THE SPORTS TURF RESEARCH INSTITUTE

STRI BINGLEY

THE EFFECTS OF FYTOGREEN FOAM ON THE SOIL PHYSICAL PROPERTIES OF SAND-DOMINATED ROOTZONES FOR SPORTS TURF

A LABORATORY STUDY

For

Fytogreen BV,
Muurhuizen 138 B,
3811 EM Amersfoort,
Holland.

By

Mr Sacha Mooney and Dr Stephen Baker
STRI
Bingley, West Yorkshire, BD16 1AU

Document No. 0066/3

22 July 1999

St. Ives Estate, Bingley, West Yorkshire BD16 1AU.
Tel 01274 565131. Fax 01274 561891. e-mail: stri@rmplc.co.uk

Chief Executive: P.M. Canaway BSc. PhD. CBiol. MI Hort. Secretary: T. Hutchinson ACMA. Patron: HRH The Duke of Edinburgh KG, KT. President: The Rt Hon. Lord Griffiths, MC. Vice Presidents: Prof A.D. Bradshaw FRS, Frank Fawcett, Peter Wilson. Chairman: R.T. Robinson. A company limited by guarantee. Registered in England No. 499164. Registered office: St. Ives Research Station, Bingley, West Yorkshire BD16 1AH.

CONFIDENTIAL

0066/3
22 July 1999

THE EFFECTS OF FYTOGREEN FOAM ON THE SOIL PHYSICAL PROPERTIES OF SAND-DOMINATED ROOTZONES FOR SPORTS TURF

SUMMARY

A laboratory experiment was designed to assess the effects of different rates of Fytogreen foam incorporation on the physical properties of three rootzones (one pure sand and two sand plus amendment) with a view to identifying those that conformed to the United States Golf Association's (USGA) criteria for the physical properties of golf green rootzones. The main results were that the incorporation of Fytogreen foam created an increased capillary porosity and subsequently water retention capacity, which accounted for a decreased hydraulic conductivity, total and air-filled porosity. A decrease in bulk density and hardness was also identified with increased Fytogreen foam application, although no relationship was identified with respect to shear strength. Out of the 15 rootzones that were tested , only one complied with less than two of the four main physical properties recommended limits (hydraulic conductivity, total porosity, air-filled and capillary porosity at two tensions). Further to this, seven rootzones were identified as conforming to all of the four, of which five contained Fytogreen foam at various incorporation rates. This study has illustrated that Fytogreen foam has potential for use in creating rootzone materials which conform to USGA limits for physical performance and that important considerations will be grade of sand, type of amendment material and rate of Fytogreen foam application.

INTRODUCTION

Fytogreen foam is a biodegradable product made by Fytogreen BV that can improve drainage, aeration and the water and nutrient retention capacities of soils. A laboratory trial was conducted to test the potential of Fytogreen foam for use as an amendment both in its own right and in combination with other amendment materials for use in sand-dominated rootzones for sports turf, particularly golf greens.

The effects of different incorporation rates of Fytogreen foam in pure sand, 80:20 sand : peat mix and 80:20 sand : soil mix rootzones on selected soil physical properties were examined in the laboratory using the USGA test methods (Hummel, 1993). The results of the tests were then compared with the recommendations for soil physical properties given by the USGA Greens Section Staff (1993) (Table 1).

MATERIALS AND METHODS

Experimental treatments

The experiment was conducted in the Soil Physics Laboratory at STRI, Bingley, UK. There were 15 experimental treatments comprising five rates of Fytogreen foam (0, 7.5, 15, 22.5, 30 % by volume) which were added to a pure sand, a 80:20 sand : peat mix, and a 80:20 sand : sandy loam mix. The level of compression can be deduced from 30 % Fytogreen foam by volume corresponding with approximately 2 % Fytogreen foam by weight. These treatments were replicated five times in a factorial design. This gave a total of 75 samples which were placed in 72 mm diameter cylinders and compacted using a packing energy of 30.3 KJ m^{-2} before physical properties were measured. The particle size distribution of the sand and amendments used in the rootzone materials are shown in Table 2. The sand used in this study was a 50:50 mix of medium (Rufford 1742) and medium-coarse sand (Chelford 30), which complied with USGA recommendations for particle size distribution of rootzone mixes. The soil amendment was a sandy loam topsoil taken from the STRI trial grounds at Bingley. The peat amendment was a *Sphagnum* moss supplied by Shamrock Peat Ltd.

Measurements

The following measurements were carried out on all of the rootzone mixes. The standard operating procedure for each method is given in Appendix I.

- Saturated hydraulic conductivity
- Water retention
- Bulk density
- Total, air-filled and capillary porosity at 30 and 40 cm tension
- Shear strength and hardness at 40 cm tension

All data underwent a statistical analysis of variance using the factorial model and the least significant difference (LSD) at the 5 % probability level (P=0.05) was determined. A regression analysis was carried out at the 5 % probability level to examine the significance of the identified relationships.

