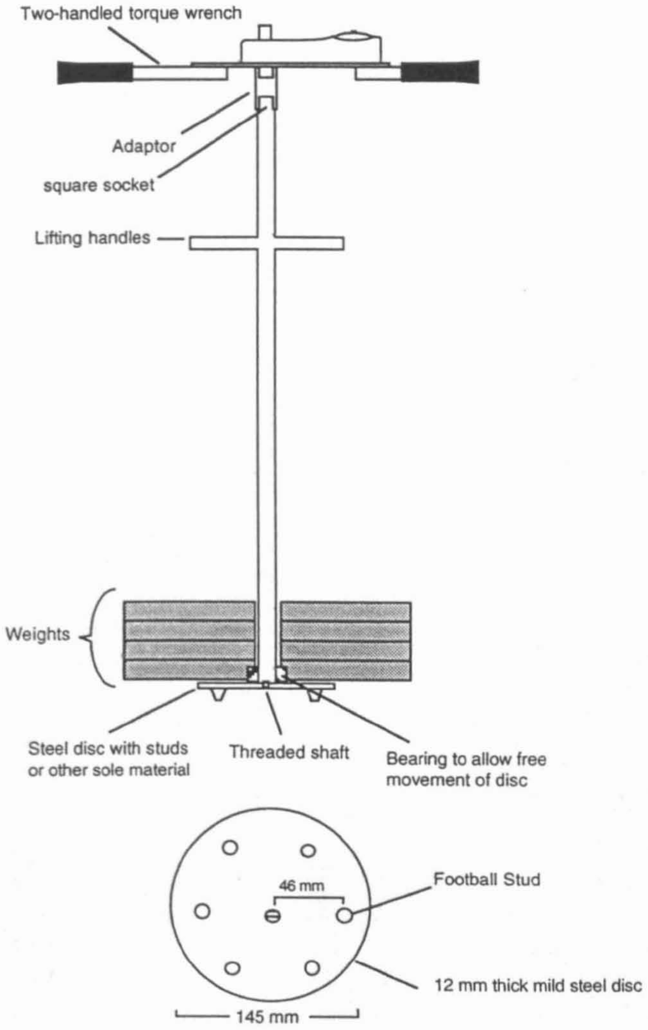

FIGURE 1. Apparatus for measuring traction on natural turf.

### Hardness

Hardness, or more strictly, stiffness and resilience of surfaces, has been measured by a variety of techniques (Baker 1990, Bell *et al.* 1985) and some of the shortcomings of these methods are discussed by Nigg (1990). However, for rapid evaluation of outdoor sports fields the Clegg Impact Soil tester (Clegg 1976) has been widely used and much experience has been gained with it under a variety of conditions. The apparatus consists of a cylindrical compaction hammer of mass 0.5 kg and a diameter of 50 mm attached to a piezoelectric accelerometer, which feeds into a peak level digital meter. The compaction hammer is released to fall down a guide tube from a height of 300 mm and after impact with the surface, the peak deceleration of the hammer is displayed in gravities on the screen display. After each test the apparatus is moved to a fresh area and the test repeated. The apparatus is shown in Plate 4.

PLATE 4. Clegg Impact Soil Tester used for measurements of hardness. The plate shows the 0.5 kg test mass containing an accelerometer at the lower right, the meter unit at the lower left and the guide tube at the rear.

## STANDARDS FOR PLAYING QUALITY OF NATURAL TURF

The aim of this work was to produce proposed standards for playing quality of football pitches based on a combination of field testing and player evaluation work (Canaway *et al.* 1990). The work has been supplemented by a further project whose object was to monitor case studies of fields with different construction in order to relate playing quality to levels of use and cost-effectiveness (Baker & Gibbs 1989). This has provided a "test bed" for the practical application of such standards in the field and has led to some modifications of the original standards. The results of this work, together with additional work needed in some areas not covered previously (e.g. grass length), have now been combined into a forthcoming publication "Specification for natural turf sports areas : Part 1 soccer pitches", which is in the final stages of preparation and will be published in the near future. This document not only contains standards for playing quality tests described above, but also for: surface evenness; grass ground cover; grass sward height; water infiltration rate and gives details of antecedent conditions for testing.

### Field testing and player evaluation work

The original work has been fully reported elsewhere (Canaway *et al.* 1990) but a brief summary is given here. The initial phase of the work comprised a review of existing literature (Bell *et al.* 1985) and development of apparatus and test methods and a pilot study on the use of such apparatus in the field (Holmes & Bell 1986). Complex electronic apparatus was rejected at an early stage bearing in mind that the tests have to be carried out during the British winter season when adverse weather is prevalent. Apparatus has to be simple, robust, easy and safe to use, portable and above all, reliable. Complex equipment involving computer data capture, whilst suitable for laboratory work was found to be temperamental in the field, with faults due to moisture and power supplies failing in extreme cold, in addition to setting up time and lack of portability on site. Examples of such apparatus include the "Stuttgart Artificial Athlete", the "Berlin Artificial Athlete" and the "impact severity test" referred to by Baker (1990) and by Nigg (1990). Sampling locations in the field testing work comprised six locations on football fields encompassing areas of high wear (goal areas), medium wear (centre circle) and light wear (wings). These are illustrated diagrammatically in Fig. 2.

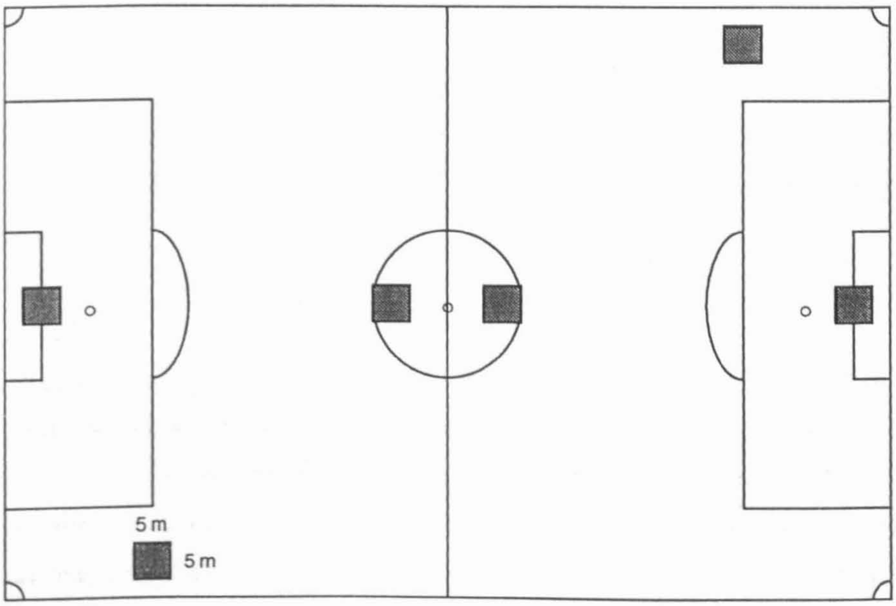

FIGURE 2. Location of six test areas on soccer fields.

Playing quality tests were carried out within 2 hours of matches on 49 football fields of different constructional make up. Each field was visited between one and five times during the period of the study and a total of 675 areas measuring 5 m x 5 m was tested. The tests were carried out within 2 hours of matches so that the opinions of players could be sought on the qualities of the surface that the mechanical tests sought to measure. Questionnaires were given out to players after matches and a total of 444 completed questionnaires were returned, which together with the 675 test results, comprised the main data set for the initial formulation of standards for playing quality for natural turf soccer fields. The questionnaire is given by Canaway *et al.* (1990) as are details of the relationships between the results of the mechanical tests and the players opinions. It was based on these opinions that standards were formulated in terms of "preferred" and slightly less demanding "acceptable" ranges for different tests. The set of standards referring to the playing quality tests discussed in detail above: i.e. ball rebound resilience; ball roll; traction and; hardness are presented in Table 1.

TABLE 1

Standards for playing quality of natural turf for football

| Test | Preferred range | Acceptable range |
|---|---|---|
| Ball rebound resilience (%) | 20-50 | 15-55 |
| Ball roll distance (m) | 3-12 | 2-14 |
| Traction (N m) | ≥25 | ≥20 |
| Hardness (gravities) | 20-80 | 10-120 |
| Ball deceleration (m $s^{-2}$) | 0.45-1.5 | ≤2.2 |

It should be noted that no upper limit for traction is given since traction values in the study were in the low to medium range and players generally did not complain of excessive "grip underfoot". The more likely response was that grip underfoot was poor. The study recorded a maximum traction value of 51.0 N m with mean values of: 27.1 N m (goal areas), 33.0 N m (wing areas) and 27.4 N m (centre circle). The values for ball deceleration are given by Baker & Gibbs 1989.

## CONCLUSION

The development of apparatus and test methods and subsequent standards for the playing quality of Association football pitches was a slow and difficult process and doubtless further refinements could be devised if funds were limitless. The process to date has enabled the playing quality characteristics of turf to be quantified in a meaningful way. It enables the performance of installations and of experimental treatments in turfgrass research to be judged. For example, previously it could only be stated that a particular treatment increased or decreased traction or ball rebound, but it could not be said whether that was good or bad. Now that limits for acceptability have been set it can be stated positively whether the treatment was beneficial or not. No claim is made that the tests used actually represent what the athlete does, or the potential for injury of the surface. The standards were based on what players preferred, not necessarily what was good for them. These may be the same but I am not qualified to judge, Nigg (1990) quite rightly pointing out the drawbacks of simple tests for prediction of the injury potential of different surface/shoe combinations.

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# PART 2

## A THEORETICAL ANALYSIS OF THE FACTORS GOVERNING PLAYING QUALITY OF SPORTS FIELDS

### SUMMARY

Playing quality is essentially an abstract concept based on human perception of how a surface "plays". However, certain objective measures can be made on playing surfaces which correlate with the player's perception. These include ball rebound, ball roll, traction and hardness. These components of playing quality are affected by the nature of the playing surface, which is comprised of plant and soil constituents. A conceptual model is used to illustrate the effects of external factors and wear on the eventual playing quality of the surface.

The soil factor grouping in general, and more specifically soil moisture content and water movement, are considered to be the key variables in determining playing quality of sports surfaces. Examples are given from studies on the effects of rootzone construction on playing quality and the effects of antecedent rainfall are discussed. Wear is shown to be a key regulating factor mediating the response of soil factors on playing quality. Studies on playing quality in the absence of wear are considered of limited value in climates where rainfall exceeds evapotranspiration during the playing season.

Plant factors affecting playing quality include turfgrass species, cultivar, biomass, density, ground cover, height of cut, and root biomass. An example is given illustrating the effects of eight turfgrass species and two contrasting rootzones on playing quality. Correlations among variables are discussed indicating the importance of grass ground cover in determining traction in several studies. Ball roll distance of footballs is highly correlated with sward cutting height.

Many other factors influence playing quality indirectly either via the soil factor complex, e.g. sand top dressing or via the plant component of the turf, e.g. fertiliser nitrogen. Others, such as rootzone amendments, may affect both soil properties and aid plant growth thus acting through both soil and plant components of the turf in determining playing quality.

### INTRODUCTION

Soccer and Rugby have their origins in the cool-temperate climate of Britain where rainfall exceeds evapotranspiration (ET) for at least part of the playing season. In most of Europe the playing season typically starts in late summer and ends in late spring or early summer of the following year. In countries with maritime climates, play continues throughout the winter, those with colder winters have a mid-season break during the coldest months, and in the boreal regions of Scandinavia the season becomes compressed into those months when play is feasible. In all of these cases playing quality of fields presents no problem in the early part of the playing season when there is full grass cover and ET exceeds rainfall. When fields are frozen or snowbound, play is precluded; and if there is no play possible, consideration of playing quality becomes of somewhat academic interest. It is the intervening parts of the playing season, typically in late autumn, through the winter in maritime climates, and early spring when rainfall exceeds ET that problems of poor playing quality occur. It is therefore perhaps no surprise that research on playing quality has been concentrated in those countries experiencing such problems, notably the United Kingdom (UK), Germany and The Netherlands. In part 1 of this chapter and elsewhere (Baker & Canaway 1993) the historical development of research on playing quality and apparatus and test methods are described. However, it is worth stating the aims of playing quality research as follows: [1] to provide objective measures of the performance of playing surfaces, which have traditionally been assessed subjectively; this is especially valuable in comparing different facilities or in the event of litigation; [2] to provide objective measures of performance in response to experimental treatments in research work, because to judge the benefits of, say, a novel fertiliser on turf performance we need to have adequate measures to judge the players' perceptions of quality; [3] following from the above, to provide standards and specifications for the various components of playing quality as aids: [a] to quality control in construction and maintenance operations; [b] to help determine the level of field quality and; [c] to establish what levels of quality indicate that a field is fit for play. All of this can be seen as part of the process of standardisation of methods and products which is taking place both at national and international levels.

## A CONCEPTUAL MODEL

In part 1 of this chapter, the concept of playing quality was introduced and apparatus and test methods were described for measurement of the components of playing quality for football, namely: ball rebound resilience, ball roll, traction and hardness. These, in turn, are affected by soil physical and other factors. The objective of the present part is to discuss the factors governing playing quality of natural turf playing surfaces for soccer and related sports, such as Rugby, Gaelic football and Australian rules football. The major factor groupings that determine playing quality are shown in Fig. 1. These include the nature of the turf, including its soil and plant constituents; the influence of external factors, which in the present model includes environmental factors, such as rainfall, management practices, such as mowing, irrigation and other 'external' agents such as pests and disease; and the effects of play in producing wear. It is important to separate play from wear in the model shown since play includes psychological and emotional elements plus game-oriented elements (e.g. scoring) which have little to do with wear. Thus 'play' is a much larger domain than merely physical side-effects of damage to the playing surface which we call wear. In the model the term 'wear' is preferred to the terms 'traffic' and "use intensity" because 'wear' more accurately describes the damage produced by balls, implements (hockey stick, polo mallet, lacrosse stick [crosse]), and maintenance equipment as well as by foot and vehicular traffic. Wear is most important in determining the way other variables are expressed and is thus shown as a regulating factor in the model, hence the 'valve' shaped icon in Fig. 1. Its importance cannot be stressed strongly

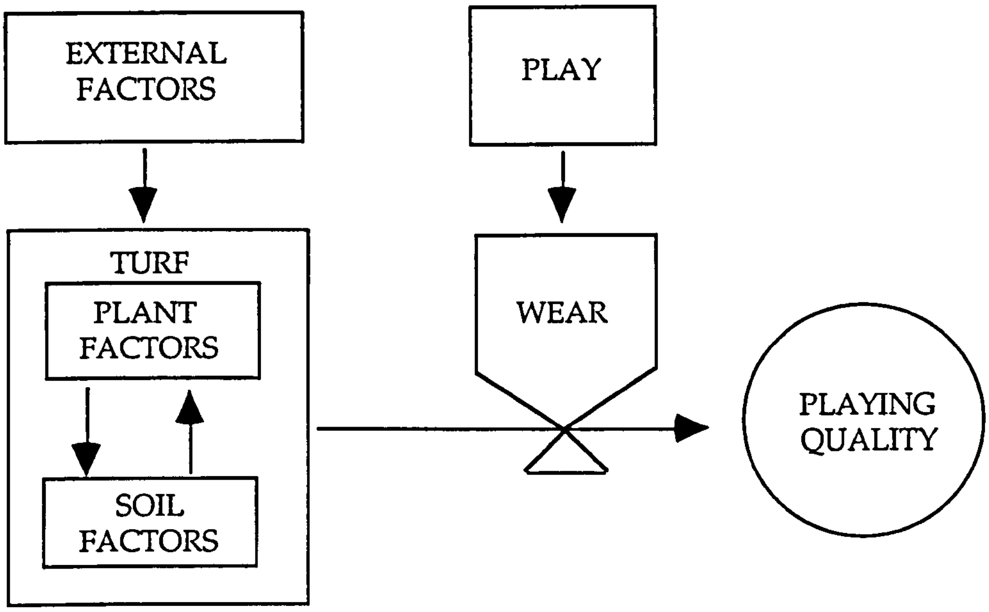

FIGURE 1. A conceptual model indicating the main factor groupings determining the playing quality of sports turf.

enough. A trial may be made without wear and show a particular response to the experimental treatments, however, if wear is carried out the response may disappear, be reversed or enormously magnified as shown below. It is no exaggeration to state that research on playing quality of sports turf has restricted value without the inclusion of wear treatments.

## SOIL FACTORS

In one of the pioneering pieces of work on playing quality, Langvad (1968) stated: "It was found that the kinds of soil in a football ground have a greater effect on bouncing than mowing height." Langvad's early insight was to be confirmed by subsequent research in that the soil factor grouping is the most important as far as playing quality is concerned, the key variables being rootzone composition and drainage in the broad sense. More specifically, it is how these factors affect moisture retention and water infiltration and their interaction with wear that largely determines playing quality of sports fields.

van Wijk (1980a, 1980b) carried out extensive work relating soil and moisture conditions to the firmness of the surface as determined by penetrometer measurements. Playing quality was strongly influenced by both rootzone and subsoil composition and by the nature of any drainage systems that were installed. In Part 3 of this chapter research conducted from 1986 onwards is described, in which the effects of rootzone composition and drainage were studied on the cost-effectiveness and playing quality of sports turf for football. The work is described in detail in Part 3 of this chapter, but the present section would be incomplete without some reference to that study. In brief, the experiment comprised a study of five different constructional methods (Baker & Canaway 1990) encompassing a wide range of those used in the UK and elsewhere. The constructional types were as follows: [1] Pipe drainage (PD). The indigenous sandy loam soil was provided with 60 mm plastic drain pipe at a depth of 600 mm, together with the required aggregate backfill etc. [2] Slit drainage (SD). Constructed as PD but with the addition of slit drains cut transversely to the pipe drain at 600 mm centres. [3] Slit drained with sand top (SS). Constructed as SD but with the addition of a 25 mm firmed depth of medium-fine sand at the surface. [4] Sand carpet (SC). Pipe drainage and slit drains at 1.5 m centres were installed in the topsoil then 100 mm medium-fine sand spread to form a sand playing surface. [5] Sand profile (SP). This was a soil-less construction comprising 250 mm rootzone sand, 50 mm coarse sand and 100 mm gravel drainage layer. Turf management was carried out to a relatively high standard and the trial received artificial wear treatments to simulate use by players during the playing season.

The effects of the different constructional treatments on soil moisture content and water infiltration rate are shown in Fig. 2A and 2B. These examples are taken from the early part of the experiment in September 1987. A progressive decrease in soil moisture was observed, being greatest in the rudimentary type of constructional profile (PD) and least in the most costly sand-based construction (SP). Conversely water infiltration rate increased greatly over the range of constructional types.

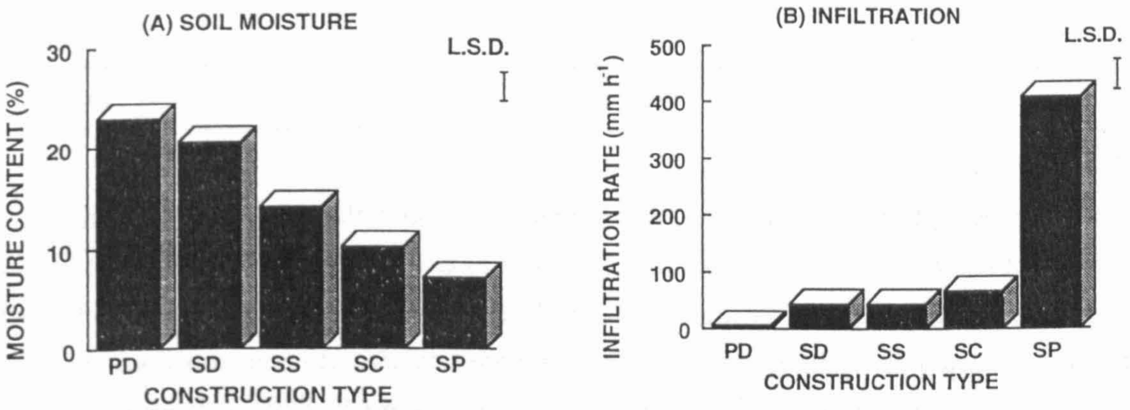

FIGURE 2. Moisture content (% by weight) and water infiltration rate of a range of constructional types taken in September 1987 (LSD = least significant difference at $p < 0.05$).

Similar responses were observed on subsequent dates of measurement, although the absolute values changed with time as shown for infiltration rates in Fig. 3. This also serves to emphasise the importance of maintaining infiltration rates by appropriate management techniques to alleviate the decrease in infiltration rates, which can occur even on very permeable rootzones.

The differences in infiltration rates, as expected, have a large influence on the occurrence of standing water or "ponding" on the playing surface. Standing water, by common experience, reduces ball rebound and ball roll to virtually zero. Traction and hardness would also be grossly affected. The incidence of ponding over two playing seasons, which closely reflects the differences in infiltration rates seen above, is shown in Table 1.

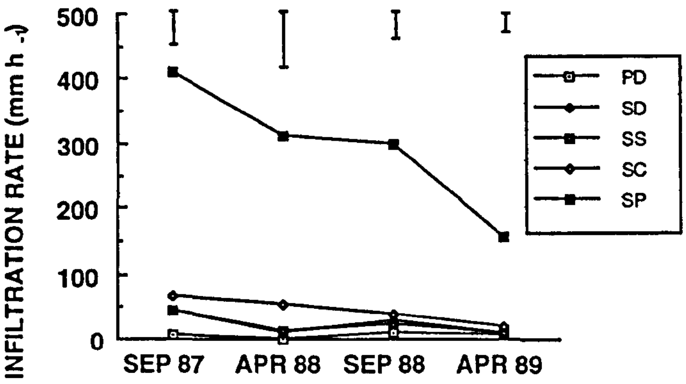

FIGURE 3. Temporal changes in water infiltration rates of five constructional types. (N.B. the graph for SD followed a nearly identical course to that for SS. Vertical bars indicate the LSD at $p < 0.05$.)

TABLE 1
Number of days with surface ponding in relation to construction type.

| | 1987-88 | 1988-89 |
|---|---|---|
| Recording days | 119 | 152 |
| Pipe drained | 82 | 92 |
| Slit drained | 41 | 34 |
| Slit drained (sand top) | 16 | 12 |
| Sand carpet | 2 | 5 |
| Sand profile | 0 | <1 |
| LSD (5%) | 12.0 | 15.6 |

The consequences of the differences in rootzone composition in terms of playing quality is illustrated by the following examples of results on ball rebound (Fig. 4) and ball roll (Fig. 5) from the same experiment. What is noticeable here is the manner in which wear, in conjunction with soil moisture content, mediates the effects of construction on playing quality. Prior to wear in September 1987, there was little difference in ball rebound among constructional treatments, all having values around 40%. During wear, however, in December 1987, apart from a general reduction of the SS, SC and SP treatments to nearer 30%, there is a gross reduction in ball rebound to around 5% on the PD construction and a lesser reduction on the SD areas. Ball rebound is a function of the condition of the playing surface, particularly its hardness. In the case of the PD construction in particular, infiltration rates fell so low by December (0.5 mm $h^{-1}$) that the surface became soft and muddy with the consequent gross reduction in ball rebound.

Similar effects were observed for ball roll (Fig. 5). Ball roll was expressed in terms of ball deceleration, i.e. a surface with a low ball deceleration is a "faster" surface than one with a high deceleration figure, which conversely would rate as "slower". Before wear in September 1987 there was no significant difference among constructional types (Fig. 5A). However, during wear in December 1987 there was a gross increase in ball deceleration for the PD construction in response to the effects of wear on rootzone of already low permeability (Fig. 5B).

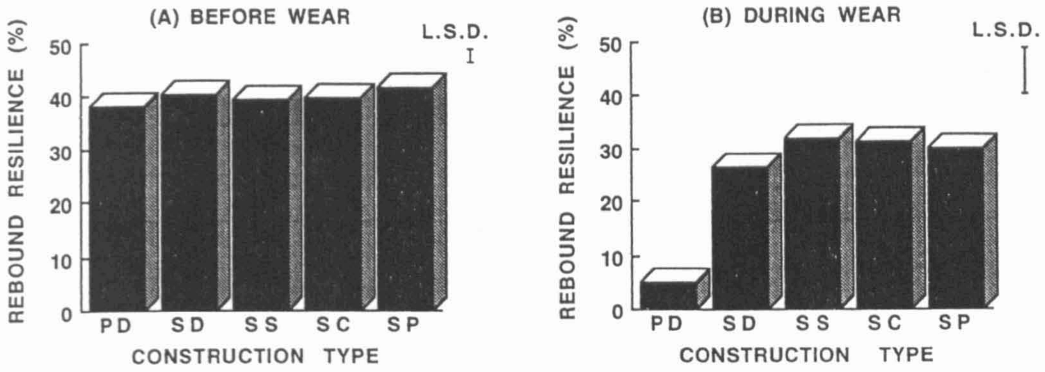

FIGURE 4. Ball rebound resilience on different constructional types: [A] before wear; [B] during wear. (LSD = least significant difference at $p < 0.05$.)

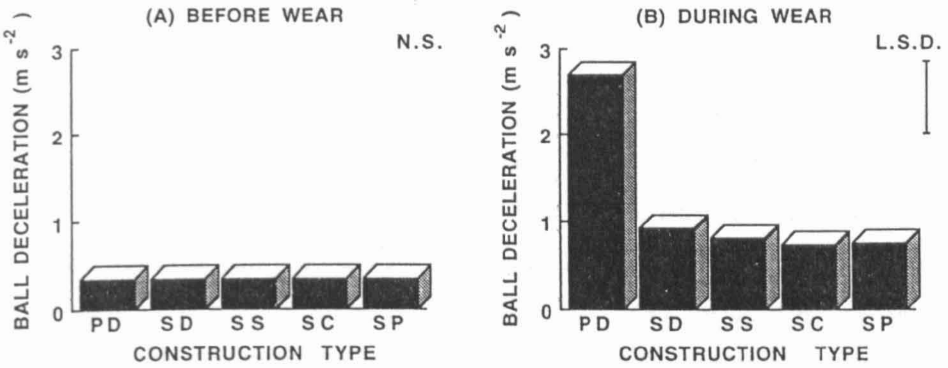

FIGURE 5. Ball deceleration on different constructional types: [A] before wear; [B] during wear. (LSD = least significant difference at $p < 0.05$.)

Baker (1991a) reported results of a study of playing surfaces for soccer that were established using different mixes of sand and soil. In studying temporal variations in playing quality he showed that soil moisture was the dominant factor controlling surface hardness in mixes where soil was the dominant part. Hardness fell below the preferred lower limit of 20 gravities when soil moisture content reached around 34-39%. Ball rebound follows a close relationship with hardness (Bell & Holmes 1988) and consequently a similar conclusion would be expected had ball rebound been measured also. In contrast, however, Baker (1991a) also showed that for sand-dominated rootzones moisture content had little effect on playing quality which was in agreement with the findings given above, with the implication being that once a certain level of specification is reached (SS in Figs. 4 and 5) little further change in playing quality occurs. Baker (1991a) continued the argument to show that antecedent rainfall also had little influence on hardness of sand-based rootzones, but for those with a significant soil content hardness (and hence ball rebound) was closely dependent on antecedent rainfall. He showed that hardness failed to reach the lower preferred limit of 20 gravities where antecedent rainfall exceeded 5 mm in the previous 24 hours; 15 mm in the previous 72 hours, or 35 mm in the previous week. Baker & Gibbs (1989) in a study of natural turf soccer fields also found that soil moisture had a controlling effect on both ball rebound resilience and hardness but that player traction was largely controlled by grass ground cover (see below). They also analysed the effects of antecedent rainfall but in this study found only weak or non-significant relationships between antecedent rainfall and playing quality. This result was thought to be due to factors associated with testing on real sites as distinct from experimental grounds, including timing of maintenance operations, surface run-off, and rainfall which occurred during testing. Baker *et al.* (1992) reporting on the same study showed that not only was playing quality improved on better constructed fields, but also levels of use were increased substantially from <50 adult games per season for a pipe-drained field on a poor draining soil to 125-180 adult games per season for a sand carpet or sand profile type of construction.

To summarise the discussion on soil factors, it is rootzone composition and drainage, with the implications for soil moisture content and throughput, mediated by wear, that has a major influence on playing quality especially ball rebound and hardness.

It naturally follows that maintenance operations, e.g. sand top dressing (Baker & Canaway 1992) or rootzone amendments (Baker & Hacker 1988, Baker 1991b, Canaway 1992), also have a marked influence on playing quality through their direct effects on the soil especially under wear. As a final point it should be stressed that on natural soils loss of soil structure, as a consequence of wear and compaction, is an important factor in bringing about the decrease in infiltration rate and increase in moisture content, often observed.

## PLANT FACTORS

Plant factors affecting playing quality include species, cultivar, biomass, density, ground cover, height of cut, and root biomass. In many instances differences due to plant factors are much less than those due to soil factors, but they are still important and substantial. As far as different components of playing quality are concerned, plant effects on traction have been the most widely studied, with apparatus having been developed for studying traction in the 1970's (Canaway, 1975; Liesecke & Schmidt, 1978). Studies on the effects of plant factors in ball rebound, ball roll and hardness are mainly of more recent occurrence. An example is given from a study on the relative effects of species and construction on playing quality and the subsequent effects of wear (Canaway 1983). The experiments comprised eight turfgrass species grown on adjacent areas, one consisting of a natural sandy loam topsoil with pipe drains at 5 m centres and the other consisting of a medium-fine sand profile construction similar to that already described. The trials were managed as a soccer field and artificial wear treatments were carried out during the playing season. Measurements of traction, ball rebound and grass ground cover were made on several occasions and above-ground plant biomass was also measured before the start of wear in September 1982.

Results for traction and ball rebound on two of the assessment dates (before wear in September 1982 and after wear treatments in January 1983) indicate that before wear both for traction and ball rebound, the eight turfgrass species exhibited similar ranges of values on both sand and soil constructions, albeit with significant differences among species (Table 2). After wear gross reductions in the values were obtained on the soil-based rootzone. Analysis of the relationships among variables showed that before wear both ball rebound and traction were negatively correlated with grass ground cover and biomass. For traction this was thought to be due to the high biomasses of species such as *Poa annua* L. preventing the studs of the traction apparatus from penetrating the rootzone, and for ball rebound high biomass was thought to absorb the energy of the ball to a greater extent giving lower rebound. During wear, however, the situation changed to one in which the correlation between cover and traction disappeared on the sand and became positive on the soil construction. Baker & Gibbs (1989), on actual fields, showed that traction was strongly linked to ground cover over two seasons of play on both undrained and sand carpet constructions. Baker & Isaac (1987), Baker (1991a) also showed that traction was correlated with ground cover on four rootzone mixes and where only a single species was involved. Shildrick & Peel (1984) demonstrated cultivar differences in traction and that traction was positively correlated with biomass, shoot density and ground cover. Rogers & Waddington (1989) showed increases in traction with greater biomass (verdure) in *F. arundinacea* Schreb. and also demonstrated the importance of roots in increasing traction. Adams & Jones (1979), Tanavud (1982), Adams *et al.* (1985) showed that the presence of roots increased resistance to shear in a range of sand/soil mixes. Schmidt (1980) studied the effects of root biomass on traction in *Lolium perenne* L. cultivars but found no correlation, which he attributed to the dominant effects of the soil in his study. The loss of grass cover and hence root organic matter has particularly severe consequence on pure sand pitches (Baker & Gibbs, 1989; Gibbs *et al.*, 1989), where extensive erosion hollows can develop, particularly if the surface is allowed to dry out and is not rolled to restore stability. In the erosion hollows the sand is loose and easily kicked out and this has major effects on traction, hardness and ball rebound resilience.

TABLE 2

Traction and ball rebound of eight turfgrass species on two rootzone types, before and after the application of soccer-type wear

| | Traction N m | | | | Ball rebound % | | | |
|---|---|---|---|---|---|---|---|---|
| | Before wear | | After wear | | Before wear | | After wear | |
| Species | Sand | Soil | Sand | Soil | Sand | Soil | Sand | Soil |
| *Poa annua* | 55e | 52e | 56e | 40a | 30d | 29e | 27c | 11d |
| *Lolium perenne* | 72bc | 66bc | 62cd | 35b | 38a | 37ab | 32a | 21a |
| *Poa pratensis* | 72bc | 70b | 71a | 39a | 36b | 35c | 30ab | 17b |
| *Phleum pratense* | 78a | 71a | 59de | 31c | 37ab | 37b | 31ab | 16b |
| *Festuca arundinacea* | 69cd | 64c | 55e | 26d | 39a | 38ab | 30ab | 11d |
| *Agrostis castellana* | 66d | 57d | 61d | 28d | 33c | 32d | 29bc | 8e |
| *F. rubra* ssp. *commutata* | 77a | 68b | 69ab | 35b | 38a | 37ab | 29bc | 12cd |
| *F. rubra* ssp. *rubra* | 74b | 71a | 66bc | 33bc | 39a | 38ab | 30b | 14bc |
| Experiment mean | 70.3 | 64.5 | 62.4 | 33.6 | 36.1 | 35.2 | 29.8 | 13.7 |

†Within each column means without a common letter were significantly different at k = 100 using Waller and Duncan's multiple comparisons procedure. Comparisons are not valid between columns using the letters. Some anomalies may appear due to rounding off the results to whole numbers.

Rogers & Waddington (1989) also studied the effects of three cutting heights on hardness, expressed as impact absorption, of *F. arundinacea* swards and the results suggested an increase in impact absorption with increasing cutting height, although the results were not conclusive. Studies on the effects of cutting height on football (soccer) roll are, however, well established despite only a limited number of studies having been carried out. Langvad (1968) first demonstrated that ball roll distance was reduced by increasing cutting height. Bell & Holmes (1988) and Richards & Baker (1992) fitted negative exponential models to ball roll over a range of cutting heights, showing that ball roll decreased as cutting height increased. In both Bell & Holmes' (1988) study and that of Richards & Baker (1992) the predominant response was linear. The correlation coefficient for the relationship between distance rolled and cutting height was –0.81 in Bell & Holmes' study. In Richards & Baker's (1992) study measurements were made when the sward was both dry and wet. The correlation coefficients were –0.98 (dry) and –0.93 (wet).

As in the section on soil factors it is implicit in the above that management inputs which directly affect plant growth, density, etc. have an indirect effect on playing quality via the plant component of the turf. These include fertiliser as discussed in detail in Chapter 4 and rootzone amendments, which have already been referred to in the context of their direct effects on the rootzone. They also influence plant growth by increasing rootzone moisture and nutrient retention. Examples where playing quality effects have been observed include studies on: peat (Baker & Hacker, 1988); a polyacrylamide gel (Baker 1991b) and; a seaweed based soil improver (Canaway 1992) the latter being described in Chapter 3.

## CONCLUSION

In conclusion, research on the characterisation of sports turf surfaces has shown that playing quality is determined by the nature of the main components of the turf - plant and soil - and the way these interact with wear. If we were to single out the most important factor, or factor grouping, in determining playing quality, it would be rootzone construction, and its influence on moisture retention and throughput, mediated by wear. The amount of work relating to playing quality has increased considerably in recent years. However, this increase has been concentrated in European countries, the UK in particular. The USA, which has the greatest potential for turfgrass research has, with some notable exceptions, generally been slow to recognise the importance of player oriented means of evaluating sports field turf. It has also been slow, again with notable exceptions, in implementing adequate simulation of wear in turf trials.

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## PART 3

# A LARGE-SCALE EXPERIMENT ON THE EFFECTS OF FIVE CONSTRUCTION METHODS ON THE PERFORMANCE OF NATURAL TURF FOR ASSOCIATION FOOTBALL

## SUMMARY

Over the years different methods of football pitch construction have been developed. An experiment was carried out to determine the performance and cost-effectiveness of five different construction methods for Association football. These comprised: [i] pipe drainage; [ii] slit drainage; [iii] slit drainage with the addition of 25 mm sand top; [iv] sand carpet and; [v] sand profile. Data were collected on grass ground cover, playing quality, water infiltration rate, the presence of standing water and soil moisture content. Playing quality measures included ball rebound resilience, ball roll, traction and hardness. The experiment was subjected to artificial wear treatments during the playing seasons of 1987-1988 and 1988-1989 to simulate the effects of play.

Before wear, ground cover and playing quality showed small differences among treatments, however, during wear differential treatment effects were observed. These effects were dominated by the rapid and gross deterioration in the quality of the pipe drained construction and to a lesser extent, the slit drained construction. Cover and playing quality were consistently good in the slit drained with a sand top, sand carpet and sand profile constructions.

In contrast to wear and playing quality, soil moisture content and water infiltration rates showed large differences among constructions before wear and these differences persisted throughout. Differences in water infiltration rate were also reflected in the presence of surface ponding on the trial, which was most prevalent on the pipe drained construction and least prevalent on the sand profile construction.

Implications for the practical use of the different construction methods and their cost-effectiveness are discussed.

## INTRODUCTION

As indicated in the second part of this Chapter, rootzone construction and its influence on moisture retention and throughput, is the most important factor or factor grouping affecting the playing quality of natural turf for football. This is particularly so in cool, temperate climates where rainfall exceeds evapotranspiration for periods of the playing season. For most natural soils the ability to transmit water away from the surface is insufficient and when subject to wear, leads to the familiar mud baths and poor playing conditions seen on lower quality pitches at present and formerly, even on Football League grounds.

For many years there has been an understanding of these basic principles, the fundamentals having been outlined by Adams *et al.* (1971a). This paper set out the requirements of sports field drainage and outlined the size of sand being required to permit free drainage when compacted. Design rates of 25 mm $h^{-1}$ were suggested, obtainable by the use of sand in the range 0.1-0.6 mm in diameter. A further paper (Adams *et al.* 1971b) concentrated on selection of suitable sands for sports field use and gave recommendations for soil amendment, pure sand rootzones and slit drainage. Practical examples of the use of these principles soon followed, for example the all the sand football field (Davis *et al.* 1974). Slit drainage aims to bypass impermeable layers by providing an alternative means for water to pass from the surface to the pipe drainage system. It was thought to have been pioneered in Britain at Twickenham (Clark 1970) during the 1960's, although Adams *et al.* (1971b) point out that slit drainage is a natural progression from the principle of a French drain. This view finds support in that one of the earliest references to slit drains (Werminghausen 1970) mentions slit drains up to 100 mm wide, which would be wide by modern standards where c. 50 mm would be aimed for. Although the term 'slit drain' was used by Werminghausen (1970), terminology was inconsistent in the early years, 'sand slit' being used commonly, e.g. Adams *et al.* (1971b), whereas Fisher & Ede (1974) used the term 'vertical bands' to describe the same form of construction.

Sand carpet constructions incorporate both the use of sand and slit drainage in a composite construction originally called the Prunty-Mulqueen or PM pitch (Prunty 1970). First developed to cope with high rainfall conditions in Northern Ireland, it comprised a slit drain system in the topsoil with pipe drains laid beneath and then a 100-150 mm sand layer spread to provide a free-draining playing surface. The 'PM pitch' was a patented construction, but both before and after the expiry of the patent, which was never tested in court to my knowledge, numerous such "sand carpet" pitches were constructed.

Practical experience on improved pitch construction was followed by a number of field studies in which different constructions were compared. For example Müller-Beck (1977a, b) studied the botanical and soil physical properties of different constructions. Baker & Gibbs (1989) and Baker *et al.* (1992) in a study parallel to the one described below studying playing quality and levels of use on a number of football pitches constructed by different methods. Gibbs & Baker (1989) in the same project studied soil physical properties of the different constructions. These studies, whilst giving interesting comparisons between pitches constructed by different means, suffered from the major drawback that on field sites it is not feasible to use experimental designs to control unwanted variation and to provide a framework for subsequent statistical analysis. Furthermore, even with the best of intentions it is difficult to ensure that maintenance and usage are identical on different sites and in practice this is nearly impossible to achieve. The aim of the present work was therefore to undertake a study

TABLE 1

Approximate costs (1993) prices) of five different football pitch construction and drainage methods

| Construction and drainage method | Installation cost (£) |
|---|---|
| Pipe drainage, 10 m spacing | 9,000 |
| Slit drainage at c. 1 m centres plus pipe drains | 22,000 |
| Slit drainage as above with 25 mm sand top layer | 25,000 |
| Sand carpet, 100-150 mm sand overlying slit drain and pipe drain system | 65,000 |
| Sand profile, over gravel drainage layer | 110,000 |

N.B. Costs for sand carpet and sand profile would include overhead irrigation system costing c. £25,000

of five different constructional types under controlled experimental conditions, using artificial wear treatments to provide a uniform level of wear across the experiment during the playing season.

Improvements in construction and drainage, whilst being highly desirable from the player's point of view, do have major cost implications. Table 1 gives the cost of five commonly used methods of pitch improvement or construction, figures are approximate since actual costs vary greatly depending on the nature of the site, for example severe gradients or difficult excavation conditions due to rock, could add greatly to costs. Therefore whatever findings were obtained would have to be tempered by the reality of the cost of the construction when applied to practical situations. Gibbs *et al.* (1992) gave the results of their appraisal of the cost-effectiveness of different constructions in their case studies approach as a companion paper to those cited above.

## MATERIALS AND METHODS

### Construction

The existing turf was stripped from a sloping area of land at the STRI experiment ground (NGR SE 095 391) in July 1986. The existing sandy loam topsoil was stripped and stacked on an adjacent area for re-use. Next the subsoil was graded to a fall of 1:100 using earth moving equipment to form a sub-base for the experimental area. Constructional treatments were as follows, the bulk of the work being carried out in August 1986. Final levelling and sowing were carried out in September 1986 (see below).

#### *[1] Pipe drainage*

Topsoil was re-spread over the subsoil to a depth of 250 mm. A drain trench was excavated and plastic drain pipe (60 mm diameter, perforated type) was laid at a depth of 600 mm below the surface level. The drain trench was backfilled with 5-10 mm aggregate to within 200 mm of the ground surface and blinded with 50 mm of coarse sand, in order to prevent contamination of the drain backfill with topsoil, this being an accepted procedure. Topsoil was re-spread over the coarse sand to give 150 mm depth over the drain trench and 250 mm elsewhere. Abbreviated to 'PD' in the Results section.

### *[2] Slit drainage*

Topsoil was re-spread and pipe drainage was installed as described above. Slit drainage was not installed at the time of construction because narrow slit drain trenches are difficult to create in a new seed bed and prone to collapse from the sides. Therefore the sward was allowed to establish until the following May before installation of the slit drains. This would also be a typical procedure on actual sports fields. On 26 May 1987, 50 mm wide slit drain trenches were excavated 600 mm apart using specialist trenching equipment. The depth of the slit drains was 225 mm. The lower 125 mm was filled with 6 mm diameter 'Lytag' lightweight synthetic drainage aggregate. The upper 100 mm was filled with coarse sand. The drainage aggregate in the slit drain trenches interconnected with that above the pipe drain in order to provide a continuous path for water movement from the surface through to the outfall. Abbreviated to SD in the Results section.

### *[3] Slit drainage with sand top*

Topsoil was re-spread to a depth of 225 mm and pipe drainage was installed as described as above. Then a 25 mm thick firmed layer of medium-fine sand was spread to provide the 'sand top'. Installation of slit drainage was carried out on 26 May 1987 in the same manner as that given in [2] above. Abbreviated to SS in the Results section.

### *[4] Sand carpet*

Topsoil was re-spread to a depth of 150 mm. Pipe drainage was installed as described in [1] above, the depth of the pipe being 500 mm below the topsoil surface. The drain trench was backfilled with aggregate as previously and blinded with 50 mm coarse sand. Slit drain trenches 50 mm wide and 200 mm deep were cut at a spacing of 1.5 m between slit drains. These were filled with 150 mm depth of 5-10 mm diameter gravel and 50 mm depth of coarse sand. Afterwards, 100 mm of medium-fine sand was spread to form the "sand carpet" element of the rootzone comprising the playing surface. Abbreviated to SC in the results section.

### *[5] Sand profile*

In the case of the sand profile it was necessary to excavate an additional 150 mm of the subsoil to provide the required depth for the construction. Pipe drainage was installed at a depth of 250 mm below the subsoil formation level and backfilled with 5-10 mm gravel drainage aggregate. Above this, 100 mm depth of 5-10 mm gravel was spread to form a drainage layer. This was blinded with a 25 mm thickness of coarse sand to prevent ingress of the rootzone layer into the gravel drainage layer. Finally, 250 mm of medium-fine sand was spread forming the rootzone layer. Abbreviated to SP in the Results section.

The construction plots were 13 m x 6 m in size and isolated from adjacent treatments by a polythene membrane to prevent moisture migration from one construction type to another. Construction treatments were arranged in randomised blocks with two replications. Because of the requirement for artificial wear on the experiment (see below) which necessitated turning areas for the wear machine, the actual plot area used for each construction was 8 m x 6 m.

Particle size distribution of the material used in construction is given in Table 2.

TABLE 2
Particle size distributions of the materials used in construction (% in each size category)

| Category | Diameter (mm) | Topsoil | Rootzone sand & top dressing | Blinding sand | Sand for slit drains |
|---|---|---|---|---|---|
| Stones | >8 | – | 0 | 1 | 0 |
| Coarse gravel | 8–4 | – | 0 | 7 | 12 |
| Fine gravel | 4–2 | – | T | 14 | 16 |
| V. coarse sand | 2–1 | 5 | T | 10 | 7 |
| Coarse sand | 1–0.5 | 13 | 1 | 29 | 15 |
| Medium sand | 0.5–0.25 | 16 | 40 | 27 | 39 |
| Fine sand | 0.25–0.125 | 15 | 57 | 10 | 8 |
| V. fine sand | 0.125–0.05 | 12 | 2 | 1 | 1 |
| Silt | 0.05–0.002 | 23 | 0 | 1 | 1 |
| Clay | <0.002 | 16 | 0 | | |

N.B. T = trace

The experimental area was sown with *Lolium perenne* L. 'Elka' on 19 September 1986. The trial was allowed to establish until October 1987 when artificial wear (see below) commenced. As an additional part of the experiment, reported elsewhere (Baker & Canaway 1990, 1992), differential sand top dressings of 0, 4, 8 and 16 kg m$^{-2}$ per annum were applied to 4 m x 3 m sub-plots within each constructional type. Application of sand top dressing commenced on 26 June 1987. The trial has continued in different variations until 1993, but in the present chapter only the period up until spring 1989 is described.

### TRIAL MANAGEMENT

The aim of trial management was to simulate that which might be given on a good standard club football pitch subjected to annual cycles of wear and renovation after an initial period of establishment. This entailed the following procedures:

#### [1] Mowing

As the sowing was relatively late, no mowing was carried out in autumn 1986. The first cut was made on 16 March 1987 at a height of 58 mm. The cutting height was gradually reduced during the growing season until it was at its final height of 25 mm by 13 July 1987. In 1988 following the renovation (see below) at the end of the playing season, mowing height was also gradually reduced from a similar height, reaching 25 mm cutting height on 11 July 1988.