TABLE 1

The USGA recommended ranges for the selected physical properties of rootzone mixes

Physical property		Recommended range
Saturated hydraulic conductivity (mm h^{-1})	Normal range Accelerated range	150 – 300 300 – 600
Total porosity (%)		35 – 55
Air-filled porosity (%)		15 – 30
Capillary porosity (%)		15 – 25

TABLE 2

Particle size distribution and organic matter content of the rootzone mixes (mm)

Rootzone Mix	Very coarse sand (2-1)	Coarse sand (1-0.5)	Medium sand (0.5-0.25)	Fine sand (0.25-0.125)	Very fine sand (0.125-0.05)	Silt and clay (<0.05)	Organic matter (%)
Pure sand	0.3	17.3	71.2	10.5	0.4	0.5	ND
80:20 Sand:Soil†	0.9	16.6	63.2	10.5	2.1	6.1	1.2
80:20 Sand:Peat	0.4	19.5	67.5	10.2	0.8	1.7	2.4

ND = Not Determined

† 0.6 % was > 2 mm (i.e. gravel)

RESULTS

The mean values, standard errors and LSD's following the five replications for selected physical properties are presented in Figures 1-6 and Appendix II. The main findings from this can be summarised as decreased bulk density, hydraulic conductivity, air-filled porosity and hardness and increased water retention with increased Fytogreen foam applications. No relationship was established for shear strength. An analysis of variance table illustrating the significance of the main treatment effects namely amendment material, rate of Fytogreen foam and the interaction of the two is shown in Table 4. The type of amendment material had a highly significant (P<0.001) effect on all the measured properties with the exception of shear strength for which statistically significant differences were still recorded (P<0.05).

The rate of Fytogreen foam added to the rootzone mixes was highly significant (P<0.001) for all the measured properties with the exception of hardness and shear strength. Hardness values were still statistically significant with respect to Fytogreen foam application rate (P<0.05) where as variations in shear strength were not significant. The interaction between the amendment materials and rate of Fytogreen foam incorporation represents the combined effect of both these factors on the measured properties which is important because if significant it denotes that the combined effect of the factors is different to the effect of each of the factors individually. Bulk density, total porosity, hardness and shear strength were not influenced any differently by the interaction of both amendment material and rate of Fytogreen foam application than it was affected by them individually. For the remaining properties statistically significant differences (P<0.05) were recorded with respect to the interaction of the main treatment effects.

TABLE 4

Summary of significant results with respect to treatments effects from statistical analysis

Measured Property	Amendment material	Rate of Fytogreen foam	Interaction between amendment material and rate of Fytogreen foam
Bulk density	***	***	NS
Hydraulic conductivity	***	***	***
Total porosity	***	***	NS
Air-filled porosity at 3kPa	***	***	*
Capillary porosity at 3kPa	***	***	*
Air-filled porosity at 4kPa	***	***	*
Capillary porosity at 4kPa	***	***	*
Hardness	***	*	NS
Shear strength	*	NS	NS

*** < 0.001
** < 0.01
* < 0.05
NS Not Significant

Hydraulic conductivity

Increased application of Fytogreen foam significantly reduced the hydraulic conductivity typically in the order of *ca.* 50 mm h^{-1} for each increment, although a drop as high as *ca.* 200 mm h^{-1} was recorded between 0 and 7.5 % Fytogreen foam in the pure sand rootzone (Figure 1). When comparing rootzone materials with the same Fytogreen foam rate, it was observed that the highest values were associated with the pure sand rootzone, with values slightly higher in the peat amendment rootzone than the soil amendment rootzone. For the 15 rootzone mixes, 11 conformed to the USGA recommendations of which four were within the designated normal range (seven within the accelerated range). Of the four rootzone mixes that failed to comply with the USGA criteria, three exceeded the accelerated range (pure sand rootzones with 0, 7.5 and 15 % Fytogreen foam) and one fell below the normal range (soil amendment with 30 % Fytogreen foam).

Total porosity
Increased application of Fytogreen foam significantly reduced total porosity, although when observed from Figure 2 the differences appear to be slight. The difference in the mean porosity values between the rootzones with 0 and 30 % Fytogreen foam never exceeded 5 % for any rootzone. The highest total porosity values were recorded in the peat amendment rootzone, with the pure sand and soil rootzones behaving similarly. Of the 15 rootzone materials, four did not satisfy USGA recommendations namely, pure sand (22.5 and 30 % Fytogreen foam) and soil amendment (22.5 and 30 % Fytogreen foam).

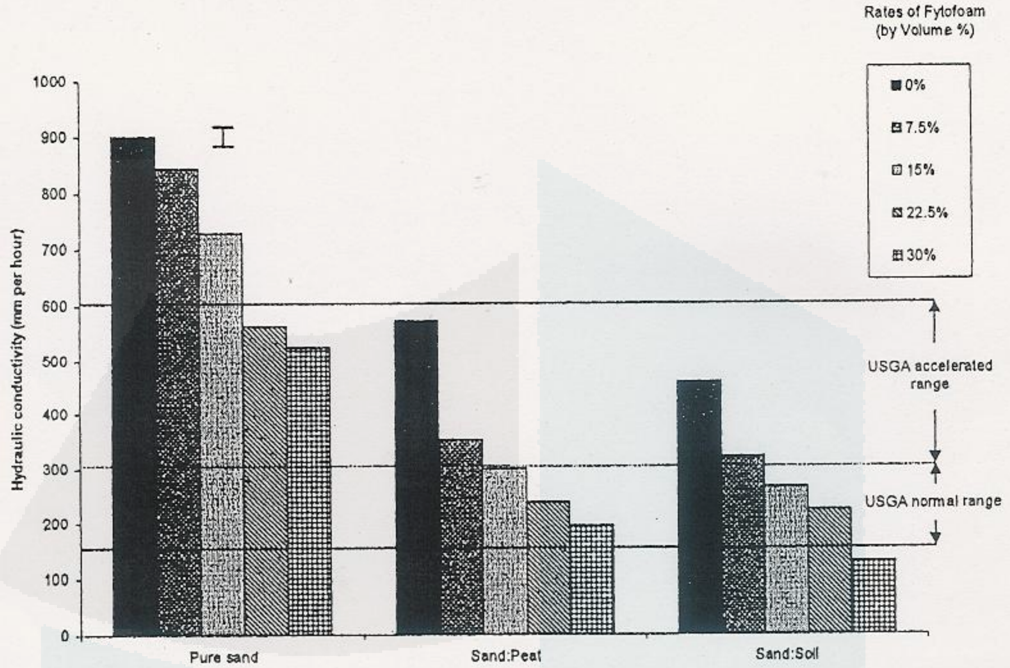
Air-filled porosity (at 3 and 4 kPa)
Air-filled porosity significantly decreased as the rate of Fytogreen foam increased at both 3 and 4 kPa (Figure 3 and 4). The highest values were associated with the pure sand rootzones, while the soil amendment rootzones generally had slightly higher values than the peat amendment rootzones. At a tension of 3 kPa, seven of the 15 rootzones fell within the USGA recommended limits, namely pure sand (0-22.5 % Fytogreen foam), peat amendment (7.5 % Fytogreen foam) and soil amendment (0-7.5 % Fytogreen foam). The rootzone mixes that did not comply fell below the 15 % lower limit. At a tension of 4 kPa, 11 out of the 15 rootzones conformed to the suggested USGA limit. Out of the four mixes that did not comply, one exceeded the upper limit (pure sand with 0 % Fytogreen foam) and three fell below the lower limit (peat amendment with 30 % Fytogreen foam and soil amendment with 22.5 and 30 % Fytogreen foam).

Capillary porosity (at 3 and 4 kPa)
Capillary porosity was significantly increased by additional applications of Fytogreen foam (figure 5 and 6). The highest values were observed in the peat amendment rootzones and the lowest in the pure sand rootzones. At a 3 kPa tension, only seven of the 15 rootzones mixes conformed to the USGA recommended limits. All the peat amendment rootzones and the soil amendment rootzone with 30 % Fytogreen foam exceeded the upper limit of 25 %, whereas the pure sand rootzone with 0 and 7.5 % Fytogreen foam fell below the 15 % lower limit. At a 4 kPa tension, nine of the 15 rootzones fell within the desired USGA range. The reduced capillary porosity values ensured that only one peat amendment rootzone mix exceeded the limit (30 % Fytogreen foam), however this accounted for the soil amendment with 0 % Fytogreen foam and all but one (30 % Fytogreen foam) pure sand rootzone falling below the lower limit.

Compliance with USGA recommendations
Out of the 15 rootzones, only one complied with less than two of the four physical properties recommended limits (hydraulic conductivity, total porosity, air-filled and capillary porosity at either tension). Further to this, seven rootzones were identified as conforming to all of the four, of which five contained Fytogreen foam at various incorporation rates. None of the pure sand rootzones complied with all four physical property recommended limits.

FIGURE 1

Hydraulic conductivity of rootzone mixes containing different amounts of Fytogreen foam. The horizontal lines indicate the USGA recommended limits for golf green rootzones. The vertical bar represents the standard error of difference of means (P=0.05) for the interaction between Fytogreen foam application and amendment type.