[2] Fertiliser

During preparation of the seed beds in 1986, a pre-seeding, slow release fertiliser was used which supplied the following nutrients (as kg $ha^{-1}$ N, 112; $P_2O_5$, 68 and $K_2O$, 112. In addition, 75 g $m^{-2}$ Alginure seaweed extract (see Chapter 3) was worked into the top 50 mm of the sand profile and sand carpet constructions in order to aid moisture retention during establishment. In 1987 five fertiliser applications were made, one of slow release nitrogen and 4 compound granular formulations supplying in total of (as kg $ha^{-1}$): N, 249; $P_2O_5$, 76 and $K_2O$, 153. In 1988, 4 dressings of compound granular fertiliser were applied supplying (as kg $ha^{-1}$): N, 172; $P_2O_5$, 93 and $K_2O$, 140.

[3] Irrigation

During the initial period of seedling establishment, frequent light watering was carried out. This was particularly important on the sand constructions. Subsequently, when dry weather prevailed, the aim was to supply 25 mm of water per week. In order to make up for estimated evapotranspiration losses of c. 18 mm per week, the balance being an allowance for evaporation during watering and wind drift of fine droplets.

[4] Control of *Poa annua* L.

*P. annua* ingress was controlled using ethofumesate applied at 2.0 kg $ha^{-1}$ ai diluted in 400 l $ha^{-1}$ of water. Three applications were made between 16 June and 10 August 1987 and a further three applications were made between 15 July and 30 August 1988.

[5] Artificial wear treatments

Football-type artificial wear was applied using the differential slip wear machine (Canaway 1976) with a pulley ratio of 1.36:1. In the 1987-1988 playing season 120 passes of the machine were made, commencing on 5 October 1987 and continuing until 15 April 1988. The trial received 120 passes of the wear machine in this period with the exception of the pipe drained construction, which received only 104 passes because of its deterioration into an unplayable condition during heavy rain combined with wear. In the 1988-1989 playing season the whole experiment received 136 passes in the period 14 September 1988 to 2 May 1989.

[6] Mechanical treatments

Slit tine aeration was carried out weekly using a pedestrian operated Sisis AutoOutfield spiker fitted with tines 125 mm in length from 20 October 1987 until 8 April 1988. Slit tine aeration treatments were repeated in the 1988-1989 playing season from 21 October 1988 until 10 February 1987.

### [7] Renovation

At the end of each playing season renovation was carried out. This entailed the production of a shallow surface tilth using a Sisis AutoSeeder and re-seeding with *L. perenne* 'Elka' at 28 g m$^{-2}$.

### DATA COLLECTION AND STATISTICAL ANALYSIS

Data were collected before, during and after the end of the period of wear in each of the 1987-1988 and 1988-1989 playing seasons. Details of data collected are given in Table 3.

TABLE 3
Summary table giving details of data collection, dates and methods used

| Type of data | Date of sampling | | Method used |
|---|---|---|---|
| | 1987/88 | 1988/89 | |
| Ground cover of live *L. perenne* | 1 Sep. 1987<br>2 Nov. 1987<br>14 Dec. 1987<br>29 Feb. 1988<br>18 Apr. 1988 | 5 Sep. 1988<br>31 Oct. 1988<br>13 Dec. 1988<br>6 Mar. 1989<br>2 May 1989 | Optical point quadrat of Laycock & Canaway (1980), 100 points per sub-plot, arranged in 20 frames of 5 points, systematically within sub-plots. |
| Ball rebound resilience | 2 Sep. 1987<br>3 Nov. 1987<br>14 Dec. 1987<br>7 Mar. 1988<br>20 Apr. 1988 | 5 Sep. 1988<br>1 Nov. 1988<br>16 Dec. 1988<br>7 Mar. 1989<br>2 May 1989 | % rebound determined by the release of a FIFA approved football (Mitre Delta 1000) inflated to 70 kPa from a 3 m high ball bounce apparatus. Four readings per sub-plot. |
| Ball deceleration | 3 Sep. 1987<br>4 Nov. 1987<br>14 Dec. 1987<br>8 Mar. 1988<br>20 Apr. 1988 | 6 Sep. 1988<br>1 Nov. 1988<br>16 Dec. 1988<br>8 Mar. 1989<br>No data | Ball deceleration was determined by change in velocity of the ball over a 2 m section of turf using infra red timing gates for determination of initial and final velocity. The ball was released down a 1 m high 45° ramp to provide standard initial conditions. Four readings per sub-plot. |
| Traction | 2 Sep. 1987<br>3 Nov. 1987<br>14 Dec. 1987<br>7 Mar. 1988<br>20 Apr. 1988 | 5 Sep. 1988<br>1 Nov. 1988<br>No data<br>7 Mar. 1989<br>2 May 1989 | Apparatus of Canaway & Bell (1986) excluding the transportation trolley. Maximum torque (N m) required to tear the turf surface. Four readings per sub-plot. |
| Hardness | 3 Sep. 1987<br>3 Nov. 1987<br>14 Dec. 1987<br>7 Mar. 1988<br>20 Apr. 1988 | 5 Sep. 1988<br>31 Oct. 1988<br>16 Dec. 1988<br>7 Mar. 1989<br>2 May 1989 | Clegg Impact Soil Tester (Clegg 1976). The peak deceleration (in gravities) of a 0.5 kg, 50 mm diameter test mass dropped from a height of 300 mm, was recorded on impact with the turf. Four observations per sub-plot. |
| Soil moisture content | 2 Sep. 1987<br>2 Nov. 1987<br>14 Dec. 1987<br>7 Mar. 1988<br>20 Apr. 1988 | 5 Sep. 1988<br>1 Nov. 1988<br>16 Dec. 1988<br>7 Mar. 1989<br>2 May 1989 | Soil cores, 50 mm in diameter and 30 mm trimmed depth were removed, three from each sub-plot, weighed fresh, dried at 105°C for 24 hours and reweighed. Moisture content was expressed as % of fresh weight. |
| Water infiltration rate | 28 Sep. 1987<br>22 Apr. 1988 | 8 Sep. 1988<br>3 May 1989 | A 1.8 m x 1.8 m ponding infiltrometer was used, one measurement per sub-plot. The infiltrometer was purpose built to encompass the position of three slit drains, normal concentric infiltrometers being rendered impractical by the presence of the slit drains. Water temperature was recorded and rates were standardised to 10°C. |
| Surface ponding from<br>until | 19 Oct. 1987<br>19 Apr. 1988 | from 3 Oct. 1988<br>until 12 May 1989 | Visual inspection of the trial daily at 1330 hrs for the presence of standing water (weekends and public holidays excepted). 119 recording days in the first season and 152 recording days in the second season. |

Due to equipment failures, data were not obtained for traction in December 1988 and for ball deceleration in May 1989.

Statistical analysis entailed analysis of variance of the split-plots model. Least significant differences (LSDs) were calculated at $p = 0.05$ for the different strata within the design. For the purposes of the present description, only the LSDs for the main effects of construction are presented.

## RESULTS

### Ground cover

Before wear, in both seasons (see Figs. 1 and 2) there were no significant differences among constructions, pre-wear ground cover averaging 92% in 1987 and 88% in 1988. In both seasons ground cover fell as wear progressed, but more rapidly on the constructionswith soil exposed at the surface, especially the PD construction. SD also fell more rapidly than the constructions with sand at the surface, but less rapidly than PD. In both seasons the maximum ground cover at the end of wear was c. 40%. In 1987/1988 season this occurred on the SS construction, but in 1988 it was on the SP, SC being intermediate in both cases.

### Ball rebound resilience

Results for ball rebound resilience are shown in Figs. 4 and 5. The results are characterised by small differences before wear, values being c. 40% in both seasons. The application of wear treatments soon led to a rapid deterioration in ball rebound on the PD construction, falling below the acceptable limit of 15% on four occasions in the two seasons. The SD construction deviated from the preferred range for ball rebound resilience (20-50%) on two occasions. On one occasion (December 1988) it fell into the acceptable but low category and on the other occasion (May 1989) it was in the acceptable but high category. All of the constructions with a sand playing surface remained in the preferred range for ball rebound resilience throughout both seasons.

### Ball roll

The results for ball roll are shown in terms of ball deceleration in Figs. 5 and 6. It must be noted that the greater is the deceleration, the slower is the ball roll and the smaller is the distance travelled by the ball. On six out of nine occasions there was no significant difference among treatments in the analyses of variance. Considering $2.2 \text{ m s}^{-2}$ to be the acceptable limit for ball deceleration, the PD construction failed on three occasions - December 1987, October 1988 and December 1988. All of these occasions were characterised by wet, muddy conditions and indeed, ball roll was so low that on some occasions during data collection the football failed to reach the second pair of timing gates on the PD construction. In such cases deceleration was calculated from the initial velocity and distance travelled. In October and

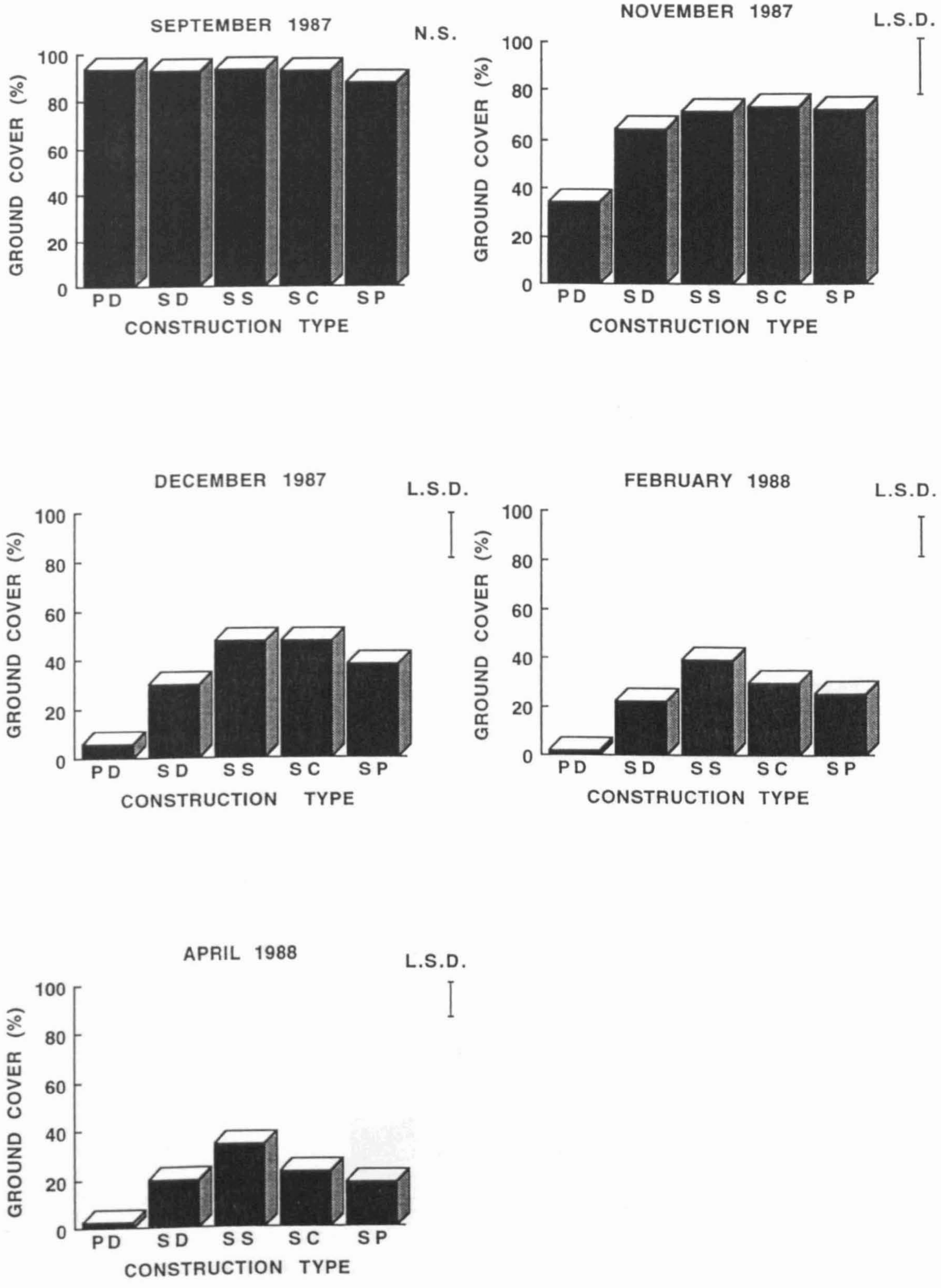


FIGURE 1. Ground cover of five construction types during 1987-1988. (PD = pipe drainage, SD = slit drainage, SS = slit drained with sand top, SC = sand carpet, SP = sand profile.) Vertical bars denote least significant difference (LSD, p = 0.05), N.S. = not significant.

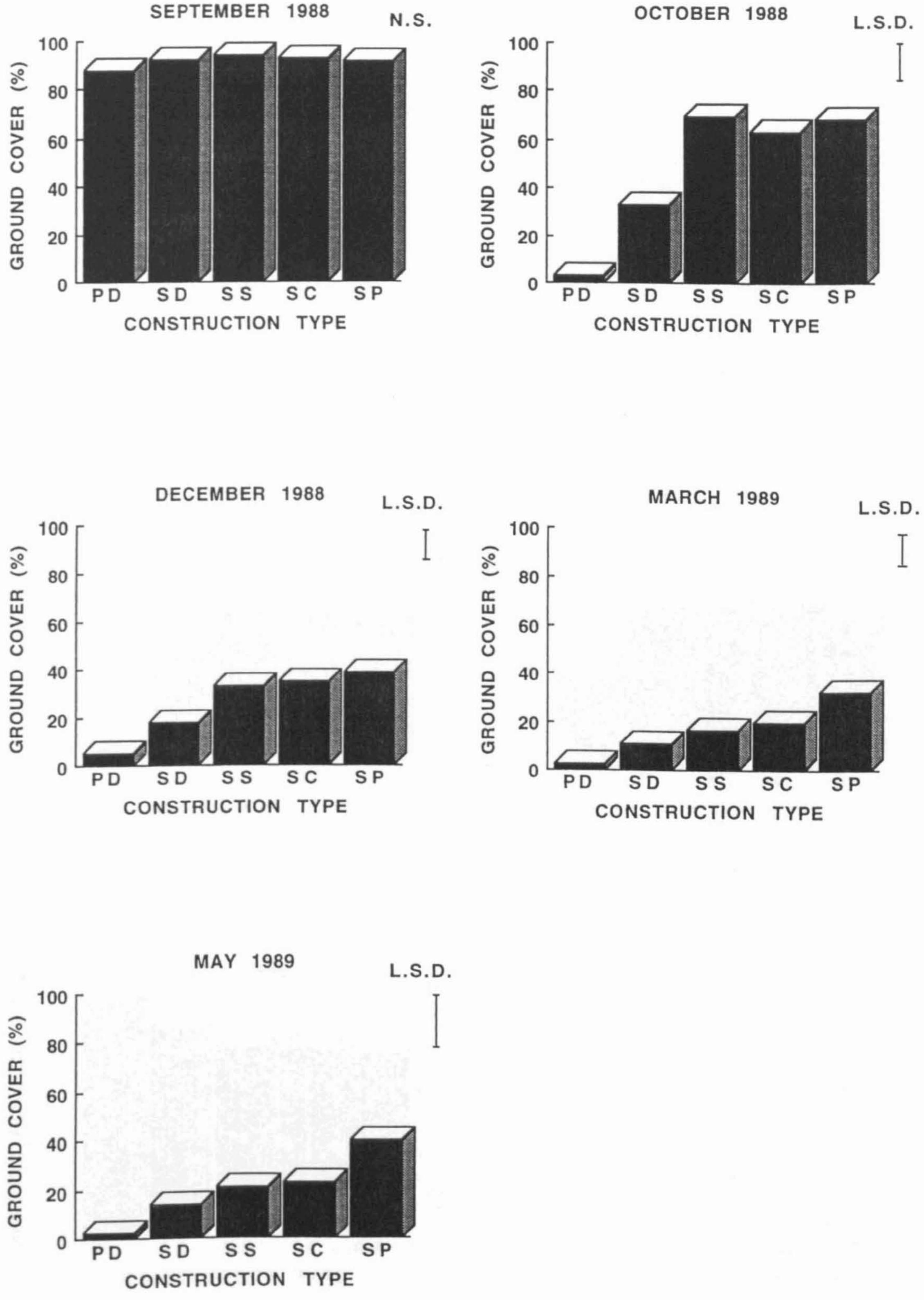


FIGURE 2. Ground cover of five construction types during 1988-1989.

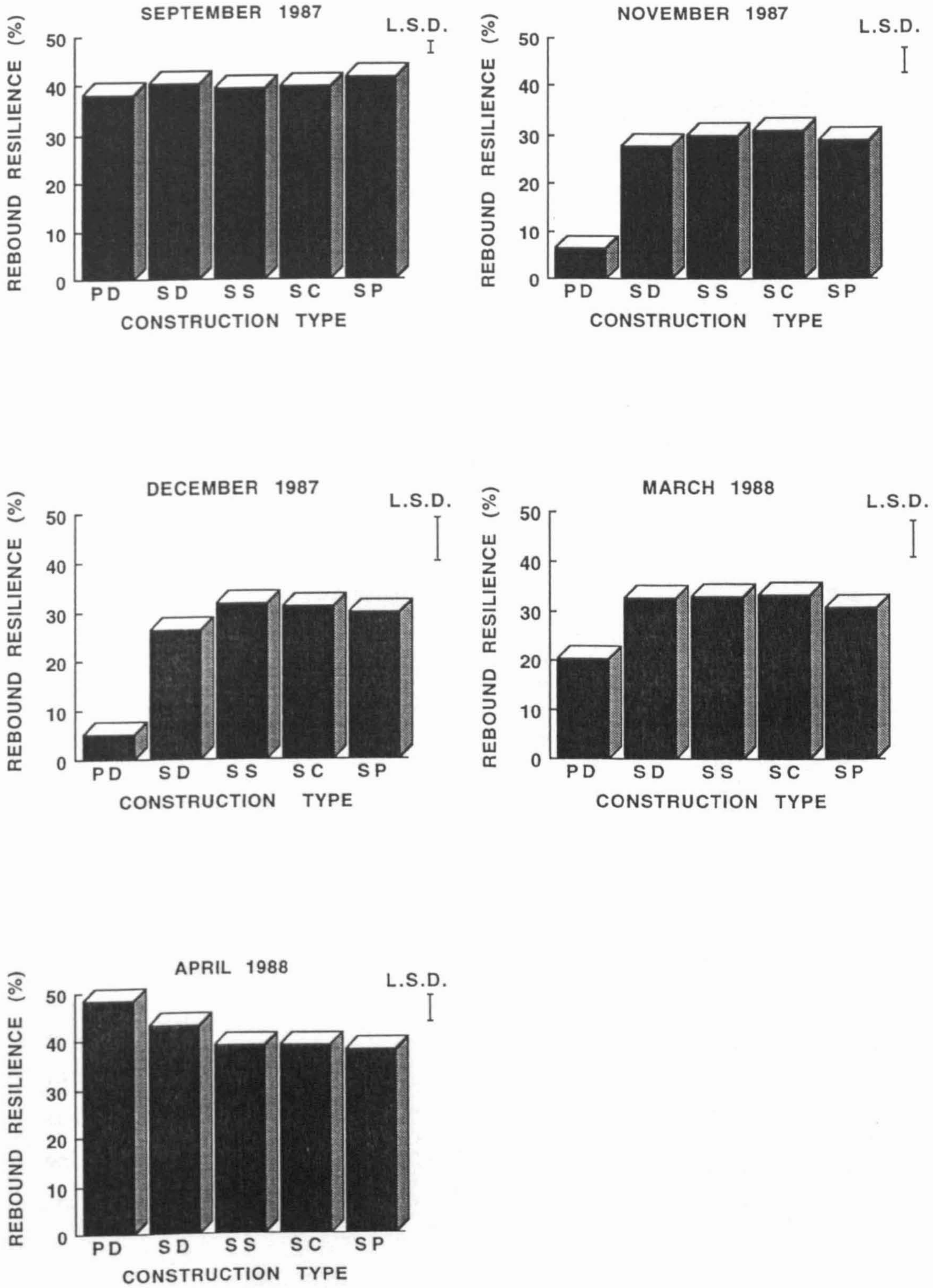


FIGURE 3. Ball rebound resilience for five construction types during 1987-1988. Vertical bars denote least significant difference (LSD p = 0.05) between means.

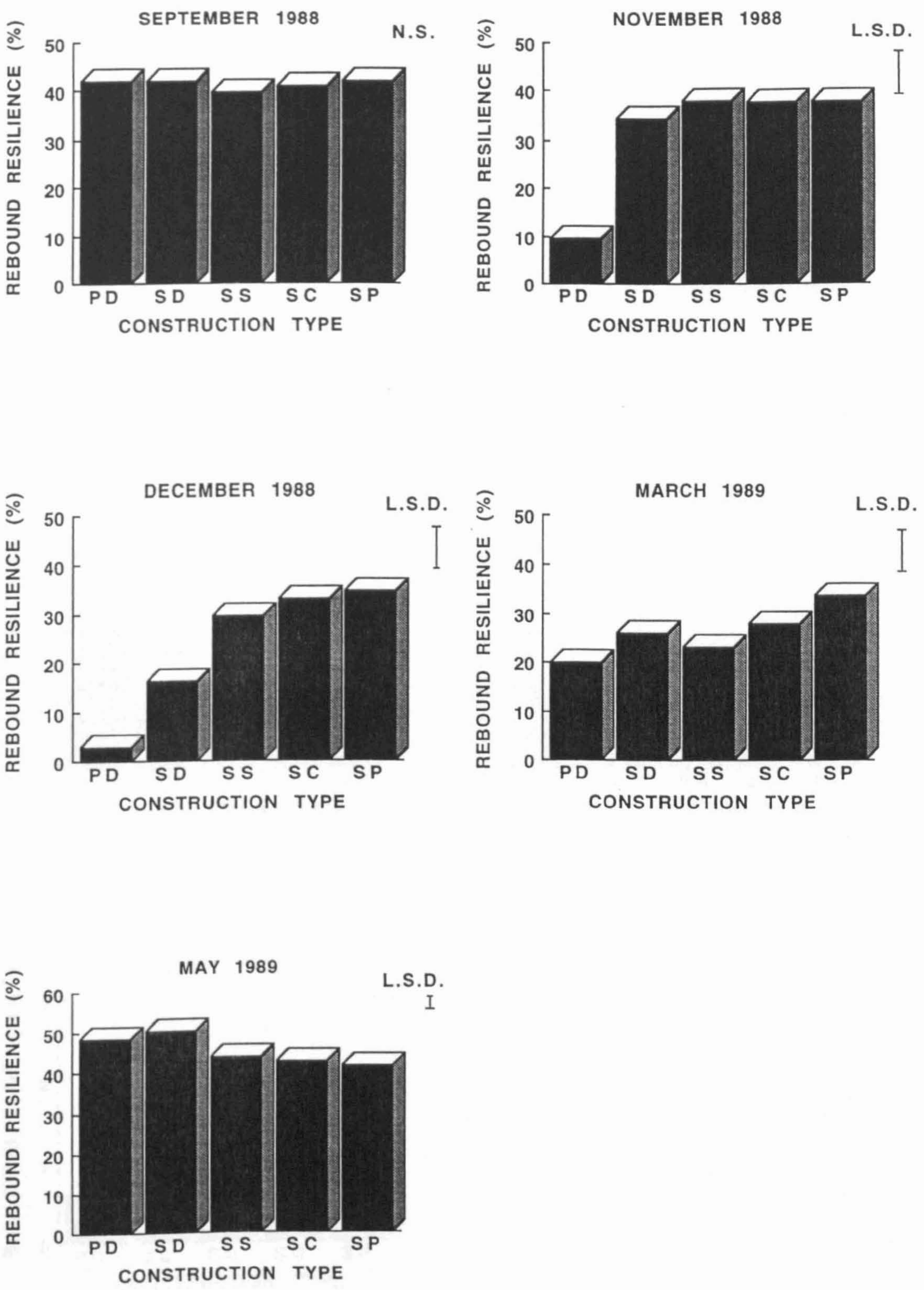


FIGURE 4. Ball rebound resilience for five construction types during 1988-1989. Vertical bars denote least significant difference (LSD $p = 0.05$) between means. N.S. denotes not significant.

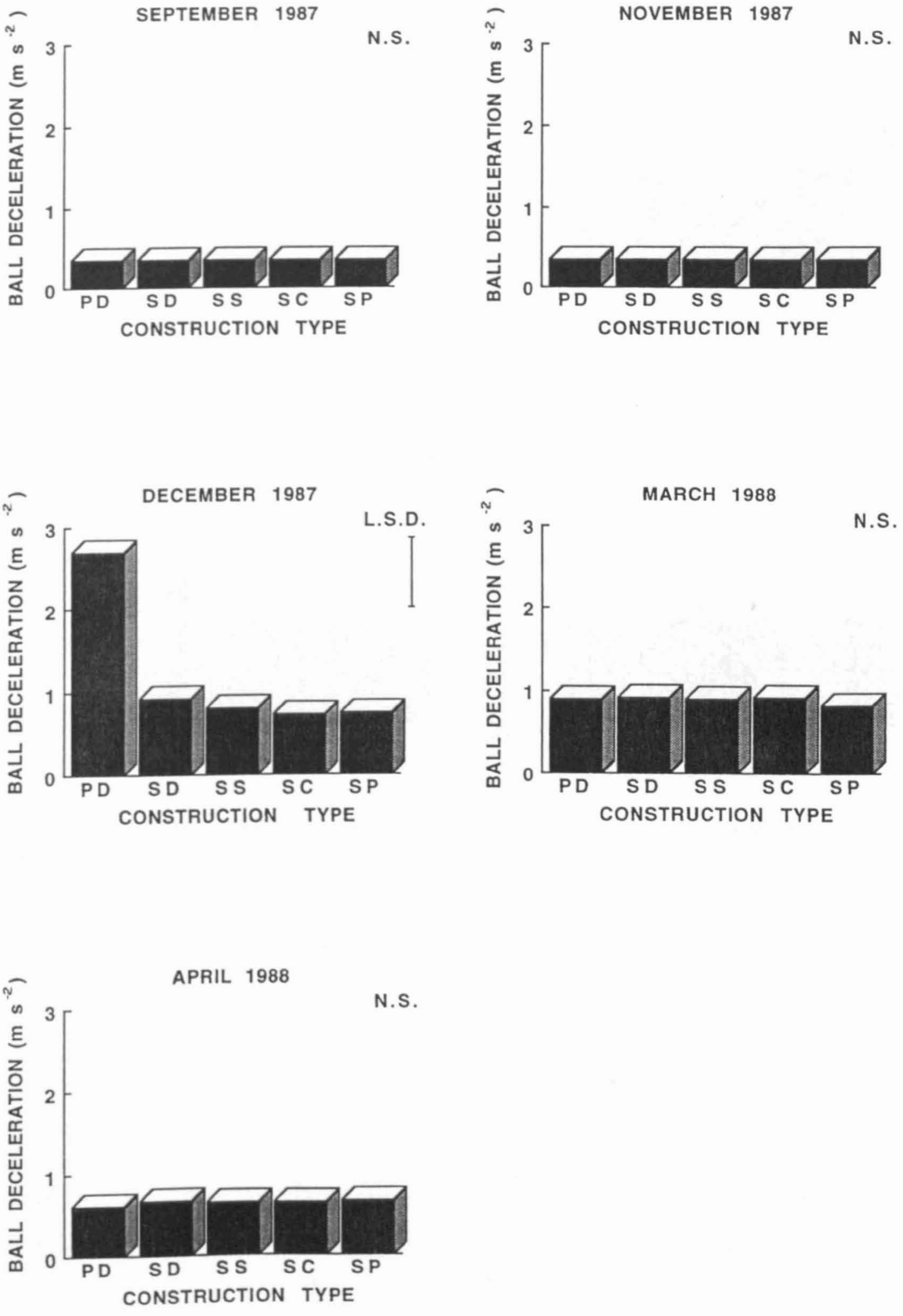


FIGURE 5. Ball deceleration for five construction types during 1987-1988. Vertical bars denote least significant difference (LSD p = 0.05) between means. N.S. denotes not significant.

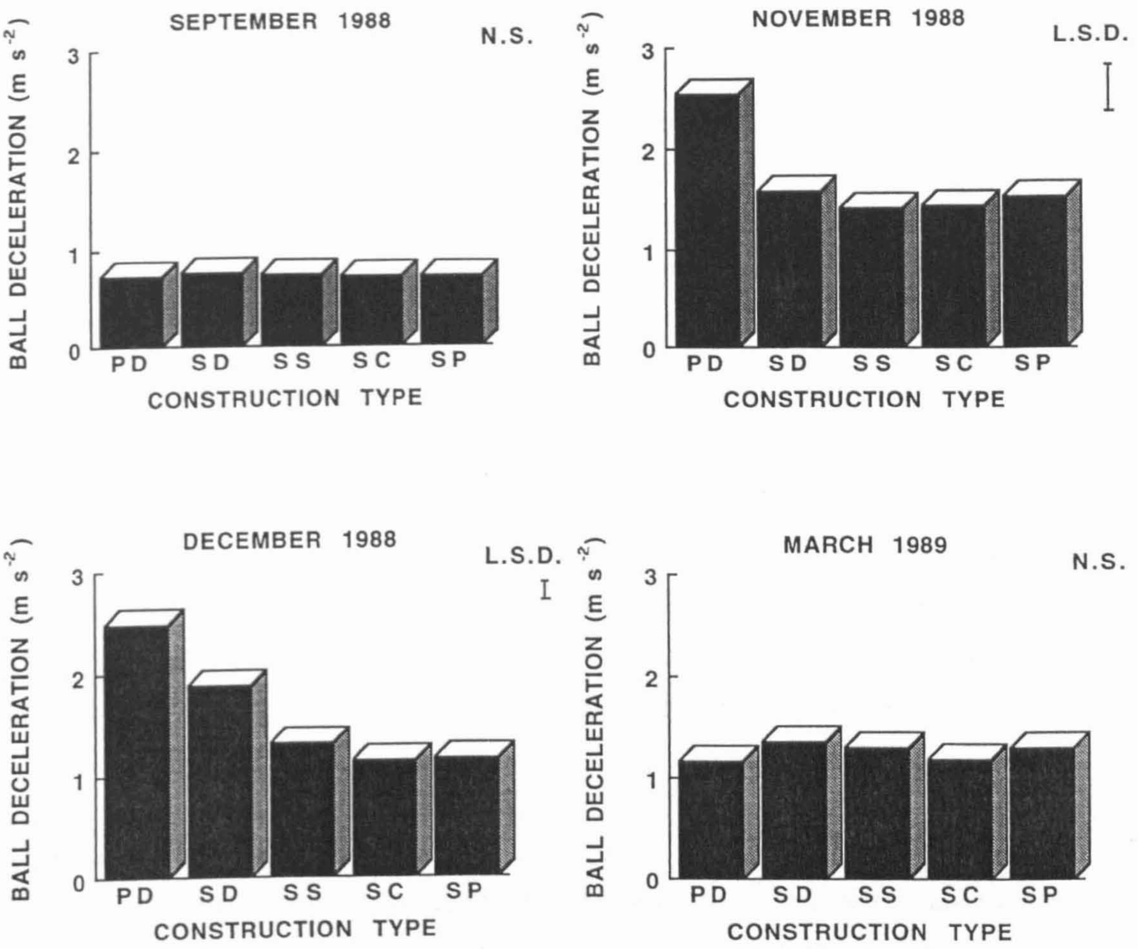


FIGURE 6. Ball deceleration for five construction types during 1988-1989. Vertical bars denote least significant difference (LSD p = 0.05) between means. N.S. denotes not significant.

December 1988 the SD construction exceeded the preferred limit of 1.5 m $s^{-2}$ and therefore was in the acceptable but slow category. All of the remaining constructions (SS, SC and SP) remained in the preferred range for ball roll throughout both seasons.

### Traction

Results for traction are shown in Figs. 7 and 8. Before wear in September 1987 there were no significant differences among treatments. In September 1988 the treatment effect in the analysis of variance was significant, but the values all lay in the range 47-54 N m and hence, were all well above the preferred minimum value of 25 N m. With the application of wear treatments combined with wetter ground conditions, traction on all constructions was reduced during the playing season, recovering again at the end of the playing season with the resumption of sward growth and prevalent drier conditions. The PD construction gave unacceptably low traction in December 1987 and March 1989 and acceptable but low traction in October 1988. The SD construction gave unacceptably low traction on one occasion (March 1989) and the SS, SC and SP constructions fell into the acceptable but low category (<25 N m but > 20 N m) in March 1989.

### Hardness

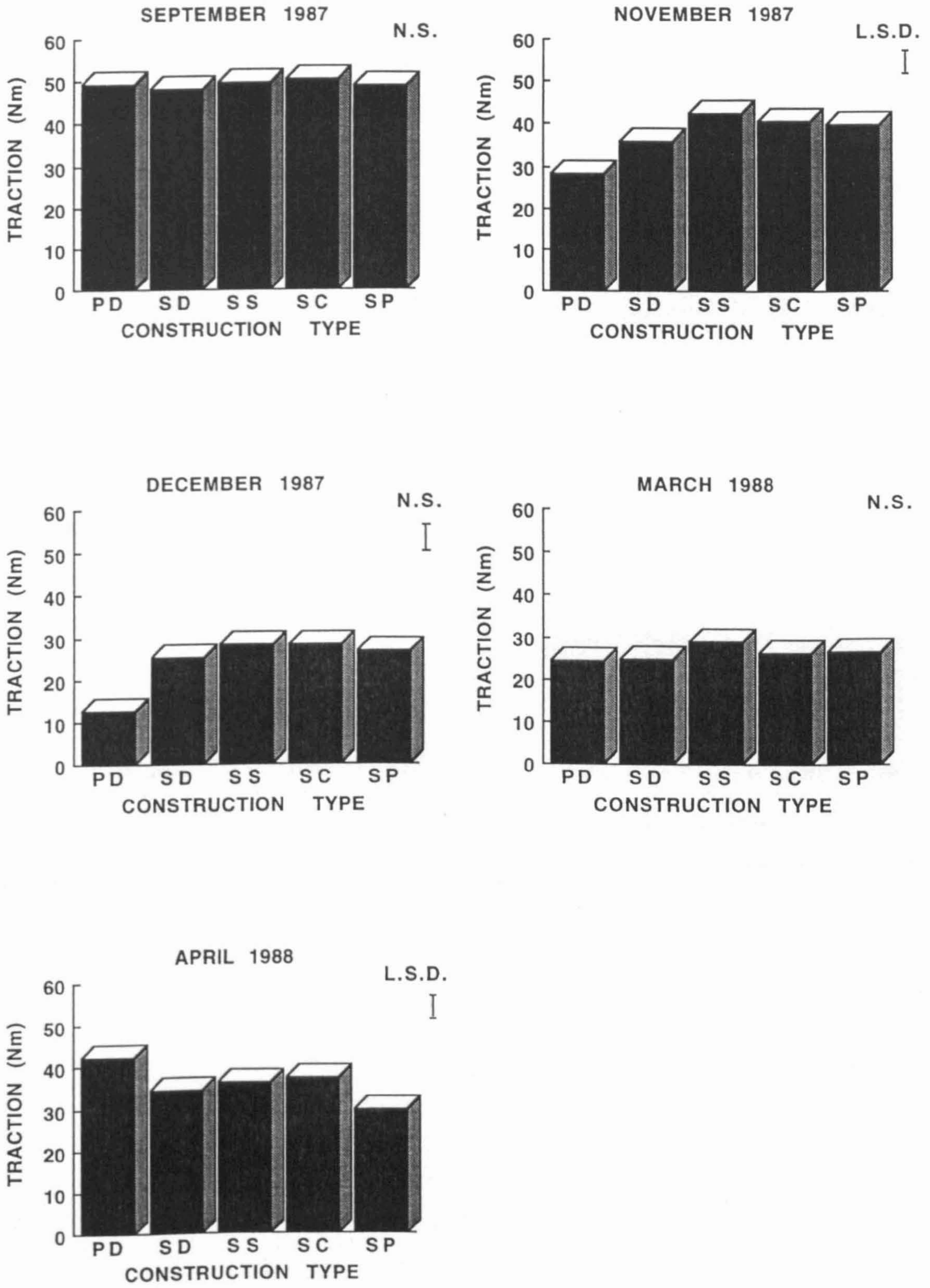
Results for hardness are given in Figs. 9 and 10. Before wear, in both seasons, there were no significant differences among treatments. During wear hardness was much reduced and then it increased again at the end of the playing season, especially on the PD and SD constructions. The PD construction was unacceptably soft in November and December 1987 and unacceptably hard in May 1989. The SD construction was in the hard but acceptable category in May 1989 and the SS, SC and SP constructions remained in the preferred range of hardness of 20-80 g throughout both playing seasons.

### Soil moisture content

Results for soil moisture content over the two playing seasons are given in Figs. 11 and 12. The results showed a clear general trend of decreasing moisture content with increasingly sophisticated construction type. As would be expected there was seasonal variation in moisture content imposed on the constructional effects, moisture content generally increasing in the winter months and decreasing again in the April and May measurements.

### Water infiltration rate and surface ponding

Detailed results for water infiltration rates and surface ponding were given in Chapter 2, Part 2, Figs. 2B and 3 and Table 1 and therefore the figures and the table are not repeated here. However, of all the data collected, water infiltration varied the most among treatments, ranging in September 1987 from 6 mm $h^{-1}$ on the PD construction up to 411 mm $h^{-1}$ on the sand profile. Although rates on the SP and SC declined during the course of the experiment



SEPTEMBER 1987

NOVEMBER 1987

DECEMBER 1987

MARCH 1988

APRIL 1988

FIGURE 7. Traction for five construction types during 1987-1988. Vertical bars denote least significant difference (LSD p = 0.05) between means. N.S. denotes not significant.

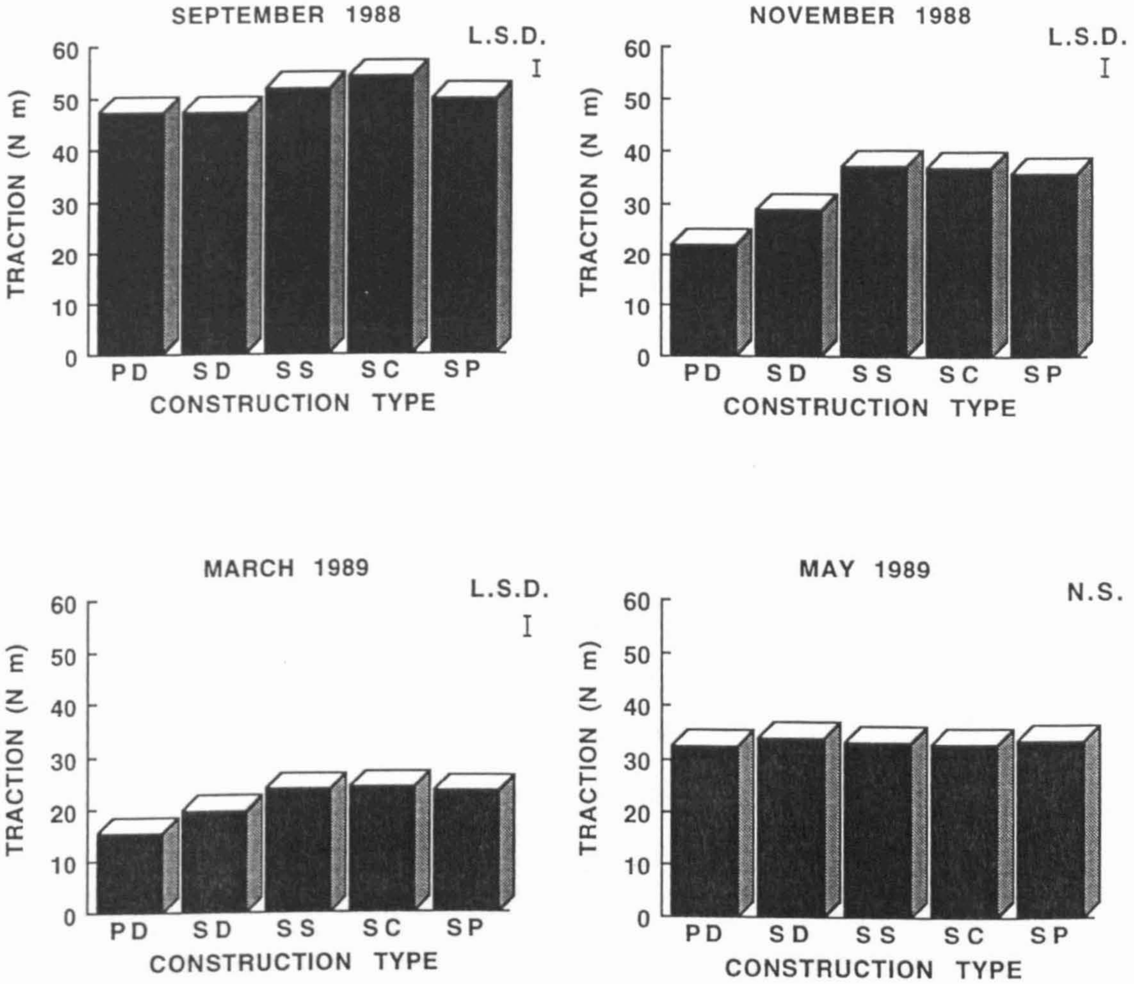


FIGURE 8. Traction for five construction types during 1988-1989. Vertical bars denote least significant difference (LSD $p = 0.05$) between means. N.S. denotes not significant.

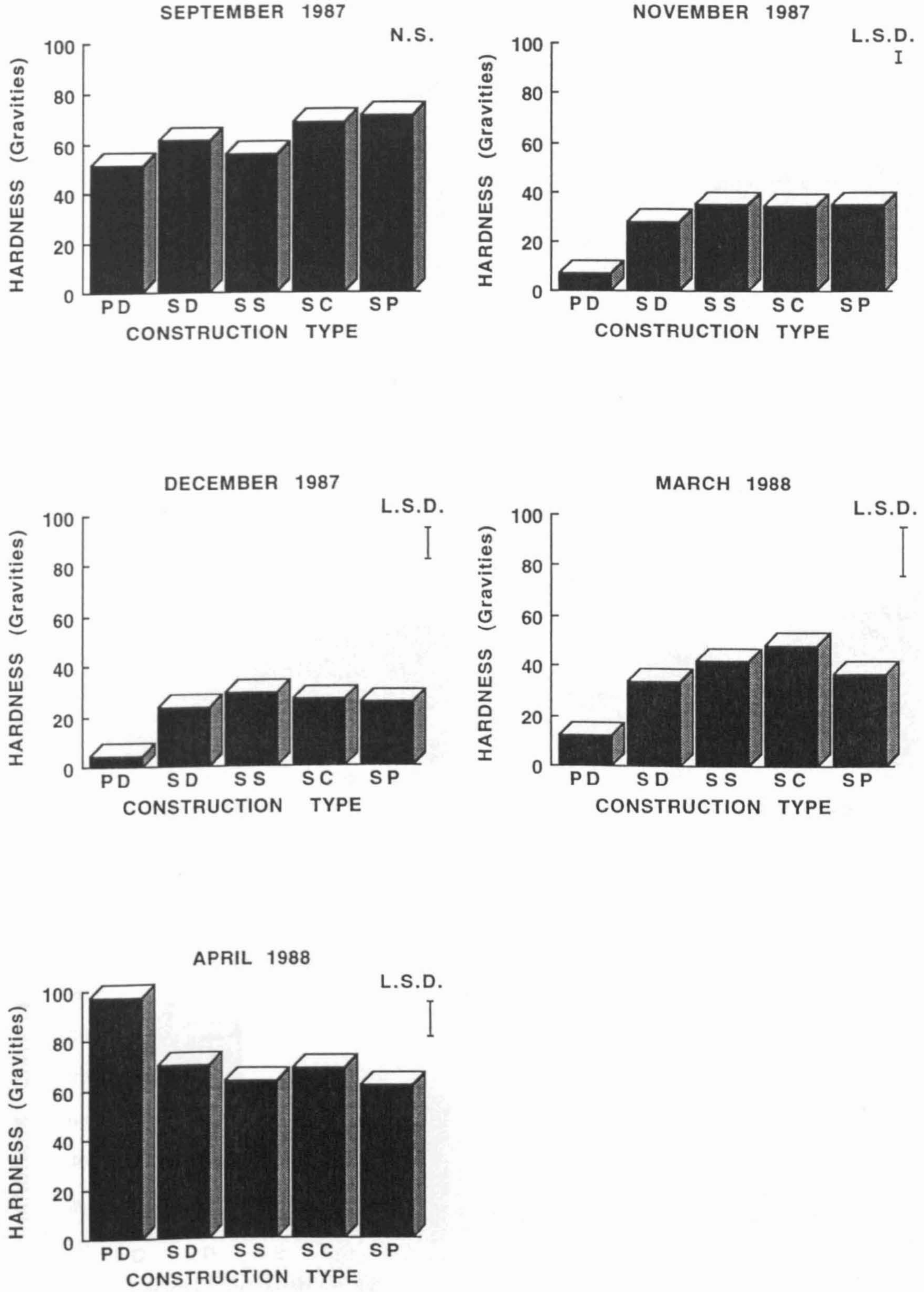


FIGURE 9. Hardness for five construction types during 1987-1988. Vertical bars denote least significant difference (LSD p = 0.05) between means. N.S. denotes not significant.