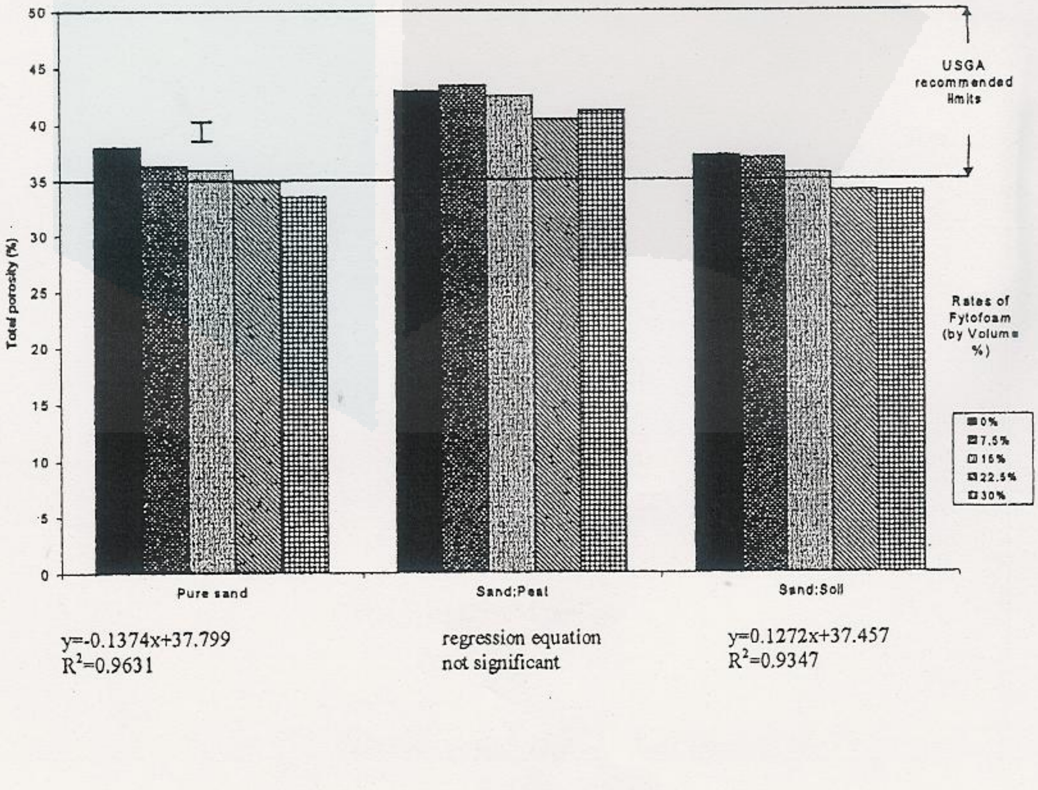
y=-14.385x+916.64 R^2=0.9695

y=-11.133x+490.76 R^2=0.8693

y=9.675x+427.32 R^2=0.9671

FIGURE 2

Total porosity of rootzone mixes containing different amounts of Fytogreen foam. The horizontal lines indicate the USGA recommended limits for golf green rootzones. The vertical bar represents the standard error of difference of means (P=0.05) for the interaction between Fytogreen foam application and amendment type.



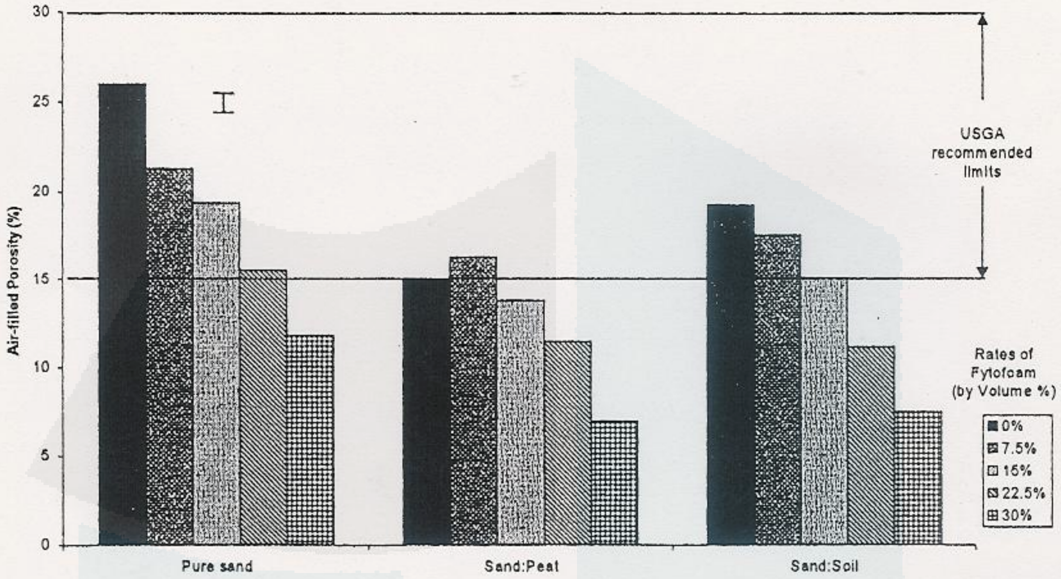
y=-0.1374x+37.799 R^2=0.9631

regression equation not significant

y=0.1272x+37.457 R^2=0.9347

FIGURE 3

Air filled porosity at a 3 kPa tension of the rootzone mixes containing different amounts of Fytogreen foam. The horizontal lines indicate the USGA recommended limits for golf green rootzones. The vertical bar represents the standard error of difference of means (P=0.05) for the interaction between Fytogreen foam application and amendment type.



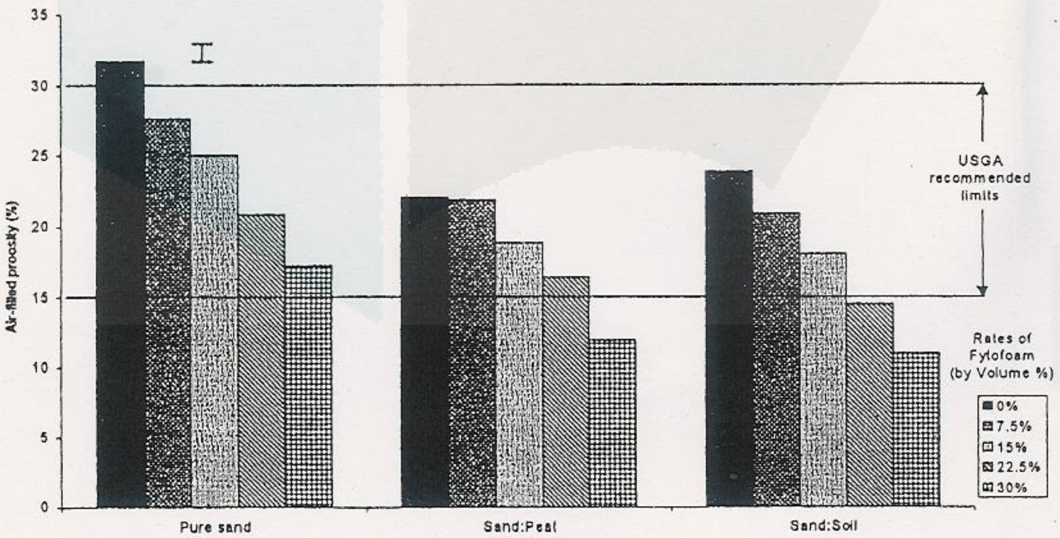
y=-0.4537x+25.611
R^2=0.9892

y=-0.2768x+16.823
R^2=0.8076

y=0.3978x+20.061
R^2=0.9744

FIGURE 4

Air-filled porosity at a 4 kPa tension of the rootzone mixes containing different amounts of Fytogreen foam. The horizontal lines indicate the USGA recommended limits for golf green rootzones. The vertical bar represents the standard error of difference of means (P=0.05) for the interaction between Fytogreen foam application and amendment type.



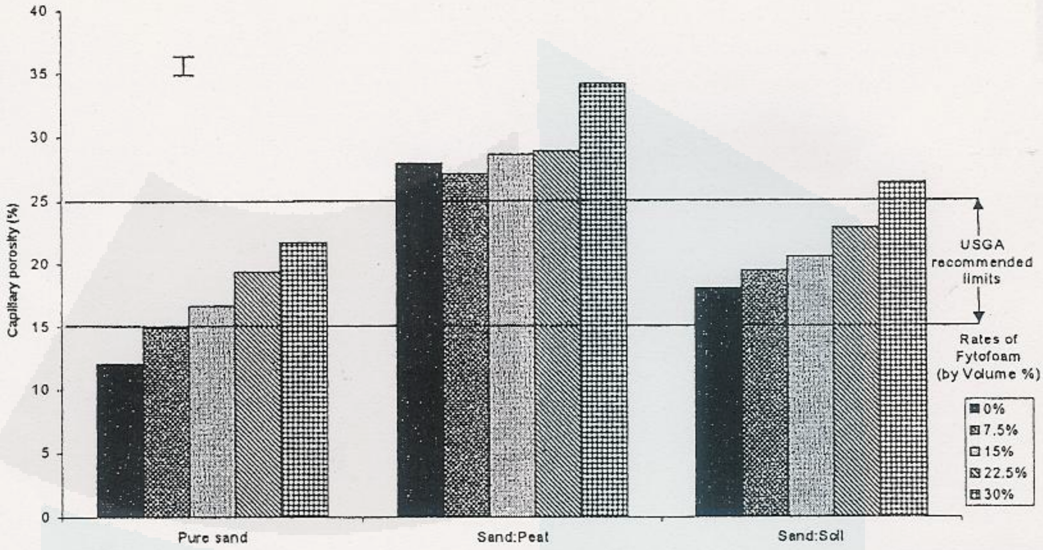
y=-0.4756x+31.578
R^2=0.9952

y=-0.3432x+23.361
R^2=0.9265

y=0.4279x+24.071
R^2=0.9974

FIGURE 5

Capillary porosity at a 3 kPa tension of the rootzone mixes containing different amounts of Fytogreen foam. The horizontal lines indicate the USGA recommended limits for golf green rootzones. The vertical bar represents the standard error of difference of means (P=0.05) for the interaction between Fytogreen foam application and amendment type.



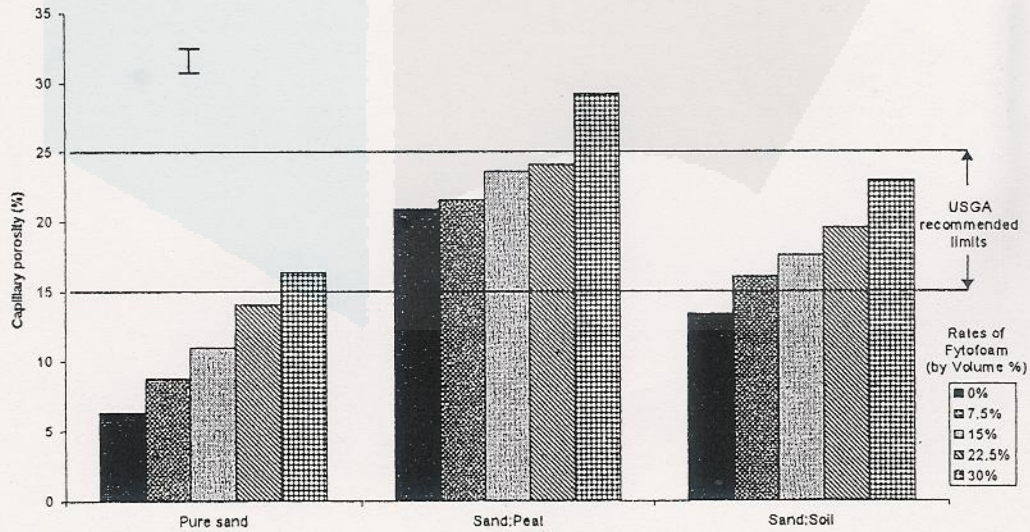
$y=0.3163x+12.189$
$R^2=0.9952$

regression equation not significant

$y=0.2706x+17.396$
$R^2=0.9451$

FIGURE 6

Capillary porosity at a 4 kPa tension of the rootzone mixes containing different amounts of Fytogreen foam. The horizontal lines indicate the USGA recommended limits for golf green rootzones. The vertical bar represents the standard error of difference of means (P=0.05) for the interaction between Fytogreen foam application and amendment type.