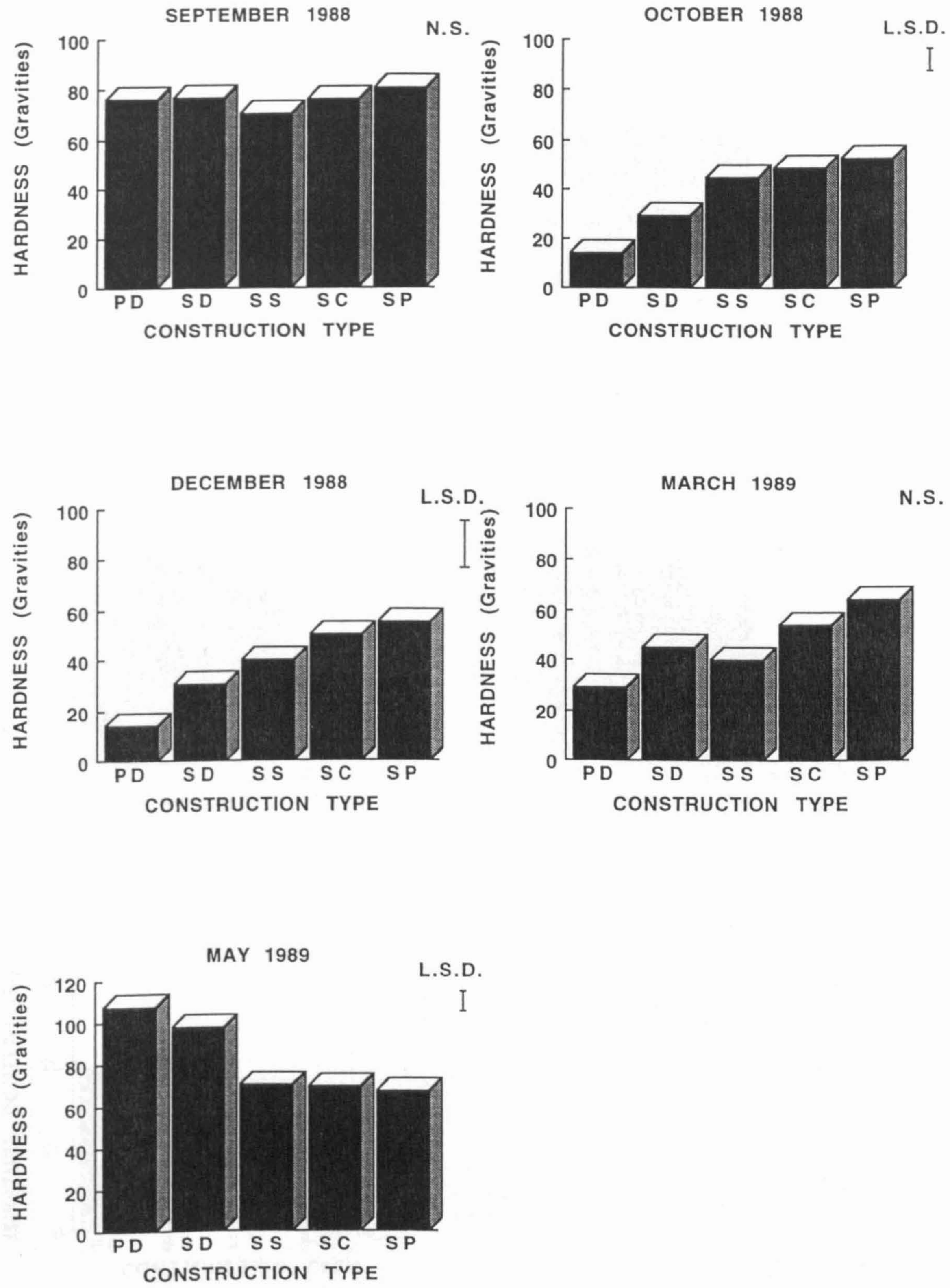


FIGURE 10. Hardness for five construction types during 1988-1989. Vertical bars denote least significant difference (LSD p = 0.05) between means. N.S. denotes not significant.

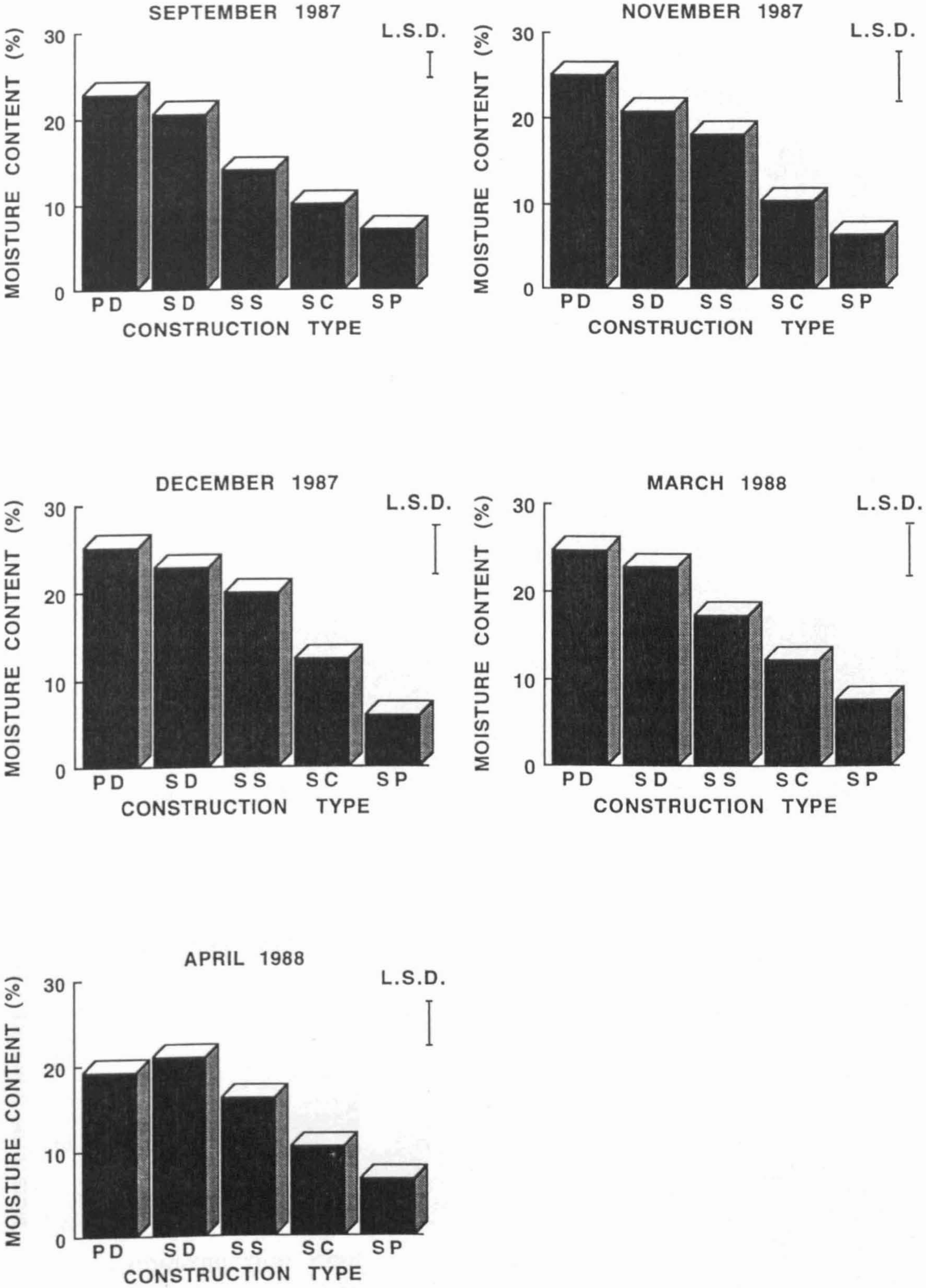


FIGURE 11. Soil moisture content (% fresh weight basis) for five construction types during 1987-1988. Vertical bars denote least significant difference (LSD p = 0.05) between means.

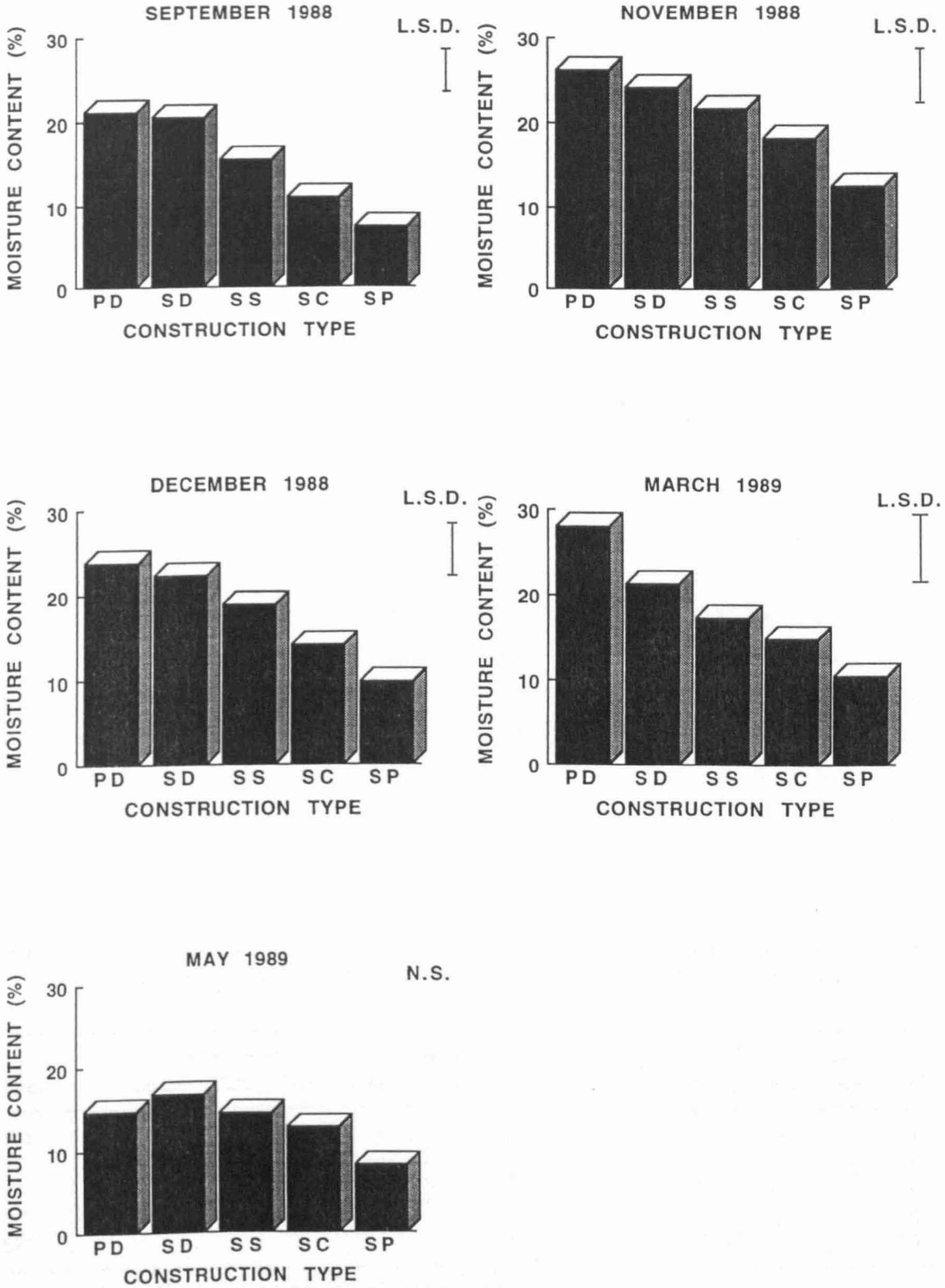


FIGURE 12. Soil moisture content (% fresh weight basis) for five construction types during 1988-1989. Vertical bars denote least significant difference (LSD $p = 0.05$) between means.

they remained sufficient for removal of most surface water, as reflected in the ponding results. In contrast, values on the PD plots fell as low as 0.5 mm $h^{-1}$ with ponding of surface water being frequently observed. On occasion water stood for 4-5 days on the PD plots after heavy rainfall. With the SD construction there was a significant interaction with top dressing treatment, many of the ponding records being observed on the SD sub-plots where no top dressing was applied.

## DISCUSSION

Ground cover and playing quality were greatly influenced by construction method, especially during the playing season. The pattern which emerged was one of small or non-significant differences before wear, with much larger differences developing during wear. Many of the differences which were observed during wear were a consequence of the high moisture content and low water infiltration rates observed on the PD construction and to a lesser extent on the SD construction, especially those sub-plots in the latter case, where no sand top dressing had been applied. Standing water was frequently seen which, by common observation, has a severely detrimental effect on playing quality. For example, referees will frequently cancel a match if there is standing water on the pitch even though there is minimal danger to the players. The performance of the five constructions in terms of playing quality is summarised in Table 4, which shows the extent to which the different constructions met the proposed playing quality standards given in Chapter 2, Part 1, Table 1. These it will be recalled, give 'preferred' limits, slightly wider 'acceptable' limits, outside which playing quality would be considered unacceptable.

TABLE 4
Classification of playing performance for seasons 1987-1988 and 1988-1989 showing the number of times the different constructions met the preferred or acceptable standards for playing or conversely were unacceptable

| | Ball rebound | | | Ball roll | | | Traction | | | Hardness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pitch | Unacc. | Acc. | Pref. | Unacc. | Acc. | Pref. | Unacc. | Acc. | Pref. | Unacc. | Acc. | Pref. |
| PD | 4 | - | 6 | 3 | - | 6 | 2 | 1 | 6 | 3 | 4 | 3 |
| SD | - | 2 | 8 | - | 2 | 7 | 1 | 1 | 7 | - | 1 | 9 |
| SS | - | - | 10 | - | - | 9 | - | 1 | 8 | - | - | 10 |
| SC | - | - | 10 | - | - | 9 | - | 1 | 8 | - | - | 10 |
| SP | - | - | 10 | - | - | 9 | - | 1 | 8 | - | - | 10 |

Unacc. = unacceptable, Acc. = acceptable, Pref. = within preferred range.

It was notable that the SS, SC and SP constructions remained in the preferred range throughout the playing season for ball rebound, ball roll and hardness. Only on one occasion (March 1989) did these three constructions fall into the low-acceptable category for traction, remaining in the preferred range for the eight other dates of assessment. These findings have major implications for improvement and/or reconstruction of sports fields and in turn, the cost-effectiveness of the higher specification constructions (SS, SC and SP) must be considered.

Clearly the results showed that pipe drainage alone is not a cost-effective means of improving sports field drainage, since unacceptable playing conditions are still likely to occur with standing water, a frequent occurrence. The problem here is that the water is simply not getting through to the drains. With slit drainage a bypass system is provided and hence, the significant improvement seen. However, the slit drains were readily capped by the transfer of soil from areas between slits rapidly reducing their effectiveness. A significant further improvement in performance was seen with the incorporation of a shallow 25 mm sand top in the SS construction. This greatly enhanced the effectiveness of the slit drainage system and for the most part was not significantly different in terms of playing quality from the SC and SP constructions. In practice, the sand top can be achieved either at the construction stage (as in the SS construction) or by subsequent heavy sand top dressing. In the part of the experiment concerned with top dressing reported elsewhere (Baker & Canaway 1990, 1992) it was shown that the performance of the SD construction could be greatly enhanced, nearly to that of the SS construction by the application of high rates of sand top dressing. Conversely SD sub-plots with no top dressing deteriorated into a condition similar to that of the PD areas. It follows from the above that if pipe drainage is installed it should only be done as part of a programme involving subsequent installation of slit drains and a sand top. If slit drainage is installed at a cost of c. £22,000 per pitch, this will be largely wasted unless there is a commitment to maintaining the integrity of the slits, either through installation of the sand top during the construction process, or subsequently through top dressing. This cannot be stressed enough.

In consideration of the relative cost-effectiveness of the SS, SC and SP constructions, clearly there is a high variation in cost from c. £25,000 for the SS construction to c. £110,000 for the sand profile. Is the extra cost worthwhile? On the basis of the playing quality results, the answer would be no. However, consideration of the data on water infiltration rates and particularly the data on the presence of standing water on the surface give a different picture. In the two playing seasons surface ponding was observed on 28 days on the SS, 7 days on the SC as was only of transient occurrence on the SP (<1 day). The cost-effectiveness of these constructions then largely depends on how essential it is that play can take place. For a professional football club who must play at 3.30 pm on a certain date come what may, and with a large loss of gate revenue at stake, it is worthwhile investing in the most free-draining construction. The same would apply to top flight amateur clubs where sufficient funds were available for construction and sufficiently skilled ground staff available for maintenance of these more demanding sand profile constructions. Examples include the Metropolitan Police sports club at Imber Court, near Esher, Surrey and the Don Valley Stadium, Sheffield. For schools and local authorities wishing to install a good quality pitch, with less demanding maintenance but where play cannot be completely guaranteed, the choice is between the SS and SC constructions and there are pros and cons to both. The sand carpet, because of the

100-150 mm sand layer is nutritionally more demanding (see Chapter 4) and normally requires an irrigation system with consequent additional costs. However, the relatively thick sand layer acts as a buffer in the event of heavy rain, with consequently fewer days when surface ponding occurs. Also the thick sand layer completely protects the integrity of the underlying slit drainage system. Examples of successful sand carpet constructions include numerous examples in Northern Ireland, e.g. Queen's University, Belfast and nearer to home, Westholme School, Blackburn and local authority pitches in the Blackburn area. SS constructions are of significantly lower cost than sand carpets, therefore for the cost of one sand carpet we could build two or more SS pitches. In view of the observed playing quality SS pitches are therefore attractive at least in the short-term. The main problem is maintaining the integrity of the slit drainage system. The 25 mm thickness of sand can be disrupted by play, exposing the underlying soil which then has potential for capping the slit drains if further spread by players. Examples of successful SS constructions can be found at Leeds Grammar School and several other grounds.

In conclusion, pipe drainage alone was not found to be a cost-effective means of pitch improvement. Slit drainage could be but was found to be vulnerable to the action of wear in capping the slit drains, hence reducing their effectiveness. The presence of a sand layer over the slits provided a good quality playing surface, as did the more costly sand carpet and sand profile constructions. Which of these three latter constructions is actually chosen depends on finance available and the degree to which surface ponding can be tolerated.

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# PART 4
## GOLF GREEN AGRONOMY AND PLAYING QUALITY – A REVIEW OF PAST AND CURRENT TRENDS

### SUMMARY

The growth of turfgrass science parallels the growth in the game of golf. A brief historical review is made of trends in Britain and in the USA. The overall picture is one of steady growth in research and development in the USA contrasted with slower progress in Britain further disrupted by two World Wars.

The aim of golf green management is to provide good conditions for the player, defined here as playing quality. Various groups of factors affect playing quality which include: sward factors; soil factors; wear; external factors and management factors. Components of playing quality include: ball roll (green speed); ball bounce (rebound resilience); ball impact behaviour and hardness. Methods of measurement of playing quality are briefly described and some examples from a golf green study are given.

Finally, attention is drawn to the need for a more 'ecological' approach to understanding of the multivariate data encountered in golf green research. Examples of the use of principal components analysis in a golf green experiment are given.

### INTRODUCTION – TRENDS IN BRITAIN AND THE USA

"Golf - it is a science - the study of a lifetime, in which you may exhaust yourself but never your subject" (D.R. Forgan, cited by Beard 1982).

The growth of turfgrass science seems to have paralleled the growth in the game of golf. In Scotland there were only 43 courses prior to 1880 but 266 by 1910 (Price 1989). A similar upsurge in the number of courses occurred in the USA between 1895 and 1900, and an even larger growth took place between 1920 and 1930 (Beard 1982). Turfgrass research had started in the USA in the late nineteenth century and a milestone was reached with the publication in 1917 of the work 'Turf for Golf Courses' by the pioneering agronomists C.V. Piper and R.A. Oakley. Europe at this time, however, was plunged deep in the horror of the 'Great War' and the need was for agricultural production. It is no surprise therefore that when course construction resumed after the Great War agricultural principles were often invoked in course management. This was despite the fact that it had been realised even before the Great War that golf turf and agricultural grassland were of a greatly different nature. Hall (1912) stated "The use of potash manures should be avoided on the golf links, and lime or fertilisers containing lime, such as basic slag, must be used with discretion". In 1920 in his famous treatise on golf architecture Mackenzie (1920) stated succinctly: "It must be borne in mind that the turf required for a golf course is entirely different to that required from a farming point of view". Despite these, and similar observations agricultural practices of liming and use of lime-containing fertilisers continued. Beale (1924) describing the construction of a golf course on heathland stated "That an ample provision must be made in the budget for chalk, manure and fertilisers". "It (lime) counteracts sourness ..... and practically no form of manure can feed turf satisfactorily without the co-operation of lime". Meanwhile in the USA matters had progressed further with the formation in November 1920 of the United States Golf Association (USGA) Green Section. In the UK the work of Piper and Oakley became known, Oakley visiting in England in 1926 where he established a rapport with Norman Hackett a keen amateur and businessman who was later influential in setting up the then Board of Greenkeeping Research (now The Sports Turf Research Institute) in 1929. Much was achieved in improving courses according to 'non-agricultural' principles until the outbreak of war again in Europe in 1939. In post-war years the research effort into golf agronomy in Britain dwindled through lack of funds in contrast to the vast growth in agricultural research. In the USA, on the other hand, steady progress was made on all fronts. One of the consequences of this imbalance in research in the USA and Britain led to the adoption of American practices on British golf courses, particularly the use of heavy fertilisation programmes coupled with lavish irrigation. This, together with injudicious use of lime, led once again to the old mistake being made such that during the 'sixties' and 'seventies' many greens became *Poa annua* dominated 'sponge puddings' incapable of sustaining winter play, totally at variance with the sound principles outlined by the early golf constructors and agronomists. Mackenzie (1920) wrote "The course should be equally good during winter and summer .....". Piper & Oakley (1917) stated "good grass turf is conditioned by two great factors, climate and soil. The latter can be modified but the former must be accepted as it is". Piper and Oakley were keenly aware of the climatic differences between the USA and Britain and strove to adopt agronomic practices accordingly. The corollary, of course, is that we can not expect to transplant agronomic practices wholesale from the USA to Britain and expect success, failure is guaranteed in the long run, even if temporary success in the short-term is achieved. Mackenzie (1920) in his usual concise manner stated "A common mistake in greenkeeping is to imagine that because one form of treatment benefits one course that it will necessarily benefit another". Mackenzie was referring to different courses within Britain but the argument applies even more strongly when comparing conditions in Britain on the one hand and the USA on the other hand. The main climatic differences between Britain and the northern parts of the USA are the greater extremes of heat in summer and cold in winter experienced in the USA.

In Britain cool summers, mild winters and rainfall fairly evenly distributed throughout the year make for favourable growing conditions for grass and also permit golf to be played all year round. Fortunately recent years have seen a return to more "British" management of golf courses with more judicious use of water and fertiliser. The abandonment once again of the use of lime and an increase in the amount of research in Britain largely due to the initiative of the Royal and Ancient Golf Club of St Andrews (R & A). Readers interested in the inter-relation between changing fashions within the game and agronomic practices in Britain should read the series of articles written by Park (1986). In the USA golf-orientated research has continued to prosper with numerous research programmes at different research institutions. The USGA Green Section Research Summary for 1988 (Anon. 1989) listed 21 different USGA funded projects at 14 different Institutions ranging through turfgrass breeding, water usage, pathology, soil compaction and information science. The estimated budget for 1989 was $620,300 - an impressive programme indeed. In Britain, from 1985 to 1990 the R & A financed projects on sand green nutrition, control of fairy rings and studies on the behaviour of golf balls impacting with the green and it also financed work on construction, nutrition and irrigation of golf greens, potassium and phosphorus requirements of fine-leaved fescues and bents, and work on the phenomenon of "dry patch" where parts of greens become hydrophobic.

The development of golf course agronomy in Britain and the USA over the last 70 years provides a stark contrast, with the USGA Green Section providing continuity and a well organised but practically orientated research programme. In Britain on the other hand we have seen a large and highly successful publicly funded agricultural research sector but no continuity of funding for turfgrass research. The result has been a stop-go process of learning interrupted by two World Wars, and furthermore the lessons of the past were often forgotten with dire consequences. As Park (1986) expresses it: "The British game *is* golf, the best and original concept. Or, if it is not the best, we have only ourselves to blame".

## AIM OF GOLF GREEN MANAGEMENT – PLAYING QUALITY

It may seem a statement of the obvious that the aim of golf green management should provide good conditions for play together with aesthetic appeal. Whilst an aesthetically pleasing and beautiful environment is an important part of the golfing experience, on the green itself - where the game is won or lost, playing quality is of paramount importance. Whilst this seems a simple objective of management, the means of achieving it are complex (see Fig. 1).

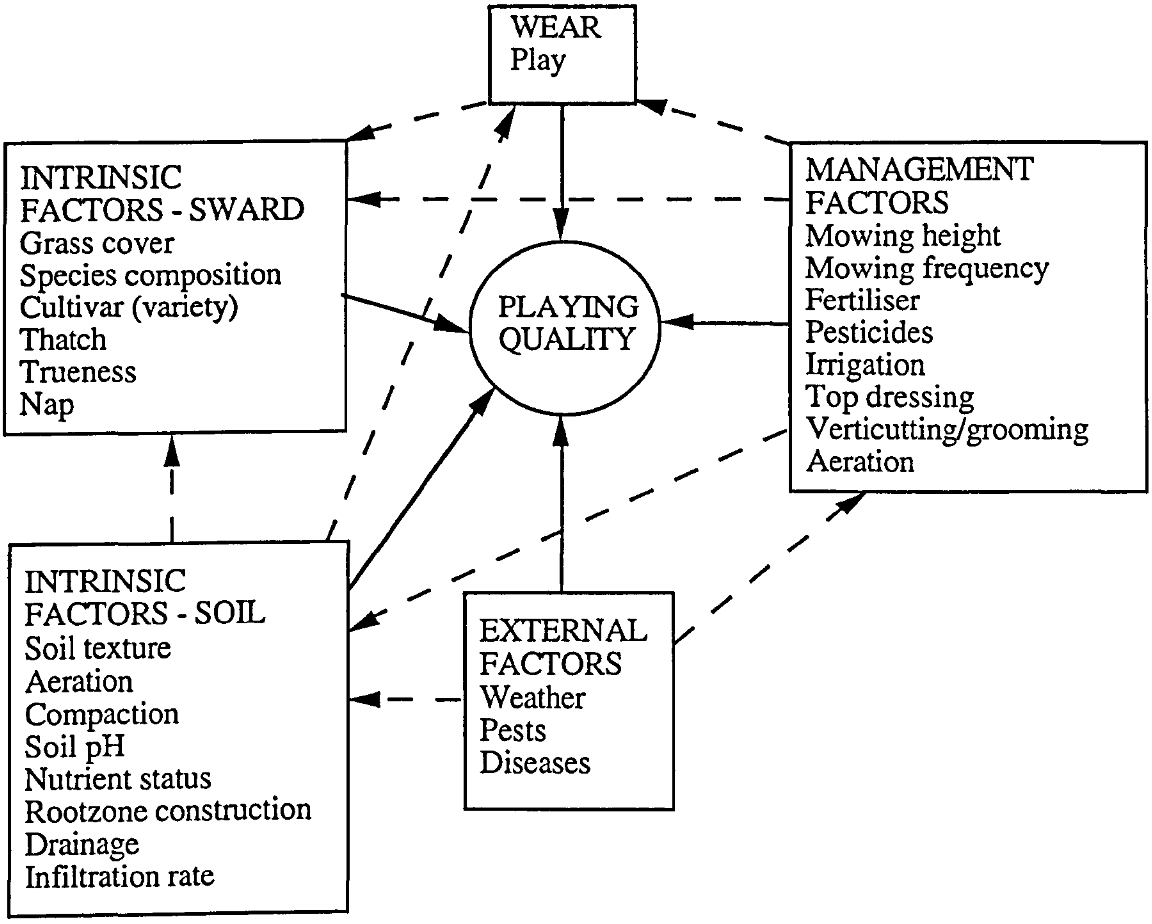

FIGURE 1. Schematic illustration of factors affecting playing quality of golf greens. Thick arrows indicate direct effects on playing quality, dashed arrows indicate some of the more important interactions amongst the main factor groupings.

Similarly although the botanical composition of the sward is extremely simple - usually one or two sown species - the means of maintaining that sward are also potentially complex in terms of the interactions between numerous variables which affect species composition and hence playing quality. These variables are illustrated schematically in Fig. 1.

The factors are considered in terms of major groupings: the 'given' or intrinsic factors, plant and soil; the management factors; the 'external' factors including environmental factors such as rainfall etc. which have been grouped under 'weather' together with pests and diseases; and last but not least the effects of wear due to play. It can be seen at once that there are a great number of variables to consider, many of which can be sub-divided further, e.g. fertiliser-nitrogen, phosphorus, potassium etc. and many of which can also be considered in terms of a quantitative range of the factor in question, e.g. the possible range of mowing *heights* and *frequencies*, fertiliser *rate* and so forth. It is not my intention to review agronomic progress on all these areas since this is the scope of a text book, a number of which already exist, e.g. Madison (1970); Beard (1973 and 1982), Turgeon (1985), but rather to illustrate the *multivariate* nature of the system we are dealing with. Add the further dimension of *time* - bearing in mind that golf greens should be considered as permanent - and we have a very complex problem to analyse, particularly in view of the strong inter-relation between groups of variables.

As was stated earlier, although the objective of producing a green which plays well is a simple one, the means of arriving at it are potentially very complex. By contrast most agronomic research into golf green related problems entails, usually by financial necessity, small experiments to investigate just one or two variables. It follows that multi-factor experiments combined with multivariate approaches to analysis are likely to be a fruitful way forward for research on golf green management. Such methods are widely used in ecological research and perhaps a more 'ecological' approach is sometimes needed. Before considering examples of such methods we might use it if necessary to clarify what is meant by 'playing quality'.

## PLAYING QUALITY

Playing quality can be defined as the subject of variables which determine whether a particular surface is good for the sport in question (Canaway 1985). For golf greens, components of playing quality include:- ball roll, ball bounce (low energy, e.g. short chip), ball impact behaviour including effects of spin (e.g. iron shot to the green) and green hardness.

### Ball roll or green 'speed'

Ball roll or green 'speed' measured as the distance rolled by a golf ball when released from a standard ramp known as the 'Stimpmeter' (Stimpson 1974, Radko 1977, 1980; Thomas 1978) is one of the few components of playing quality to have been widely studied, particularly at the instigation of the USGA which has published standards for the speed of greens at different levels of play (Radko 1977, 1980). This is the sole example of a published standard for playing quality of greens and is given in metric form in Table 1.

### Ball bounce

Ball bounce, or more correctly, ball rebound resilience, can be measured using a simple apparatus where a ball is released from a standard height and the rebound observed against a graduated scale. In an experiment concerned with the fertiliser nutrition of sand greens (Canaway *et al.* 1987, Colclough & Canaway 1988, Colclough 1989), a 5 m high apparatus was used together with a video camera to record the data. Scale intervals were set at 1% of the height of the apparatus, i.e. every 50 mm so that the percentage rebound could be recorded directly. On the sand green tested, rebound values were low and the typical response of rebound to fertiliser nitrogen is shown in Fig. 2 where bounce increased with increasing nitrogen (Colclough 1989).

TABLE 1

Standards for the speed of golf greens using the USGA green speed test

| | Distance rolled (m) | Green speed rating |
|---|---|---|
| For regular membership play | 2.59 | Fast |
| | 2.29 | Medium fast |
| | 1.98 | Medium |
| | 1.68 | Medium slow |
| | 1.37 | Slow |
| For tournament play | 3.20 | Fast |
| | 2.90 | Medium fast |
| | 2.59 | Medium |
| | 2.29 | Medium slow |
| | 1.98 | Slow |

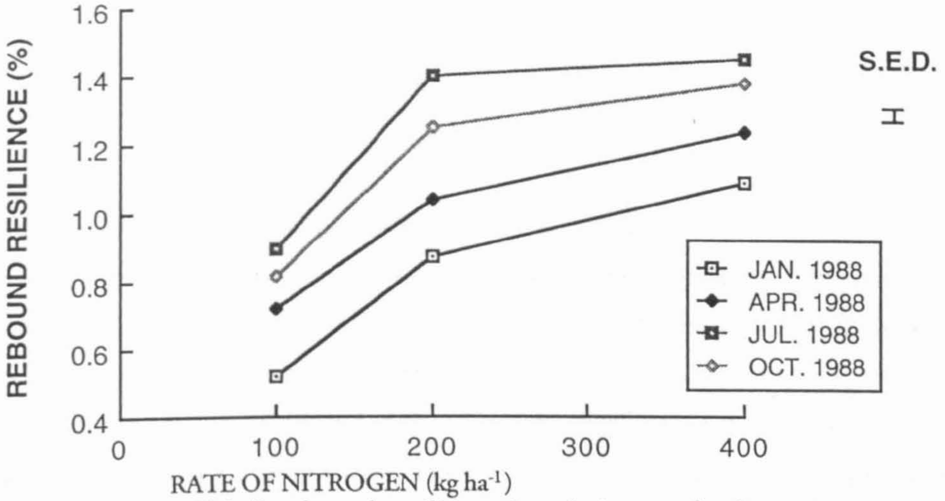

FIGURE 2. Golf ball rebound resilience in relation to fertiliser nitrogen on all sand green constructions.

## Ball impacts

Recent work by Haake (1987, 1989) on the ball impact properties of greens has been fruitful in developing apparatus and test methods, and in providing some preliminary results on the behaviour of different greens. The system consists of a ball projecting device and stroboscope-camera arrangement to record the impacts. Colclough (1989) used the ball projecting device to produce data on green "holding power" in response to different fertiliser treatments. Titleist 384 balls fired at the turf with a velocity of 19 m s$^{-1}$ and a backspin of approximately 5500 rpm and at an angle of 55°. The horizontal distance from the ball's pitchmark and its final resting point was measured. Fig. 3 shows the response of the distance it took balls to stop in relation to fertiliser nitrogen. Stopping distance decreased with increasing nitrogen, i.e. the ability of the green to hold the ball increased with increasing nitrogen. It has to be said that this arrangement can be criticised since the total distance from the pitchmark to its final resting position is comprised of two phases:- the initial bounce or bounces; and then a rolling phase. Reduction in the distance it takes the ball to stop can thus be achieved by a reduction in either the bouncing or the rolling phase, or both. Nonetheless the method showed significant differences amongst fertiliser treatments as shown in Fig. 3.

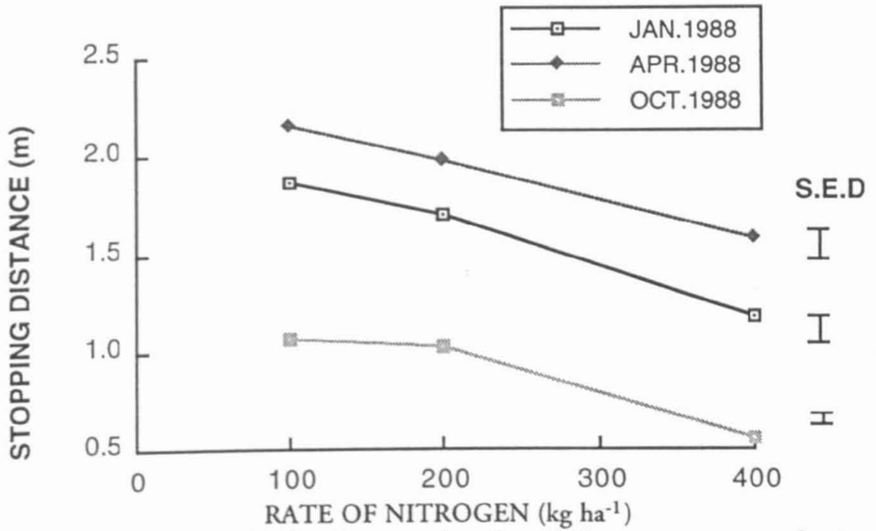

FIGURE 3. Changes in the distance taken for a ball to come to rest after impacting on the green in relation to fertiliser nitrogen on an all sand green.

### Hardness

Hardness of greens is of importance in its relation to bounce and holding power. A mechanical 'hardness tester' was developed for greens by Buchanan (1984) which consisted of a spherical metal indenter, the diameter of a golf ball, which was dropped on greens from a standard height and the degree of penetration observed. In recent years, however, instrumented tests for measuring hardness in sports turf have been used such as the Clegg Impact Soil Tester (Canaway *et al.* 1987, Colclough & Canaway 1988, Colclough 1989, Rogers & Waddington 1989) the latter also using a Bruel and Kjaer Vibration Analyser for this purpose. The use of the Clegg Impact Soil Tester (Clegg 1976) for measurement of hardness on football pitches was described in Part 1 of this Chapter and the same principles apply to its use on a golf green. The harder is the green the higher is the value of deceleration experienced by the hammer. The apparatus is extremely quick and easy to use, enabling many readings to be taken from test areas. Results for green hardness in relation to applied nitrogen on sand greens are shown in Fig. 4, hardness decreasing with increasing nitrogen rate (Colclough 1989).

Other methods of measuring hardness on sports turf were reviewed by Bell *et al.* (1985).

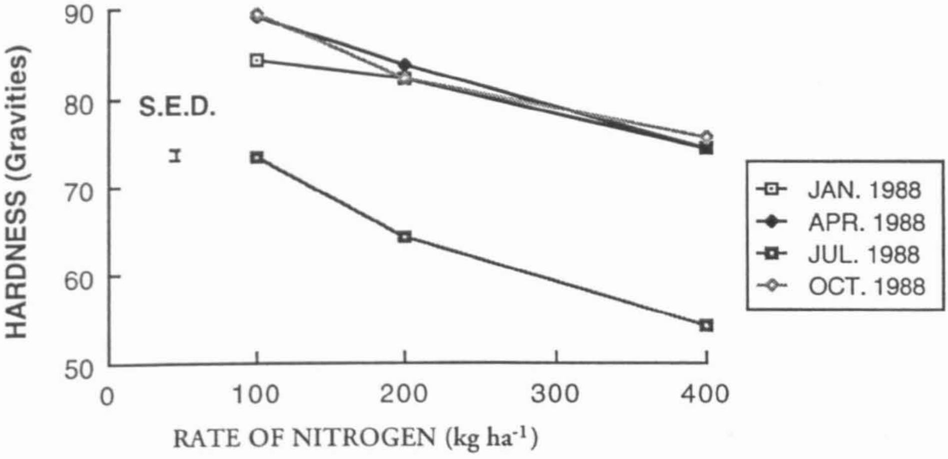

FIGURE 4. Response of hardness to fertiliser nitrogen on an all sand green.

In summary, playing quality measurements are a useful and player-orientated supplement to traditional agronomic measurements of grass cover, species composition and so forth, and the methods described are, in some cases, e.g. ball rebound resilience, extremely sensitive in detecting out differences between different agronomic treatments, in the examples given, differing fertiliser treatments. For routine measurement ball roll, hardness and ball bounce are relatively straightforward to measure. The holding power test requires the relatively cumbersome ball firing device and there is the uncertainty over the relative sizes of the bouncing and rolling phases after impact, particularly at different rates of backspin. In future, playing quality measures will become more important, particularly if standards for the different components of playing quality are devised in an analogous manner to the USGA standards for green speed.

## AGRONOMY OR ECOLOGY

It could be argued that the science of soils and vegetation on golf courses has more in common with ecology than agronomy, particularly if one includes the wildlife and conservation aspects. To many people agronomy has connotations of crop production rather than its broader dictionary definition as the science of land management and rural economy which certainly does encompass golf course science. Furthermore to add to this impression the well known 'Agronomy Journal' is almost entirely devoted to crop science despite the handful of turfgrass science articles which appear in its pages. Many golf course advisers have their background in agricultural science and even if they have eschewed agricultural principles as applied to golf courses the methods and working practices persist, which we could caricature as the "feed, spray and water" approach. Ecologists by contrast frequently deal with natural or semi-natural ecosystems, multivariate in nature and have accordingly developed methods for understanding them divergent from the agricultural approach. There may come a time in the not so distant future, when because of environmental and other considerations we can no longer "feed, spray and water" as we do now. Therefore, we should consider some of the possible ecological approaches to the interpretation of complex data structures. These range from simple data presentation techniques such as star diagrams, triangular ordinations - similar to the soil textural triangle with which readers may be familiar - to more formal multivariate statistical methods. For an overview of the subject the reader should consult an appropriate text such as Digby & Kempton (1987). An example is given here of the use of one of the many possible multivariate methods - that of the use of principal components analysis in a golf green experiment. The experiment has already been referred to above (Canaway *et al.* 1987, Colclough & Canaway 1988, Colcough 1989) and the principal components analysis was done by Lodge (unpublished). The experiment was concerned with fertiliser nutrition of sand greens and contained three levels each of nitrogen, potassium and phosphorus, with, and without, lime. Data collected from the trial included botanical, playing quality and soil data.

Principal components analysis aims to summarise multivariate data by representing the experimental data in a smaller number of dimensions whilst retaining as much of the original variation as possible. It also allows the data to be represented graphically in an easily comprehensible form. Whilst it is not intended to go into detail, suffice to say that the major axes of variation within the data are expressed as 'components' (component 1, component 2, etc) which can subsequently be identified, it is hoped, with one of the variables being studied. In addition these variables can be plotted on the ordination diagram as lines or 'vectors' from the origin which help to show not only the relationship of components and variables but also the relationships amongst variables. Such diagrams are known as 'biplots'. Figs. 5 and 6 show biplots for the sand green fertiliser experiment.

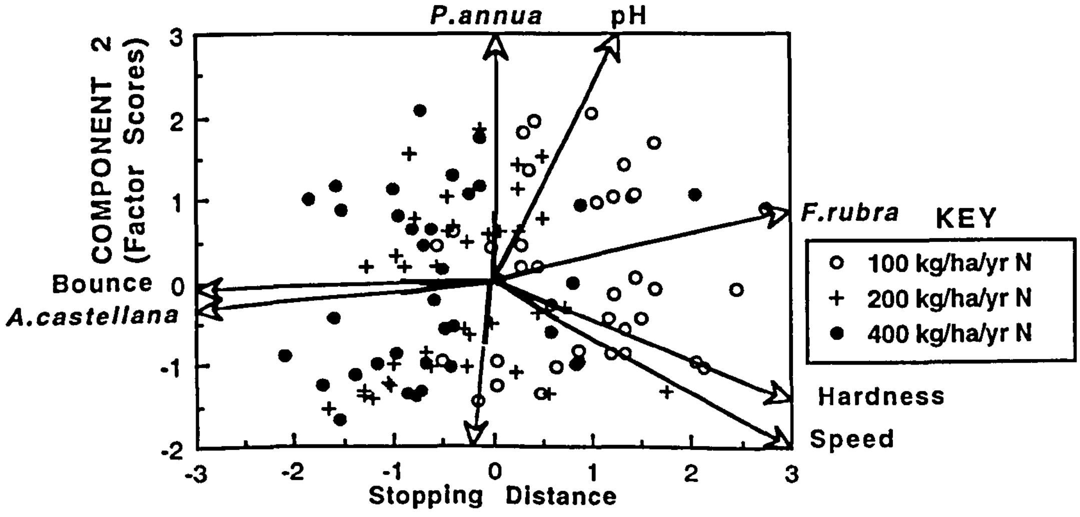

FIGURE 5. Biplot for a fertiliser trial on a pure sand green. Component 1 represents mainly variation in nitrogen content, and component 2 the effect of lime.

Figure 5 shows a biplot in which the individual data points are marked according to the level of nitrogen applied. Most of the low (100 kg ha$^{-1}$ yr$^{1}$ N) treatments occur on the right of the biplot and the high (400 kg ha$^{-1}$ yr$^{1}$ N) occur on the left and as such, component 1 is interpreted into terms of changing nitrogen level. It can also be seen that bent (*Agrostis*) content, and ball bounce increased with increasing nitrogen but fescue (*F. rubra*) hardness and speed increased with decreasing nitrogen. In the second biplot, component 2 is emphasised (Fig. 6).

Component 2 is related to the application of lime treatments which, combined with the different acidifying rates of the acidifying nitrogen fertiliser ammonium sulphate here given rise to different levels of soil pH. Data points with, and without, the lime treatments are shown. Soil pH and content of *Poa annua* (annual meadow-grass) are closely related. The vector for green speed is at 45° to components 1 and 2 and is therefore affected by both lime and nitrogen, green speed increasing with less nitrogen and in the absence of lime. Clearly, similar biplots can be produced for the other fertiliser treatments in the experiment or, indeed, for a wide variety of other situations. Their use provides a relatively straight forward graphical representation in contrast to the more cumbersome tables of means for 'main effects' and 'interactions' in this type of factorial experiment.

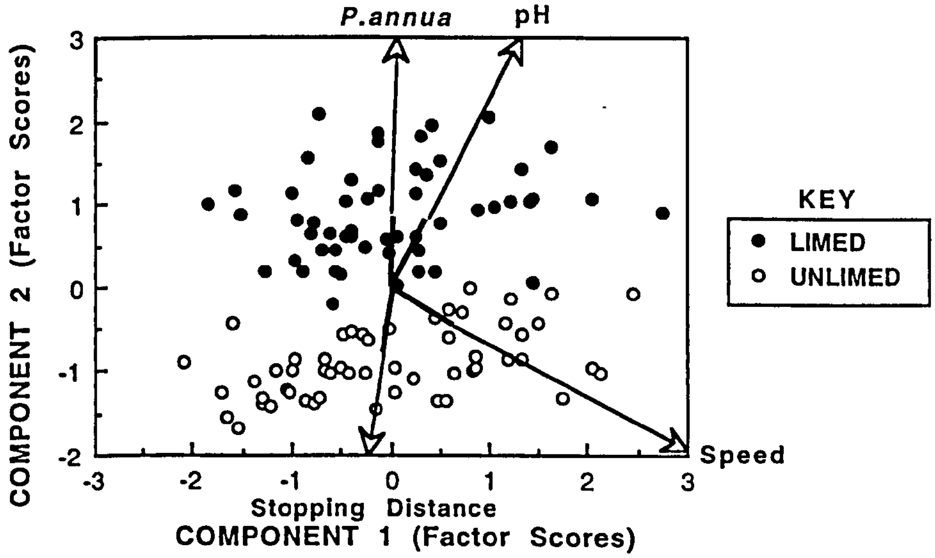

FIGURE 6. Biplot for fertiliser trial on a pure sand green. Component 2 is emphasised in relation to the application of lime.

Looking towards the future I foresee a greater need for a more 'ecological' approach to golf course science not only in the restricted sense of understanding and manipulating data but also in the wider sense of appreciating the environmental implications of golf especially with regard to use of pesticides, fertilisers and water. The wildlife and conservation value of golf courses will also grow in importance as other green areas are lost to agriculture, housing development and road building. Pesticide and fertiliser use will become more restricted due to legislation and water use by availability and cost. It is therefore prudent to prepare the ground by further research into these areas so we are well prepared when the legislator comes knocking at the door.