$y=0.3383x+6.2215$
$R^2=0.9976$

$y=0.2561x+19.988$
$R^2=0.8532$

$y=0.3007x+13.385$
$R^2=0.9833$

TABLE 5

Summary table showing the soil physical properties that comply with the USGA recommendations for each rootzone mix

Rootzone mix	Fytogreen foam (% applied on a volume basis)				
	0	7.5	15	22.5	30
Pure Sand	TP AFP (3 kPa)	TP AFP (3 kPa) AFP (4 kPa)	TP AFP (3 kPa) CP (3 kPa) AFP (4 kPa)	HC (A) AFP (3 kPa) CP (3 kPa) AFP (4 kPa)	HC (A) CP (3 kPa) AFP (4 kPa) CP (4 kPa)
80:20 Sand:Peat mix	HC (A) TP AFP (4 kPa) CP (4 kPa)	HC (A) TP AFP (3 kPa) AFP (4 kPa) CP (4 kPa)	HC (N) TP AFP (4 kPa) CP (4 kPa)	HC (N) TP AFP (4 kPa) CP (4 kPa)	HC (N) TP
80:20 Sand:Soil mix	HC (A) TP AFP (3 kPa) CP (3 kPa) AFP (4 kPa)	HC (A) TP AFP (3 kPa) CP (3 kPa) AFP (4 kPa) CP (4 kPa)	HC (N) TP AFP (3 kPa) CP (3 kPa) AFP (4 kPa) CP (4 kPa)	HC (N) CP (3 kPa) CP (4 kPa)	CP (4 kPa)

HC (N) = Hydraulic conductivity (Normal range) ; HC (A) = Hydraulic conductivity (Accelerated range)
TP = Total porosity; AFP (3 kPa) = Air-filled porosity at 3 kPa; CP (3 kPa) = Capillary porosity at 3 kPa
AFP (4 kPa) = Air-filled porosity at 4 kPa; CP (4 kPa) = Capillary porosity at 4 kPa
NB: Shading represents rootzone that comply with ranges set for Hydraulic conductivity, Total porosity, and both Air-filled and Capillary porosity at either tension.

TABLE 6

Comparison of the performance of the raw amendments with Fytogreen foam

Physical property	Sand + 20 % Fytogreen foam	Sand + 20 % Peat	Sand + 20 % Soil
Hydraulic conductivity (mm hr^{-1})	629	555	446
Total porosity (%)	35.1	42.9	37.2
Air-filled porosity at 3 kPa (%)	16.5	14.9	19.2
Capillary porosity at 3 kPa (%)	18.5	28.0	18.0
Air-filled porosity at 4 kPa (%)	22.1	22.0	23.8
Capillary porosity at 4 kPa (%)	13.0	20.9	13.4
Hardness (gravities)	113.2	88.1	172.3

To assess the use of Fytogreen foam as a sole rootzone amendment, the regression equations (Figures 1 to 6) were used to extrapolate the response of physical properties for a 20 % Fytogreen foam incorporation. This allowed direct comparisons with the peat and soil amendments (Table 6). As a sole amendment with pure sand, the hydraulic conductivity was highest in Fytogreen foam. With respect to total porosity and capillary porosity at both tensions Fytogreen foam appeared to behave similarly to the sand : soil rootzone. Fytogreen foam hardness was greater than the sand : peat rootzone but less than the sand : soil rootzone.

DISCUSSION

The incorporation of Fytogreen foam into pure sand and sand / amendment rootzone mixes resulted in an increased capillary porosity and subsequently water retention within the rootzone. As a direct result of an increased water capacity, the air-filled porosity and hydraulic conductivity of the rootzone mixes decreased. By contrast, changes to the total porosity appeared to be relatively small, although a statistically significant decrease in total porosity was identified with an increased volume application of Fytogreen foam. It was also established that increased applications of Fytogreen foam accounted for reductions in surface hardness and bulk density because of an increased volume of an energy absorbing material.

None of the pure sand rootzone mixes had full compliance with the recommended limits with respect to the four main soil physical properties (hydraulic conductivity, total, air-filled and capillary porosity). This was a result of water flow rates exceeding the recommended upper limit in the three lowest Fytogreen foam application rates (0-15 %). In addition, the rootzone mixes with the increased Fytogreen foam (22.5 and 30 %) fell below the lower limit for total porosity (albeit by less than 3 %).

The sand : peat amendment performed the best of the rootzone materials, with four of the five mixing ratios fulfilling the criteria for all four physical properties (at any tension). The main exclusions were associated with the 30 % Fytogreen foam application whereby capillary porosity (water retention) exceeded the upper limit and subsequently the air-filled porosity fell below the required limit. This can be accounted for by the combined water retention properties of peat coupled with those of Fytogreen foam. It was also noted that at a tension of 3 kPa, sand : peat rootzone mixes tended to exceed the limit for capillary porosity and fall below the limit for air-filled porosity, whereas at a 4 kPa tension only the 30 % Fytogreen foam rootzone did not fall within the recommended range. The pure sand used in this study was a 50:50 mix of a medium and medium coarse sand that conforms to USGA recommendations. It is possible to speculate that the use of a slightly coarse sand and / or a slight reduction in Fytogreen foam by volume would have created a series of rootzone mixes that would all comply to the specified criteria.

Three out of the five sand : soil rootzone mixes conformed to the recommended limits for the main physical properties, with two (7.5 and 15 %) having full compliance for every measure (at both tensions). At Fytogreen foam applications of 22.5 and 30 %, water retention was significantly increased and as a result total and air-filled porosity values fell below the desired range.