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# PART 5

# AN EXPERIMENT ON THE BALL ROLL CHARACTERISTICS OF FIVE TURFGRASSES USED FOR GOLF AND BOWLING GREENS

## SUMMARY

Ball roll tests were carried out to determine the green speed on five turfgrasses: *Festuca rubra* ssp. *litoralis* 'Dawson', *F. rubra* ssp. *commutata* 'Frida', *Agrostis capillaris* 'Bardot', *A. castellana* 'Highland' and *Poa annua.* Measurements were made on four occasions for bowls and three for golf under variations in mowing height and surface moisture. Averaged over all assessment dates *F. rubra* ssp. *litoralis* provided the fastest surface for both golf and bowls, and *P. annua* was consistently the slowest. *Agrostis* species did not provide the fastest playing surface on any occasion, although 'Highland' ranked second overall for bowls. Surface moisture decreased green speed and a reduction in cutting height generally increased it, although there were some inconsistencies. In view of the differences found it is suggested that further research should be carried out on playing quality of grass species and cultivars.

## INTRODUCTION

In Part 4 of this Chapter ball roll properties of fine turf for golf greens were discussed. In bowls, where the bowl remains in contact with the turf during its entire travel from hand to jack, ball roll behaviour is of great importance. A ball (or bowl) decelerates as it moves across the playing surface because of the effects of rolling resistance, which can be considered as a force acting at the point of contact between the ball and the surface in a direction opposing that of forward motion (Bell *et al.* 1985). The effects of rolling resistance are referred to by players in terms of green "speed", the "faster" is the surface, the lower is its rolling resistance and *vice versa.* Although bowlers and golfers would both agree on what is a fast green the means of characterising the surface have developed in different directions in the two sports. In flat green bowls the method which has been developed and generally used has been to record the *time taken in seconds* for a biased bowl to travel from the bowler's hand and come to rest within 0.15 m of a jack (target ball) sited 27.4 m (30 yards) away. Because on a fast surface the bowl decelerates more slowly it can be released at a lower initial velocity and it also travels in a wider arc, this leads to the seemingly paradoxical situation where a fast green has a higher value, e.g. 15 s, than a slow green, e.g. 12 s. Bell & Holmes (1988) studied the speed of 74 bowling greens and obtained questionnaires from 774 bowlers to determine minimum standards for green speed and these, together with earlier standards, are given in Table 1. No upper limits were proposed for green speeds, players generally equating faster greens with a demand for a greater level of skill.

In golf the approach has been to measure the *distance rolled* by a golf ball when released from a standard ramp known as the stimpmeter (Stimpson 1974). Because of the importance of green speed in tournament conditions, a green speed test comparison table was proposed by the United States Golf Association (USGA) as long ago as 1977 (Radko 1977). This is reproduced in its metric equivalent in Table 2 (also given in Part 4 but repeated here for ease of reference).

TABLE 1
Standards for green speeds on bowling greens

| Source of reference | Green speed(s) | Subjective description |
|---|---|---|
| Escritt (1978) | 15 | Fast |
| | 10 | Slow |
| Anon. (1983) | 15 | Very fast |
| (Converted by Bell & Holmes | 12 | Satisfactory |
| 1988) | 10 | Slow |
| Bell & Holmes (1988) | 12 | Preferred minimum speed |
| | 10 | Acceptable minimum speed |

TABLE 2
USGA green speed test comparison table (Radko (1977) after conversion to SI units)

| | Distance rolled (m) | Green speed |
|---|---|---|
| Regular membership play | 2.59 | Fast |
| | 2.29 | Medium-fast |
| | 1.98 | Medium |
| | 1.68 | Medium-slow |
| | 1.37 | Slow |
| Tournament play | 3.20 | Fast |
| | 2.90 | Medium-fast |
| | 2.59 | Medium |
| | 2.29 | Medium-slow |
| | 1.98 | Slow |

Because of its ease of operation the stimpmeter has been widely used in the USA, both in preparation of courses for tournaments (Thomas 1978) and in research studies, for example, the effects of mowing (Engel *et al.* 1980), cultivars of ryegrass for overseeded greens (Batten *et al.* 1981, Dudeck & Peacock 1981). In the UK Lodge & Baker (1991) studied the effects of irrigation, construction and fertiliser nutrition on golf green speed. However, there have been no systematic studies of green speed of different grasses used for fine turf. The objective of the work therefore was to study the green speed for both bowls and golf of some grass species commonly used for fine turf in the UK.

## MATERIALS AND METHODS

### Trial construction and management

The trial was conducted on a loamy sand soil (9% clay, 10% silt, 81% sand) at the Sports Turf Research Institute, Bingley (NGR SE 095 391). The average slope in the direction of roll was <0.01%. The trial was laid out in four randomised blocks with the plots of the different grasses being 7.5 m in length by 1 m width. The five grasses included in the work and their sowing rates were as follows:

| | |
|---|---|
| *Festuca rubra* L. ssp. *litoralis* (G.F.W. Meyer) Auquier 'Dawson' (slender creeping red fescue) | 35 g m$^{-2}$ |
| *Festuca rubra* L. ssp. *commutata* Gaud. 'Frida' (Chewings fescue) | 35 g m$^{-2}$ |
| *Agrostis capillaris* L. 'Bardot' (browntop bent) | 10 g m$^{-2}$ |
| *Agrostis castellana* Boiss. & Reuter 'Highland' (Highland browntop bent) | 10 g m$^{-2}$ |
| *Poa annua* L. "Commercial" (annual meadow-grass) | 35 g m$^{-2}$ |

The seedbed fertiliser was a 15:9:15 ($N:P_2O_5:K_2O$) material containing IBDU and 2% MgO, which was applied at a rate of 50 g m$^{-2}$. Both seed and fertiliser were applied on 20 June 1986 and the subsequent maintenance treatments are given in Table 3.

TABLE 3
Maintenance treatments

| | |
|---|---|
| Mowing | First cut on 30 July 1986 at 50 mm and the cutting height was gradually reduced through the first year of growth reaching 10 mm on 1 December 1986. The cutting height was further reduced in 1987, down to 8 mm on 3 April, 6 mm on 1 June and 5 mm on 22 June. |
| Fertiliser | The total fertiliser inputs (kg ha$^{-1}$) were:<br>N $P_2O_5$ $K_2O$<br>1986 170 45 107 in three applications including seedbed fertiliser<br>1987 155 0 64 in four applications<br>The 1986 fertiliser programme included compound granular fertilisers plus ammonium sulphate. The 1987 programme included ammonium sulphate, potassium sulphate, sulphate of iron and dried blood. |
| Irrigation | During seedling establishment and until 24 July 1986 the trial was watered on a total of ten occasions to ensure that the seedbed remained moist. Thereafter no irrigation was applied, except for the light applications to wet the surface during monitoring work (see main text). |
| Top dressing | One light application of a 3:1 mix of sand and sterilised compost in 1986 and two applications of 1.5 kg m$^{-2}$ in 1987. |
| Mechanical treatments | The trial was verticut on six occasions between 29 July 1987 and 5 October 1987 and spiked on eight occasions between 3 April 1987 and 24 December 1987. |

## Measurement techniques

For bowls, green speed was obtained by releasing an unbiased bowl from a height of 0.5 m down a standard ramp (Bell & Holmes 1988) inclined at an angle of 30° to the horizontal. Six measurements were made on each plot with three tests in opposite directions. The distance travelled (R, in metres) and the time taken before the ball stopped (T, in seconds) were recorded. Green speed (in seconds) was calculated using an equation given by Bell & Holmes (1988).

$$\text{Green speed} = \sqrt{\frac{27.4}{R/T^2}}$$

TABLE 4
Measurement dates, cutting height and antecedent rainfall

| Date (1987) | Bowls | Golf | Cutting height mm | Antecedent rainfall (mm) | | |
|---|---|---|---|---|---|---|
| | | | | Previous day | Previous 3 days | Previous week |
| 29 May | ✓ | | 8 | 1.6 | 1.6 | 5.2 |
| 1 June | ✓ | | 6 | 0.7 | 1.7 | 3.3 |
| 5 June | | ✓ | 6 | 0.1* | 22.0 | 27.2 |
| 27 July | ✓ | | 5 | 10.3 | 10.3 | 11.9 |
| 30 July | | ✓ | 5 | 12.5 | 13.6 | 25.0 |
| 31 July | | ✓ | 5 | 0.2 | 13.8 | 24.1 |
| 23 Oct. | ✓ | ✓ | 5 | <0.1 | 16.0 | 33.5 |

*Rain during day of testing.

For golf the speed of the surface was assessed using a stimpmeter (Radko 1977) and the distance rolled was measured. A total of six measurements were made per plot, with three readings in opposite directions. The measurement dates, cutting heights and antecedent rainfall conditions are given in Table 4.

The initial measurements were recorded as either dry or moist, depending whether there had been recent rainfall. The surface was subsequently irrigated using a watering can immediately before measurement on each plot, adding a depth of water equivalent to 1.2 mm.

### Statistical analysis

Analysis of variance was used to examine differences in ball roll behaviour of the grass species and subspecies (simply referred to as 'species' hereafter). In the tables and diagrams the least significant difference (LSD) at $p = 0.05$ is given to allow comparison of the treatment means. The effect of irrigation was examined using paired t-tests, again using a significance level of $p < 0.05$.

## RESULTS

### Bowls

Green speed values for the individual measurement dates are given in Table 5 and mean values over all dates in relation to species composition are given in Fig. 1.

Grass species caused a significant difference in green speed on all sampling occasions, except on 27 July following irrigation. Green speed was greatest on *F. rubra* ssp. *litoralis*, averaging 11.45 seconds over all sampling dates, whilst *P. annua* gave the slowest surface with an average green speed of 10.45 seconds.

Green speed appeared to increase as the cutting height was lowered and was greatest on 27 July 1987 at a cutting height of 5 mm. The effect was, however, not entirely consistent and, for example, there was no difference in ball roll values at the 8 mm and 6 mm cutting heights.

The effect of irrigation was also inconsistent. On 29 May and 1 June 1987 green speed decreased after irrigation but on 27 June 1987 there was a significant increase in green speed (p <0.05) after irrigation.

TABLE 5

Effect of grass species and moisture conditions on bowls green speed (s) (all dates 1987)

| | 29 May | | 1 June | | 27 July | | 23 Oct. |
|---|---|---|---|---|---|---|---|
| | Dry | Wet | Dry | Wet | Dry | Wet | Moist |
| *F. rubra* ssp. *litoralis* | 11.3 | 11.2 | 11.4 | 11.3 | 11.7 | 11.9 | 11.2 |
| *F. rubra* ssp. *commutata* | 10.8 | 10.5 | 10.3 | 10.4 | 11.6 | 11.6 | 10.9 |
| *Agrostis capillaris* | 10.7 | 10.2 | 10.8 | 10.4 | 11.2 | 11.4 | 10.7 |
| *Agrostis castellana* | 11.1 | 10.7 | 11.2 | 10.6 | 11.4 | 11.5 | 10.8 |
| *Poa annua* | 10.4 | 10.1 | 10.3 | 9.7 | 10.7 | 10.9 | 10.1 |
| LSD (5%) | 0.59 | 0.58 | 0.57 | 0.71 | 0.47 | NS | 0.66 |

NS = not significant

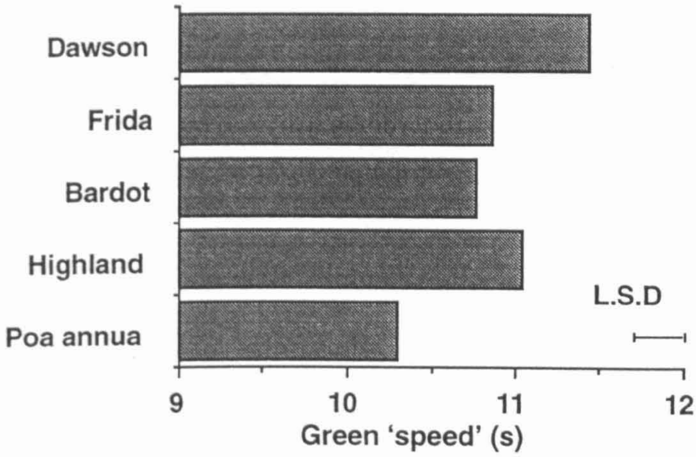

FIGURE 1. Green speed for bowls for the different grass species averaged over all sampling dates. (In both figures Dawson = *F. rubra* ssp. *litoralis*, Frida = *F. rubra* ssp. *commutata*, Bardot = *A. capillaris* and Highland = *A. castellana.*)

## Golf

The pattern for ball roll for golf was similar to that for bowls (Fig. 2, Table 6). Averaged over all dates the rolling distance was greatest for *F. rubra* ssp. *litoralis*, i.e. 1.96 m and least for *P. annua*, averaging only 1.57 m.

There was a significant difference in ball roll (p <0.001) following irrigation, averaging 1.87 m when dry and 1.76 m when wet. Ball roll values were greatest under dry conditions at a cutting height of 5 mm on 30 July 1987 when ball roll for all the grasses except *P. annua* was greater than 2 m.

Over all dates, ball roll ranged from 1.37 m for *P. annua* on 5 June 1987 at a cutting height of 6 mm and after irrigation to 2.21 m for *F. rubra* ssp. *litoralis* under dry conditions on 30 July 1987 (5 mm cutting height).

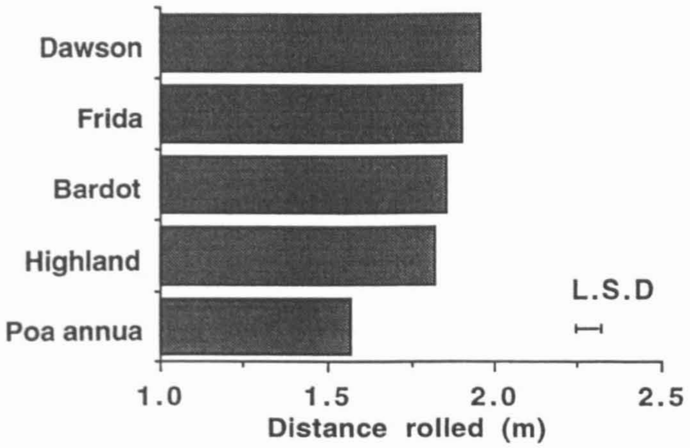

FIGURE 2. Distance rolled by a golf ball for the different grass species averaged over all sampling dates.

TABLE 6
Effect of grass species and moisture conditions on distance rolled (m) for golf (all dates 1987)

| | 5 June | | 30/31 July | | 23 Oct. |
|---|---|---|---|---|---|
| | Moist | Wet | Dry | Wet | Moist |
| *F. rubra* ssp. *litoralis* | 1.87 | 1.78 | 2.21 | 2.01 | 1.93 |
| *F. rubra* ssp. *commutata* | 1.72 | 1.69 | 2.10 | 1.95 | 2.05 |
| *Agrostis capillaris* | 1.69 | 1.67 | 2.10 | 1.92 | 1.91 |
| *Agrostis castellana* | 1.73 | 1.66 | 2.09 | 1.93 | 1.71 |
| *Poa annua* | 1.49 | 1.37 | 1.72 | 1.64 | 1.62 |
| LSD (5%) | 0.182 | 0.140 | 0.232 | 0.185 | 0.131 |

## DISCUSSION

Considering first the results for bowls, none of the measurements reached the preferred minimum speed of 12 s given by Bell & Holmes (1988). However, only one species (*P. annua*) failed to reach the acceptable minimum speed of 10 s on one occasion of measurement. Overall, *F. rubra* ssp. *litoralis* 'Dawson' always gave the fastest surface and *P. annua* always gave the slowest surface. The two *Agrostis spp.* and *F. rubra* ssp. *commutata* were intermediate in performance and not statistically different from one another except on 1 June when *A. castellana* was significantly faster than *F. rubra* ssp. *commutata*. Overall, it would be fair to state that these three species were comparable in performance. Evans (1988) stated "long experience indicates that the most common causes of excessive slowness are the dominance of annual meadow-grass in the sward and the presence of a sub-surface thatch or fibre layer". The trial certainly confirmed this long held view of *P. annua*. Evans (1988) also stated "fescue produces a tough wiry type of turf and a fast bowling surface". The trial also bore out this comment although clearly the type of fescue which is chosen could have a large bearing on the speed of the green. Newell & Gooding (1990) demonstrated a considerable range of values for: shoot density, leaf width, leaf numbers, shoot phytomass and thatch depth for a number of species and sub-species of *Festuca* and hence there could be a large, undiscovered source of variation in green speed among different fescues.

For golf, during the trial no attempt had been made to emulate tournament preparation and hence the trial would equate with regular club greens. The figures given in Table 2 for golf green speeds should not necessarily be equated with those given for "minimum standards" for green speed of bowling greens in Table 1. The purpose of the USGA green speed comparison table was not to propose minimum standards for different categories of green speed, but rather to provide an objective test of green speed to enable superintendents to work towards more uniform putting conditions over 18 greens (Engel *et al.* 1980). Indeed, it is not stated whether the figures given refer to the minimum value for each category or its mid-point. Furthermore, the inference is that such precision was not intended. However, some general comparisons can be made. The *P. annua* gave consistently the slowest surface and would have corresponded with slow to medium-slow in the USGA table. Only the *F. rubra* ssp. *litoralis* would have been rated medium-fast on 30 July (dry). All of the remaining data fell into the medium or medium-slow categories.

The effect of moisture was generally to decrease green speed for both bowls and golf as would be expected, although it apparently increased for bowls on one occasion of measurement. Results of t-tests carried out on the pooled data for wet versus dry showed significant differences for both bowls ($t = 2.23$, $p = 0.04$) and for golf ($t = 5.61$, $p = 0.0003$). The effect of moisture was greater for the smaller golf ball than for the relatively massive bowl. Only 1.5% reduction in green speed due to wetness was observed for bowls, whereas the reduction was 6% for golf (calculated as (dry – wet/dry) x 100).

Overall, the trial showed interesting species differences in ball roll characteristics, which suggests that a wider screening of species and cultivars, for use on UK golf greens, for green speed could yield fruitful results, especially for seed companies marketing cultivars for the golf course market. It was originally intended to continue the trial for a further year, however, significant amounts of *P. annua* invaded the plots of the other species (a mean of 12% on the worst affected species, with some plots having individual amounts up to 35%). It was felt that this *P. annua* contamination would undoubtedly mask species differences and therefore the trial was ended.

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# DISCUSSION

The apparatus and test methods described in Part 1 were originally constructed or purchased as research tools, however, such has been their acceptance that they now form the basis for either British, or forthcoming European standards. The ball rebound and ball measurement techniques are incorporated into the British Standard for Artificial Sports surfaces BS 7044 (British Standards Institution 1989). For ball roll two methods are offered, as in Part 1 of this chapter, namely distance rolled and ball deceleration. For the latter method the results are expressed in terms of velocity change rather than ball deceleration, as described in Parts 1, 2 and 3. The traction apparatus (Canaway & Bell 1986), derived from my earlier version (Canaway 1975) has also been incorporated into another part of BS 7044 (British Standards Institution [1990]) with a suitable sole for artificial, as distinct from natural turf. The results are expressed in terms of the traction coefficient rather than the torque required to turn the apparatus as in this work. However, this is a simple mathematical operation:

$$\text{traction coefficient} = \frac{3T}{WD}$$

where:

T = torque in N m
W = applied vertical force (i.e. weight) in N
D = diameter of test disc in m.

This procedure has not been adapted in measurements on natural turf where the unmodified torque value is presented. The apparatus, test methods and standards derived from them, form the basis for forthcoming European (EN) standards, which will eventually supersede British standards. Since for golf and bowls there are no existing British Standards, the test methods described for these sports will form the basis for discussion by the working groups on development of European standards for these sports. For golf, apart from the USGA green speed comparison table, there is no existing published work relating playing quality measurements to player's preferences and hence there is a lack of information as compared with football. At the time of writing, a project is being undertaken involving a major survey of golf green playing quality, coupled with player evaluation work, to provide the necessary data to produce a draft European standards for playing quality of golf green turf.

Arising from the work described in Part 5 there is clearly a large unexplored source of variation in playing quality attributable to species and cultivars which would be a fruitful area for future research.

The research on construction described in Part 2 represented a major step forward in our knowledge of the performance of different constructional types for football pitches, especially when taken together with the case studies on real pitches carried out in conjunction with the University College of Wales, Aberystwyth (Baker & Gibbs 1989, Gibbs & Baker 1989, Baker, Gibbs & Adams 1992). The results were presented at conferences in Japan, the USA, Canada, Belgium and venues in the UK. These results were essentially of practical significance and have enabled advisers to give better guidance to clients on their options for construction and the likely cost benefits. The research was widely publicised in popular magazines as it is important that the fruits of research are disseminated at a "grass roots" level, as well as in learned journals.

As a final point the informed reader might well ask why it was that an ameliorated rootzone, i.e. a mixture of sand and soil, was not included in the construction experiment since these are widely used at professional football grounds, e.g. Liverpool, Everton, Manchester United etc. The answer to this question is two-fold. Firstly, budgetary considerations restricted the number of constructions to five and it was felt that an extreme range of constructions should be used. Secondly, a detailed experiment on ameliorated rootzones had been started in 1984 in which the sixteen sand and sand-soil rootzone materials were studied, in terms of their wear tolerance (Baker & Isaac 1987a), playing quality (Baker & Isaac 1987b) and soil physical properties (Baker 1988). This study showed that the greatest wear tolerance was achieved on pure sand rootzones or those with sand contents exceeding 90%. Effects on playing quality were dominated by the fact that on rootzones with less than 90% sand, muddy conditions developed under wear giving reduced ball rebound, traction and hardness. Infiltration rates were least (1 mm $h^{-1}$) and surface ponding was most frequent on rootzones with <90% of sand. Pure sand rootzones retained the best infiltration rates and least incidence of ponding throughout the experiment. In conclusion, ameliorated rootzones for football have been thoroughly studied and therefore it was justifiable to exclude this type of rootzone material from the construction experiment, although we certainly would have included one out of interest had funds permitted.

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# CHAPTER 3

# ESTABLISHMENT

## INTRODUCTION

Seed and sod have always been considered as viable alternatives in establishment of both coarse and fine turf. Evans (1992) cites a bill preserved in the Royal Archives for the construction of a bowling green in 1663. "May 11 1663. To W. Herbert for making ye bowling green and walks £10, and for cutting Turfe for ye green £3-12s and in all £13-12s ......" Beale (1924) suggests the use of either sod or seed for establishment of football and hockey pitches. For putting greens he addressed the question directly. "Turf versus seed." "If expense is no object and speed a consideration, turf should be used, because, if it can be obtained of suitable quality ..... and in sufficient quantity, the greens can be played upon with certainty the following season."

The first two parts of this chapter concern different approaches to the establishment of a sward for football on a sand rootzone during the close season. In Part 1 a field experiment on different methods of establishment is described, incorporating three different experimental treatments using seed and three treatments using different types of turf or sod. In Part 2 a field experiment on the effects of two moisture-retentive soil amendments on establishment and playing quality of swards for football is described. In Part 3 a further field experiment on different methods of establishment using seed and sod is described, this time in relation to golf green establishment.

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## PART 1

# A COMPARISON OF DIFFERENT METHODS OF ESTABLISHMENT USING SEED AND SOD ON THE COVER AND PLAYING QUALITY OF TURF FOR FOOTBALL

## SUMMARY

An experiment involving six establishment treatments - three using seed and three using sod - was laid down on a pure sand construction in June 1985 and then subjected to artificial wear treatments during the subsequent football season, concluding in April 1986. The treatments included: normal seeding (NL) with *Lolium perenne* 'Loretta' at 22 g $m^{-2}$; seeding with pre-germinated seed (PG); double seed rate (DR), i.e. 44 g $m^{-2}$; 'Bravura' seedling sod (BVA); Rolawn mature sod (RLN); and Bingley mature sod (BLY).

Data were collected on ground cover, traction, ball rebound resilience, hardness, water infiltration rate, soil organic matter and moisture content. Swards established using sod gave good cover and playing quality but plots established from seed gave unacceptably low cover at the start of the playing season and poor traction during the playing season. A disadvantage of the use of sod was a large reduction in water infiltration rate relative to turf established using seed once wear treatments started, even though there were no differences in infiltration rates before wear. Infiltration rate at the end of the experiment was highly correlated with the amount and depth of organic matter present in the immediate surface of the rootzone. The implications of the results for the establishment and management of sand rootzones are discussed.

## INTRODUCTION

Previous experiments on sand rootzones described in Chapter 2 and elsewhere(Canaway 1984a, b; 1985a, b, c) and practical trials (Davis *et al.* 1974) have shown that once established, turf grown on sand can provide good grass ground cover and good playing conditions for football. However, experience has shown that the establishment of turf on sand may be slow and patchy in the early stages despite irrigation. It is well known that sands have low water and nutrient retention and that leaching losses of nutrients from seedbeds in the early stages of establishment may be high (Dancer 1975, Marrs & Bradshaw 1980, Marrs, *et al.* 1980). In the UK the Association football season extends from mid-August, through the winter months until the following mid-May. Therefore, any reconstruction work on Football League grounds must be carried out in the close season between May and August, with full grass cover ready for the start of the new season in the latter part of August.

In view of the problems of establishment of turf from seed within such a short time-scale where there is little margin for error, the other possibilities are to use purpose-grown turf, termed "sod" in the industry, either as mature sod or seedling sod for re-establishment of a reconstructed pitch during the close season. This would be expensive - an extra cost of c. £10,000 might be involved depending on haulage costs for delivery etc.

One of the fears of using sod is that the addition of extraneous soil material along with the sod would cause a reduction in water infiltration rate which is one of the properties for which sand pitches are constructed, i.e. to provide a free-draining surface. To overcome this problem possible solutions would be: [1] to use seedling turf grown on a soil-free medium; [2] to use sod grown on sand; [3] the use of washed sod, where most of the soil is washed away using water jets. Further possibilities include: increasing the seed rate to compensate for poor establishment and the use of pre-germinated or "advanced" seed (Lush & Birkenhead 1987) to speed up establishment. The objectives of the work were therefore to investigate effects of various seeding treatments and different types of sod on establishment, subsequent playing quality and water infiltration rate of turf for football pitches where only a short period of establishment is possible. Washed sod was not commercially available at the time the work was done and therefore this was not evaluated.

## MATERIALS AND METHODS

### Trial construction

The experimental area was originally constructed in 1981 and the details of the construction were described by Canaway (1983). Since 1981 trials of grass species and experiments on fertiliser treatments were conducted on the area leading to an accumulation of organic matter and possible residual nutrients in the rootzone. The original construction consisted of a 250 mm depth of medium-fine sand, 50 mm depth of coarse sand and a gravel drainage carpet of 100 mm depth with pipe drains at 10 m centres. In May 1985 the existing turf and the upper 75 mm of the sand rootzone were removed and replaced with new sand. This was again a medium-fine sand with 91% of the particles between 0.125 and 0.5 mm.

The sieve analysis is given in Table 1. The pH of the sand was 5.9. The new sand was placed *in situ* on 23 May, levelled and firmed.

TABLE 1
Particle size distribution of the rootzone sand (% by weight in each size fraction)

| Category | Diameter (mm) | % |
|---|---|---|
| Stones | >8 | 0 |
| Coarse gravel | 8-4 | 0 |
| Fine gravel | 4-2 | 0 |
| V. coarse sand | 2-1 | 0 |
| Coarse sand | 1.0-0.5 | 6 |
| Medium sand | 0.5-0.25 | 60 |
| Fine sand | 0.250-0.125 | 31 |
| V. fine sand | 0.125-0.050 | 2 |
| Silt + clay | <0.05 | 1 |

### Seedbed preparation

After levelling the newly-imported sand, seedbed fertiliser was applied to provide the following nutrients (kg ha$^{-1}$): N, 75; $P_2O_5$, 50; $K_2O$, 50. 'Micromax' micronutrient fertiliser was also applied at 500 kg ha$^{-1}$. This contained the following micronutrients: S (15%), Fe (12%), CaO (7.5%), MgO (4.5%), Mn (2.5%), Zn (1%), Cu (0.5%), B (0.1%), Mo (0.005%).

### Experimental treatments

The experimental treatments together with their abbreviations used in the subsequent Figures were as follows: (1) Normal seeding (NL); (2) Seeding with pre-germinated seed (PG); (3) Double seed rate (DR); (4) Bravura seedling sod (BVA); (5) Rolawn mature sod (RLN); (6) Bingley mature sod (BLY).

Details of the experimental treatments were as follows:

[1] Normal seeding. Sown with *Lolium perenne* L. 'Loretta' at 22 g m$^{-2}$.

[2] Pre-germinated seed. 0.5 g 'Benlate' fungicide (benomyl 50% by weight) was made into an aqueous suspension in 1 litre of water. For each 100 g of seed 80-100 ml of the benlate suspension was mixed with seed of *L. perenne* 'Loretta' until the seed was thoroughly wetted. The seed was placed in a lighted incubator at 21°C, and turned 3 times per day until ready for sowing. The pre-germination was started on 31 May five days prior to sowing by which time the radicles had emerged.

[3] Double seed rate. Originally a second seedling sod was to be tested in addition to the Bravura product detailed below but since it was essential to start all the treatments simultaneously, when the company in question failed to deliver the seedling sod, a third treatment using seed at twice the normal rate was included as a replacement, i.e. sowing at 44 g m$^{-2}$ of *L. perenne* 'Loretta'.

[4] Bravura seedling sod was a commercially available product which was grown on a thin, sterile growing medium placed directly on top of a polythene laminate until ready for sale, typically at six to eight weeks of age. The material was weed and soil free. The samples supplied for the trial consisted of a pure stand of *L. perenne* 'Loretta'.

[5] Rolawn sod. This was a commercially grown mature sod 'RB Medallion' which was sown in October 1984 with *L. perenne* 'Barclay', (40% by weight), *Festuca rubra* L. ssp. *litoralis* 'Dawson' (30%), *F. rubra* L. ssp. *commutata* Gaud. 'Waldorf' (10%), *F. rubra* ssp. *commutata* 'Frida' (10%) and *Agrostis castellana* Boiss & Reut. 'Highland' (10%). The sod was 20 months old at the time of delivery to the site for laying. The seed specification has been changed from the above as improved cultivars have become available. The mechanical analysis of the soil on which mature sod was grown is given in Table 2 and is texturally classified as a sand (USDA classification). The soil pH was 6.2.

TABLE 2
Particle size distribution of the soil on which the Rolawn sod was grown
(% by weight in each category)

| Category | Diameter | % |
|---|---|---|
| Stones | >8 | 0 |
| Coarse gravel | 8-4 | T |
| Fine gravel | 4-2 | T |
| V. coarse sand | 2-1 | 1 |
| Coarse sand | 1.0-0.5 | 2 |
| Medium sand | 0.5-0.25 | 9 |
| Fine sand | 0.250-0.125 | 46 |
| V. fine sand | 0.125-0.050 | 30 |
| Silt | 0.050-0.002 | 5 |
| Clay | <0.002 | 7 |

T = trace

[6] Bingley mature sod. The 'Bingley' sod was taken from the sand rootzone adjacent to the new experimental area. It was originally sown in August 1981 with *L. perenne* 'Loretta' as a surround to trials described by Canaway (1983), Canaway *et al.* (1986), and had been subject to annual cycles of wear during the football season and renovation at the end of each football season which included overseeding with *L. perenne* 'Loretta'. In this time some ingress of *Poa annua* L. had occurred. The sieve analysis of the medium-fine sand on which the turf was grown was given by Canaway (1983).

The different types of sod were laid and the seed sown on 5 June 1985. Plot size was 2 m x 2 m laid out in a randomised block design with five replications.

## Trial management

The management of the trial after the initial setting out is detailed in Table 3.

TABLE 3
Summary of trial management details

| | |
|---|---|
| Mowing | Initially mowing was at 50 mm height and this was gradually reduced to 25 mm by early August 1985 and subsequently maintained at that height. Clippings removed. |
| Fertiliser | The following nutrients were supplied as proprietary fertiliser mixtures in five applications between 4 July and 10 September 1985. Initially soluble fertilisers were used but rapid leaching with subsequent yellowing of the sward took place and therefore the final application was a slow-release, IBDU-containing product. Rates as kg ha$^{-1}$<br>N $P_2O_5$ $K_2O$<br>223 28 69 |
| Irrigation | The aim was to supply 25 mm of water per week to make up for evapotranspiration losses of c. 18 mm per week, the difference between the two figures being an allowance for drift and evaporation during watering. Frequency was daily until 19 June after which frequency was gradually reduced as the swards established. |
| Wear treatments | Artificial wear treatments were applied with the D.S. machine (Canaway 1976), 4 passes twice weekly starting on 8 October 1985 and finishing on 9 April 1986. |

## Data collection and analysis

The details of the data collected from the experiment are given in Table 4. The results were subjected to analysis of variance and Waller & Duncan's multiple comparisons procedure (Waller & Duncan 1969, 1972) was used to detect significant treatment effects using a error-weight ratio of k = 100 which replaces the significance level of $p < 0.05$ in the earlier range test of Duncan (1955).

At the end of the trial on 29 April 1986 three cores 50 mm deep and 38 mm in diameter were removed from each plot for determination of organic matter content. Depth of the organic layer at the surface was measured by taking 5 measurements per core to the nearest mm, and the content of organic matter was determined by loss on ignition of the dried cores at 400°C for four hours.

TABLE 4
Summary table giving details of data collection, dates and methods used

| Type of data | Dates of sampling | Method used |
|---|---|---|
| Ground cover of live plant material | 17 Sep. 1985<br>6 Nov. 1985<br>3 Dec. 1985<br>7 Apr. 1986 | Optical point quadrat of Laycock & Canaway (1980), 100 points per plot in frames of 5, arranged systematically within plots |
| Traction | 18 Sep. 1985<br>6 Nov. 1985<br>3 Dec. 1985<br>7 Apr. 1986 | Using traction apparatus of Canaway & Bell (1986), the torque to shear the turf was measured |
| Ball rebound resilience | 18 Sep. 1985<br>7 Nov. 1985<br>4 Dec. 1985<br>11 Apr. 1986 | % rebound determined by release of FIFA approved football (Mitre Max) inflated to 70 kPa from 3 m high ball bounce apparatus, 4 observations per plot |
| Hardness | 17 Sep. 1985<br>7 Nov. 1985<br>4 Dec. 1985<br>7 Apr. 1986 | Clegg Impact Soil Tester (Clegg 1976). The peak deceleration (in gravities) of a 0.5 kg, 50 mm diameter hammer dropped from a 300 mm height, was recorded on impact with the turf, 5 observations per plot |
| Water infiltration rate | 23-24 Sep. 1985<br>4-5 Dec. 1985<br>22-24 Apr. 1986 | Using double ring infiltrometers of 300 and 500 mm diameter, flooded and allowed to reach a steady state before measurements water temperatures corrected to 10°C, three measurements per plot |

N.B. On 17 Sep. 1985, 7 Nov. 1985, 3 Dec. 1985 and 7 Apr. 1986, 5 cores, 50 mm in diameter and 30 mm trimmed depth were removed for determination of moisture content of the rootzone.

## RESULTS

### Ground cover

Results for total cover are shown in Figure 1. Before wear, in September 1985 (Figure 1A) all of the sod treatments showed high ground cover in the range 91-94%, the seeded treatments being significantly lower, in the range 67-79%. Of these the double rate showed significant benefits over the normal and pre-germinated treatments. Cover on all the seeded treatments, particularly the NL and PG treatments, was unacceptably low for a high quality sports pitch at the beginning of the playing season. In November 1985 (Figure 1B) the pattern of results was similar to that seen before wear but a significant difference was observed between the RLN and the BLY sods with the BVA being intermediate. Of the seeded treatments the DR still showed a significant improvement over the NL and PG treatments. In December 1985 (Figure 1C) the sod treatments had ground cover values in the range 57-62% whereas the seeded treatments were significantly lower at between 42 and 47%. By April 1986 (Figure 1D) there was no longer a significant treatment effect in the analysis of variance although the sod treatments (18.2-21.4%) still showed marginally greater ground cover values than the seeded treatments (14.6-18.0%).

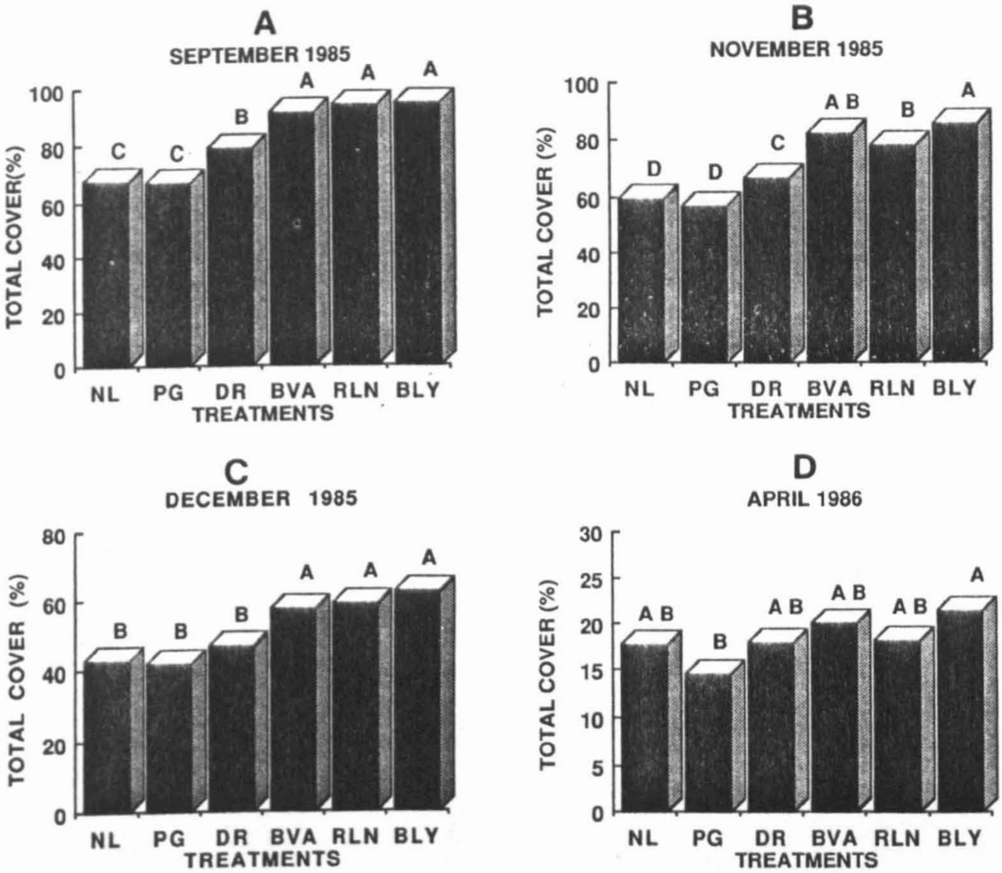

FIGURE 1. Ground cover of turf in response to the six methods of establishment: 1A, September 1985; 1B, November 1985; 1C, December 1985; 1D, April 1986. Treatments without a common letter were significantly different at k = 100 using Waller & Duncan's multiple comparisons procedure.

### Traction

Results for traction are shown in Figure 2 and soil moisture contents (as % of fresh weight) are given in Table 5. Before wear, in September 1985 (Figure 2A) traction was greatest on the sod plots with values in the range 43-50 N m whereas the seeded plots were much lower, in the range 26-34 N m. Of the sod treatments in September 1985 the BLY sod had significantly greater traction than the RLN and BVA, and of the seeded treatments the PG treatment was lowest. During wear, November 1985 (Figure 2B) the broad pattern of results was similar with the sod plots giving traction values in the range 44-47 N m and the seeded plots 25-30 N m. On this occasion however, the position of the BLY sod was reversed and the PG was no longer significantly worse than NL. In December 1985 (Figure 3C) traction had fallen generally, with the turfed plots in the range 39-46 N m, and the seeded plots in the range 20-24 N m. The position of the BLY sod remained the same as in November and there was a significant effect of the DR over the other two seeded treatments. By

April 1986 (Figure 2D) traction had decreased further in the sod plots (33-39 N m) and also on the seeded plots (19-21 N m). The BLY sod was still the lowest of the sod treatments but there was no significant difference among the seeded treatments.

TABLE 5
Soil moisture content (% of fresh weight) of cores taken on each date of measurement of traction and ball rebound resilience

| Date | Mean | S.E. |
|---|---|---|
| 17 September 1985 | 24.9 | 0.60 |
| 7 November 1985 | 27.8 | 1.47 |
| 3 December 1985 | 22.7 | 0.91 |
| 7 April 1986 | 22.4 | 2.50 |
| 11 April 1986 | 21.6 | 2.05 |

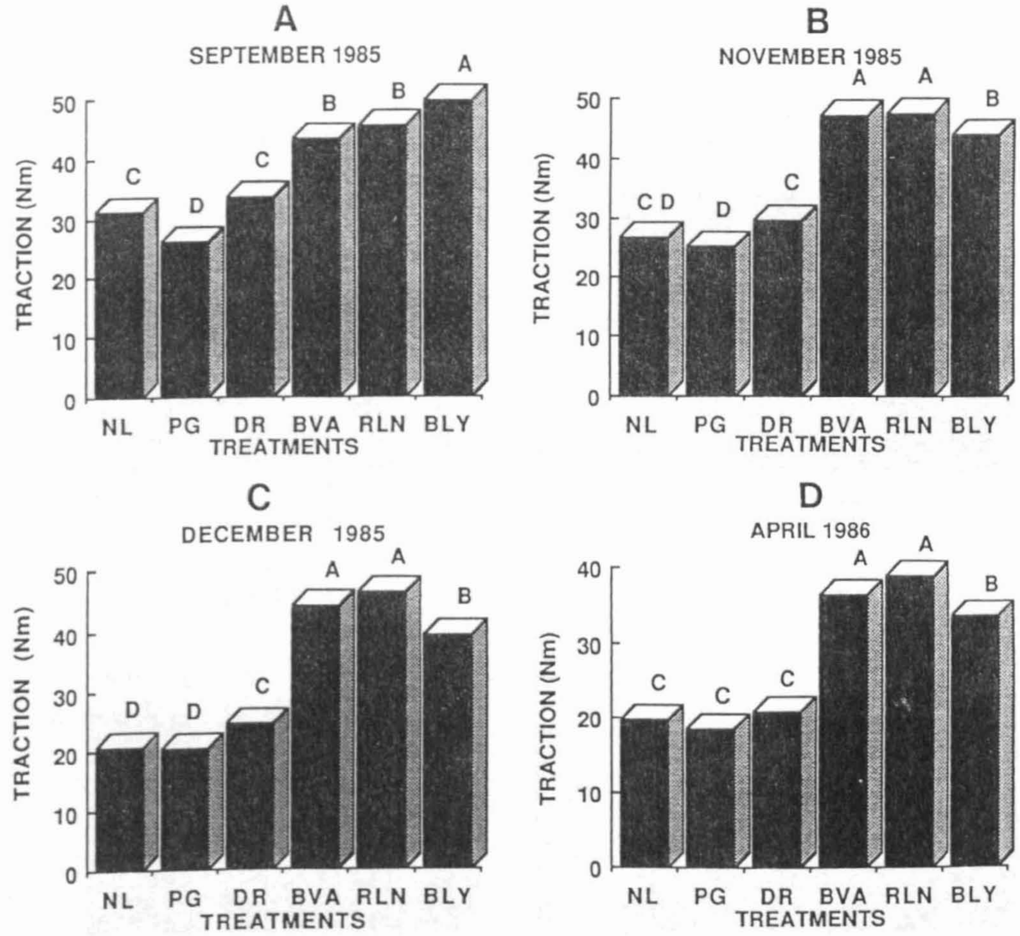

FIGURE 2. Traction of turf in response to the six methods of establishment: 1A, September 1985; 1B, November 1985; 1C, December 1985; 1D, April 1986. Treatments without a common letter are significantly different at k = 100 using Waller and Duncan's multiple comparisons procedure.

## Ball rebound resilience

Results for ball rebound resilience are shown in Figure 3. Before wear, in September 1985 (Figure 3A) ball rebound was greatest on the seeded plots, the NL being significantly greater than the DR treatment. The range for the seeded treatments was 33-36%, whereas that for the sod plots was 24-30%, the BLY sod giving the greatest rebound resilience of the turfed treatments. The treatments effect in the analysis of variance was significant at p <0.001, whereas by November after only a short period of wear the treatments effect was no longer significant and the differences between treatments were small (Figure 3B). The range was only 35-40% for all treatments, although the BLY sod still gave a higher rebound resilience than the RLN and BVA as judged using the Waller & Duncan LSD. By December 1985 (Figure 3C) the range of values over the treatments was even smaller (29-32%) and the treatments effect in the analysis was not significant. By April 1986 (Figure 3D) rebound resilience had fallen to 21-23% on the seeded plots whereas on the sod plots it remained at 29-30% and the treatments effect in the analysis of variance returned to its pre-wear level of p <0.001.

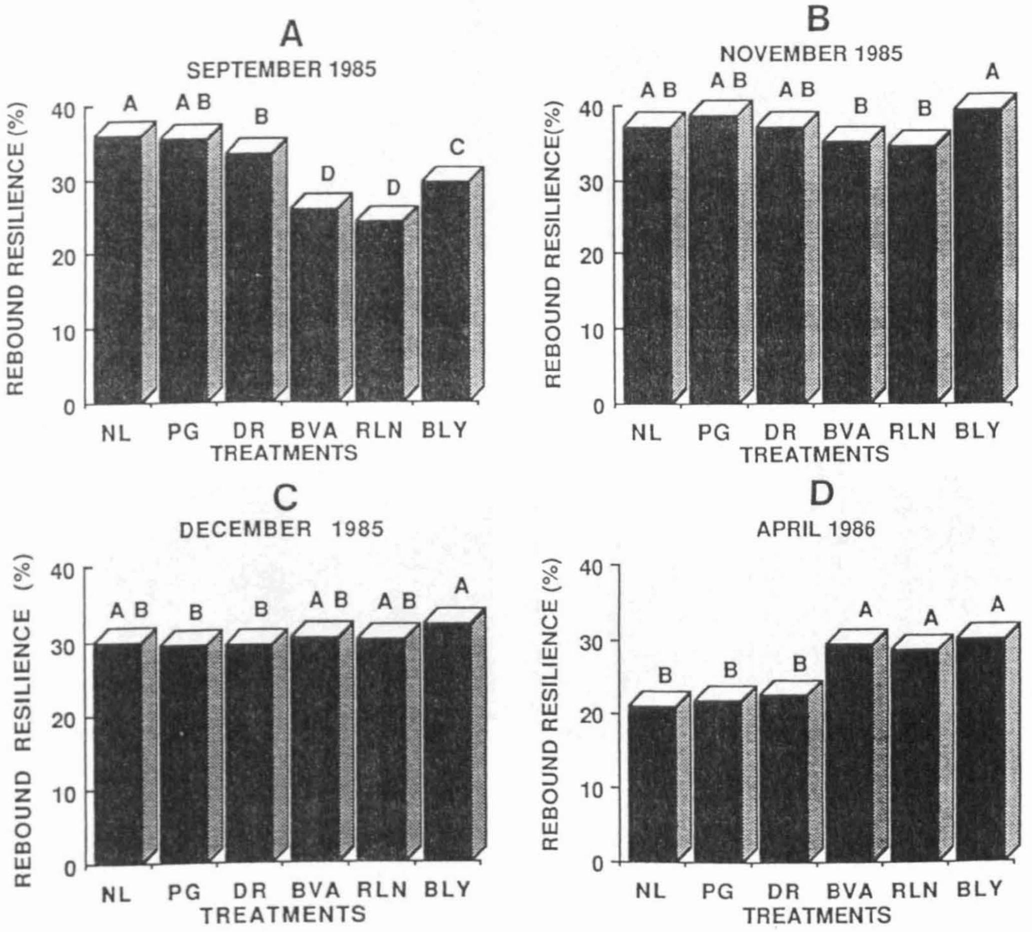

FIGURE 3. Ball rebound resilience of turf in response to the six methods of establishment: 3A, September 1985; 3B, November 1985; 3C, December 1985; 3D, April 1986. Treatments without a common letter are significantly different at k = 100 using Waller & Duncan's multiple comparisons procedure.