This study has illustrated that Fytogreen foam can have a positive effect on rootzone mixes with respect to conforming to USGA recommendations for soil physical properties and creating a suitable medium for use in golf green construction. The main benefits are improving water retention and subsequently reducing over rapid drainage of solutes. This has many important implications with respect to avoiding drought and nutrient stress. The sand plus amendment mixes performed the best as hydraulic conductivity was typically too rapid in pure sand for USGA specifications. The soil and peat amendments behaved in a fairly similar manner, although the water retentive and highly porous properties of peat appeared to compliment the application of Fytogreen foam best. Although a tendency to retain too much water in the higher Fytogreen foam applications was identified. It has also been illustrated that Fytogreen foam has the potential to be used with sand as a sole amendment for a golf green rootzone material in terms of the assessed physical properties, although some adjustment to the percentage added by volume would be required to conform to the USGA criteria. An important consideration of a good playing surface is to be able to establish and support a healthy turfgrass sward over a significant period of time. Considering this, a field trial shall be established to examine the effects of Fytogreen foam with respect to establishing and maintaining a healthy grass sward over a ten month period. After which the specific water retentive qualities of Fytogreen foam shall be tested by examining sward response and survival under drought conditions.

REFERENCES

Hummel, N.W. 1993. Laboratory methods for evaluation of putting green root zone mixes. In: *USGA Green Section Record*, Mar./Apr. United States Golf Association, Golf House, Far Hills, NJ, USA.

USGA Green Section Staff 1993. USGA recommendations for a method of putting green construction. In: *USGA Green Section Record*, Mar./Apr. United States Golf Association, Golf House, Far Hills, NJ, USA.

QUALITY STATEMENT

We confirm that this report is a true representation of the original data collected and that the Standard Operating Procedures referred to in the STRI Manual of Standard Operating Procedures, and those relevant to data collection, data preparation, archiving of data and preparation of reports have been implemented in full.

Prepared by: 21/7/99 (Signature and date)

Checked by: 22/7/99. (Signature and date)

Final version checked and reviewed by: Stephen Baker 23/7/99 (Signature and date)

POLITE REMINDER

Please ensure that your Sales/Marketing Department is aware that this research has been carried out under contract and that the consent of the STRI must be obtained where information contained in the report is to be used in advertising or promotional literature.

APPENDIX I

STANDARD OPERATING PROCEDURE NO 6A1098

USGA METHOD FOR DETERMINING SATURATED HYDRAULIC CONDUCTIVITY, WATER RETENTION, POROSITY AND BULK DENSITY FOR SPORTS TURF ROOTZONE MIXES.

[1] Scope

This standard operating procedure specifies the USGA method for the determination of saturated hydraulic conductivity, water retention, total porosity, air-filled porosity, capillary porosity and bulk density of sports turf rootzone mixes.

[2] Principal

Saturated hydraulic conductivity is determined for soil cores that have received a standard compaction treatment. The water flow throughout the core is maintained at a constant head until an equilibrium flow rate has been achieved at which time the outflow is measured.

Water retention is obtained from the cores by means of a tension table which will extract water at a matric potential set to correspond with the depth of the rootzone. The weight of the core is recorded once an equilibrium has been reached. Water retention is calculated on an oven dry basis. The oven dry weight of the soil in the core divided by its volume gives the dry bulk density.

Particle density is determined using glass pycnometers and is used in the calculation of total porosity. Total porosity, capillary porosity and air-filled porosity are derived from the measured parameters.

[3] Procedure

Measurements and calculations are undertaken in accordance with the methods given in the accompanying ASTM document (Designation : F1815-97) entitled 'Standard test methods for saturated hydraulic conductivity, water retention, porosity, particle density and bulk density of putting green and sports turf root zones'. Particle density is measured using method C-1 in this document.

STANDARD OPERATING PROCEDURE NO. 1B0398

DETERMINATION OF SOIL STRENGTH USING A SHEAR VANE

[1] Scope

This standard operating procedure specifies a method of test for the determination of soil strength on natural turf surfaces.

[2] Principle

The "strength" of soil is determined by measuring the resistance to shear stress of the turf surface.

[3] Apparatus

A Geonor inspection vane borer as described in the manufacturer's booklet "Working instructions For Inspection Vane Borer" dated January 1966 (attached).

[4] Procedure

Select the appropriate vane size for the surface under test. The small, medium and large vanes measure shear strengths of 0-20, 0-10 and 0-5 t m^{-2} respectively. (Note: a series of preliminary readings may be needed to determine the most suitable size.) Hold the vane perpendicular to the turf surface, and press into the turf until the top of the vane is level with the surface. Twist the vane until shear resistance is overcome. Remove the vane from the turf and take the reading from the graduated scale.

[5] Number of Measurements

Take at least 8 measurements at random on areas less than 100 m^2, 9-15 on areas of 100-1000 m^2, 16-20 on areas of 1000-5000 m^2. Larger areas should be subdivided prior to testing.

[6] Expression of Results

Correct the readings from the graduated scale, for vane size, as follows: For small blades (16 x 32 mm) multiply the reading by 2, for medium blades (20 x 40 mm) multiply by 1 and for long blades (25 x 50 mm) multiply by 0.5.

This gives the shear strength as t m^{-2}. Convert to kPa using the relationship 1 t m^{-2} = 9.81 kPa.

The mean value in kPa shall be given.

STANDARD OPERATING PROCEDURE NO. 200695

DETERMINATION OF HARDNESS

[1] Scope

This standard operating procedure specifies a method of test for the determination hardness of turf surfaces.

[2] Principle

A cylindrical mass is released from a standard height and its peak deceleration during impact with the turf surface is recorded.