## Hardness

Results for hardness are shown in Figure 4. Before wear, in September 1985 (Figure 4A) BVA and RLN (both 57 gravities) were significantly softer than the remaining treatments which were not significantly different from each other (all 67-71 gravities). In November 1985 (Figure 4B) the sod treatments were generally softer (42-51 gravities) then the seeded treatments (55-67 gravities). In December 1985 (Figure 4C) the treatments effect in the analysis of variance was not significant but the Waller & Duncan procedure separated out the BVA and DR treatments as being significantly different at k = 100, however there was no clear pattern of results in terms of sod versus seeding treatments. In April 1986 (Figure 4D) the sod treatments (50-55 gravities) were harder than the seeded treatments (37-41 gravities).

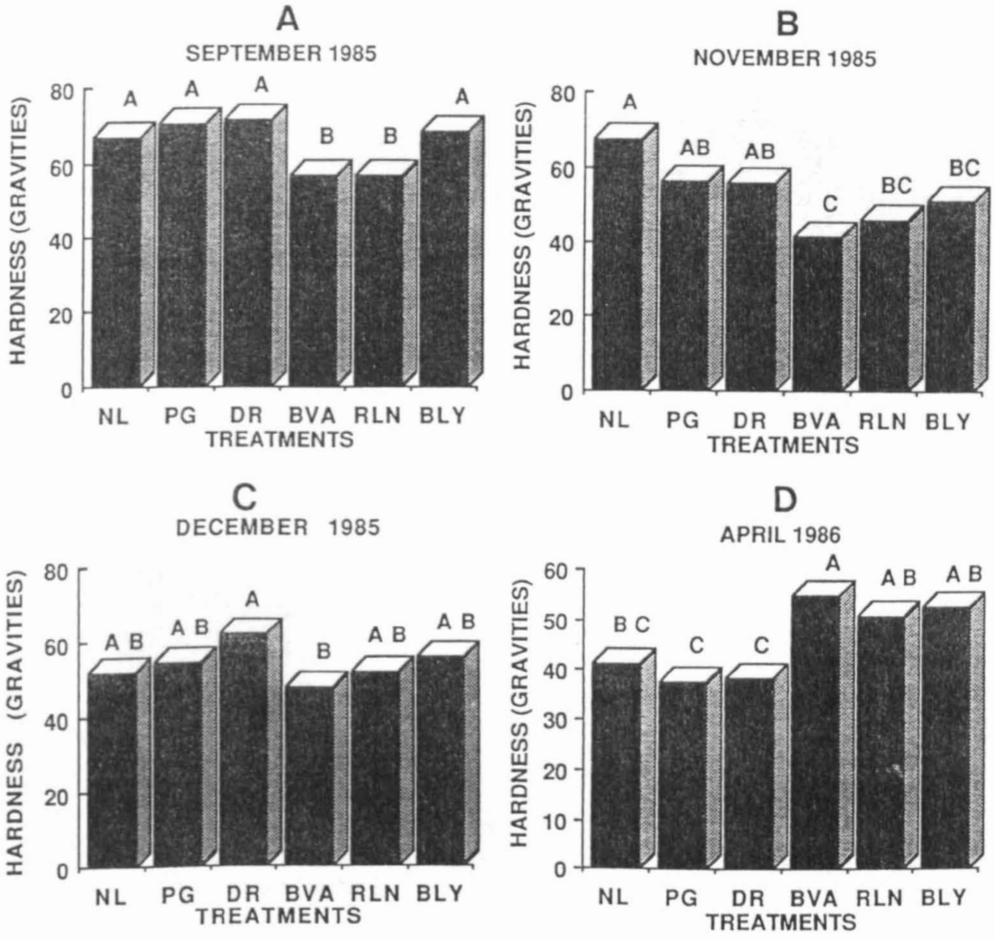

FIGURE 4. Hardness of turf in response to the six methods of establishment: 4A, September 1985; 4B, November 1985; 4C, December 1985; 4D, April 1986. Treatments without a common letter are significantly different at k = 100 using Waller & Duncan's multiple comparisons procedure.

### Water infiltration rate

Results for water infiltration rate are shown in Figure 5. Before wear, in September 1985 (Figure 5A) there were no significant differences among treatments and the treatments variance ratio in the analysis of variance was too small to perform the Waller & Duncan range test. All the treatments lay between 112 and 138 mm $h^{-1}$. In December 1985 (Figure 5B) the pattern of results was totally different, the treatments now ranging from 9 mm $h^{-1}$ on the BLY sod to 88 mm $h^{-1}$ on the NL treatment. In April 1986 (Figure 5C) the range of values increased further, from 3 mm $h^{-1}$ on the BLY sod to 139 mm $h^{-1}$ on the NL seeded treatments. The seeded treatments were all above 100 mm $h^{-1}$ and the BVA and RLN were 24 and 12 mm $h^{-1}$ respectively.

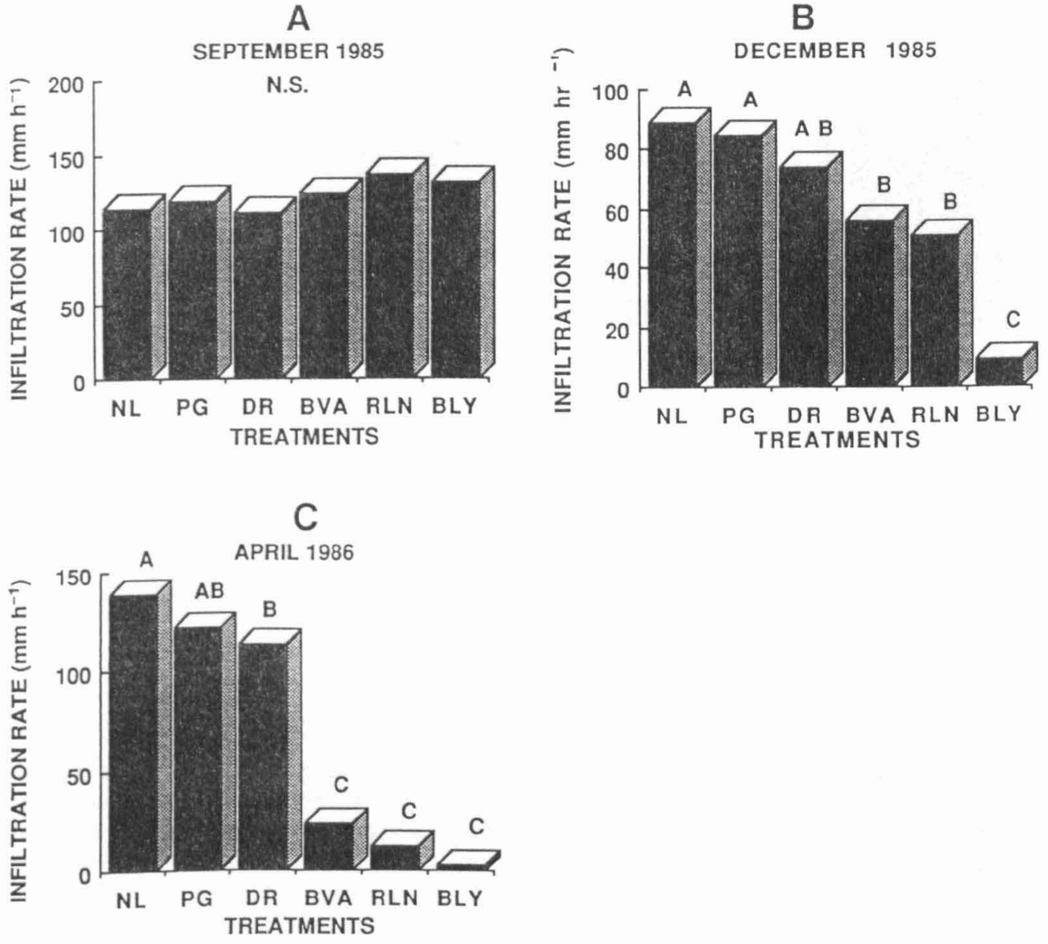

FIGURE 5. Water infiltration rate of turf in response to the six methods of establishment; 5A, September 1985; 5B, December 1985; 5C, (April 1986). Treatments without a common letter are significantly different at k = 100 using Waller & Duncan's multiple comparisons procedure.

### Organic matter

Depth of the layer of organic matter at the end of the experiment is shown in Figure 6A and the % loss on ignition in Figure 6B. Both figures show a similar pattern of results with the seeded treatments showing small depths (6.3-6.5 mm) of organic matter and low values for loss on ignition (0.4-0.5%) whereas the BVA, RLN and BLY sod showed an ascending series of values for both depth of organic matter and loss on ignition.

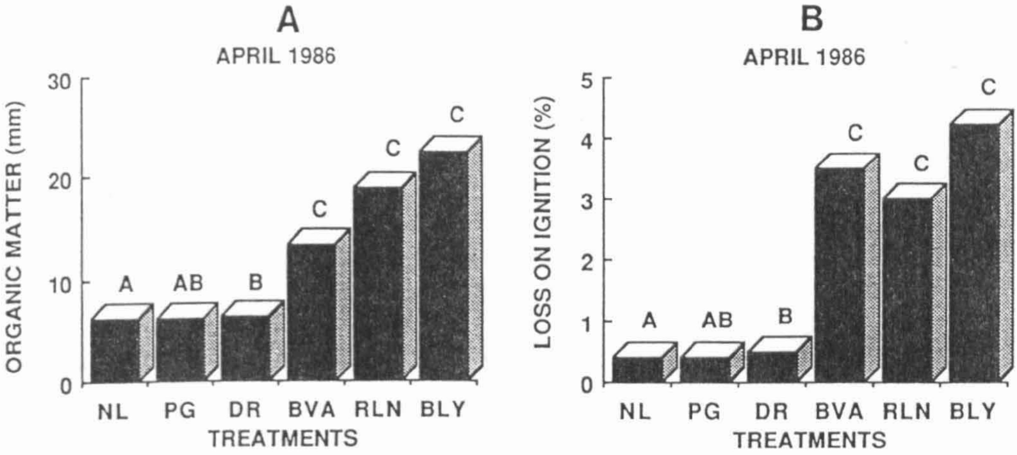

FIGURE 6. Organic matter present in cores taken from the turf in response to the six methods of establishment: 6A, depth of the organic layer; 6B, % loss on ignition of dried cores. Treatments without a common letter are significantly different at k = 100 using Waller & Duncan's multiple comparisons procedure.

## DISCUSSION

For a high-cost installation it is essential that cover at the beginning of the playing season is as near to 100% as possible and in this respect the seeded treatments were unacceptably low. Therefore seeding would be considered a high risk operation for a pure sand over gravel construction on a Football League ground and therefore sod would have to be used, despite its extra cost. If some flexibility were possible regarding the start of play then a double seed rate should be used since it showed some benefits in the experiment and would be recommended on this type of construction if turfing could not be carried out on the grounds of cost. There was no advantage seen in using pre-germinated seed, either in terms of cover or playing quality.

There were some differences in cover between the different types of sod used, in particular the Rolawn sod had lower cover than the Bingley sod in November 1985. This may reflect either the difference in age and species composition of the sod, the Bingley sod being dominated by *L. perenne* and *P. annua* both of which are extremely wear tolerant (Canaway 1983) whereas the Rolawn turf contained a number of less wear tolerant species such as *F. rubra* and *A. castellana.*

As far as the playing quality tests were concerned the sod treatments were again superior to those using seed. Comparing the results with published standards for playing quality referred to in Chapter 2, for traction the minimum acceptable limit is 20 N m and the minimum preferred limit is 25 N m (Canaway *et al* 1990). The treatments which used sod all remained above either of the preferred limits, whereas those using seed were on the borderline of acceptability at around 20 N m. Limits for ball rebound are 20-50% (preferred) and 15-55% (acceptable). All treatments remained within the preferred range throughout the experiment although the seeded plots fell to the lower end of the preferred range by the end of the experiment. For hardness the preferred range is 20-80 gravities and all treatments remained within this range also.

The benefit of establishment using sod in terms of cover and traction was partly offset by a large reduction in water infiltration rate during the period of wear. It is worth commenting on the fact that there were no significant differences before wear in September 1985, tenfold differences by December 1985 and forty-sixfold differences by April 1986, which illustrates the importance of wear in sports turf situations. The most likely explanation for these changes is the incorporation, by the wear treatments, of the organic and mineral fraction contained within the sod into the sand rootzone, thereby obstructing the large pores responsible for providing free water movement away from the surface. Indeed the depth of organic matter and water infiltration rate in April 1986 were highly negatively correlated ($r = -0.92$, $p < 0.001$), as was loss on ignition ($r = -0.84$, $p < 0.001$), i.e. the greater the organic matter content the lower the water infiltration rate which lends further support to the above explanation. If this is the case then sod washing may not be as beneficial as might be expected and its additional expense may not be justified but further work is needed to resolve the issue.

As far as acceptability of the observed infiltration rates is concerned, only the Bingley turf at 3 mm $h^{-1}$ would have been unacceptable, since although there are at present no published standards for infiltration rate the Rolawn turf at 12 mm $h^{-1}$ at the end of the playing season would have provided the capacity to remove 288 mm of water in a day - a very large amount. It would not cope with torrential downpours, however, but would be sufficient for most situations. The Bingley turf was atypical in terms of its age for transplantation having originally been sown in 1981 and was therefore nearly four years old at the start of the experiment. However, considering it was grown on pure sand the reduction in infiltration rate was unexpectedly large, and attributable to blockage of the pore system by organic material as discussed above. This has implications for the management of sand constructions in that it is clear that steps must be taken to control the effects of organic matter accumulation, both directly by scarification and superficial cultivation at the end of each playing season, and indirectly by the regular use of sand top dressing. Whether or not washed sod would have performed better than the unwashed Rolawn sod is conjectural. However, in view of the massive reduction in infiltration rate seen in the sand-grown Bingley turf it seems that the presence of organic matter at the surface is at least as important, if not more so, than the small quantity of mineral matter imported with the turf provided that the latter is grown on sandy soil and hence only small amounts of silt and clay are introduced. Further research is needed to evaluate the benefits of washed sod which has recently become commercially available and also to determine whether the results apply to other types of pitch construction.

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## PART 2

## THE EFFECTS OF TWO ROOTZONE AMENDMENTS ON COVER AND PLAYING QUALITY OF A SAND PROFILE CONSTRUCTION FOR FOOTBALL

### SUMMARY

Two rootzone amendments were studied: [1] a seaweed extract ('Alginure') applied at rates of 0, 25, 50, 75, 100, 125, 150 and 175 g $m^{-2}$ and; [2] a synthetic polymer material ('Erosel') applied at 0 and 10 g $m^{-2}$. The treatments were combined factorially. The trial was carried out on a sand rootzone and received football-type artificial wear once established. Data were collected on grass ground cover, player traction, ball rebound resilience, hardness and water infiltration rate. Ground cover was determined both by point quadrats and using a reflectance ratio meter to determine the usefulness of the meter in such studies. The results showed that Alginure had positive benefits on ground cover and playing quality but did not have any adverse effects on water infiltration rate. The Erosel showed no significant effects at the rate used on any of the variables measured. Before wear ground cover and traction increased linearly with increasing rate of Alginure but ball rebound resilience and hardness decreased. As wear progressed the responses became more variable but significant effects persisted through the full duration of the playing season. It is recommended that Alginure or a similar product is used in the establishment of turf on sand rootzones for football.

### INTRODUCTION

As illustrated in Chapter 2, sand rootzones provide free-draining conditions and good playing quality for football pitches, once established (Baker & Isaac 1987a, b; Canaway 1984a, b; Canaway 1985a, b, c; Davis *et al.* 1974). However, the low inherent moisture and nutrient retention of sands results in slow and difficult establishment on some occasions. For this reason soil amendments especially peat (Baker & Hacker 1988) have been used to aid establishment.

The objectives of the present study were to determine the effects of two contrasting rootzone amendment materials on the establishment, playing quality and water infiltration rate of a sand profile construction for football. A supplementary objective was to investigate the use of a reflectance ratio meter for measuring grass cover during the study in contrast to the previously used, and laborious, point quadrat method. The two products studied were a seaweed extract ('Alginure') and a synthetic polymer material ('Erosel'). These were chosen because of their availability on the UK market and the Institute's advisory staff were being asked for recommendations on the use of such products. Furthermore, there was no research data at the time to provide such recommendations.

Seaweed has been used as a soil conditioner by coastal people since time immemorial in the UK, particularly by the inhabitants of the north-western coast of Scotland and the Hebrides.

This practice spread into greenkeeping for production of composts for use on golf links in Scotland. The use of seaweed is mentioned in older agricultural literature (Murray 1925) and later in turfgrass books (Faulkner 1950). Trials of seaweed meal were conducted by the Sports Turf Research Institute in the period 1954-1957 (Dawson 1956, 1958) to study its use as a top dressing material on turf and it was suggested that the use of seaweed meal might confer some drought resistance. Extraction of alginates from seaweed developed into a specialised industry with applications in pharmaceuticals, cosmetics, textiles etc. These two strands combined in the late 1950's and early 1960's with the production of a processed seaweed (*Ascophyllum nodosum*) extract containing sodium alginate for horticultural use at a reasonable price (pure sodium alginate being expensive by comparison). The then Oxford Horticultural Laboratories Ltd. wrote to the Institute in February 1963 suggesting trials on the product (Alginure) which was then being marketed. Recent use of sand constructions for sports use has once again brought the need for water retentive products to the fore and hence the inclusion of Alginure in the work reported here.

The other product by contrast, was a relatively new invention being a synthetic anionic polymer, which the manufacturers claimed to encourage germination once incorporated with sand. The polymer rapidly absorbs water and on drying has the effect of binding together the sand grains to form a stabilised, moisture retentive surface. The recommended rate of application allowed some latitude depending on the degree of stabilisation required, from 5-20 g $m^{-2}$. A rate of 10 g $m^{-2}$ was recommended by the manufacturer for the trial. A number of related products are currently available, although the manufacturer of Erosel is reported to have ceased trading.

## MATERIALS AND METHODS

### Trial construction

The details of the trial construction are given in previous papers (Canaway 1983, 1990). The important points to note are that the experiment was carried out on a 250 mm deep pure sand rootzone, overlying a 100 mm thick gravel drainage carpet, blinded with 50 mm of coarse sand. Beneath the drainage carpet a pipe drainage system was installed in the subsoil with pipes at 10 m centres.

### Seedbed preparation

After levelling the sand, seedbed fertiliser was applied to provide the following nutrients (kg $ha^{-1}$): N, 75; $P_2O_5$, 50; $K_2O$, 50.

### Experimental treatments

Eight rates of Alginure were used: 0, 25, 50, 75, 100, 125, 150 and 175 g $m^{-2}$. Erosel was applied at 0 and 10 g m$^{-2}$. The Alginure and Erosel treatments were combined factorially to give a total of 16 treatments. These were arranged in randomised blocks with two replications. Plot size was 2 m x 2.25 m and plots were separated with 25 mm deep polythene dividers to prevent moisture migration among plots. The soil amendments were applied evenly by hand and the plots were sown with *Lolium perenne* L. 'Loretta' at a rate of 22 g m$^{-2}$ on 5 June 1985. The seed and amendments were together raked into the top (25 mm approximately) layer of sand. The seedbeds were then firmed with a tamp (a roller could have caused cross contamination of treatments) and watered daily under dry conditions to encourage establishment.

### Trial management

The management of the trial after the initial setting out is detailed in Table 1.

TABLE 1
Summary of trial management details

| | |
|---|---|
| Mowing | Initially mowing was at 50 mm height and this was gradually reduced to 25 mm by early August 1985 and subsequently maintained at that height. Clippings removed. |
| Fertiliser | The following nutrients were supplied as proprietary fertiliser mixtures in five applications between 4 July and 10 September 1985. Initially soluble fertilisers were used but rapid leaching with subsequent yellowing of the sward took place and therefore the final application was a slow-release, IBDU-containing product.<br>Rates as kg ha$^{-1}$<br>N $P_2O_5$ $K_2O$<br>223 28 69 |
| Irrigation | The aim was to supply 25 mm of water per week to make up for evapotranspiration losses of c. 18 mm per week, the difference between the two figures being an allowance for drift and evaporation during watering. Frequency was daily until 19 June after which frequency was gradually reduced as the swards established. |
| Wear treatments | Artificial wear treatments were applied with the D.S. machine (Canaway 1976), 4 passes twice weekly starting on 8 October 1985 and finishing on 9 April 1986. |

### Data collection and analysis

The details of the data collected from the experiment are given in Table 2. The data were subjected to analysis of variance using the Genstat statistical program at Bradford University Computing Laboratories. Simple linear or quadratic models were fitted to the resulting responses. In general, linear models were used, quadratic models only being used where the quadratic term was significant in the analysis of variance. Correlation among variables was studied using Pearson's product moment correlation coefficient. For percentage data an arcsin square root transformation was carried out prior to analysis of variance.

## RESULTS

There were no significant effects of the Erosel polymeric soil conditioner, at the rate applied,

TABLE 2

Summary table giving details of data collection, dates and methods used

| Type of data | Dates of sampling | Methods used |
|---|---|---|
| Ground cover of live plant material | 17 Sep. 1985<br>6-7 Nov. 1985<br>3 Dec. 1985<br>7-10 Apr. 1986 | [1] Optical point quadrat of Laycock & Canaway (1980), 100 points per plot in frames of 5, arranged systematically within plots<br>[2] Using a Reflectance Ratio Meter similar in principle to that described by Haggar *et al.* (1983), 4 observations per plot |
| Traction | 18 Sep. 1985<br>6 Nov. 1985<br>3 Dec. 1985<br>7 Apr. 1986 | Using traction apparatus of Canaway & Bell (1986), the torque required to shear the turf was measured, 4 observations per plot |
| Ball rebound resilience | 18 Sep. 1985<br>7 Nov. 1985<br>4 Dec. 1985<br>11 Apr. 1986 | % rebound determined by release of FIFA approved football (Mitre Max) inflated to 70 kPa from 3 m high ball bounce apparatus, 4 observations per plot |
| Hardness | 17 Sep. 1985<br>7 Nov. 1985<br>4 Dec. 1985<br>7 Apr. 1986 | Clegg Impact Soil Tester (Clegg 1976). The peak deceleration (in gravities) of a 0.5 kg, 50 mm diameter hammer dropped from a 300 mm height, was recorded on impact with the turf, 5 observations per plot |
| Water infiltration rate | 25-26 Sep. 1985<br>6 Dec. 1985 | Using double ring infiltrometers of 300 and 500 mm diameter, flooded and allowed to reach a steady state before measurements. Water temperatures were corrected to 10°C, three measurements per plot |

N.B. In order to check for variations in gravimetric soil moisture content 5 cores, 50 mm in diameter and 30 mm trimmed depth, were taken from the path areas surrounding the trial on the following dates (moisture content, % by weight is given in brackets ± standard error): 17 Sep. 1985 (24.9 ±0.60); 7 Nov. 1985 (27.8 ± 1.47); 3 Dec. 1985 (22.7 ± 0.91); 7 Apr. 1986 (22.4 ± 2.50).

on any of the variables measured during the experiment and therefore, the remaining results are confined to the effects of Alginure.

## Ground cover

Results for ground cover are shown in Fig. 1. In September 1985, before wear (Fig. 1A), ground cover exhibited a positive linear response to increasing Alginure rate, the mean ranging from 58% for the zero rate of Alginure up to 83% for the highest rate of Alginure. With the onset of wear treatments, significant quadratic effects were observed in the analysis of variance and simple quadratic responses were fitted to the means (Figs. 1B-1D). With time the results became more variable as indicated by the size of the standard error of the difference between means. The fit of the quadratic models was generally good having R values of 0.94 or more except for that in December 1985 where the means for 125 and 150 g $m^{-2}$ of Alginure showed values widely divergent from the fitted model with a consequently lower value of R (0.87).

### Reflectance ratio

Results for reflectance ratio are shown in Fig. 2. Before wear in September 1985 reflectance ratio increased with increasing Alginure rate from a value of 53 at the zero Alginure rate to 83 at the highest rate of Alginure application. There was a significant quadratic effect in the analysis of variance and curved response was fitted (Fig. 2A). As wear progressed, as in the case of cover, the curves became more pronounced with optima at less than the maximum rate of Alginure applied (Figs. 2B-2D). The December 1985 results (Fig. 2C) were much less variable than those for cover, the standard error being smaller than that seen for cover. Also the fit to the quadratic model was also better ($R = 0.94$). The mean values for reflectance ratio were strongly correlated with those for cover for all dates of measurements. Pearson's product moment correlation coefficients for cover and reflectance are given in Table 3. Absolute values of ground cover and reflectance ratio differed notably in December 1985 and April 1986.

### Traction

Results for traction are shown in Fig. 4. Before wear, in September 1985, traction showed a strong positive response to increasing rate of applied Alginure (Fig. 3A), traction increasing from 28 N m at zero rate of Alginure to 39 N m at the rate of 175 g $m^{-2}$. With the onset of wear variability increased but significant effects of Alginure were observed throughout the period of wear and the response remained positive (Figs. 3B and 3C). At the end of April 1986 an effect of Alginure was still observed. In this case a significant quadratic effect was found in the analysis of variance and consequently a quadratic model was fitted to the mean values (Fig. 1D) which ranged from 20 N m at the zero rate and 27 N m for the rate of 150 g $m^{-2}$ of Alginure.

TABLE 3

Correlation between reflectance ratio and ground cover expressed as the product moment correlation coefficient

| Date of assessment | Correlation coefficient | Significance level |
|---|---|---|
| Sep. 1985 | 0.98 | $p < 0.001$ |
| Nov. 1985 | 0.97 | $p < 0.001$ |
| Dec. 1985 | 0.93 | $p < 0.001$ |
| Apr. 1986 | 0.89 | $p < 0.005$ |

### Ball rebound resilience

Results for ball rebound resilience are shown in Fig. 4. Before wear in September 1985, ball rebound decreased with increasing Alginure rate (Fig. 4A). During wear, in November and December 1985, there was no significant effect of Alginure on ball rebound (Figs. 4B and 4C). However, after wear in April 1986, ball rebound increased in response to increasing the rate of Alginure, significant linear and quadratic responses being observed in the analysis of variance. The fitted quadratic model is shown in Fig. 4D.

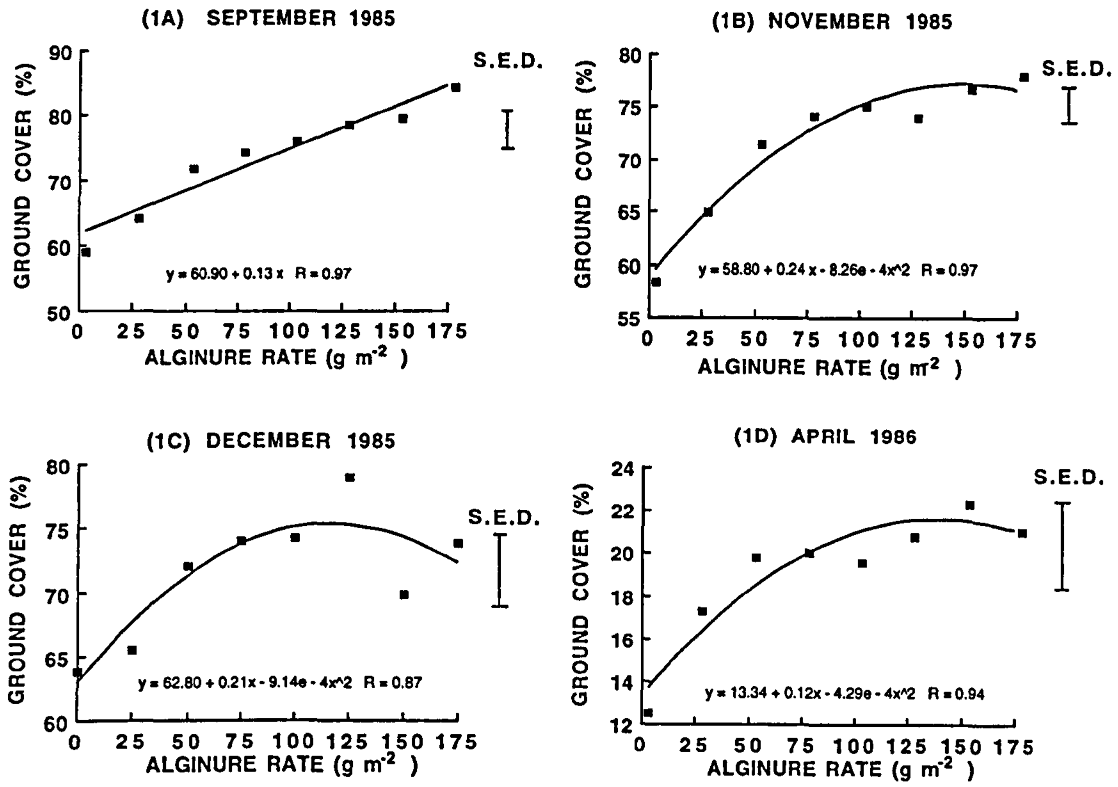

FIGURE 1. Ground cover in response to increasing rate of applied Alginure. 1A September 1985; 1B November 1985; 1C December 1985; 1D April 1986. S.E.D. = standard error of the difference of means.

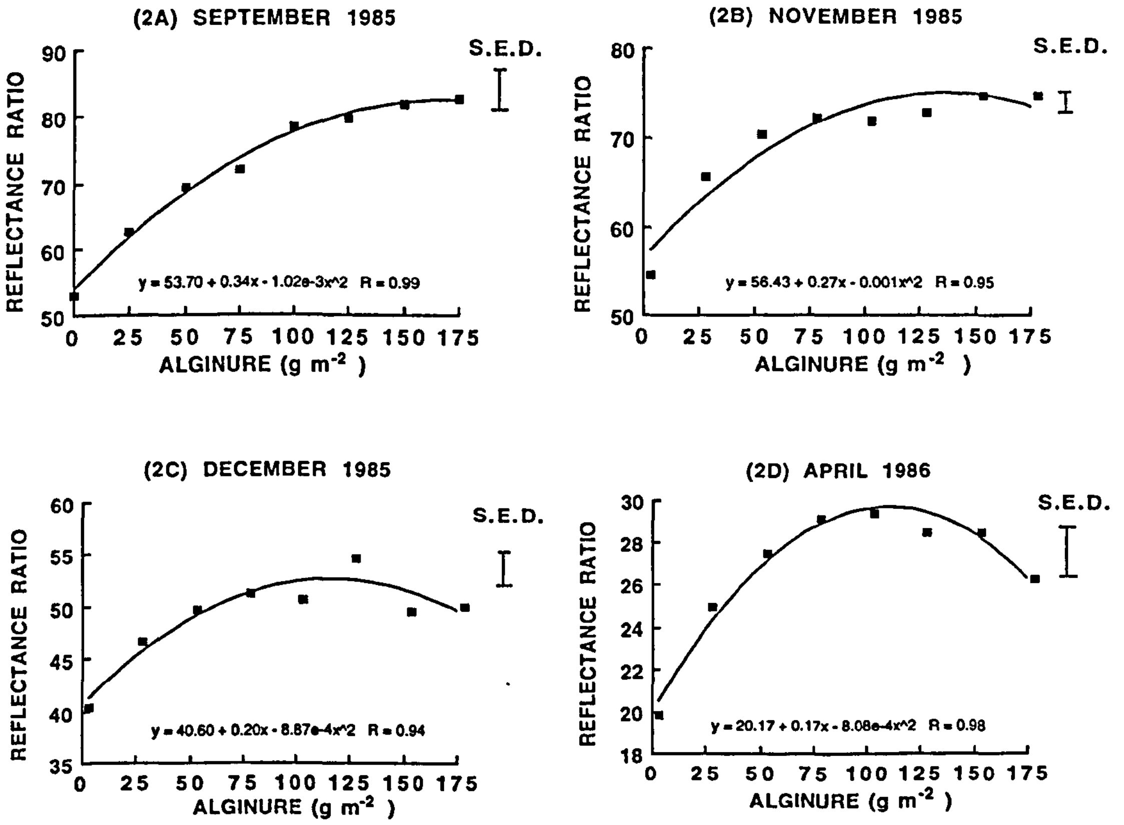

FIGURE 2. Reflectance ratio in response to increasing rate of applied Alginure. 2A September 1985; 2B November 1985; 2C December 1985; 2D April 1986. S.E.D. = standard error of the difference of means.

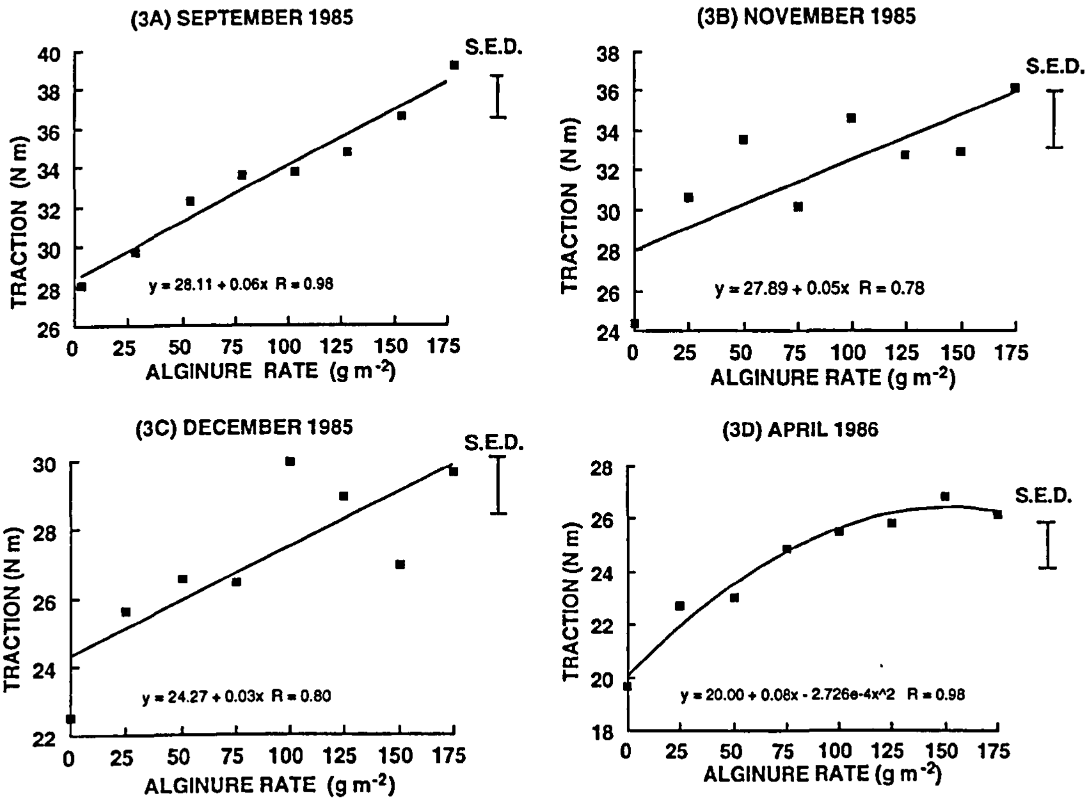

FIGURE 3. Traction in response to increasing rate of applied Alginure. 3A September 1985; 3B November 1985; 3C December 1985; 3D April 1986. S.E.D. = standard error of the difference of means.

### Hardness

Results for hardness are shown in Fig. 5. Before wear, in September 1985, as in the case of ball rebound, hardness decreased with increasing rate of applied Alginure (Fig. 5A). In November 1985, during wear (Fig. 5B) the pattern of response was reversed with a general increase in hardness with increasing the rate of Alginure, although some of the points on the graph showed large deviations from the fitted linear model. In December 1985 (Fig. 5C) there was no significant effect of Alginure in the analysis of variance nor was there any correlation between hardness and Alginure rate when a linear model was fitted. In April 1986 (Fig. 5D), once again a significant effect was observed, hardness increasing with increasing rate of applied Alginure. Ball rebound and hardness were positively correlated before wear and after wear but during wear Pearson's product moment correlation coefficients were not significant (Table 4).

TABLE 4

Correlation between ball rebound resilience and hardness expressed as the product moment correlation coefficient

| Date of assessment | Correlation coefficient | Significance level |
|---|---|---|
| Sep. 1985 | 0.86 | $p < 0.01$ |
| Nov. 1985 | 0.38 | N.S. |
| Dec. 1985 | 0.25 | N.S. |
| Apr. 1986 | 0.86 | $p < 0.01$ |

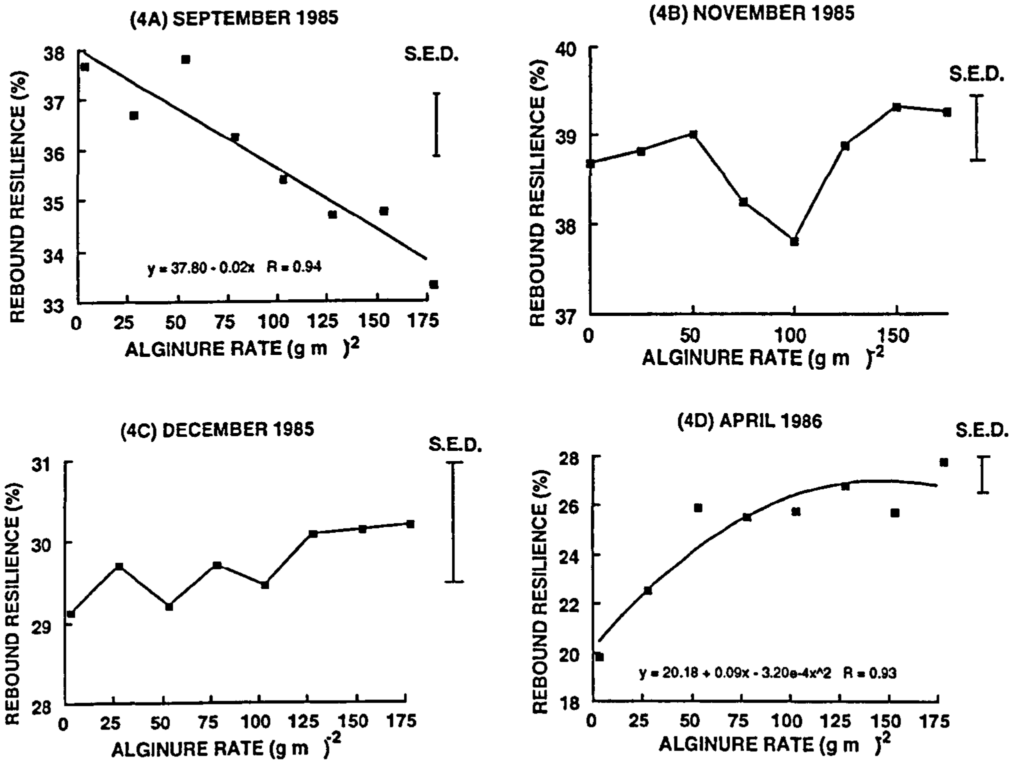

FIGURE 4. Rebound resilience in response to increasing rate of applied Alginure. 4A September 1985; 4B November 1985; 4C December 1985; 4D April 1986. S.E.D. = standard error of the difference of means.

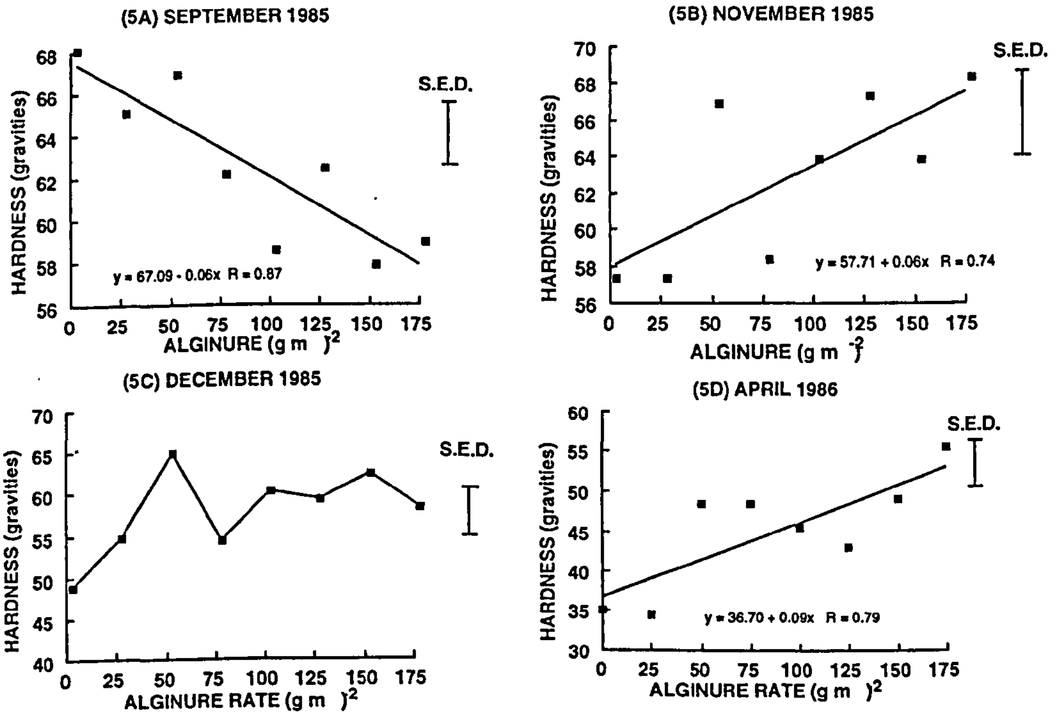

FIGURE 5. Hardness in response to increasing rate of applied Alginure. 5A September 1985; 5B November 1985; 5C December 1985; 5D April 1986. SED = standard error of the difference of means.

### Water infiltration rates

Measurements of water infiltration rates showed no significant effects of Alginure on either occasion of measurement. Results are shown in Table 5. Infiltration rates fell substantially from an average before wear of 204 mm $h^{-1}$ to an average value of 135 mm $h^{-1}$ in December 1985.

TABLE 5

Water infiltration rate (mm $h^{-1}$) measured in September and December 1985, in response to Alginure treatments

| Alginure rate (g $m^{-2}$) | September 1985 | December 1985 |
|---|---|---|
| 0 | 232 | 160 |
| 25 | 187 | 121 |
| 50 | 208 | 148 |
| 75 | 207 | 115 |
| 100 | 199 | 124 |
| 125 | 191 | 115 |
| 150 | 195 | 150 |
| 175 | 212 | 149 |
| S.E.D. | 19.2 | 16.4 |

S.E.D. denotes standard error of the differences of means.

## DISCUSSION

The negligible effect of the Erosel polymer soil conditioner was probably a result of the very low rate used (the manufacturers recommended rate at the time) rather than it being completely ineffective. Baker (1991), in a trial of an acrylic co-polymer, used six rates from zero to 0.5% polymer by weight, when mixed with rootzone sand and found strong responses in terms of ground cover and playing quality, not dissimilar to those seen for Alginure in the present experiment. Indeed in another experiment (Baker 1990), a polymer material was found to be more effective than Alginure in aiding establishment of grass on VHAF (a needle-punched polypropylene reinforcement material). However, as the present trial has shown for Alginure and Baker's (1991) trial showed for a polymer, the rate chosen is very important and in Baker's (1990) trial on VHAF the rate of polymer used was high compared with that used in the experiment reported here (0.2% w/w) and the Alginure rate was moderate (75 g $m^{-2}$), so the initial choice of rate could have determined the relative performance of the products. By contrast the equivalent rate by weight of Erosel in the trial reported here would be 0.025% w/w, an eighth of that used by Baker (1990). The choice of underlying rootzone construction may also be important in determining the response of turf to moisture retentive additives. The present trial was carried out on the most demanding type of construction (sand rootzone above a gravel drainage layer), whereas a sand carpet rootzone, for example, would be expected to have a higher moisture content than a sand profile construction under the same conditions as seen in Chapter 2.

The response in terms of cover to Alginure was such that it was of great benefit in re-establishment of turf in the short period of the football close season, the trial having been sown in June 1985 and the pre-wear data collected in September 1985. However, although there was a linear response initially subsequent responses showed little benefit of application rates above 75 g $m^{-2}$ (hence the amount used by Baker 1990). Therefore, this would be the rate recommended to aid establishment of turf on sand rootzones.

Reflectance ratio proved to be a quick and easy method of estimating cover in the trial taking about half an hour as distinct from a whole day for the point quadrats. Correlation was near perfect for the first two assessment dates but the value of the correlation coefficient fell during wear to 0.93 in December 1985 and 0.89 in April 1986. Field trial plots tend to become more variable as wear treatments progress and lower correlation coefficient may reflect this effect. Alternatively there may be some genuine reason for the poorer correlation at the end of the trial. The difference in absolute values of ground cover and reflectance ratio was almost certainly due to a calibration effect of the reflectance ratio meter and hence, where absolute estimates of cover are required on different dates the meter must be used with caution.

As far as the values of the correlation coefficients are concerned, Kramer (1976) comparing subjective and objective sensory evaluation techniques in general, stated that the correlation coefficient for different measures of the same attribute should exceed 0.9 where possible, but that a value of "0.8 to 0.9 is also considered satisfactory". In the present study the lowest value of the correlation coefficient was 0.89 and therefore the reflectance ratio meter appeared to be satisfactory in this respect. It is important to note that reflectance ratio is influenced by both cover and colour (Gooding & Gamble 1990) but provided the field plots are uniform in colour, reflectance ratio appears to be a very effective labour saving technique for estimating cover.

Playing quality tests showed strong responses to Alginure and the results can be compared with the published standards given in Chapter 2 (Canaway *et al.* 1990) for different components of playing quality (Table 6).

TABLE 6
Preferred and acceptable limits for traction, ball rebound resilience and hardness given by Canaway *et al.* (1990). Note no upper limit for traction was given

| Test | Preferred limits | Acceptable limits |
|---|---|---|
| Traction | >25 N m | >20 N m |
| Ball rebound resilience | 20-50% | 15-55% |
| Hardness | 20-80 *g* | 10-100 *g* |

For player traction only the zero rate fell below the acceptable limit and even at the end of the trial those plots treated with 75 g $m^{-2}$ of Alginure gave values of traction of c. 25 N m or greater, once again suggesting that this rate of application was beneficial.

Ball rebound resilience remained in the preferred range throughout except for the zero rate in April 1986, which fell below 20%, although the response to Alginure changed from negative to positive as discussed below. Hardness remained in the preferred range throughout the experiment but also showed a reversal in response to Alginure from negative to positive. These reversals seemed to be related to physical changes in the playing surface caused by wear. Before wear in September 1985 the responses in terms of ball rebound and hardness were dominated by the large effects of Alginure on grass cover, higher ground cover producing a softer surface with consequently lower ball rebound. With the application of wear treatments the vegetation was flattened and the ball rebound of the surface was dominated by the physical properties of the rootzone material. In previous trials of fertiliser nitrogen (Canaway 1984b, 1985b, c) strong responses to nitrogen were observed before wear, which became small or inconsistent during wear. In this case the Alginure seems to have had a firming and stabilising effect on the sand rootzone possibly because of its moisture retentive properties. Thus, hardness whilst initially decreasing with increasing Alginure, later increased with increasing Alginure, although there was still an element of inconsistency with the December 1985 results showing no discernible response. Ball rebound was correlated with hardness both before wear and after wear, no correlation being observed in the transitional period during wear. Some of the observed effects could also have been due to differences in moisture content of the different experimental plots and with hindsight it would have been useful to take cores for determination of moisture content in response to the individual experimental treatments rather than just from the adjacent paths.

Alginure had no detrimental effects on water infiltration and the values fell with the effects of wear as would be expected.

Overall, the Alginure treatments had a beneficial effect on cover and playing quality and for purposes of general recommendation a rate of 75 g $m^{-2}$ for sand rootzones would provide most of the benefits for the least cost.

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# PART 3

# EFFECTS OF USING SEED, SOD AND JUVENILE SOD FOR THE ESTABLISHMENT OF AN ALL-SAND GOLF GREEN TURF AND ON ITS INITIAL PERFORMANCE UNDER WEAR

## SUMMARY

A trial was established in late April 1990 with the objective of comparing different methods of establishment of golf greens on a sand-based rootzone and their effects on subsequent performance. The methods included grades of mature sod, washed sod, juvenile sod grown on a soil-less medium and seed sown at two rates (35 and 100 g $m^{-2}$). Data were collected before, during and after the imposition of artificial wear treatments on grass ground cover, *Poa annua* ingress, green speed, hardness and water infiltration rate.

Before wear all treatments established satisfactorily although differences in cover and playing quality were evident. Infiltration rates were all >200 mm $h^{-1}$. Once artificial wear treatments started, however, massive reductions in water infiltration rates were observed, especially in the case of grades of mature sod falling to as low as 12 mm $h^{-1}$ in one case. Sod washing was of some benefit in retaining permeability but rates fell to 50-70 mm $h^{-1}$. Juvenile sod and seeded treatments all retained water infiltration rates >100 mm $h^{-1}$ even after wear. Infiltration rates were negatively correlated with the thickness of the surface layer of mineral/organic matter imported along with the sod and with organic matter content of the surface layer, and together these are thought to be responsible for the reductions seen in permeability. The implications of these findings for golf green construction on sandy media are discussed.

## INTRODUCTION

With increasing commercial pressure to bring newly established golf courses into play as quickly as possible, it is often no longer feasible to allow long periods for greens to establish following sowing. The temptation, or indeed the necessity, is to use mature sod for establishment of new greens to minimise the time needed before play can commence. However, the use of mature sod carries with it risks. Modern methods of golf green construction involve the use of rootzones with a very high sand content, sometimes pure sand, to provide free-draining conditions and hence the ability to play even after heavy rainfall. The importation of turf on to such rootzones brings with it the indigenous soil on which turf was grown and the risk that fine silt and clay particles within this soil will 'cap' the sand rootzone, much reducing its drainage capacity. The experiment reported in Part 1 of this chapter (Canaway 1990) showed that even sod grown on pure sand could cause a great reduction in infiltration rate due to the importation of an organic layer at this rootzone surface. On golf greens such layers can become buried by top dressing applications to present an intractable problem in subsequent years. A further risk is that weed grasses such as *P. annua* L. (annual meadow-grass) present in the sod production fields will also be imported along with the sod.

Ways to reduce or overcome these problems include the use of sod grown on soil compatible with the rootzone (USGA 1973), the use of sod washing, where the soil is washed from the sod before re-laying, or the use of "juvenile sod" typically grown on soil-less media and harvested 6-8 weeks after sowing (Guérin & Leboucher 1985; Lin Wu 1988). The juvenile sod tested in the experiment reported here is known as 'Coronet Turf' and is grown on a thin soil-less mulch placed on polythene sheeting in the field. Various grades can be produced for different purposes.

The objective of the work was to compare the effects of different establishment methods, including seed (two rates), mature sod (two grades), washed sod and juvenile sod on grass ground cover, *P. annua* ingress, playing quality and water infiltration rate of golf green turf established on a sand rootzone.

## MATERIALS AND METHODS

### Trial construction

The experimental area was originally constructed in 1981 and consisted of 250 mm medium-fine sand, overlying 50 mm coarse sand which formed a blinding layer above a 100 mm deep gravel drainage carpet. Full details of the construction are given by Canaway (1983). Since 1981 the area had been used for turf trials, the rootzone sand being periodically renewed to remove unwanted residual treatment effects. In March 1990 the existing *Lolium perenne* L. turf was stripped, the upper 100 mm of the existing sand rootzone was removed and replaced with a medium-fine sand with 91% of the particles between 0.125 mm and 0.5 mm in size. Its pH was 5.6 and it contained 36 mg $l^{-1}$ of phosphate ($P_2O_5$) and 23 mg $l^{-1}$ of potash ($K_2O$) (0.5 M acetic acid extraction) indicating low levels of available nutrients.

### Seedbed preparation

The sand was allowed to settle for one month before final firming and levelling on 18-20 April 1990. 'Alginure' soil conditioner (reported on in the previous part of this chapter) was applied at 50 g $m^{-2}$ to aid moisture retention and also provide a supply of micronutrients. A proprietary fertiliser was applied to the seed bed to provide the following amounts (as kg $ha^{-1}$) of: nitrogen (N), 100; $P_2O_5$; 25; $K_2O$, 40 and; magnesium (MgO), 10. The fertiliser contained a slow-release form of nitrogen (IBDU) to reduce the potential leaching losses of nitrogen from the seed bed. Both Alginure and the fertiliser were raked into the upper 50 mm of the seed bed.

### Experimental treatments

The experimental treatments comprised different methods of establishment of golf green turf which are detailed as follows:

[1] Seed sown at 35 g $m^{-2}$. Sown with the following mixture (% by weight); 40% *Festuca rubra* L. ssp. *commutata* Gaud. (Chewings fescue) 'Waldorf'; 45% *F. rubra* ssp. *litoralis* (slender creeping red fescue) 'Dawson' (25%) and 'Jupiter' (20%); 7.5% *Agrostis capillaris* L. (browntop bent) 'Bardot' and 7.5% *A. castellana* Boiss. & Reuter (browntop bent) 'Highland'.

[2] Seed sown at 100 g $m^{-2}$. The above mixture was sown at 100 g $m^{-2}$.

[3] Juvenile sod. This was a commercially available juvenile sod known as 'Coronet Turf'. It was grown on a netted, organic, soil-less mulch and shipped typically at 6-8 weeks after sowing. The plastic mesh netting was incorporated by the grower to facilitate lifting and handling of the juvenile sod. The netting was not visible at any point in the trial after laying, and it is not thought to have made any contribution to the results. The juvenile sod was produced using the same seed mixture given above.

[4] Sod grown on sandy soil. This was a mature sod sown with a mixture of 80% *F. rubra* ssp. *commutata* and 20% *Agrostis* spp. (*A. capillaris* and *A. stolonifera* L.). On delivery it comprised (on the basis of point quadrat analysis): 51% *Agrostis* spp.; 41% *F. rubra*; 7.2% dead matter and traces of *Poa* spp. (*P. annua* and *P. pratensis*). The soil adhering to the sod was defined as a sand in textural classification and determined by mechanical analysis and contained 89% sand, 7% silt and 4% clay.

[5] Sod grown on heavy soil. This was mature sod which consisted on delivery of: 65% *F. rubra*; 15% *Agrostis* spp.: 7% *P. annua*; 1% *P. pratensis* and the remaining 12% comprised dead matter or bare ground. The soil adhering to the sod was described as a clay loam in textural classification as determined by mechanical analysis and contained 35% sand, 33% silt and 32% clay.

[6] Washed sod. Turf as described in [4] above was also supplied with much of the soil removed by washing, using high pressure water jets.

The experimental treatments were laid out in randomised blocks with five replications and plot size was 2 m x 2 m.

## Trial maintenance

The aim was to encourage the grass to establish as quickly as possible with a target date for the start of artificial wear c. four months after initial sowing and sod laying. Details of the trial management are summarised in Table 1.

TABLE 1
Summary of trial management.

| | |
|---|---|
| Mowing | Initially at a height of 25 mm, height being gradually reduced to 5 mm by 3 Sep. 1990, mown twice weekly, clippings removed. |
| Fertiliser | In addition to seedbed fertiliser (detailed above), 5 applications were made in 1990 (on 9 May, 7 June, 23 July, 16 Aug. and 11 Sep.) supplying 175 kg ha$^{-1}$ N and 54 kg ha$^{-1}$ $K_2O$. In spring 1991 a single application was applied on 12 Apr. supplying 28 kg ha$^{-1}$ N. |
| Irrigation | Applied frequently (twice daily if needed) in the early stages to prevent moisture stress. Thereafter approximately 25 mm per week was applied after allowance for rainfall. Watering continued until 13 Sep. 1990. |
| Top dressing | Using the same type of sand as had been used in construction at a rate of 1 kg m$^{-2}$ on 5 occasions (22 June, 23 July, 6 Sep., 24 Sep. and 24 Oct.). To match the levels of the plots established using seed with the remaining plots, the former received additional dressings of 1 kg m$^{-2}$ on 22 June and 2 July. |
| Wear | Wear treatments were carried out using a differential slip wear machine (Canaway 1982) fitted with golf spike rotors using a pulley ratio of 1.11:1 at a rate of 4 passes per week between 6 Sep. and 27 Nov. 1990 (total 52 passes) and at a rate of 8 passes per week between 27 Feb. and 30 Apr. 1991 (a further 64 passes). Recovery growth occurred in Sep. 1990, Oct. 1990 and Apr. 1991 but little took place in winter months. |
| Mechanical treatments | From late July a drag brush was used to lift procumbent growth and lightly scarify the surface on each occasion of mowing. Light verticutting was also carried out in late July. No coring or slitting was carried out. |

## Data collection and analysis

Data were collected on three occasions during the experiment: before the start of wear (28-31 Aug. 1990); after the first period of wear (3-6 Dec. 1990) and; at the end of the trial (1-8 May 1991). Details of data collected and methods used are given in Table 2. In addition, after the experiment had ended (on 14 May 1991) further destructive sampling was carried out to establish the thickness of the layer of organic and/or mineral matter imported with the turf or which had developed subsequently in the case of seeded treatments. For this purpose three cores 50 mm deep and 38 mm in diameter were removed from each plot and the thickness of the surface layer measured at 5 points round the circumference of the core to the nearest mm. Organic matter content was determined, after removal of the surface vegetation, by loss on ignition of the dried cores at 400°C for four hours.

TABLE 2
Details of data collection

| Type of data | Method used |
|---|---|
| Ground cover and species composition | Optical point quadrat of Laycock & Canaway (1980), 100 points per plot in frames of 5, arranged systematically within plots. |
| Ball roll | A golf ball was released from a height of 200 mm from an inclined ramp ball roll apparatus (Lodge 1992) and the distance rolled recorded. Six rolls per plot, three in opposing directions. |
| Hardness | Using the Clegg Impact Soil Tester (Clegg 1976) the peak deceleration of a 0.5 kg, 50 mm diameter test mass was recorded on impact with the playing surface after release from a height of 300 mm. Five observations per plot. |
| Water infiltration rate | Using double ring infiltrometers of 300 mm and 500 mm diameter for the outer and inner rings respectively, flooded and allowed to reach steady state before measurement. Water temperatures corrected to 10°C. Three measurements per plot. |

Data were analysed using analysis of variance and a LSD ($p \leq 0.05$) calculated where treatment effects were significant. Where analysis of variance was not possible the standard errors of the means were calculated. Relationships between water infiltration rate and other variables were explored using regression and correlation.

## RESULTS

Before wear (Table 3) differences in ground cover of desirable grasses were small, the value for the sod grown on heavy soil being reduced because of its *P. annua* content (ground cover values specifically exclude *P. annua* which is listed separately in Table 3). Only the sod grown on heavy soil had a notable contamination with *P. annua*. Ball roll distances ranged from 1.32 m to 1.48 m, equivalent to stimpmeter green speeds of 1.48 m and 2.11 m respectively (calculated using the equation given by Lodge, 1992), which would equate with 'medium' green speeds as given by Radko (1977) for regular membership, rather than tournament play. There were large differences in Clegg hardness among treatments, the seeded treatments giving values approximately twice as great as those on the plots established using sod. The juvenile sod was the softest surface at this stage. There were no significant differences in water infiltration rate although note should be taken of the high values (all >200 mm $h^{-1}$).

In December 1990, after the first period of wear (Table 4) a reduction in total ground cover of desirable species had occurred, together with an increase in *P. annua* content. Ball roll was greater, ranging from 1.67 to 2.03 m, equivalent to stimpmeter green speeds of 2.30 m and 2.65 m, which would equate with medium-fast and fast green speeds as given by Radko (1977). Differences in Clegg hardness were not as great as before wear, the plots established using sod having become firmer and those with seed less hard. Infiltration rates showed a general reduction over the pre-wear values which was most extreme on the treatments involving mature unwashed sod. Washed sod showed some improvement over unwashed material. The juvenile sod and the swards established from seed gave values >100 mm $h^{-1}$ which, although lower than initially, could still cope with heavy rainfall without surface ponding.

TABLE 3
Effects of six establishment treatments on ground cover, *P. annua* cover, playing quality and water infiltration rate on sand golf green turf before wear, August 1990

| Establishment treatments | Ground cover (%) | *P. annua* cover (%) | Ball roll (m) | Clegg hardness (gravities) | Infiltration rate (mm $h^{-1}$) |
|---|---|---|---|---|---|
| Seed 35 g $m^{-2}$ | 92 | 0.0 | 1.38 | 102 | 254 |
| Seed 100 g $m^{-2}$ | 97 | 0.0 | 1.32 | 100 | 233 |
| Juvenile sod | 90 | 0.0 | 1.43 | 43 | 293 |
| Sod, sandy soil | 93 | 0.6 | 1.42 | 54 | 290 |
| Sod, heavy soil | 88 | 6.8 | 1.36 | 52 | 211 |
| Washed sod§ | 94 | 0.2 | 1.48 | 59 | 220 |
| LSD $p < 0.05$ | 5.0 | 1.66† | 0.066 | 6.9 | NS≠ |

†Standard error of the mean for sod, heavy soil. Analysis of variance was not valid due to large number of zero elements in the data matrix. §Initial sod was the same as "sod, sandy soil". ≠NS = not significant.

TABLE 4
Effects of six establishment treatments on ground cover, *P. annua* cover, playing quality and water infiltration rate on sand golf green turf after the first period of wear, December 1990

| Establishment treatments | Ground cover (%) | *P. annua* cover (%) | Ball roll (m) | Clegg hardness (gravities) | Infiltration rate (mm $h^{-1}$) |
|---|---|---|---|---|---|
| Seed 35 g $m^{-2}$ | 70 | 0.2 | 1.97 | 82 | 150 |
| Seed 100 g $m^{-2}$ | 77 | 0.0 | 2.03 | 75 | 112 |
| Juvenile sod | 82 | 0.0 | 1.93 | 66 | 109 |
| Sod, sandy soil | 77 | 3.4 | 1.67 | 65 | 32 |
| Sod, heavy soil | 66 | 13.8 | 1.81 | 55 | 12 |
| Washed sod | 81 | 0.8 | 1.77 | 63 | 51 |
| LSD $p < 0.05$ | 7.0 | 1.88† | 0.096 | 12.5 | 31.6 |

†Standard error of the mean for sod, heavy soil. Analysis of variance was not valid due to large number of zero elements in the data matrix.

After wear, in May 1991 (Table 5), ground cover was further reduced and the *P. annua* content of the unwashed sod grown on heavy soil was greatest. Amounts of *P. annua* in other treatments were small. Ball roll was intermediate between the December and August values, ranging from 1.53 m to 1.78 m, equivalent to stimpmeter green speeds of 2.16 m and 2.41 m respectively, the whole range falling into the medium-fast category of green speed. There was further convergence in Clegg hardness values, differences among treatments being less pronounced than in December 1990. However, infiltration rates once again showed gross differences among treatments, the unwashed mature sod producing the lowest values. Sod washing seemed again to show some benefit in this respect and the juvenile sod and seeded treatments again gave values >100 mm $h^{-1}$. Infiltration rates in May 1991 were negatively correlated with the thickness of the organic/mineral layer found at the surface ($r = -0.82$, $p < 0.001$). The data for organic matter content as determined by loss on ignition formed two disparate clusters when plotted against infiltration rate and hence a spurious correlation could result. However, Spearman's rank correlation showed a significant negative relationship between these variables ($r_s = -0.54$, $p < 0.005$). Thickness of the surface layer ranged from 3 mm in the seed 35 g $m^{-2}$ treatment to 17 mm in the sod grown on heavy soil, loss on ignition ranged from 1% to 2.7% for the same treatments. The juvenile sod had the highest value of loss on ignition at 3.3% (LSD = 0.31).

TABLE 5

Effects of six establishment treatments on ground cover, *P. annua* cover, playing quality and water infiltration rate on sand golf green turf after wear, May 1991

| Establishment treatments | Ground cover (%) | *P. annua* cover (%) | Ball roll (m) | Clegg hardness (gravities) | Infiltration rate (mm $h^{-1}$) |
|---|---|---|---|---|---|
| Seed 35 g $m^{-2}$ | 47 | 0.0 | 1.66 | 77 | 199 |
| Seed 100 g $m^{-2}$ | 37 | 0.2 | 1.72 | 66 | 179 |
| Juvenile sod | 52 | 0.0 | 1.78 | 74 | 105 |
| Sod, sandy soil | 67 | 0.0 | 1.58 | 76 | 27 |
| Sod, heavy soil | 37 | 16.2 | 1.53 | 83 | 47 |
| Washed sod | 62 | 1.2 | 1.60 | 68 | 70 |
| LSD $p < 0.05$ | 8.2 | 1.98† | 0.110 | 8.7 | 45.6 |

†Standard error of the mean for sod, heavy soil. Analysis of variance was not valid due to large number of zero elements in the data matrix.

## DISCUSSION

The most significant finding of the experiment was the massive reduction in water infiltration rate in a relatively short time, resulting from the use of mature sod in the establishment of a sand golf green. The negative correlations seen between water infiltration rates and the depth of the surface layer imported along with turf, and with the organic matter content as determined by loss on ignition implicates the upper layer of imported sod as the causal factor. Sod washing reduced this effect to some extent but not as much as the use of juvenile sod or establishment using seed. With further wear one would expect infiltration rates to fall still further. The USGA (1973) specified that the sandy rootzone mixtures for golf greens should have infiltration rates of 50-75 mm $h^{-1}$ in the laboratory. There was also a recognition of the potentially detrimental effects of using imported sod for establishment. "This is acceptable only if the sod is grown on exactly the same soil mixture as is used in the green. If the sod is grown on any other type of soil and moved onto the porous putting green soil, failure is a predictable certainty." (USGA 1973.) In the experiment reported in Part 1 of this chapter (Canaway 1990), it was shown that even sod grown on pure sand was capable of causing a gross reduction in infiltration rate due to the presence in the sod of a layer of organic matter derived both from leaf debris and root production, the latter probably contributing greatly to pore blockage in the sod layer. One might argue that a sward established from seed or juvenile sod will also produce organic matter and so, in time, the situation will be no different. Although this is true if no remedial action is taken, the aim of top dressing with sandy materials, as part of a golf green management programme, is to dilute the organic matter with a permeable material as the organic matter accumulates. In contrast, in sod production fields, this top dressing would not be carried out and furthermore, clippings would be returned at least at some stages of the sod growing period, further aggravating accumulation of organic matter at the surface.

In conclusion, the use of mature sod for establishment of golf greens has increased greatly over the past 20 years and it seems likely on the basis of the results presented here that we may be actively causing problems of our own making by such use of sod. Even if we choose sod grown on very sandy soil is used (the sandy soil was of textural classification 'sand'), very large reductions in infiltration rate can ensue even in a relatively short period of time. This could in turn lead to the development of anaerobic conditions, "black layer" and so forth. This problem can be reduced by the use of washed sod or better by juvenile sod where there is insufficient time for establishment using seed. Juvenile sod had no detrimental effects on playing quality apart from initial softness which soon disappeared. Juvenile sod was completely free of *P. annua* contamination, which was a particular problem on one of the sod samples. However, its high loss on ignition values attributable to the organic mulch used in production does raise questions about the long-term effects of this organic matter, even though in this relatively short trial, no detrimental effects were evident. If time permits, use of seed would still be the preferred method of establishment since no extraneous layer of organic or mineral matter is placed onto the permeable rootzone surface with potential for reduction in its permeability. The trial also underlines the need for remedial action, after construction, in cases where sod has been used due to pressure of time. This could take the form of intensive hollow-tine coring to remove some of the organic and mineral matter, together with sand top dressing to provide permeable channels for the movement of water and air into the profile.

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# DISCUSSION

The aims of the work on rootzone amendments were straightforward and the results showed that the Alginure had benefits in terms of increased ground cover and improved playing quality. The response to Alginure in terms of cover showed that a rate of 75 g $m^{-2}$ gave the most cost-effective use of the product and subsequently, this rate has been used by STRI agronomists in the construction of sand-based sports fields. The results for the polymer product were inconclusive since only one low rate was used in contrast to the eight rates used for the Alginure, which provided a good basis for examination of the sward response. The other objective, namely evaluation of the reflectance ratio meter as a means of estimating cover was also achieved. With hindsight, the nutritional management of the experiment could have been improved, since some transient symptoms of nitrogen deficiency induced by the rapid leaching of nitrogen from the rootzone were observed despite the frequent fertiliser applications. Were I repeating the experiment I would use an IBDU-containing product throughout.

The two experiments on establishment methods showed that concerns expressed about the use of sod on free-draining rootzones were well founded. Infiltration rate fell to lowest values of 3 mm $h^{-1}$ in the football experiment and to 12 mm $h^{-1}$ in the golf experiment in a relatively short time. The football experiment showed the lowest rate of 3 mm $h^{-1}$ on turf grown on pure sand which initially was a very surprising result. It was only when the organic matter measurements had been made and the strong negative correlations with infiltration rates observed, that it was fully appreciated that the organic fine particles produced by the action of wear could so effectively block the previously free-draining rootzone. In the golf experiment a similar conclusion was reached where both the thickness of the combined organic/mineral surface layer and organic matter content, as determined by loss on ignition, were significantly negatively correlated with water infiltration rate.

In today's commercial environment there is almost overwhelming temptation or necessity to use sod in constructional work, simply because it buys time. This is especially true in golf green construction. For football pitches the additional cost for such a large area is still a deterrent. Furthermore, if sod establishment is not sufficient, turves can be lifted by the action of players with disastrous consequences. The conclusion of the above experiments is that it would be a much better solution to use juvenile sod where no extraneous material is imported and much smaller reductions in infiltration rate were observed. Unfortunately, however, such products are of extremely limited availability in the UK, as compared with mature sod. Sod washing was shown to be beneficial in maintaining the infiltration rates on the golf green rootzone and therefore, its use would also be recommended. However, again limited availability and greater additional cost (rumoured to be c. twice the price of mature sod) are serious deterrents to its use.

As a result of these experiments a much greater emphasis is placed by STRI agronomists in mitigating the effects of sod on infiltration rates where sod has been used out of necessity. Steps taken include: selection of the sod from fields with a sandy soil; intensive hollow tine coring following establishment in order to provide free passage of water; establishment of a sand top dressing programme, coupled with further aeration work in order to dilute surface accumulations of organic matter and maintain water infiltration rates.

# CHAPTER 4
## NITROGEN NUTRITION

### INTRODUCTION

It was clear from earlier experiments that levels of fertiliser nitrogen could have a profound effect on both playing quality of turf and its ground cover under wear (for references see Part 1 Introduction). However, earlier work done by the author on fertiliser nitrogen had been carried out on extreme forms of rootzone construction, either a pure sand overlying a gravel drainage carpet as compared with an indigenous sandy loam topsoil. In the latter experiments optimum nitrogen levels had been found, with levels higher or lower than the optimum, leading to poorer performance expecially in relation to ground cover under wear. But what about less demanding constructional types? Would these too have optimum levels of nitrogen input and if so, would these be different than for pure sand rootzones or indigenous topsoil? These are the questions that are described in this chapter in relation to the fertiliser nitrogen requirements of one particular form of rootzone construction, which might be considered intermediate between pure sand on the one hand and topsoil on the other hand. The results proved very interesting, not just for the management of particular forms of construction but also for the relation between wear and nitrogen nutrition in general.

# PART 1

# THE RESPONSE OF *LOLIUM PERENNE* L. GROWN ON A PRUNTY-MULQUEEN SAND CARPET ROOTZONE TO FERTILISER NITROGEN

# I. GROUND COVER RESPONSE AS AFFECTED BY FOOTBALL-TYPE WEAR

## SUMMARY

The response of *Lolium perenne* L. to fertiliser nitrogen was studied on a sand carpet rootzone constructed to the Prunty-Mulqueen (PM) pitch specification. The experiment was sown in September 1983 and during 1984 and 1985 the following nitrogen treatments were applied: 0, 25, 100, 225, 400, 625 kg ha$^{-1}$ N. Ground cover was measured before, during and after periods of artificial wear treatments to simulate the action of play during the 1984/1985 and 1985/1986 football seasons.

The results showed that before wear ground cover increased rapidly with increasing nitrogen, with little evidence of an optimum rate. However, once wear treatments had started, turf receiving high levels of nitrogen deteriorated at a greater rate than turf receiving an intermediate level of nitrogen so that an optimum level became evident. These responses were fitted by an inverse polynomial function and the optimum nitrogen level was calculated at each date. During each football season the optimum nitrogen level decreased as wear treatments progressed, however, the average optimum annual input for maximum ground cover was 177 kg ha$^{-1}$ N for the two seasons combined.

## INTRODUCTION

As detailed in Chapter 2, in the United Kingdom the most important factor limiting the use of pitches for sports such as Association Football, Rugby Football and hockey during the winter months is the inability of most natural soils to transmit water away from the surface at a sufficient rate. This, together with the effects of play on soil structure, means that many sports fields are unfit for use during periods of rainfall and the playing quality of such pitches deteriorates as the season progresses, providing poor playing conditions.

This has led increasingly to the use of sand-based rootzones for sports fields, in the extreme case pure sand, to provide a free-draining surface and good playing conditions throughout the season. For a time the understanding of the soil physics of water movement through sand profiles far exceeded the knowledge of the nutrition of turf grown on sand rootzones. For example, Adams (1981) stated that, "A stage has now been reached when soil design for reconstruction or amendment can be formulated with confidence. This, however, is only one aspect of coping with an ever-increasing demand for use. There is a need to understand and broadcast the particular nutritional implications of sand rootzones".

At the time Adams' (1981) paper was published there had been no definitive work on the response to nitrogen of heavy duty sports turf subjected to wear under UK conditions. Previous work had either not involved wear (Adams 1980, Adams *et al.* 1973) or had too few levels of nitrogen to draw any firm conclusion about the optimum rate (e.g. Shildrick 1980, 1981). Trials in the Netherlands and West Germany, however, suggested an optimum annual nitrogen input for maximum ground cover during wear of between 200 and 300 kg $ha^{-1}$ N (van der Horst & Kamp 1974; Riem Vis 1974, 1978, 1983; Skirde 1974; Leyer & Skirde 1980).

With this background, in 1981 two experiments were set up at the Sports Turf Research Institute, one on a sandy loam soil with pipe drains at 5 m centres and the other on a 250 mm thick sand rootzone overlying a gravel drainage carpet, to determine the response of *Lolium perenne* turf to a wide range of nitrogen treatments. The details of the construction of the experimental areas were given by Canaway (1983) and the details of the nitrogen trials by Canaway (1984a, b, c; Canaway 1985a, b, c, d).

The results of the experiments showed that indeed the sand rootzone retained more ground cover during wear (Canaway 1984a, 1985a) and provided better playing quality in terms of player traction (the amount of grip or purchase available to the player when turning, accelerating, stopping, etc.) and ball rebound resilience (Canaway 1984c, 1985c). The experiments also showed that although the turf on the soil rootzone deteriorated much more rapidly than the sand rootzone, the optimum annual nitrogen input required to maximise ground cover was similar at around 289 kg $ha^{-1}$ N in the first season of use and 264 kg $ha^{-1}$ in the second season (Canaway 1984a, 1985a). This similarity in the optimum nitrogen input for the contrasting constructional types was a surprising result in view of the poor nutrient retention and leaching potential of the sand rootzone as compared with topsoil.

Sand carpet constructions aim to combine the best aspects of both sand and soil rootzones. The normal method of construction is to lay 100-150 mm of carefully chosen sand over the existing topsoil into which a system of pipe drains and slit drains are installed. It is important during construction to loosen the topsoil between the slit drains to encourage grass roots to grow through the sand and into the topsoil below. The Prunty-Mulqueen (or PM) pitch is a patented type of sand carpet pitch construction (Prunty 1970). Sand carpet pitches therefore provide free drainage at the surface with consequent good playing conditions, together with the possibility of storage and retention of nutrients in the topsoil layer below.

The objective of the work was to explore the response to a wide range of nitrogen levels of ground cover and playing quality of a PM pitch subjected to artificial wear treatments applied during the football season. This Part describes the results for ground cover over a period from July 1984 to April 1986. Playing quality responses are described in Part 2.

## MATERIALS AND METHODS

### Construction and establishment of field experiment

The experiment was carried out at Myerscough College of Agriculture and Horticulture, Bilsborrow, Preston. Details of the site location are given in Table 1.

The trial area was constructed in July 1983 to the Prunty-Mulqueen (PM) pitch specification. This was carried out as follows: 80 mm diameter pipe drains were installed at 5 m centres into the existing clay loam topsoil on the site and the drain trenches backfilled with 5-10 mm gravel. Slit drains were next installed at right angles to the pipe drains and backfilled with 6 mm Lytag (a synthetic granular aggregate) to the surface of the slits. The backfilling in the slits connected with that above the pipe drains to permit free passage of water to the pipe drains. The slits were 300 mm deep, 50 mm wide and 1 m apart. The topsoil between the slits was then loosened with a subsoil cultivator prior to spreading 100-150 mm of Southport dune sand to form the finished levels. The sand was a uniform medium-fine wind-sorted dune sand with 96% of the sand particles between 0.125 mm and 0.5 mm in size and with no silt or clay. The particle size distribution of the sand is given in Table 2. The pH of the sand was 8.5. Details of seed bed fertiliser, sowing and experimental design are given in Table 1.

TABLE 1
Experimental details

| Site details | | |
|---|---|---|
| Grid Reference of Myerscough College | SD 494401 | |
| Altitude (m) | | 14 |
| Rainfall totals (mm) | 1983 | 1002 |
| | 1984 | 1018 |
| | 1985 | 999 |
| Seed bed fertiliser (kg ha$^{-1}$) | N | 65 |
| | $P_2O_5$ | 90 |
| | $K_2O$ | 120 |

TABLE 1 (cont)

| | |
|---|---|
| Experimental design | Randomised blocks<br>5 replications<br>2.5 m x 2.5 m plots |
| Sowing | *Lolium perenne* 'Majestic' at 40 g $m^{-2}$ on 30 September 1983. |

TABLE 2
Particle size distribution of the Southport dune sand used in the construction of the experimental area

| Particle diameter (mm) | % by weight in each size fraction |
|---|---|
| 4-8 | 0 |
| 2-4 | T |
| 1-2 | T |
| 0.5-1.0 | 1 |
| 0.25-0.5 | 27 |
| 0.125-0.25 | 68 |
| 0.05-0.125 | 3 |
| <0.05 | 1 |

T = trace

## Fertiliser treatments

The fertiliser treatments consisted of six levels of nitrogen: 0, 25, 100, 225, 400 and 625 kg $ha^{-1}$ $yr^{-1}$ N, with phosphorus and potassium applied in proportion. The series was chosen to give a wide range of treatments and because four of the treatments (0-225 kg $ha^{-1}$) are commonly encountered in practice, furthermore the series can easily be made linear by square root transformation. Potassium was applied at a rate of 0.75 kg of $K_2O$ for each kg of N supplied (Morrison *et al.* 1980) and phosphorus at a rate of 0.25 kg $P_2O_5$ for each kg of N supplied. The zero nitrogen treatment received the same amounts of potassium and phosphorus as the treatment receiving 25 kg $ha^{-1}$ N (after Morrison *et al.* 1980). The nitrogen was supplied as ammonium nitrate, the phosphorus as superphosphate and the potassium as potassium sulphate. The nitrogen and potassium were applied in solution in eight equal applications. The phosphorus was supplied as a single dressing at the first application only. The amounts of nutrients supplied in the six treatments are given in Table 3 and the dates of applications are given in Table 4.

TABLE 3
Summary of the annual amounts of nutrients (kg ha$^{-1}$) supplied in the six treatments

| N | $P_2O_5$ | $K_2O$ |
|---|---|---|
| 0 | 6 | 19 |
| 25 | 6 | 19 |
| 100 | 25 | 75 |
| 225 | 56 | 169 |
| 400 | 100 | 300 |
| 625 | 156 | 469 |

TABLE 4
Dates of fertiliser applications (all dates 1984)

| Application | Date<br>1984 | 1985 |
|---|---|---|
| 1 | 4 April (P) | 26 April (N,P & K) |
|  | 6 April (N & K) | - |
| 2 | 4 May | 5 June |
| 3 | 8 June | 1 July |
| 4 | 10 July | 25 July |
| 5 | 31 August | 28 August |
| 6 | 14 September | 1 October |
| 7 | 3 October | 18 October |
| 8 | 31 October | 31 October |

## Trial management

The trial was mown initially at 50 mm in autumn 1983. In spring 1984 the mowing height was gradually reduced to 25 mm and subsequently maintained at that height. Clippings were removed. Irrigation was supplied as necessary in dry weather, amounts and requirement for water being judged subjectively.

Wear treatments were applied during each football season to simulate the action of play, using the differential slip wear machine described by Canaway (1976). Four passes of the machine were applied twice weekly from 17 October 1984 until 20 March 1985 in the first season and from 7 October 1985 until 16 March 1986 in the second season. At the end of the season in April 1985 the experimental area was renovated by light hand raking and overseeding with *L. perenne* ‘Majestic’ at 20 g m$^{-2}$.

## Data collection

Ground cover of live plant material was recorded using an optical point quadrat frame designed for close-mown turf (Laycock & Canaway 1980). In each plot 100 points were recorded in 20 frames of 5 points distributed systematically. Dates of recording are given in Table 5.

TABLE 5
Dates of ground cover sampling

| Assessment | 1984/1985 season | 1985/1986 season |
|---|---|---|
| Before wear - 1 | 24 July 1984 | 24 July 1985 |
| Before wear - 2 | 25 September 1984 | 5 September 1985 |
| During wear - 1 | 19 November 1984 | 16 October 1985 |
| During wear - 2 | 7 February 1985 | 26 November 1985 |
| During wear - 3 | | 13 January 1986 |
| After wear | 27 March 1985 | 17 April 1986 |

### Statistical methods

The methods used were the same as those described by Canaway (1984a, 1985a) whereby the data were subjected to analysis of variance and the standard errors of the means derived from the analyses were used to indicate the variance present in the data sets. No significance tests based on the analysis of variance were used since these would be inappropriate in an experiment concerned with increasing levels of a quantitative factor such as applied nitrogen rate (see Mead & Pike (1973) p. 812). Instead, response curves were fitted to the means for ground cover using an inverse polynomial function of the form:

$$y = \frac{a + bx}{1 + cx + dx^2}$$

where $y$ is ground cover and $x$ is the annual rate of applied nitrogen. For details of the rationale behind the use of the inverse polynomial function and further examples of its use see Nelder (1966), Sparrow (1979), Morrison *et al.* (1980), Canaway (1984a, 1985a). The best fit model was obtained for each data set by using an iterative function minimisation routine at Bradford University Computing Laboratories. Once the parameters of the curves were known, it was possible to calculate the optimum nitrogen input required to give maximum ground cover by differential calculus, since the optimum occurs at the point when $dy/dx = 0$.

## RESULTS

### 1984/1985 season

Ground cover before wear in July and September 1984 (see Figs. 1A and 1B) increased rapidly at first with increasing nitrogen but soon levelled off above about 225 kg $ha^{-1}$ $yr^{-1}$ N. Calculation of an optimum nitrogen input for these curves is of little value since there is a large 'plateau' area where ground cover changes little in response to large changes in nitrogen input. The parameter values for the fitted curves and the percentage of the total sums of squares accounted for by the fitted models are given in Table 6, where it can be seen that for the pre-wear data (July and September 1984) the models accounted for over 99% of the observed variation.

TABLE 6

Parameter values for, and the percentage of the total sums of squares accounted for by the inverse polynomial curves fitted to the mean values of ground cover during the 1984/1985 season. Values of the optimum nitrogen input calculated from the exact values of the parameters at each date are also given.

| Date | Parameter values *a* | *b* | *c* | *d* | % of total S.S. due to fitted curve | Optimum N kg ha$^{-1}$ yr$^{-1}$ |
|---|---|---|---|---|---|---|
| Jul. 1984 | 55 | 2.2 | 2.2 x 10$^{-2}$ | 3.1 x 10$^{-6}$ | 99.9 | 356 |
| Sep. 1984 | 59 | 0.76 | 6.7 x 10$^{-3}$ | 1.6 x 10$^{-6}$ | 99.2 | 472 |
| Nov. 1984 | 43 | 0.80 | 6.0 x 10$^{-3}$ | 9.3 x 10$^{-6}$ | 96.7 | 220 |
| Feb. 1985 | 19 | 5.6 x 10$^{-2}$ | -6.2 x 10$^{-4}$ | 1.1 x 10$^{-5}$ | 98.6 | 135 |
| Mar. 1985 | 16 | 8.7 x 10$^{-3}$ | -5.1 x 10$^{-3}$ | 1.7 x 10$^{-5}$ | 96.3 | 161 |

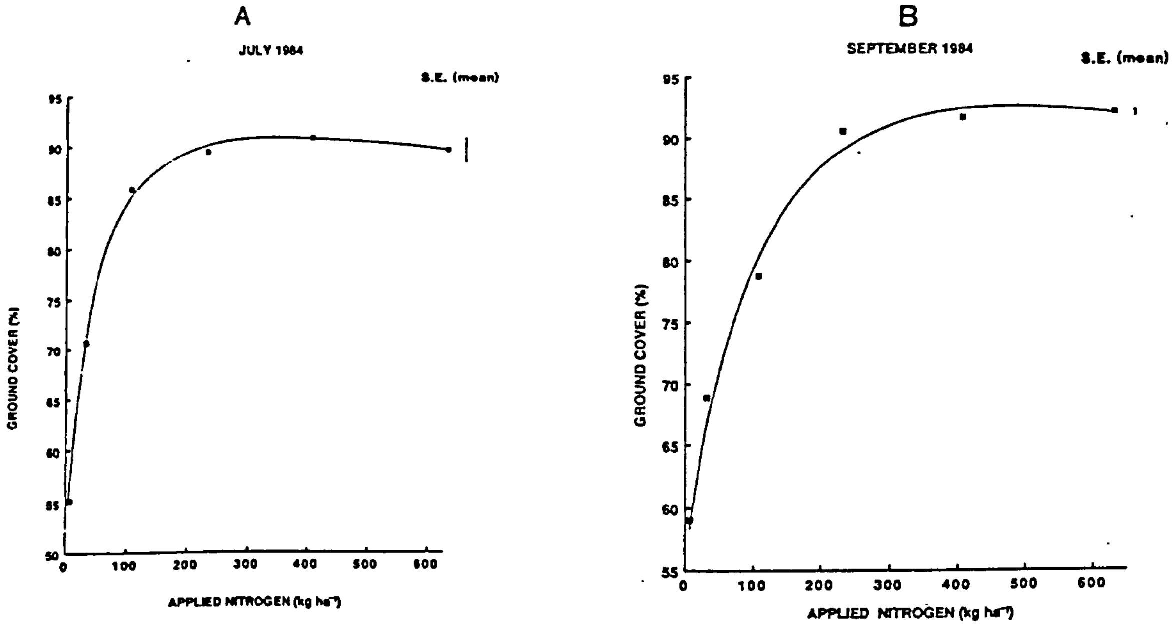

FIGURE 1. Ground cover of turf in response to fertiliser nitrogen before wear: 1A, July 1984; 1B, September 1984.

During wear (Figures 2A and 2B) and after wear (Figure 2C) ground cover at high levels of nitrogen fell faster than that at lower levels so that the response curves developed optima at intermediate levels of nitrogen. In November 1984 the first stage in the decline of the high nitrogen treatments can be seen but these still have greater ground cover than the zero and 25 kg ha$^{-1}$ N treatments, but by February 1985 and March 1985 a marked change in the response had occurred such that the 400 kg ha$^{-1}$ and 625 kg ha$^{-1}$

N treatments had lower ground cover even than the zero N treatment. The average optimum annual nitrogen input required to maximise ground cover during the period of wear was 172 kg ha$^{-1}$ N.

The changing shape of the curves is reflected in the changing values of their parameters given in Table 6. The constant $a$ represents the intercept and $b$ the initial slope and their values fell as wear progressed. The expression is dominated by the parameter $d$ which, being in the denominator, and multiplied by $x^2$ has a large effect on $y$ as $x$ increases. Consequently, the numerical values of $d$ are very small but it will be noted that the value increased from 1.6 - 3.1 x $10^{-6}$ before wear to 1.1 - 1.7 x $10^{-5}$ during and after wear. The constant $c$ which adds to, or subtracts from the effect of $d$ depending on its sign and size, became negative at the latter stages of wear but otherwise showed no consistent trend.

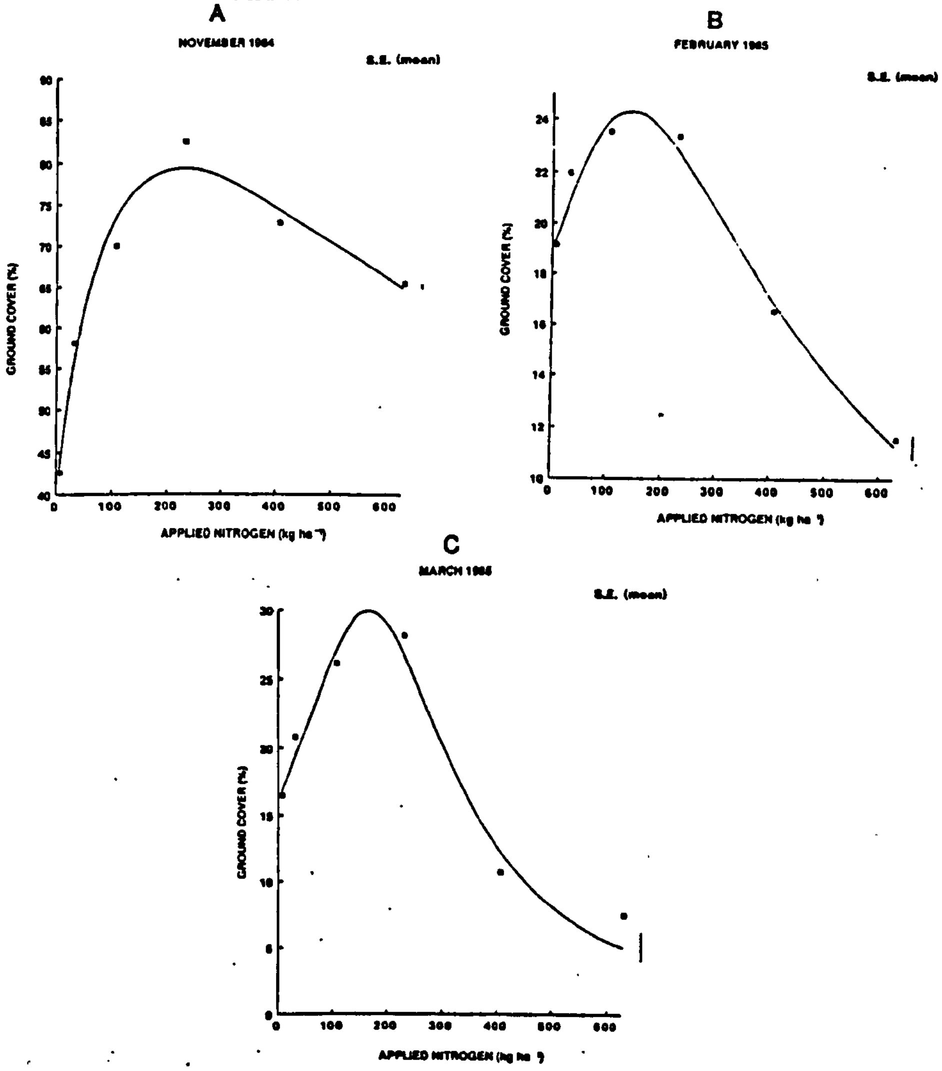

FIGURE 2. Ground cover of turf in response to fertiliser nitrogen during and after wear: 2A, November 1984; 2B, February 1985 and 2C March 1985.