[3] Apparatus

A Clegg Impact Soil Tester shall be used. The apparatus consists of a cylindrical compaction hammer with a mass of 0.5 kg and a diameter of 50 mm attached to a piezoelectric accelerometer which feeds into a peak level digital meter. The peak deceleration of the hammer on impact with the ground is displayed in gravities on the liquid crystal display of the digital meter.

(Note: Available from: Trevor Deakin Consultants Ltd, Ascot Court, White Horse Business Park, Trowbridge, Wiltshire, BA14 0XA. As delivered the instrument reads in scale of 10 gravities. It should be modified to read in units of gravities before use on natural turf surfaces.)

[4] Procedure

Ensure that the guide tube is held vertically and drop the compaction hammer down the tube from a height of 300 $\pm$ 10 mm for golf. After the impact of the hammer on the turf surface, the peak deceleration displayed by the digital meter shall be recorded in units of gravities. After each test the guide tube shall be moved so that the compaction hammer does not impact with the surface on the same spot twice.

[5] Number & Distribution of Readings

Unless otherwise specified, take at least eight readings at random on areas less than 100 m^2, taken 8-15 readings as appropriate on areas of 100 m^2 and 15-20 readings for areas of 1000 m^2 to 5000 m^2. Larger areas should be subdivided into two or more areas for testing.

[6] Expression of Results

Calculate the mean hardness value for each area.

APPENDIX II

Mean summary table of soil physical properties for the rootzone mixes containing different amounts of Fytogreen foam

Rootzone mix	Mixing ratio (% on a volume basis)	Bulk density (g cm^{-3})	Hydraulic conductivity (mm hr^{-1})	Total porosity (%)	Air-filled porosity at 3 kPa (%)	Capillary porosity at 3 kPa (%)	Air-filled porosity at 4 kPa (%)	Capillary porosity at 4 kPa (%)	Hardness (gravities)	Shear strength (kPa)
Pure Sand	0	1.68 (0.008)	900 (12.6)	38.0 (0.31)	26.0 (0.82)	12.0 (0.73)	31.7 (0.56)	6.3 (0.25)	170 (38.7)	9.6 (2.41)
	7.5	1.66 (0.029)	835 (19.0)	36.3 (1.12)	21.3 (1.87)	14.9 (1.02)	27.5 (1.31)	8.8 (0.23)	136 (26.0)	9.6 (1.79)
	15	1.59 (0.009)	717 (15.5)	36.0 (0.37)	19.4 (0.78)	16.6 (0.75)	25.0 (0.52)	11.0 (0.20)	121 (30.1)	11.6 (2.31)
	22.5	1.55 (0.016)	548 (16.7)	34.9 (0.67)	15.5 (0.39)	19.4 (0.76)	20.9 (0.75)	14.0 (0.70)	89 (25.5)	20.4 (5.93)
	30	1.51 (0.008)	504 (20.5)	33.5 (0.37)	11.9 (0.58)	21.7 (0.83)	17.2 (0.49)	16.4 (0.56)	100 (21.4)	14.9 (1.90)
80:20 Sand:Peat mix	0	1.47 (0.003)	555 (47.7)	42.9 (0.13)	14.9 (0.63)	28.0 (0.65)	22.0 (0.33)	20.9 (0.32)	88 (17.7)	17.1 (1.90)
	7.5	1.41 (0.019)	345 (19.2)	43.4 (0.75)	16.2 (1.30)	27.1 (0.82)	21.9 (1.19)	21.5 (0.51)	88 (16.1)	17.9 (2.60)
	15	1.38 (0.008)	295 (9.6)	42.4 (0.33)	13.8 (0.69)	28.6 (0.92)	18.9 (0.30)	23.5 (0.24)	64 (14.8)	16.1 (1.69)
	22.5	1.38 (0.010)	227 (16.5)	40.4 (0.44)	11.5 (0.96)	28.9 (1.29)	16.4 (1.15)	24.0 (1.47)	65 (15.2)	16.1 (2.16)
	30	1.31 (0.014)	196 (7.1)	41.1 (0.62)	6.9 (0.69)	34.2 (0.61)	11.9 (0.61)	29.2 (0.29)	59 (13.0)	19.4 (2.25)
80:20 Sand:Soil mix	0	1.68 (0.011)	446 (35.7)	37.2 (0.40)	19.2 (1.04)	18.0 (0.81)	23.8 (0.51)	13.4 (0.15)	172 (14.3)	18.4 (2.73)
	7.5	1.63 (0.011)	321 (8.3)	37.0 (0.44)	17.5 (0.56)	19.4 (0.62)	20.9 (0.40)	16.0 (0.34)	142 (21.9)	16.1 (2.64)
	15	1.60 (0.007)	288 (25.4)	35.6 (0.30)	15.1 (0.68)	20.5 (0.52)	18.0 (0.38)	17.6 (0.26)	137 (27.8)	17.9 (2.18)
	22.5	1.57 (0.007)	225 (9.2)	34.1 (0.26)	11.2 (0.34)	22.9 (0.43)	14.5 (0.38)	19.6 (0.28)	113 (29.1)	15.1 (1.77)
	30	1.52 (0.011)	131 (6.0)	33.9 (0.48)	7.5 (0.55)	26.4 (0.35)	11.0 (0.52)	22.9 (0.26)	92 (23.8)	19.4 (2.95)
LSD (rate x mix)		*NS*	*59.4*	*NS*	*2.48*	*2.19*	*1.99*	*1.46*	*NS*	*NS*

NB: Standard error values expressed in brackets