### 1985/1986 season

Ground cover before wear in July and September 1985 (Figs. 3A and 3B) increased rapidly with increasing nitrogen and, as in the previous season, the slope of the response curves decreased with increasing nitrogen, giving a 'plateau' area of the response where ground cover changed relatively little over a large range of nitrogen levels. The parameters of the curves and the percentage of the total sums of squares accounted for by the models are given in Table 7.

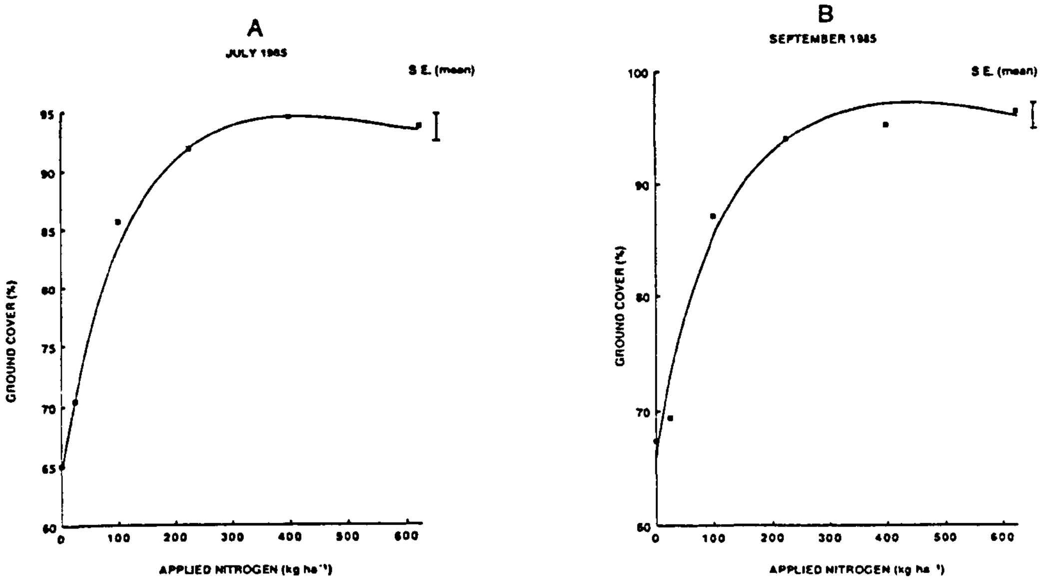

FIGURE 3. Ground cover of turf in response to fertiliser nitrogen before wear: 3A, July 1985; 3B September 1985.

TABLE 7

Parameter values for, and the percentage of the total sums of squares accounted for by the inverse polynomial curves fitted to the mean values of ground cover during the 1985/ 1986 season. Values of the optimum nitrogen input calculated from the exact values of the parameters at each date are also given.

| Date | Parameter values |  |  |  | % of total S.S. due to fitted curve | Optimum N kg ha$^{-1}$ yr$^{-1}$ |
|---|---|---|---|---|---|---|
|  | *a* | *b* | *c* | *d* |  |  |
| Jul. 1985 | 64 | 0.79 | $6.8 \times 10^{-3}$ | $1.8 \times 10^{-6}$ | 99.5 | 416 |
| Sep. 1985 | 66 | 0.69 | $5.6 \times 10^{-3}$ | $1.7 \times 10^{-6}$ | 97.6 | 436 |
| Oct. 1985 | 56 | 0.92 | $7.2 \times 10^{-3}$ | $3.1 \times 10^{-6}$ | 97.0 | 367 |
| Nov. 1985 | 24 | 0.47 | $3.8 \times 10^{-3}$ | $8.8 \times 10^{-6}$ | 96.1 | 255 |
| Jan. 1986 | 22 | 0.40 | $4.4 \times 10^{-3}$ | $1.7 \times 10^{-5}$ | 95.3 | 167 |
| Apr. 1986 | 14 | 0.34 | $2.2 \times 10^{-3}$ | $3.4 \times 10^{-5}$ | 91.7 | 126 |

During wear (Figs. 4A, 4B and 4C) and after wear (Fig. 4D) the form of the responses changed as wear progressed. In October 1985 (Fig. 4A) wear treatments had only started nine days previously and therefore, not surprisingly, the ground cover response was similar to that seen before wear. As wear progressed, however, the ground cover of plots receiving higher nitrogen levels decreased at a faster rate than those receiving intermediate levels of nitrogen so that an optimum became evident (Fig. 4B, 4C and 4D). The optimum decreased from 255 kg ha$^{-1}$ in November 1985 to 126 kg ha$^{-1}$ in April 1986. Excluding the October results which closely resembled those seen before wear, the average optimum annual nitrogen input to maximise ground cover during wear in the second season of simulated play was 183 kg ha$^{-1}$ N.

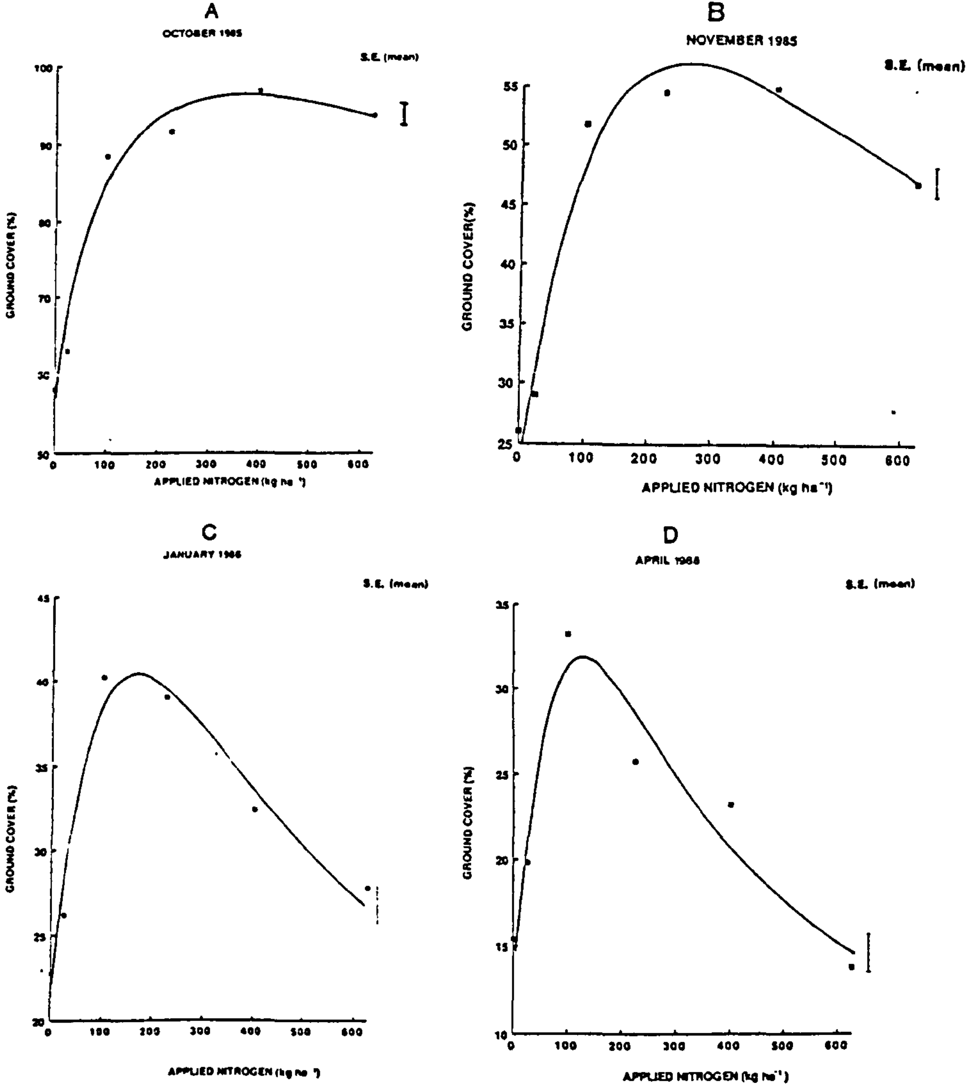

FIGURE 4. Ground cover of turf in response to fertiliser nitrogen during and after wear: 4A, October 1985; 4B, November 1985; 4C, January 1986 and 4D, April 1986.

## DISCUSSION

The results in general followed a similar pattern to that seen for the sand rootzone studied previously (Canaway 1984a, Canaway 1985a) but with some important and interesting differences which are discussed below. But first, why should there be an optimum nitrogen level for maximum ground cover during wear? Beard (1973) suggested that excessive nitrogen produces a succulent, easily damaged turf. Leyer &

Skirde (1980) found that increasing levels of nitrogen increased the moisture content of herbage and decreased total cell wall contents. Canaway (1985b) also found that moisture content progressively increased with increasing nitrogen. Canaway (1984b, 1985b) found that above-ground biomass increased rapidly at first, levelling off at higher nitrogen levels. The inference is that at low levels of nitrogen there is insufficient biomass to sustain wear but that at high levels a less wear-tolerant turf is produced, high in moisture but low in fibre. Therefore, an optimum level must be provided sufficient to maintain growth but not so high as to produce a turf lacking in wear tolerance.

Ground cover before wear in both seasons exhibited the same type of response seen in earlier work (Canaway 1984a; 1985a) with a rapid increase in ground cover initially, followed by a levelling off at higher nitrogen levels. But during wear, in contrast to the results obtained before (Canaway 1984a, 1985a), the ground cover at higher levels of nitrogen fell to such an extent that the values at 400 kg ha$^{-1}$ and 625 kg ha$^{-1}$ N were lower than that for zero N, particularly in the first season of wear. This finding seems most likely to be related to the storage of nutrients in the topsoil beneath the sand. It could be either that the zero and low nitrogen treatments are making use of small amounts of organic nitrogen in the topsoil or, as I believe, more likely that because of the storage of nutrients the higher levels of nitrogen are now excessive and the whole curve is shifted towards lower levels of nitrogen relative to the results for a sand rootzone with gravel below (Canaway 1984a, 1985a). In the previous work ground cover in the treatment of 625 kg ha$^{-1}$ N became as low as that for zero N, but never noticeably lower as in the present trial. The average optimum value for nitrogen input for the sand carpet pitch in its first season of use was 172 kg ha$^{-1}$ N as against 289 kg ha$^{-1}$ N for a sand profile type of construction (Canaway 1984a). In the second season of use the optimum annual input was 183 kg ha$^{-1}$ for the sand carpet pitch as compared with 264 kg ha$^{-1}$ for the sand profile rootzone (Canaway 1985a). Therefore, the sand carpet pitch did indeed appear to provide nutritional benefits as one might have intuitively expected. The average optimum nitrogen input for the two seasons to maximise ground cover during wear was 177 kg ha$^{-1}$ N and one could propose this value as a practical recommendation for the fertilisation of PM pitches. It is recognised, however, that there is probably no true optimum, since the calculated optimum value decreased in both seasons as wear progressed, and a similar phenomenon was observed in the earlier experiments (Canaway 1984a, 1985a) and by Riem Vis. (1983). If the assumptions about the formation of an optimum nitrogen input given above are correct, these can be used to explain the decrease in value under wear. Early in the stages of wear the *amount* of biomass is probably more important but as more plant material is lost in the process of wear, the *quality* of the remaining biomass in terms of fibrous lignified material probably assumes greater significance.

In conclusion, taking the earlier work (Canaway 1984a, 1985a) together with the present experiment, it can be definitively stated for *Lolium perenne* receiving football-type wear that:

[1] before wear the ground cover response to fertiliser nitrogen shows a rapid initial increase followed by a 'plateau' area of little change;

[2] during wear the response to nitrogen becomes progressively more 'humped' with optimum values being produced at intermediate levels of nitrogen and;

[3] that these optimum values decrease as wear progresses.

[4] For PM sand carpet pitches we should aim to supply 170-180 kg $ha^{-1}$ $yr^{-1}$ of nitrogen to maximise their durability.

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## PART 2

# THE RESPONSE OF *LOLIUM PERENNE* L. GROWN ON A PRUNTY-MULQUEEN SAND CARPET ROOTZONE TO FERTILISER NITROGEN

## II. PLAYING QUALITY

## SUMMARY

Playing quality of *Lolium perenne* L. turf subjected to football-type wear was studied in response to annual fertiliser nitrogen levels of 0, 25, 100, 225, 400 and 625 kg $ha^{-1}$ N. Playing quality was measured in terms of player traction, ball rebound resilience and hardness before, during and after periods of artificial wear treatments which broadly coincided with the 1984/1985 and 1985/1986 football seasons. Before wear, traction increased rapidly with increasing nitrogen up to a maximum level and then declined at high levels of nitrogen. During wear, this type of response became more pronounced and the average optimum level of nitrogen to provide the greatest traction for the two seasons combined was 176 kg $ha^{-1}$ N. Ball rebound resilience and hardness decreased in response to nitrogen before wear. During wear, ball rebound resilience and hardness in the 1984/1985 season showed no consistent response. However, in the 1985/1986 season, hardness showed a decreasing response which persisted during the period of wear. The PM sand carpet pitch provided good playing conditions throughout the football season in terms of standards for traction and ball rebound resilience, but the turf exceeded the acceptable limits for hardness on some occasions. These results have implications for the choice of pitch construction.

## INTRODUCTION

In Chapter 2 the subject of playing quality was considered at some length, especially in relation to construction methods. However, the effects of fertiliser on playing quality were only briefly alluded to in Chapter 2, Part 2. In Part 1 of this Chapter the effects of fertiliser nitrogen on ground cover response of a *Lolium perenne* turf grown on a Prunty-Mulqueen sand carpet construction were described. Previous work on the effects of fertiliser nitrogen on playing quality was carried out on contrasting rootzones: a sand profile construction consisting of 250 mm of rootzone sand overlying a 50 mm coarse sand layer and 100 mm deep gravel drainage layer and; an indigenous sandy loam topsoil (Canaway 1984a, Canaway 1985a, b). Initially, ball rebound and traction were studied (Canaway 1984a, 1985b) and in the latter part of the study hardness measures were also included (Canaway 1985a). These experiments showed that before wear, for ball rebound resilience and hardness, increasing levels of nitrogen resulted in a softer surface with reduced ball rebound resilience. However, once wear treatments were imposed the differences due to nitrogen became small. The main differences being observed in response to the different constructional types, as later confirmed in Chapter

2. For traction the picture was less clear. In the experiments on sand and soil constructions where the *Lolium perenne* turf was in its first season of use after establishment, the highest values of traction occurred at 225 kg ha$^{-1}$ N in five out of eight data sets, four of which were derived from the topsoil construction. In the case of renovated turf (Canaway 1985a, b), i.e. where only a limited period of time was available for re-establishment of the sward after the previous season's wear, the response curves for traction exhibited a much larger range of values, especially on the sand profile construction where traction increased steeply up to 100 kg ha$^{-1}$ N, followed by a more gradual increase to 225 kg ha$^{-1}$ N where it reached a maximum and gradually declined at higher levels of nitrogen. The topsoil construction exhibited a much smaller range of traction values, increasing up to either 225 kg ha$^{-1}$ N on some dates of assessment and up to 400 kg ha$^{-1}$ N on others and then declining at the highest level of nitrogen.

The objective of the work described in this Part was to study the response to fertiliser nitrogen of *L. perenne* turf grown on a Prunty-Mulqueen and carpet rootzone in terms of traction, ball rebound resilience and hardness over a period from July 1984 until April 1986.

## MATERIALS AND METHODS

The details of construction and establishment of the field experiment, the fertiliser treatments and the trial management, including artificial wear treatments, are given in Part 1 of this Chapter..

### Data collection

The details of the data collected are given in Table 1.

TABLE 1
Summary table giving details of data collection, dates and methods used

| Type of data | Dates of sampling<br>1984/5 season | <br>1985/6 season | Method used |
|---|---|---|---|
| Traction | 25 Jul. 1984<br>26 Sep. 1984<br>19 Nov. 1984<br>14 Jan. 1985<br>27 Mar. 1985 | 24 Jul. 1985<br>5 Sep. 1985<br>16 Oct. 1985<br>26 Nov. 1985<br>13 Jan. 1986<br>17 Apr. 1986 | Traction apparatus described by Canaway & Bell (1986). The torque to shear the turf was measured (Nm). 4 observations per plot. |
| Rebound resilience | 25 Jul. 1984<br>25 Sep. 1984<br>19 Nov. 1984<br>14 Jan. 1985<br>27 Mar. 1985 | 24 Jul. 1985<br>5 Sep. 1985<br>16 Oct. 1985<br>26 Nov. 1985<br>13 Jan. 1986<br>17 Apr. 1986 | % rebound was measured by release of a FIFA approved football ('Mitre Max') inflated to 70 kPa from a 3 m high ball bounce apparatus. 4 observations per plot. |

TABLE 1 (cont)

| Type of data | Dates of sampling<br>1984/5 season | <br>1985/6 season | Method used |
|---|---|---|---|
| Hardness | 25 Sep. 1984<br>19 Nov. 1984<br>14 Jan. 1985<br>28 Mar. 1985 | 24 Jul. 1985<br>5 Sep. 1985<br>16 Oct. 1985<br>26 Nov. 1985<br>13 Jan. 1986<br>17 Apr. 1986 | Clegg Impact Soil Tester (Clegg 1976). The peak deceleration (in gravities) of a 0.5 kg, 50 mm diameter hammer, dropped from a 300 mm height was recorded on impact with the turf. 5 observations per plot. |

N.B. On each occasion when traction, rebound resilience and hardness were recorded, 5 cores, 50 mm in diameter and 30 mm trimmed depth were removed for determination of moisture content of the rootzone.

### Statistical methods

The methods were the same as those used in the previous part of this Chapter. For traction, the inverse polynomial function of the form:

$$y = \frac{a + bx}{1 + cx + dx^2}$$

was again used, where $y$ is traction and $x$ is the annual rate of applied nitrogen. For ball rebound resilience and hardness a simple graphical presentation, without model fitting, was used.

## RESULTS

### Traction - 1984/1985 season

The response of traction before wear to increasing amounts of applied nitrogen is shown in Figs. 1A and 1B. Traction increased rapidly at first but decreased at high levels of nitrogen even before wear in contrast to the results for ground cover given in the previous paart of this Chapter. The parameter values, the percentage of the total sums of squares accounted for by the fitted curves and the calculated optimum values of applied nitrogen are given in Table 2. The soil moisture contents at each date of assessment are given in Table 3. The average optimum annual nitrogen input before wear was 282 kg ha$^{-1}$ N.

TABLE 2

Parameter values for, and the percentage of the total sums of squares accounted for by the inverse polynomial curves fitted to the mean values for traction. Values of optimum nitrogen input calculated from the exact parameter values at each date are also given.

| Date | Parameter values | | | | % of total S.S. due to fitted curve | Optimum N kg ha$^{-1}$ yr$^{-1}$ |
|---|---|---|---|---|---|---|
| | *a* | *b* | *c* | *d* | | |
| Jul. 1984 | 37 | 0.51 | $8.4 \times 10^{-3}$ | $3.4 \times 10^{-6}$ | 96.0 | 278 |
| Sep. 1984 | 44 | 0.32 | $4.6 \times 10^{-3}$ | $2.3 \times 10^{-6}$ | 95.9 | 285 |
| Nov. 1984 | 36 | 0.42 | $5.1 \times 10^{-3}$ | $8.1 \times 10^{-6}$ | 99.1 | 191 |
| Jan. 1985 | 32 | 0.28 | $4.2 \times 10^{-3}$ | $8.2 \times 10^{-6}$ | 96.8 | 167 |
| Mar. 1985 | 28 | 0.10 | $2.9 \times 10^{-4}$ | $7.7 \times 10^{-6}$ | 98.7 | 158 |

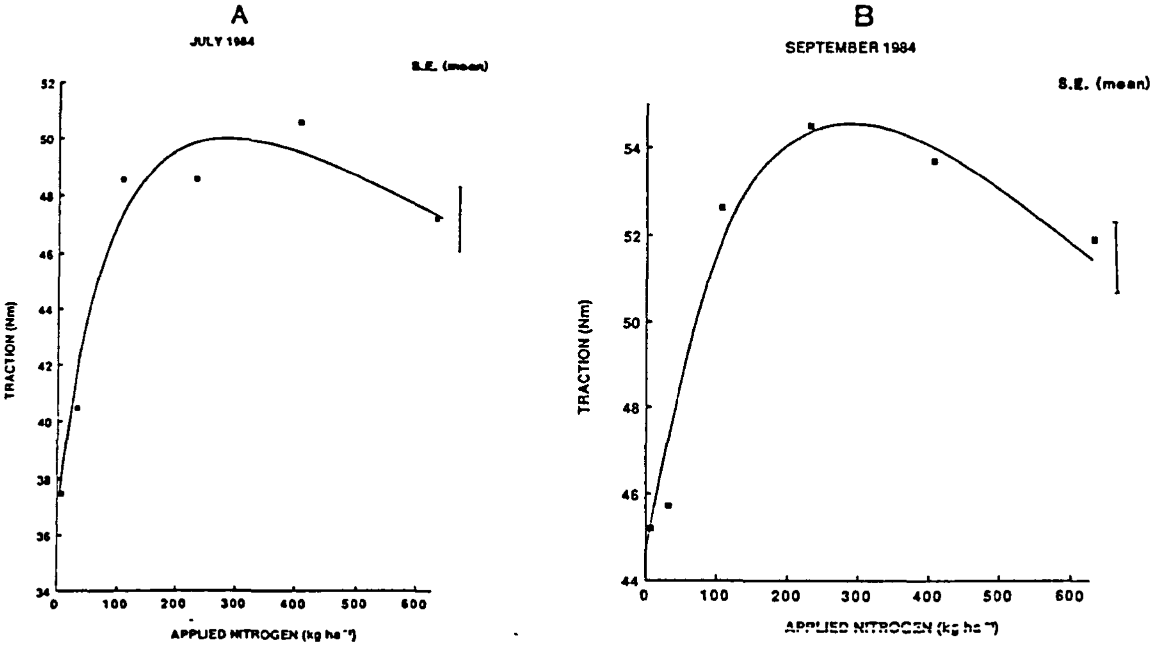

FIGURE 1. Traction of turf in response to fertiliser nitrogen before wear: 1A, July 1984; 1B, September 1984.

TABLE 3

Soil moisture content (% of fresh weight) on each date of measurement of traction, ball rebound resilience and hardness during the 1984/1985 season.

| Date of measurement | Mean | S.E. |
|---|---|---|
| 25 Jul. 1984 | 12.4 | 0.57 |
| 25 Sep. 1984 | 17.6 | 0.77 |
| 26 Sep. 1984 | 17.3 | 0.74 |
| 19 Nov. 1984 | 15.7 | 1.99 |
| 14 Jan. 1985 | 20.6 | 0.43 |
| 27 Mar. 1985 | 15.0 | 1.40 |

During wear (Figs. 2A and 2B) and after wear (Fig. 2C) the form of the responses became more steeply curved and by January 1985, and more noticeably in March 1985, the highest rate of nitrogen exhibited a lower traction value than the zero N treatment.

The values of the parameters reflected these changes, especially in the intercept *a* and the initial slope *b* which decreased as wear progressed. The average optimum annual nitrogen input for traction during wear was 172 kg ha⁻¹ N in the 1984/1985 season.

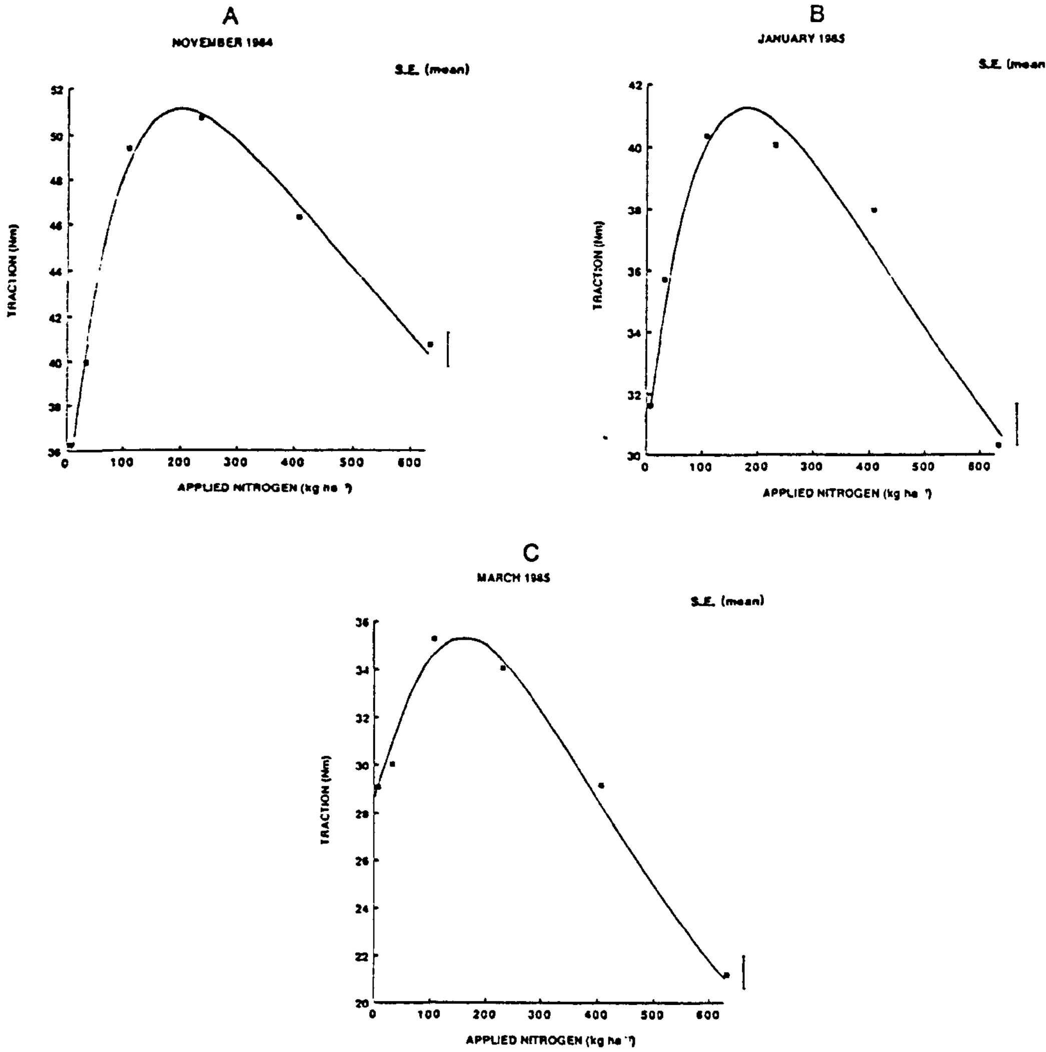

FIGURE 2. Traction of turf in response to fertiliser nitrogen during and after wear: 2A, November 1984; 2B, January 1985 and 2C March 1985.

## Traction - 1985/1986 season

Similar responses were observed to those seen in the 1984/1985 season. Before wear (Figs. 3A and 3B), traction increased rapidly with increasing nitrogen before reaching a maximum around 220 kg ha⁻¹ N and then declining at high levels of nitrogen. The parameter values, the percentage of the total sums of squares accounted for by the fitted curves and the calculated optimum values of applied nitrogen are given in Table 4. The soil moisture contents on each occasion of measurement are given in Table 5. The optimum nitrogen input before wear was 229 kg ha⁻¹ N, lower than that seen the previous season, and the goodness of fit of the models, as indicated by the percentage of the total sums of squares accounted for by the fitted curves, was also lower in general.

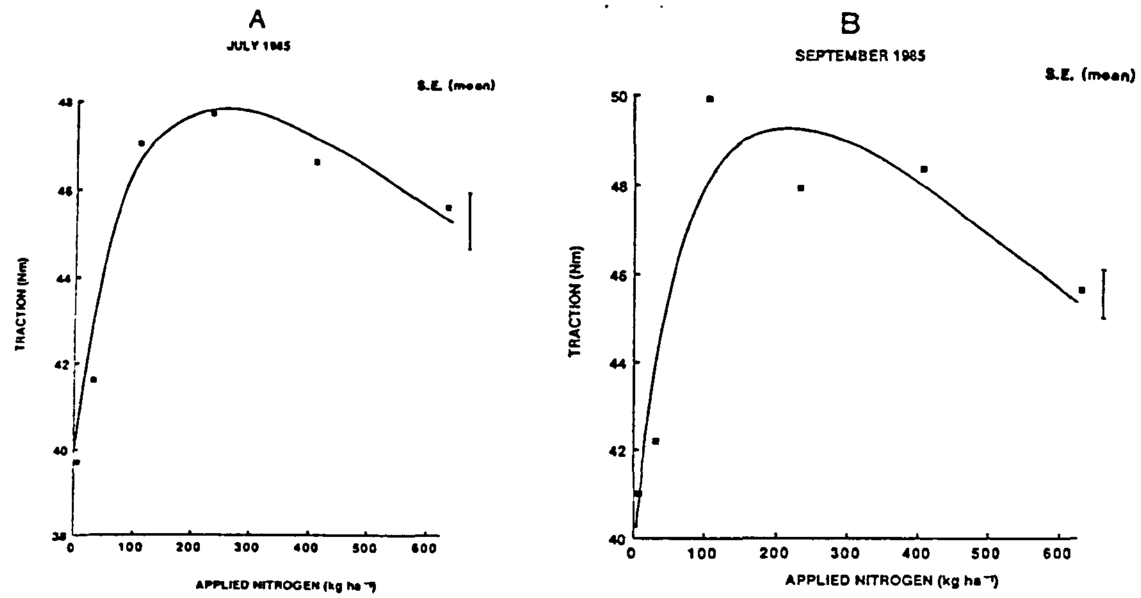

FIGURE 3. Traction of turf in response to fertiliser nitrogen before wear: 3A, July 1985; 3B September 1985.

TABLE 4
Parameter values for, and the percentage of the total sums of squares accounted for by the inverse polynomial curves fitted to the mean values for traction. Values of optimum nitrogen input calculated from the exact parameter values at each date are also given.

| Date | Parameter values *a* | *b* | *c* | *d* | % of total S.S. due to fitted curve | Optimum N kg ha$^{-1}$ yr$^{-1}$ |
|---|---|---|---|---|---|---|
| Jul. 1985 | 39 | 0.53 | $9.7 \times 10^{-3}$ | $2.9 \times 10^{-6}$ | 97.3 | 245 |
| Sep. 1985 | 40 | 0.56 | $9.8 \times 10^{-3}$ | $4.0 \times 10^{-6}$ | 87.2 | 213 |
| Oct. 1985 | 37 | 0.38 | $6.6 \times 10^{-3}$ | $3.8 \times 10^{-6}$ | 88.6 | 226 |
| Nov. 1985 | 28 | 0.42 | $9.6 \times 10^{-3}$ | $6.9 \times 10^{-6}$ | 90.1 | 180 |
| Jan. 1986 | 27 | 0.29 | $6.3 \times 10^{-3}$ | $6.5 \times 10^{-6}$ | 93.5 | 174 |
| Apr. 1986 | 26 | 0.31 | $7.7 \times 10^{-3}$ | $9.0 \times 10^{-6}$ | 92.9 | 138 |

TABLE 5
Soil moisture content (% of fresh weight) on each date of measurement of traction, ball rebound resilience and hardness during the 1985/1986 season.

| Date of measurement | Mean | S.E. |
|---|---|---|
| 24 Jul. 1985 | 9.3 | 0.56 |
| 5 Sep. 1985 | 9.7 | 1.03 |
| 16 Oct. 1985 | 12.0 | 1.39 |
| 26 Nov. 1985 | 13.1 | 0.94 |
| 13 Jan. 1986 | 15.2 | 0.87 |
| 17 Apr. 1986 | 14.3 | 0.99 |

During wear (Fig. 4A, 4B and 4C) and after wear (Fig. 4D) the form of the response changed in an almost identical manner to that seen in the 1984/1985 season, with traction decreasing at high levels of nitrogen more quickly than at intermediate levels so that the form of the responses became progressively more curved, with the turf receiving the highest level of nitrogen eventually providing less traction than the zero N treatments. The calculated optimum annual nitrogen input decreased as wear progressed in both the 1984/1985 and 1985/1986 seasons. Disregarding the October 1985 value, since wear had only started some ten days previously, the average optimum annual nitrogen input in the 1985/1986 season was 164 kg ha$^{-1}$, not dissimilar to the 172 kg ha$^{-1}$ N observed in the previous season. The optimum input under wear for both seasons combined, excluding October 1985, was 168 kg ha$^{-1}$ and including October 1985, it was 176 kg ha$^{-1}$.

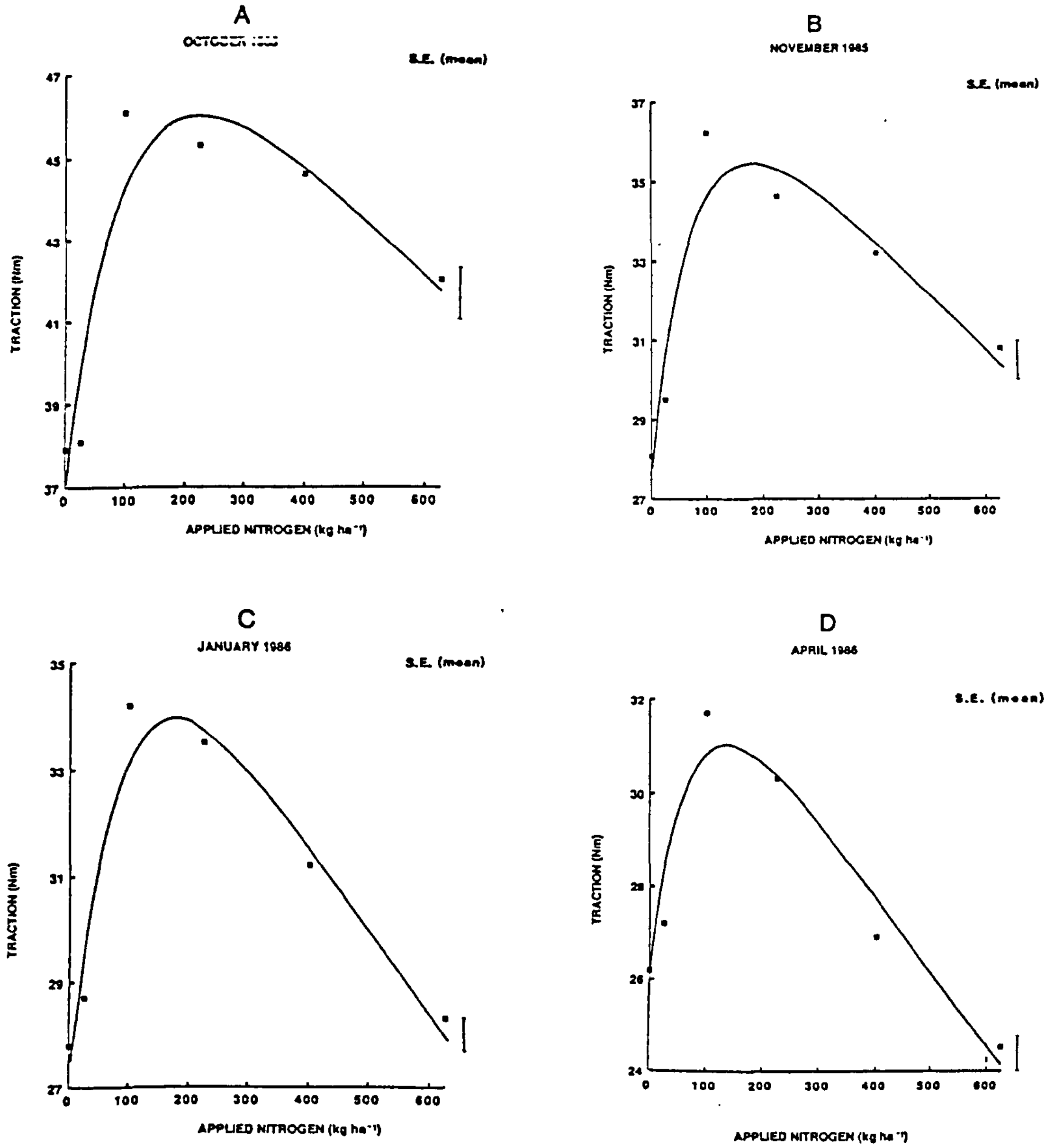

FIGURE 4. Traction of turf in response to fertiliser nitrogen during and after wear: 4A, October 1985; 4B, November 1985; 4C, January 1986; 4D, April 1986.

## Ball rebound resilience

The results for rebound resilience are shown in Fig. 5. Before wear (July and September 1984 in Fig. 5A, July 1985 in Fig. 5B and September 1985 in Fig. 5D), ball rebound resilience decreased with increasing nitrogen, particularly over the range 0 to 225 kg ha$^{-1}$ N. During wear, this response largely disappeared, ball rebound varying little over the range of treatments.

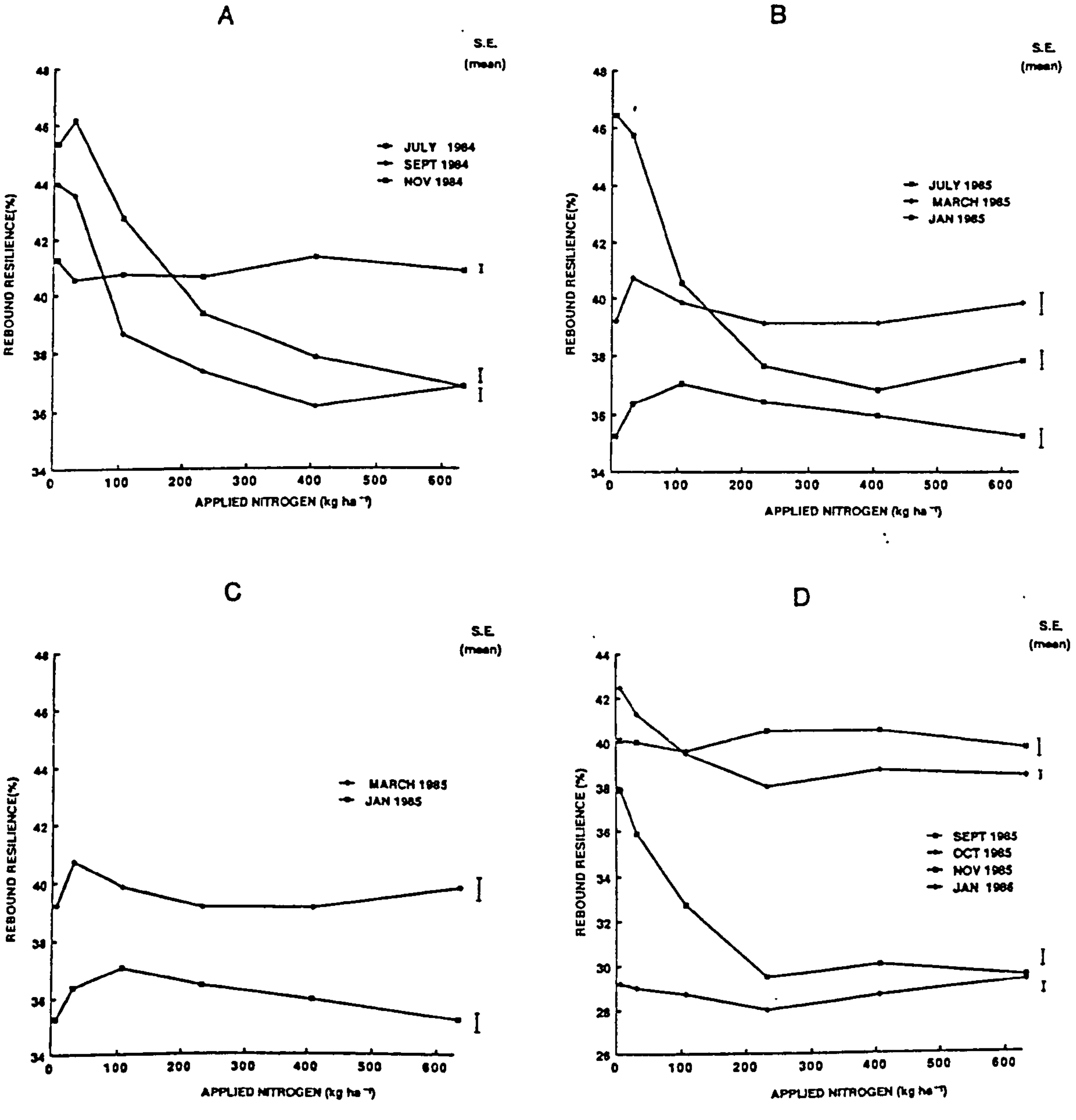

FIGURE 5. Ball rebound resilience in response to fertiliser nitrogen.

## Hardness

The results for hardness in response to nitrogen are shown in Fig. 6. As in the case of ball rebound resilience, hardness showed a large, decreasing response to nitrogen before wear (September 1984 in Fig. 6A, July 1985 in Fig. 6B and September 1985 in Fig.

6C). During wear in the 1984/1985 season these responses largely disappeared (November 1984, January 1984 and March 1985 in Fig. 6A). In 1985/1986, however, the response persisted during wear, especially in the data for January and April 1986 (Fig. 6C), although the results were not entirely consistent in that the results for November 1985 (Fig. 6B) showed no apparent response.

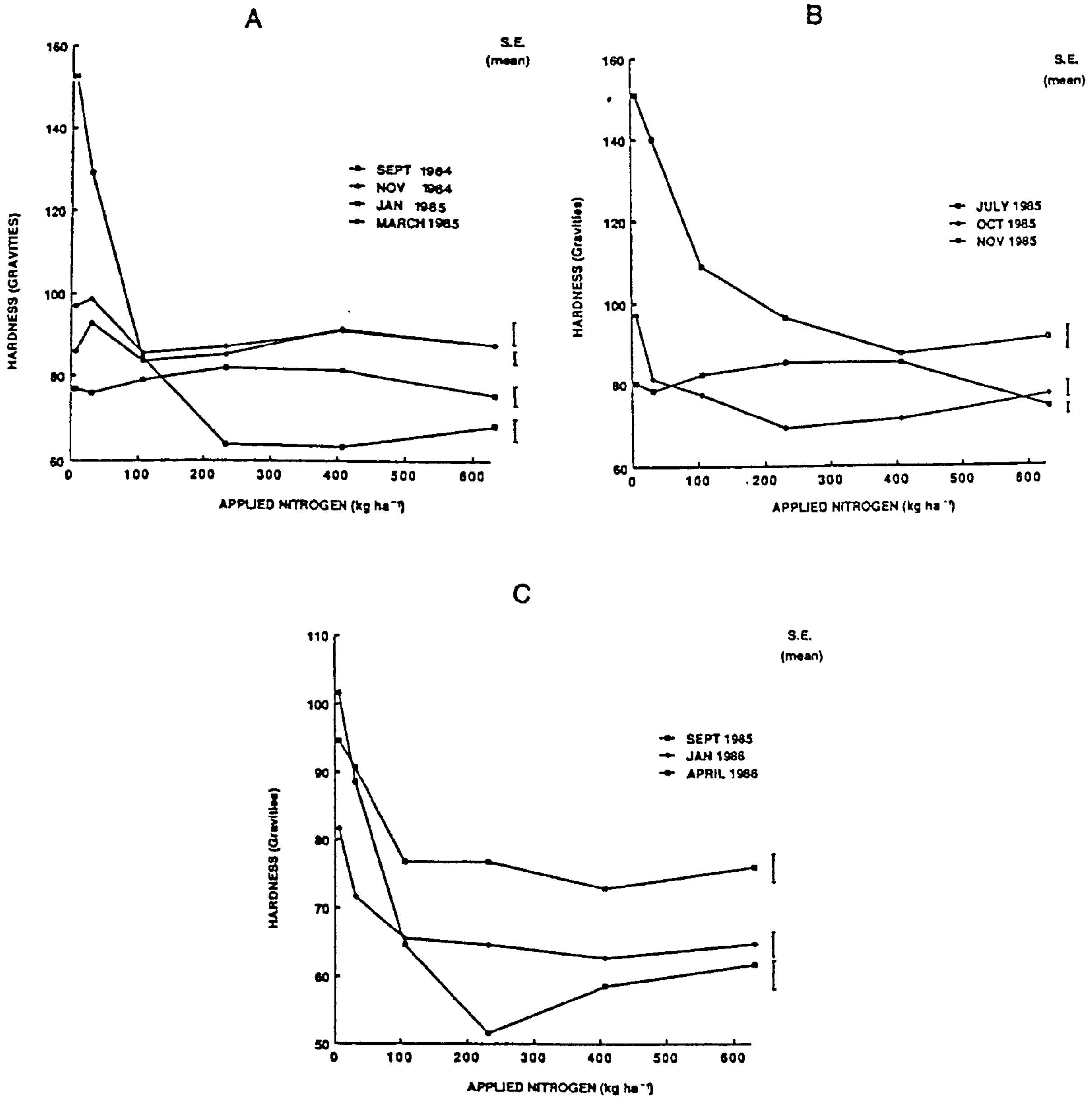

FIGURE 6. Hardness of turf in response to fertiliser nitrogen.

## DISCUSSION

Results for traction displayed a sharp decline at high levels of nitrogen not seen in previous work (Canaway 1984a, 1985a, b). In the earlier work on a sand profile overlying a gravel drainage carpet (Canaway 1984a, 1985a, b) an optimum value of around 225 kg ha$^{-1}$ N for traction was observed but not very distinctly. On the PM pitch, however, the response, in terms of traction, to applied nitrogen was very strong, with an average optimum during wear for the two seasons combined of 168 kg $ha^{-1}$ excluding, and 176 kg $ha^{-1}$ including, the October 1985 data when little wear had occurred. These figures are very close to the optimum of 177 kg $ha^{-1}$ seen in Part 1 for ground cover during wear for both seasons combined. As with ground cover, the turf receiving the highest level of nitrogen eventually had lower values of traction than the zero N treatment, especially in the 1985/1986 season with the form of the response being markedly curved. In the previous work (Canaway 1985b), traction at the highest nitrogen level only declined to a small extent in the second season of use (Canaway 1985b) and the zero and 25 kg $ha^{-1}$ treatments were far inferior to the other treatments in contrast to the present study. This supports the conclusion based upon the ground cover data given in Part 1 of this Chapter that the PM pitch provides better nutrient retention than the sand profile pitch studied previously (Canaway 1984a, 1985a, b). The reasons for the occurrence of an optimum nitrogen level for traction are probably related to the losses of above-ground cover as wear progresses and the effects of nitrogen on root production. Canaway (1984b) found a fourfold reduction in root:shoot ratio over the same range of nitrogen levels as studied in the present experiment. Also, as wear proceeds, and ground cover is lost preferentially on some of the experimental treatments, the sand surface is exposed to the action of the wear machine which causes further damage, in turn reducing traction still further on the worn plots.

Ball rebound resilience and hardness have previously shown large decreasing responses to increasing levels of nitrogen before wear with a small or inconsistent response during wear on a sand profile rootzone (Canaway 1984a, 1985a, b). Ball rebound resilience on the PM pitch showed a very similar pattern of results in both seasons of use, indicating that ball rebound resilience is determined by mechanical properties of the upper layer of the sand-based rootzone regardless of whether topsoil or a gravel layer is present beneath the sand. For hardness, a similar pattern of results was observed in the 1984/1985 season, but in the 1985/1986 season a more persistent response was observed. This could be due to the accumulation of organic matter in fertilised plots which would be expected to soften the sand surface with time, as is found in practice following establishment of sand carpet football fields. The plots receiving little or no fertiliser, on the other hand, would accumulate less organic matter in the profile with the consequence that they would tend to remain hard.

The performance of the PM pitch in relation to the standards for playing quality given in Chapter 2 are of interest. For the optimum nitrogen input, traction was always above the 'preferred' limit of 25 Nm and all of the nitrogen treatments remained above the 'acceptable' limit of 20 Nm. Ball rebound resilience was always in the preferred range of 20-50%, indeed most of the results were in a closer range of 30-45%, indicating the consistency of ball rebound resilience throughout the period of study. In contrast, as shown in Chapter 2, ball rebound resilience on soil-based pitches may fall to unacceptable levels during periods of rainfall. The PM pitch exceeded the acceptable limit for hardness of 100 gravities at low nitrogen levels before wear in both seasons of the trial but during wear, hardness remained within the acceptable limits but, nonetheless, exceeded the preferred limit of 80 gravities on some occasions. The inference is that the PM pitch would have been experienced as firm by players for much of the time, and certainly the surface was never too soft which soil-based pitches frequently are during the winter months, as shown in the pipe drained topsoil construction in Chapter 2.

Practical experience with PM pitches in Northern Ireland, where many have been constructed, also suggests that players rate the PM pitches as hard in the early stages but after a few years, the incorporation of organic matter into the sand gradually leads to a reduction in hardness. In Chapter 2 the sand carpet construction remained within the preferred limits for hardness, which lends support to the view that there is no universal hardness problem on sand carpet pitches.

In conclusion, the PM sand carpet pitch provided a robust method of sports field construction with nutritional advantages over sand profile and soil-based methods of construction and which provided good playing conditions during the football season when many soil-based pitches would have been unfit for use.

## ACKNOWLEDGEMENTS

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# DISCUSSION

Taking both parts of this study together there are some interesting similarities and differences in the response of *Lolium perenne* to fertiliser nitrogen as compared with earlier studies on sand profile and natural topsoil rootzones (Canaway 1984a, b, c; Canaway 1985a, b, c, d).

Ground cover before wear showed a similar response to that seen in previous experiments (Canaway 1984a; 1985a) cover rapidly increasing with increasing nitrogen level but with no evidence of a decline at high nitrogen levels. Once wear treatments were imposed however, the highest nitrogen levels appeared actually detrimental in terms of their effect on cover during wear, whereas the earlier studies, although showing an optimum nitrogen input, did not demonstrate any detrimental effects of high nitrogen levels. It seems likely that the sand carpet type of construction is inherently less demanding of nitrogen than the sand profile used previously, possibly due to storage of nitrogen in the topsoil layer below the sand carpet. However this explanation does not account for the response seen on the indigenous sandy loam topsoil in the experiments done previously (Canaway 1984a; 1985a). With topsoil as distinct from sand, one would have expected even greater storage of nutrients and the possibility of even stronger detrimental effects at high levels of nitrogen which were not observed. To explain this seeming anomaly we must draw on the knowledge gained from the experiment on pitch construction described in Chapter 2 where rapid deterioration of the pipe-drained construction occurred following the onset of wear treatment. In other words in the case of the nitrogen trials on topsoil the response to nitrogen was masked or moderated by the gross effects of wear on a soil-based playing surface.

Similar considerations apply to the results for traction where in previous experiments (Canaway 1984c; 1985c, d) the responses of traction were strong in the 0-100 kg ha$^{-1}$ range, but the curves flattened with large regions of similar traction values between 100 and 400 kg ha $^{-1}$ N. In the present trials the curves were much more inflected with apparent optima even before wear. During wear, the curves became even more sharply inflected with detrimental effects appearing at high nitrogen levels. From these results it was possible to calculate optimum levels of nitrogen for PM sand carpet pitches, which turned out to be very similar to the optimum values obtained for ground cover.

Finally, in agreement with the earlier experiments (Canaway 1984c; 1985c, d) results for ball rebound resilience and hardness appeared predominantly dependant on the mechanical properties of the surface rather than on nitrogen input.

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# CHAPTER 5

## STABILISATION OF SAND ROOTZONES

### INTRODUCTION

The benefits of improved constructional methods have been demonstrated in Chapter 2. Combined with adequate maintenance, especially in terms of fertiliser nitrogen(Chapter 4) there seems little excuse for the failure to produce adequate playing surfaces for football. However, sand-based rootzones, although conferring advantages in terms of enhanced water infiltration rate and playing quality, may become unstable if grass cover is lost, especially during the latter part of the playing season in April-May when drying conditions may aggravate the problem. This may lead to conditions analogous to the upper reaches of a sandy beach where dry, loose sand provides poor playing quality and the pitch may develop erosion hollows.

Systems have been devised to overcome the potential instability of sand rootzones by providing some means of artificial strengthening. These entail mixing the strengthening material with the sand-based rootzone prior to construction and then spreading the strengthened composite mixture to form the rootzone for the pitch. This chapter describes research on one particular type of strengthening system using randomly oriented tensile inclusions.

# A FIELD TRIAL ON ISOTROPIC STABILISATION OF SAND ROOTZONES FOR FOOTBALL USING NETLON MESH ELEMENTS

## SUMMARY

Sand rootzones provide free-draining playing surfaces for football but may become unstable especially when grass cover is lost. One approach to this problem is isotropic stabilisation of the rootzone using randomly orientated tensile inclusions (Netlon mesh elements). A field plot experiment is described, incorporating three rates of mesh element inclusion, plus an unreinforced control, i.e: 0, 2.5, 3.75 and 5 kg of elements $m^{-3}$ of sand, two sizes of elements: 50 mm x 50 mm and 50 mm x 100 mm, together with the addition of either normal mature turf or turf which had been washed to remove adhering soil. Artificial wear treatments were carried out during the football season and data were collected before, during and after wear on: grass ground cover, football rebound resilience, traction, hardness and water infiltration rate. Water infiltration rate was found to increase with increasing mesh element inclusion rate and effects were also observed on traction and hardness, increasing mesh element rate also improving these aspects of playing quality. Turf washing was found to increase water infiltration rate and also affected traction, hardness and ball rebound resilience.

## INTRODUCTION

Sand-based constructions have been increasingly used to provide free-draining playing surfaces for Association football and other sports including Rugby and golf. However the use of sands for the construction of sports turf rootzones, whilst overcoming problems associated with water movement away from the surface, poses other problems including lack of moisture retention under dry conditions, low nutrient content and retention; and in the case of sports where player traction is important, instability particularly under dry conditions. The problem of instability arises since sand is a granular material and normally the rootzone is bound only by plant roots and the capillary forces produced by the presence of moisture. As the season proceeds grass cover is progressively removed by the action of play and the reinforcing action of plant roots is also gradually reduced so that in heavily worn areas the sand profile is only bound by moisture. Under these circumstances, particularly towards the end of the playing season in April and May when dry weather may occur, the sand surface is no longer able to withstand the mechanical forces imparted by players and breaks up to produce a soft and unstable surface characterised by low ball rebound, hardness and player traction (Baker & Gibbs 1989, Baker, *et al.* 1992). In these latter studies localised areas termed "erosion hollows" of about 1 m diameter occurred on a sand profile pitch, which were easily disrupted by play and consequently required laborious reinstatement of levels after each match.

Strengthening of granular soils by the use of randomly oriented tensile inclusions was pioneered by Netlon Ltd. (Mercer 1983, Mercer *et al.* 1984, McGown *et al.* 1985). Although the strengthening technique using randomly oriented tensile inclusions (subsequently referred to as Netlon mesh elements) was originally devised for Civil Engineering applications its potential for use on sports turf areas was recognised at an early stage (Andrawes *et al.* 1986). Preliminary tests at a low inclusion rate showed no benefits of the mesh elements for football under artificial wear (Baker *et al.* 1988). Subsequent work by Sifers & Beard (1990) on a turf of *Cynodon dactylon* L. Pers. x *C. transvaalensis* Burtt-Davy ('Tifway' hybrid Bermudagrass) showed benefits of the mesh element reinforced rootzone. These included reduced divot size and improved recovery of areas damaged by divoting. They showed no improvement in traction, ball rebound or compression displacement but found increased soil moisture content which was attributed to increased aggregation of soil particles between the mesh apertures. The authors drew attention to the benefits of enhanced moisture content in terms of improved plant growth and reduced irrigation needs which would have been especially relevant in the southern USA where the research was carried out. Further studies in the same series of experiments were reported by Beard & Sifers (1993) who showed in addition that mesh elements produced improved soil physical conditions in the rootzone, in terms of improved throughput of water, greater soil aeration and better root growth. Although the work described by Beard & Sifers (1993) was of considerable scope it was, by its location, restricted to warm season grass species, *Cynodon dactylon* x *C. transvaalensis* 'Tifway' being used for the field plots. Research on the performance of mesh element reinforced rootzones under cool season climate conditions was also required. Hence, the objective of the experiment described here was to investigate the effects of different mesh element rates and size, together with the effects of using washed versus normal, unwashed turf on the performance of *L. perenne* dominated turf grown on a sand rootzone for football.

## MATERIALS AND METHODS

### Construction and site preparation

The experiment was carried out on an area of land which had been purpose-constructed during August 1987 for an earlier mesh element trial. The procedure had been as follows: over an area approximately 17 m x 21 m the upper 100 mm of topsoil was removed and minor grading was carried out to ensure a fall of 1:80 across the trial. The area was bounded by 125 mm diameter main, and catchwater drains; 80 mm diameter lateral drains were installed at 7 m intervals at a depth of 500 mm below the subsoil formation level and backfilled with 6 mm diameter synthetic drainage aggregate ("Lytag") to 50 mm below the subsoil formation level. The backfill was blinded with 50 mm coarse sand (Tarmac washed sharp sand ex Bellmoor). Next, 50 mm wide slit drains were installed transversely to the direction of the pipe drains at 1 m centres, to a depth of 225 mm, backfilled with 6 mm "Lytag" and blinded with coarse sand (Tarmac, ex Bellmoor). After installation of the pipe, and slit drainage system 48 sand and mesh element plots were constructed using 100 mm depth of the sand and mesh elements. Plot size was 2 m x 2 m. The plots were constructed row by row using a timber framework and timbers to level off each row as constructed. Details of the experimental design are given below, and analyses of the sands used in construction are given in Table 1.

TABLE 1
Particle size distribution of the medium-fine rootzone sand and the coarse, blinding sand used in the construction of the Netlon trial

| Particle diameter (mm) | Medium-fine sand | Coarse sand |
|---|---|---|
| 8-4 | 0 | 12 |
| 4-2 | 0 | 16 |
| 2-1 | 0 | 7 |
| 1-0.5 | 1 | 16 |
| 0.5-0.25 | 61 | 39 |
| 0.25-0.125 | 36 | 8 |
| 0.125-0.05 | 1 | 1 |
| <0.05 | 1 | 1 |

N.B. Both sands were lime-free.

### Experimental treatments

The Netlon mesh elements comprised small polypropylene "grids" with ribs protruding from the edges. The aperture of the mesh, i.e. the spacing between individual strands of polypropylene, was 10 mm. When mixed with sand or soil the mesh elements interlock with groups of particles and provide tensile resistance to the sand-mesh matrix (Mercer *et al.* 1984). Three rates of mesh elements mixed with sand were used together with a zero rate, these were 0, 2.5, 3.75 and 5 kg elements $m^{-3}$ of sand. At these rates two sizes of elements were tested 50 mm x 100 mm ('large') and 50 mm x 50 mm ('small'). In addition plots were formed with either washed, or unwashed, turf (see below). Thus there were sixteen combinations of treatments which were laid out in randomised blocks with three replications. Because of the internal replication in factorial designs this level of replication was judged adequate. For example, each mean for rates was derived from 12 plots, each mean for element size (small versus large) and turf (washed versus unwashed) was derived from 24 plots each. Only the means for the interaction of rates x size x turf were derived from three plots comprising the three replicates. The effects of the treatments were analysed statistically by analysis of variance of the factorial model using GENSTAT statistical program.

### Trial establishment

The 1987 constructed mesh element trial was reported in a confidential report to Netlon Ltd. On 9 May 1989 the existing turf was stripped using a pedestrian operated turf cutter and the turf bed kept free of weeds until required for the establishment of the trial reported here, in July 1989. On 18 July 1989 washed and unwashed turf was laid directly onto the plots constructed using different mesh element rates to give the final experiment layout. The turf had been grown on a sandy loam soil and sown with a mixture of *Lolium perenne* L. (perennial ryegrass), *Festuca rubra* L. ssp. *commutata* Gaud. (Chewings fescues), *F. rubra* L. ssp. *litoralis* (G.F.W. Meyer) Auquier (slender creeping red fescue), *F. longifolia* Thuill. (hard fescue), *Agrostis castellana* Boiss & Reuter (Highland browntop bent), *A. capillaris* L. (browntop bent) and *Phleum bertolonii* DC. (small-leaved Timothy-grass). On delivery the sward comprised: *L. perenne* c. 75%, *Festuca* spp. 15%; other species, dead matter and bare ground 10%. The washed turf was delivered washed free of most adhering soil particles; prior to laying a further washing was carried out using a high pressure hose to further reduce the amount of any soil remaining.

After turfing a slow-release fertiliser was applied at 30 g $m^{-2}$ (Floranid NPK) to supply the following nutrients (as kg $ha^{-1}$): N-45; $P_2O_5$-27; $K_2O$-45; MgO-6, together with trace elements (as mg $kg^{-1}$ of the fertiliser): B-300; Fe-3000; Mn-1000; Mo-3; Zn-200. After laying, the turf was lightly rolled using a 0.9 m wide, 100 kg roller and irrigated lightly and frequently for the first 12 days to prevent moisture stress during establishment. On 15 August 1989 the surface was firmed by rolling with a heavier roller (0.75 m wide, 500 kg weight, 4 passes) in order to further firm the rootzone.

### Trial maintenance 1989-90

The trial was first mown at a height of 38 mm on 2 August 1989, height of cut gradually being reduced to its maintenance height of 25 mm by 18 August. Mowing frequency was twice weekly and clippings were removed. Irrigation was applied to make up evapotranspiration losses of c. 18 mm per week and to maintain active growth. Wear treatments were started on 21 September 1989 and continued at a rate of 4 passes twice weekly using the differential slip wear machine (Canaway 1976). A total of 104 passes was applied between 21 September and 22 December 1989. A further 88 passes were applied between 2 January and 5 April 1990 when wear ceased. Following heavy rain in February 1990 the surface became soft and water retentive and 4 kg $m^{-2}$ of sand top dressing was applied using the same sand as had been used in construction. This rate is only equivalent to 1.5 mm thickness of sand and therefore would not adversely affect the performance of the reinforced rootzone. The trial was aerated using a Sisis Auto-Outfield spiker fitted with tines 125 mm in length, twice weekly from 15 February to 5 April 1990.

### Data collection

The details of the data collected together with the dates on which data were collected are given in Table 2. Data were collected before, during and after the period of wear treatments.

TABLE 2
Summary of data collected and methods used

| Type of data | Method used | Assessment dates |
|---|---|---|
| Ground cover | Two methods were used: [1] the optical point quadrat described by Laycock & Canaway (1980), 100 points per plot in 20 frames of 5 points;<br>[2] the percentage of green vegetation on the surface was recorded using a reflectance ratio meter similar in principle to that described by Haggar *et al.* (1984). Four observations per plot. | 5-7 Sep. 1989<br>23 Oct. 1989<br>11 Dec. 1989<br>19 Feb. 1990<br>23 Apr. 1990 |
| Ball rebound resilience | % of rebound was measured by the release of a FIFA approved football "Mitre Delta 1000" inflated to 70 kPA from a 3 m high ball bounce apparatus. Four observations per plot. | 7 Sep. 1989<br>23 Oct. 1989<br>11 Dec. 1989<br>19 Feb. 1990<br>23 Apr. 1990 |
| Traction | Traction apparatus described by Canaway & Bell (1986). The torque to shear the turf was measured (N m). Four observations per plot. | 7 Sep. 1989<br>23 Oct. 1989<br>11 Dec. 1989<br>19 Feb. 1990<br>23 Apr. 1990 |
| Hardness | Clegg Impact Soil Tester (Clegg 1976). The peak deceleration of a 0.5 kg, 50 mm diameter hammer, dropped from a 300 mm height was recorded on impact with the turf. Five observations per plot. | 7 Sep. 1989<br>23 Oct. 1989<br>11 Dec. 1989<br>19 Feb. 1990<br>23 Apr. 1990 |
| Water infiltration rate | Infiltration rates were measured using ponded, double ring infiltrometers (nominally 300 and 500 mm diameter) and the steady-state infiltration rates were standardised to a temperature of 10°C. Three measurements per plot. | 11-14 Sep. 1989<br>12-15 Dec. 1989<br>9-12 Apr. 1990 |

Soil moisture content was determined on each occasion of measurement by taking 5 cores, 50 mm in diameter and 30 mm trimmed depth. These were weighed, dried at 105°C for 24 hours, and reweighed. Moisture content was calculated from weight loss after drying as a percentage of the fresh weight. Values for soil moisture content are given in Table 3.

TABLE 3
Soil moisture content on each measurement date (% by weight)

| Date | Moisture content (mean and standard error) |
|---|---|
| 7 Sep. 1989 | 6.3 ± 1.73 |
| 23 Oct. 1989 | 14.5 ± 0.72 |
| 11 Dec. 1989 | 18.7 ± 1.29 |
| 19 Feb. 1990 | 16.6 ± 0.36 |
| 23 Apr. 1990 | 8.6 ± 0.78 |

RESULTS

September 1989

Before the start of wear treatments there were no significant differences in ground cover, ball rebound or hardness but element rate had a significant effect on water infiltration rate (Figure 1). Infiltration rate increased from 100 mm $h^{-1}$ on the control to 147 mm $h^{-1}$ at the highest rate of element inclusion.

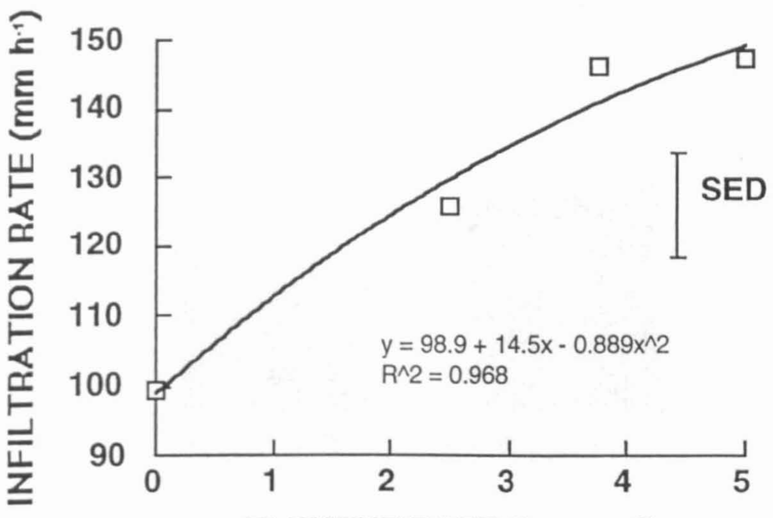

FIGURE 1. Effect of Netlon mesh elements on water infiltration rate on a sand carpet rootzone in September 1989. (SED = standard error of the difference between means.)

There was also a significant effect mesh element size on traction, small elements providing greater traction than large elements (Figure 2).

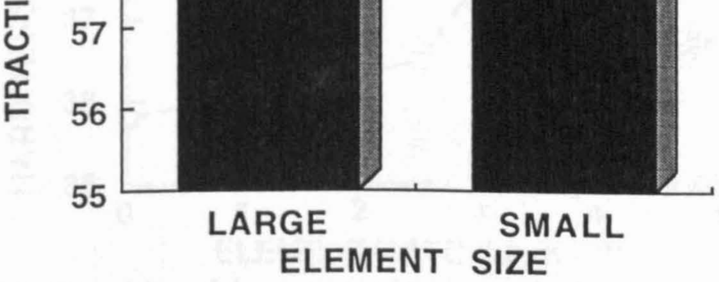

FIGURE 2. Effect of element size on traction in September 1989. (LSD = least significant difference, p = 0.05.)

October 1989

Traction and hardness showed significant differences, unwashed turf giving greater traction at this stage than washed turf (Figure 3). With the greater proportion of fine particles in the unwashed turf an increase in traction would be expected under light, or the early stages of, wear since soil resistance to shear increases with increasing content of finer particles (Adams & Jones 1979).

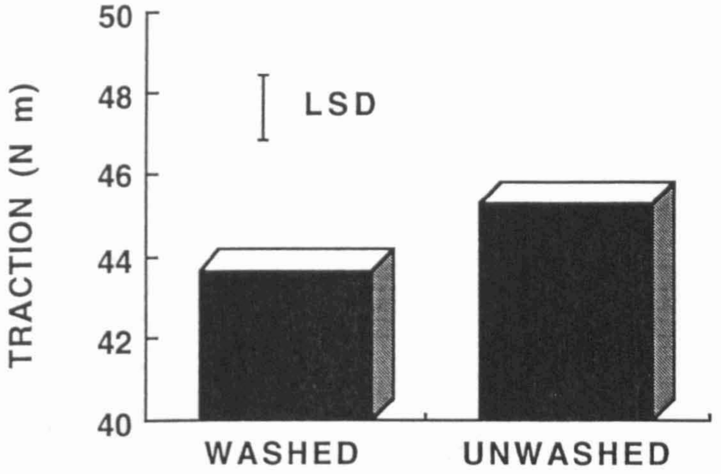

FIGURE 3. Effect of turf type, washed or unwashed, on traction in October 1989. (LSD = least significant difference, p = 0.05.)

Hardness increased with mesh element rate (Figure 4), the effect was small, however, and the values were all within the preferred limits for playing quality. No effects were observed on cover and ball rebound.

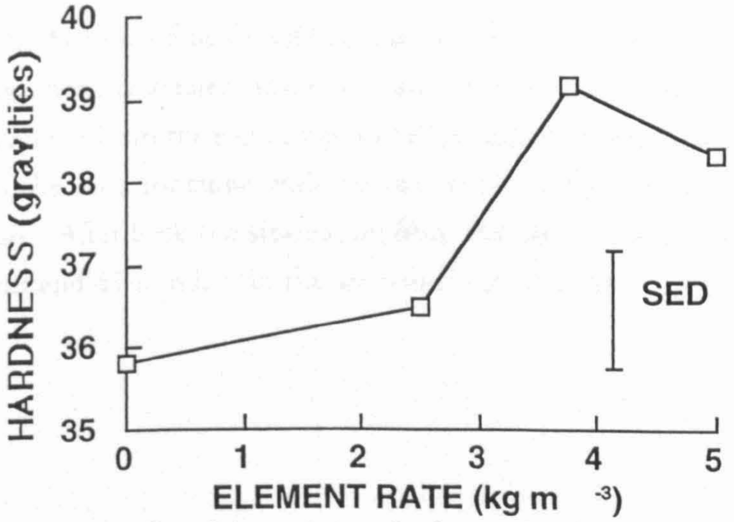

FIGURE 4. Effect of element rate on hardness in October 1989. (SED = standard error of the difference between means.)

### December 1989

Infiltrations showed a large coefficient of variation (39%) in the untransformed data, log transformation substantially reduced this (to 10%) and improved the distribution of the residuals after analysis of variance. Nonetheless effects of element rate showed no significant effect in the analysis of variance, however, when the means for infiltration rate (back transformed from the logs) were plotted against element rate squared as near perfect correlation resulted (Figure 5). Infiltration rate increased from 41 mm $h^{-1}$ in the control to 53 mm $h^{-1}$ at the highest element rate. The persistence of the effect of element rate on water infiltration rate through to the middle of the playing season was a significant finding.

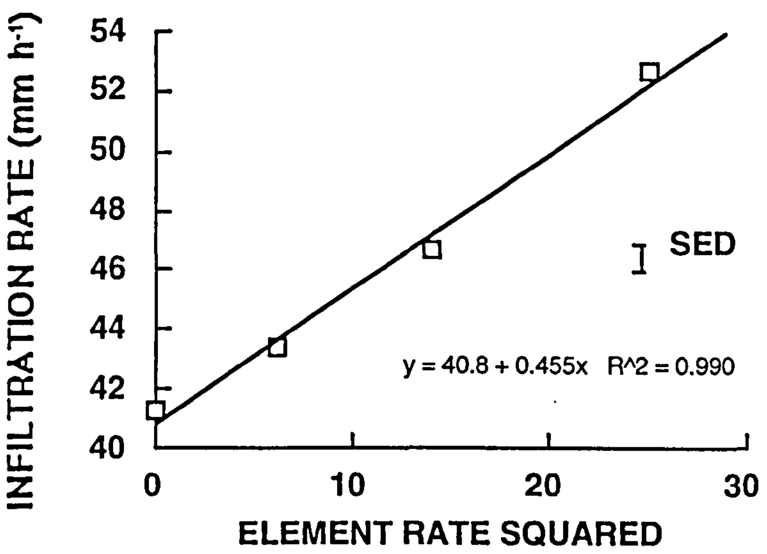

FIGURE 5. Effect of element rate (squared) on water infiltration rate (back transformed from logs) in December 1989. (LSD = least significant difference, p = 0.05.)

The benefit of turf washing was also evident at this assessment, washed turf having a significantly greater infiltration rate. It is to be assumed that by this date some of the fine material from the soil in the unwashed turf was starting to impede drainage in the surface of the sand rootzone with the consequent reduction in the measured water infiltration rate. After back transformation from the logs, the values were 52 mm $h^{-1}$ for the washed turf and 41 mm $h^{-1}$ for the unwashed turf (Fig. 6).

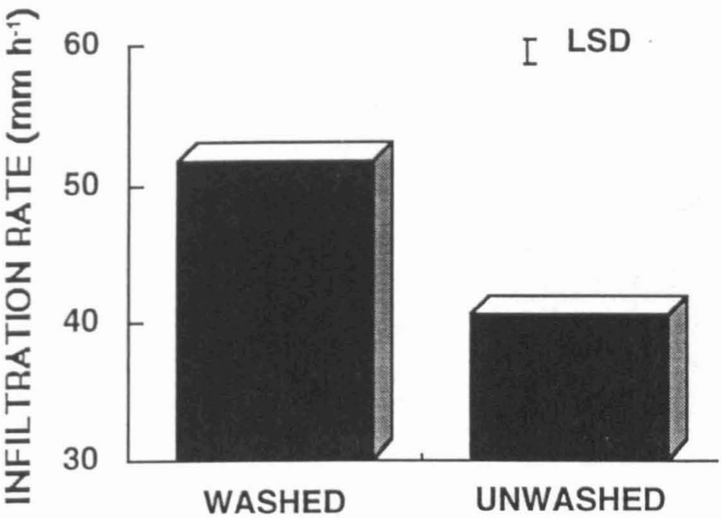

FIGURE 6. Effect of turf washing on water infiltration rate in December 1989. (LSD = least significant difference, p = 0.05.)

Turf washing also showed an effect on hardness (Figure 7), the unwashed turf being firmer than the washed turf. The absolute size of the difference, however, was only 3 gravities.

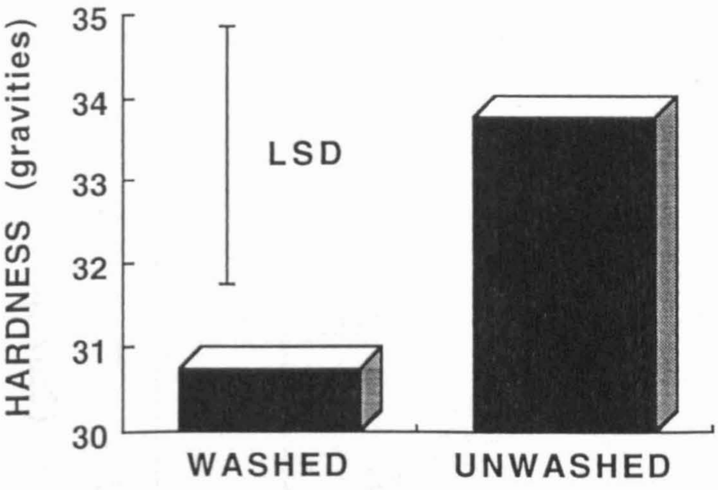

FIGURE 7. Effect of turf washing on hardness in December 1989. (LSD = least significant difference, p = 0.05.)

An effect on hardness was also seen due to element size (Figure 8), the larger elements providing slightly increased firmness over the small elements, although the absolute difference was small at around 4 gravities.

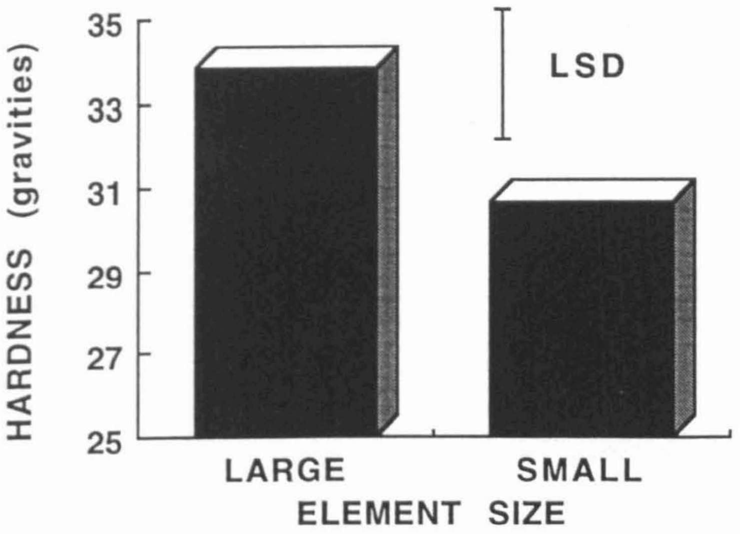

FIGURE 8. Effect of element size on hardness in December 1989. (LSD = least significant difference, p = 0.05.)

February 1990

In February 1990 under soft ground conditions following heavy rain, an effect of element rate on hardness was once again observed, hardness increasing with increasing rate of mesh element inclusion (Figure 9), unreinforced plots becoming unacceptably soft.

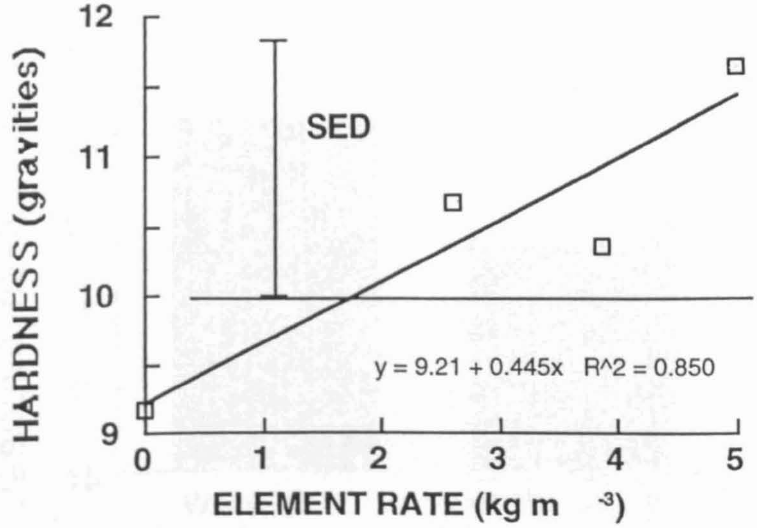

FIGURE 9. Effect of element rate on hardness in February 1990. (SED = sandard error of the difference between means, the horizontal line indicates lower acceptable limit for hardness - see discussion.)

An effect on element size on hardness was also observed, the large elements again providing a firmer surface than the small elements (Figure 10).

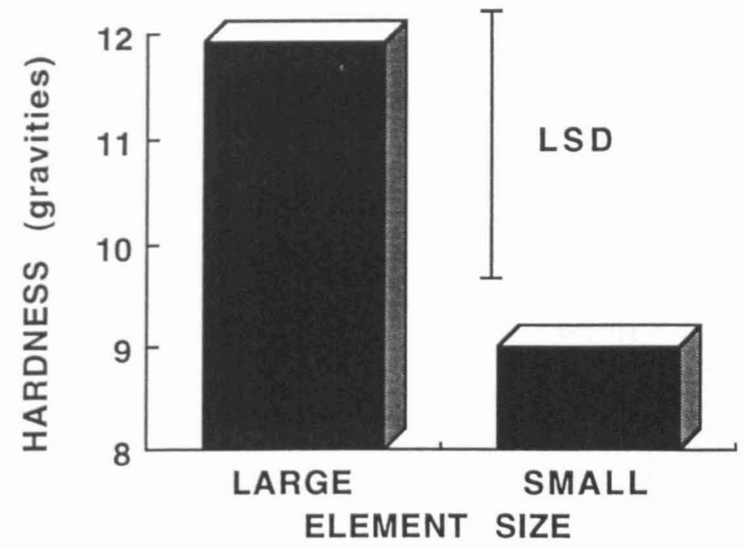

FIGURE 10. Effect of element size on hardness in February 1990. (LSD = least significant difference, p = 0.05.)

An effect of turf washing was also observed, on this occasion on ball rebound resilience (Figure 11), the washed turf giving slightly greater rebound resilience than the unwashed turf. In the case of both hardness and rebound resilience the values were towards the lower limits of the acceptable and preferred ranges respectively, due to the excessively wet conditions which had prevailed prior to sampling.

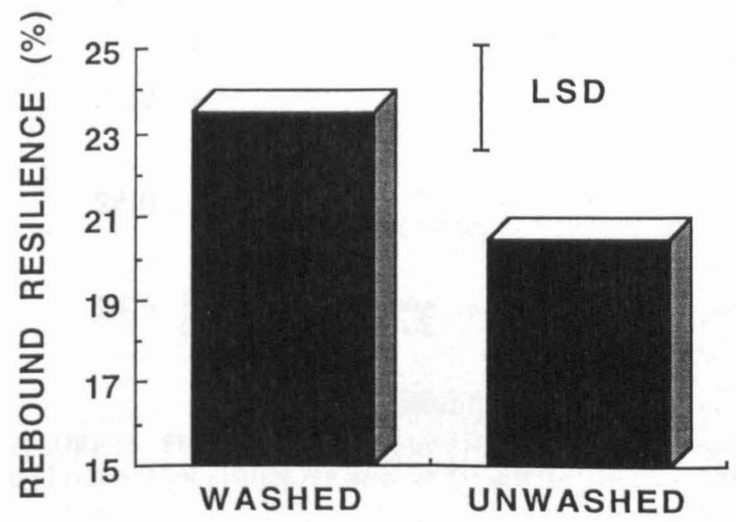

FIGURE 11. Effect of turf washing on ball rebound resilience in February 1990. (LSD = least significant difference, p = 0.05.)

Turf washing also showed an effect on hardness (Figure 12), the unwashed turf becoming unacceptably soft (the limit of acceptability being 10 gravities as measured by the Clegg Impact Soil Tester).

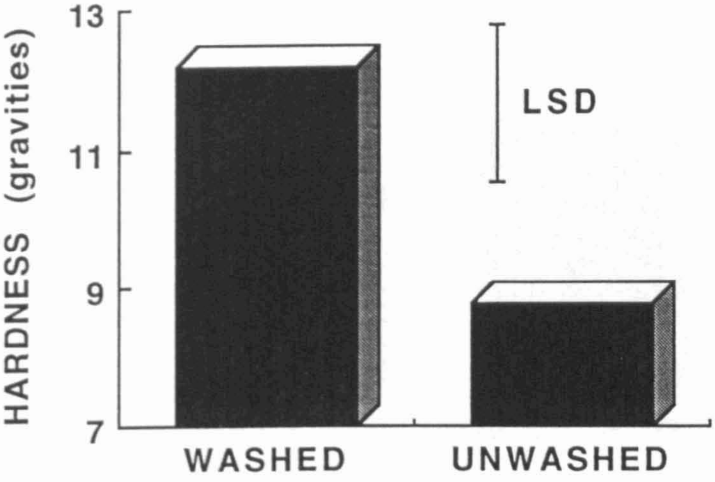

FIGURE 12. Effect of turf washing on hardness in February 1990. (LSD = least significant difference, p = 0.05.)

April 1990

In April 1990 the only statistically significant effects were on traction. Traction increased with element rate (Figure 13), although in practical terms the effect was small.

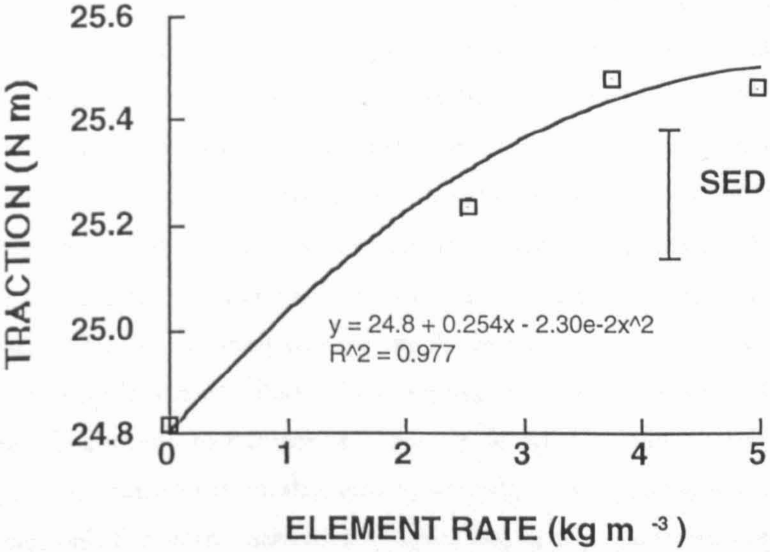

FIGURE 13. Effect of element rate on traction in April 1990. (LSD = least significant difference, p = 0.05, the horizontal line indicates the lower preferred limit for traction - see discussion.)

At the end of the season as the rootzone dried out one would once again expect the unwashed turf with its higher content of fine mineral soil to exhibit increased traction and this is what occurred (Figure 14). Again the effect was small in practical terms but highly significant statistically ($p < 0.001$).

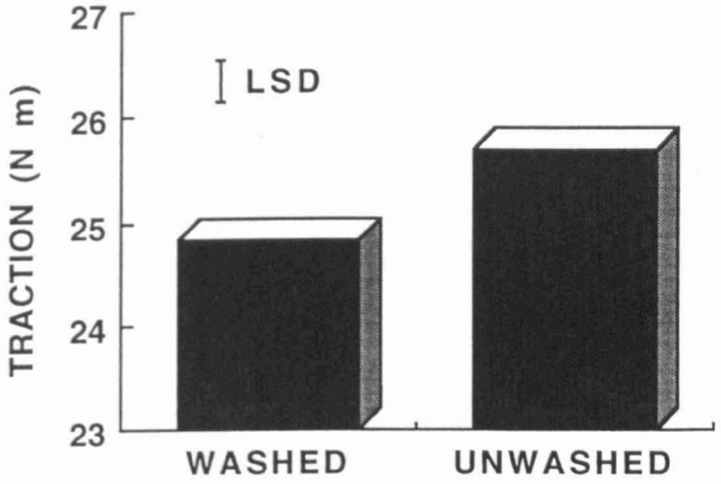

FIGURE 14. Effect of turf washing on traction in April 1990.

## DISCUSSION

The results showed 14 different instances where the experimental treatments had statistically significant effects on: either water infiltration rate, traction, ball rebound resilience or hardness. Of these six were attributable to turf washing, five to mesh element inclusion rate and three to mesh element size. The most notable effect of mesh element rate was on water infiltration rate which was measured three times during the playing season and on two of these (September and December 1989) showed a significant response confirming the findings of Beard & Sifers (1993). By April 1990, the upper 25-50 mm of the rootzone would have been contaminated with mineral matter and organic debris from the turf, worked into the surface by the wear machine, and hence this upper layer would be limiting water infiltration rather than the underlying rootzone and therefore any differences between treatments would tend to be masked. However, it is interesting to speculate on the reasons for the initial response in terms of infiltration rate. Why should the inclusion of mesh elements increase water infiltration rates? De Pew (cited by Beard & Sifers 1993) carried out photo-micrographic studies of mesh element reinforcement rootzones at Texas A & M University and found that soil voids were present around the mesh element strands. It is conceivable that such voids could provide channels for water movement, hence increasing water infiltration rate an explanation also put forward by Beard & Sifers (1993). This in turn begs the question as to why such voids should form and this was thought by De Pew to be due to flexion of the elements under applied loads or a form of "self cultivation".

Results for ball rebound, traction and hardness are considered in terms of previously published standards for playing quality of natural turf playing surfaces for football (Canaway *et al.* 1990). During the winter months under UK climatic conditions the most likely problems to be encountered are excessively soft surfaces together with low traction and ball rebound. Playing quality standards were defined in terms of "preferred" and less stringent "acceptable" limits as detailed in Table 4.

TABLE 4
Limits for playing quality standards proposed by Canaway *et al.* (1990)

| Measurement | Preferred limits | Acceptable limits |
|---|---|---|
| Ball rebound (%) | 20-50 | 15-55 |
| Traction (N m) | >25* | >20* |
| Hardness (gravities) | 20-80 | 10-100 |

*no upper limits for traction have been proposed.

During the early part of the playing season all measurements were in the preferred range for playing quality and it was only in the February 1990 data that problems were evident. In the case of hardness the mesh element reinforced plots were above the acceptable limit of 10 gravities whilst the unreinforced control fell below this limit. Similarly for traction, although the effect was small, the reinforced plots remained above the preferred limit of 25 N m whilst the control fell below at albeit by only a small amount. There were therefore demonstrable effects of the mesh element inclusion on playing quality in terms of traction and hardness during the most testing period of the trial, although no effects were observed on ball rebound resilience.

The effects of turf washing were beneficial overall, improving water infiltration rate by c. 10 mm $h^{-1}$ in the December 1989 results. This is in support of other findings on the benefit of washed turf in improving water infiltration rate during wear (Canaway 1993). In the latter study use of washed turf improved water infiltration rate by c. 20 mm above the nearest unwashed turf under golf-type wear on a sand rootzone. After heavy rainfall in early 1990 the surface of unwashed turf plots became "puddled" and moisture-retentive and this was reflected in the low values of hardness and ball rebound resilience in February 1990.

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# CHAPTER 6

# GENERAL DISCUSSION

The research that has been described was intended to provide a better understanding of the problems of maintaining grass swards used as playing surfaces for sport. It has involved detailed investigation of underlying scientific principles. But in essence the research was of an applied nature and designed to have practical implications for the management of turfgrass.

From it we now know much more about options for construction of football pitches and can give much more informed guidance to those wishing to construct pitches for their own use, in the case of private clubs or for use by schools or the general public in the case of educational and municipal authorities. The work described in Chapter 2 on pitch construction has made a significant contribution to our understanding of the subject. When taken together with other work carried out in conjunction with the University College of Wales, Aberystwyth (Baker & Gibbs 1989, Gibbs & Baker 1989; Baker, Gibbs & Adams 1992) it has led to a substantial growth in our understanding of pitch construction over a relatively short period of time.

In the establishment of new turfgrass areas we are now also much more aware of the potential dangers of the use of turf and the potential for pore blockage and loss of water infiltration rate that can result. Consequently where areas have to be turfed due to commercial pressures then immediate remedial programmes of hollow-coring and top dressing are undertaken in order to provide channels for water movement from the surface through to more permeable layers below. The benefits of turf washing were demonstrated but this has not found favour with UK turf growers, although it is widely practised in other countries notably Australia and the USA.. For amendment of sands in order to aid moisture retention during establishment Alginure has been widely recommended at a rate of 50-75 g $m^{-2}$ on the basis of the research carried out. Lastly from the practical angle, tangible benefits of isotropic stabilisation of sand rootzones have been demonstrated.

From a scientific point of view there are two major themes that run through the whole work, namely - playing quality and wear. These were dealt with at length in Chapter 2 and, throughout the research programme wear was applied, and playing quality was measured in response to wear. It cannot be claimed that the research described here was solely responsible for the development of the concept of playing quality but it certainly has made a contribution to it. Sometimes schools of thought appear and develop a particular idea and then promote it from its inception to a full blown methodology. There is no doubt that such a "school" promoting the idea of playing quality existed at the STRI commencing in the early 1980s and subsequently gathering momentum to such an extent that nowadays these principles and associated test methods are accepted world-wide. A Japanese visitor recently showed me photographs of a full set of playing quality apparatus as described in Chapter 2 which they had copied for use on their research on sports fields in Japan.

Throughout the research reference is made to the application of wear treatments. The idea is also developed that sports turf must be considered as a simple but complete system comprising soil and plant constituents as elaborated in Chapter 2, Part 2. These constituents are acted upon by various intrinsic and external factors to produce a playing surface. The performance of the playing surface is then modified by wear and the extent of that modification is in turn affected by the plant and soil elements, especially soil moisture content and throughput. This latter point is exemplified by the results of the experiment on establishment methods in Chapter 3, Part 1 where turfed and seeded plots showed no significant differences in water infiltration rate in September 1985 before wear treatments commenced. Once wear treatments were applied, 10 fold differences in infiltration rates were observed between turfed and seeded plots by December 1985 and 46 fold differences by the following April. An experiment without wear would have concluded that all of the turfed and seeded plots were of equal merit as far as infiltration rate was concerned, but it was the application of wear that really brought about a separation of the experimental treatments.

The work on nitrogen nutrition provided a further opportunity to study the interaction of wear with other factors, this time using a much more powerful experimental technique in that, since quantitative levels of fertiliser nitrogen were applied, it was then possible to study the form of response using iterative curve-fitting procedures. The fitted responses showed great changes throughout the course of the experiment developing optima in response to wear and providing a good example of how a well-designed experiment can produce results of value from both the scientific, and the practical viewpoint.

In conclusion it is clear that the research described in this volume has demonstrated the need for researchers to consider the holistic nature of turfgrass systems, the need for meaningful measures of playing quality and above all the importance of wear in mediating the interaction between plant and soil constituents and their response to experimental treatments.

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