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LARGE SCALE PRODUCTION OF SPHAGNUM SPECIES FOR BOG RESTORATION

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SUMMARY

Re-establishment of *Sphagnum* species is key to returning degraded bogs to functioning ecosystems – often limited by availability of *Sphagnum*.
Successful bulk-up of small quantities of local origin material was achieved using *in vitro* propagation and found suitable for all species tested (currently 10).
A handling and distribution method was developed, encapsulating *Sphagnum* plantlets, a few millimetres in size, in a bead (termed 'BeadaMoss™') allowing easy separation and planting onto the bog surface with seeding machines, even by helicopter for large scale restoration.
In early trials, *Sphagnum* was successfully established in the moorland environment and results show survival rates of up to 69%. Restoring large areas of denuded bog, by seeding with BeadaMoss™, to functioning ecosystems is therefore within grasp.

KEYWORDS: *Sphagnum*; Propagation; BeadaMoss™; Restoration; *In vitro*

INTRODUCTION

Re-establishment of *Sphagnum* species is key to returning degraded blanket and raised bogs to functioning ecosystems. In the South Pennine bogs of England where *Sphagnum* was almost wiped out after the Industrial Revolution (Tallis, 1997), recovery of peatlands is limited by availability of local *Sphagnum* for any restoration operation. The overall improvement in air quality recently and observations of increased diversity of *Sphagnum* species and other bryophytes since 1983/84 suggests that conditions are now suitable for *Sphagnum* growth **(**Caporn and Emmett, 2009).

Here we report some trials of a newly developed system for restoration of *Sphagnum* to degraded bogs. Novel propagules produced using *in vitro* techniques and encapsulated in a gel (BeadaMoss™) provided the opportunity to 're-seed' large areas economically.

These moss bead propagules have been the subject of extensive and on-going trials at several different locations in the UK. Here we report on some of the field trials, some originally set up in 2009, which have justified much larger scale use of the system.

MATERIALS & METHODS

Previous development work

Propagation of Sphagnum species

In the South Pennines and many other areas where restoration of *Sphagnum* is desirable there is very little material available as a source, either because it has been degraded or is protected. So the challenge of bulking up small quantities of local origin material to sufficient quantity for large scale restoration was faced and different propagation methods were tested.

Conventional propagation proved unsuitable for Sphagna, largely because, if growing conditions were optimised for *Sphagnum*, other species (moss and algae) will invade and out-compete it. Growing under glasshouse conditions allowed rapid growth. Optimum growing conditions and nutrient availability, in a hydroponic system enhanced growth considerably. However, repeated cutting and re-planting to bulk-up very soon ran into serious problems. The nutrient needed to optimise growth led to extensive growth of algae and other mosses.

Isolation of the *Sphagnum* was therefore required and *in vitro* techniques were developed. Methods used for many native bog plant species (by Micropropagation Services) were modified to the specific needs of *Sphagnum*. A successful rapid propagation method, suitable for all species tested (currently 10) was developed and large quantities can be routinely produced. Methods to 'toughen' beads to make them more tolerant of tough *in vivo* conditions were also developed and applied.

Distribution of Sphagnum onto the bog

Sphagnum is very difficult to handle and distribute, because when removed from the growing medium surface it acts like a wet blanket and is difficult to separate individual plantlets. A method has been developed to encapsulate *Sphagnum* plantlets, a few millimetres in size (termed 'BeadaMoss™') allowing easy separation and planting onto the bog surface. The beads produced by this system have enabled handling with air-seeding machines and distribution from a helicopter (Fig. 1), thus making large scale planting viable and achievable. They can equally be handled and planted by ground based machines on suitable surfaces, such as cut-over peat bog surface.

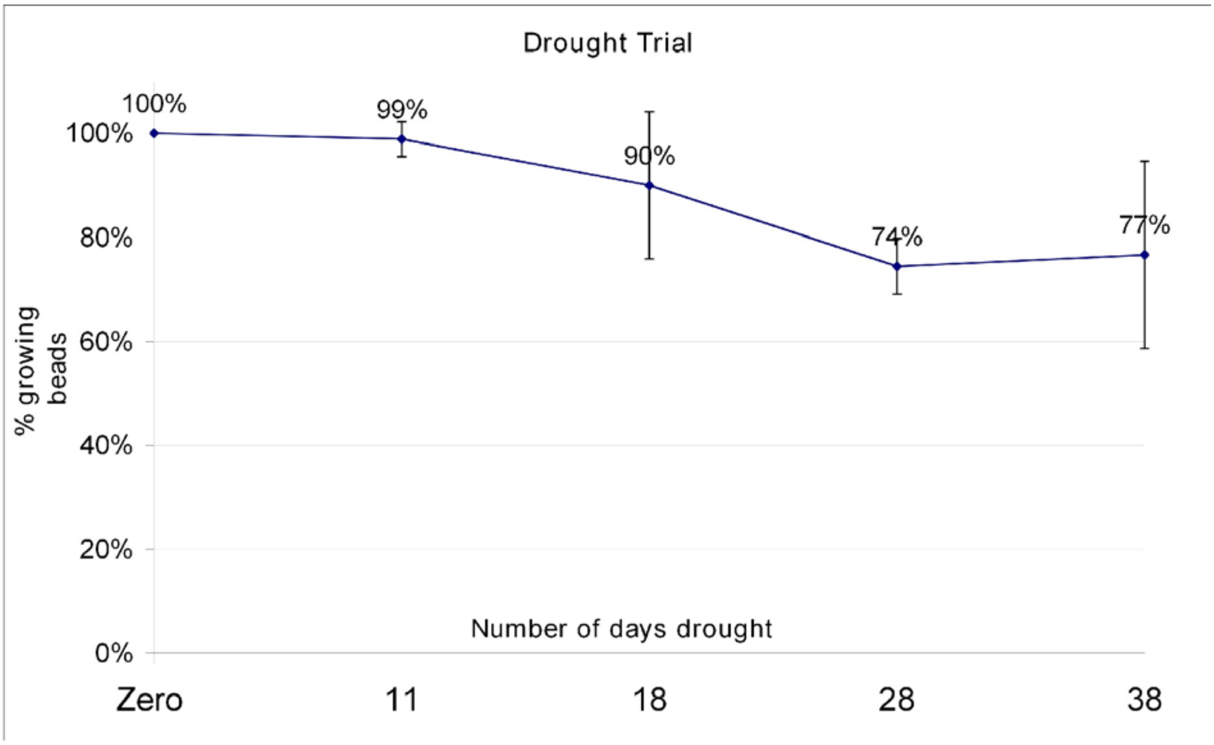

Fig. 1 Helicopter mounted seeder applying BeadaMoss™

Testing growth' in vivo'

Sphagnum plantlets in beads (BeadaMoss™) produced recognisable *Sphagnum* growth within 2-3 weeks of being placed onto commercial peat in a glasshouse at ~20 ^{o}C. Within 8-10 weeks these had grown to approx 1 cm in diameter.

Sphagnum beads were tested for their ability to grow if buried in substrate and were found to be able to grow to the surface within 8-10 weeks even if buried to 30mm. On the surface 100% of beads grow, 75% if buried 10mm, 25% if buried 20mm and 10% if buried 30mm.

Cold tolerance was also tested: at temperatures down to 0 ^{o}C there was no deterioration in growth rate or survival, at -5 ^{o}C after 10 weeks growing, 70% of beads grew, but growth was delayed by 2-3weeks compared to controls.

Drought trials:

Beads were planted onto commercial peat and grown in a glasshouse for 20 weeks at ~ 20 ^{o}C. Water was applied after a period of drought for 0,11,18,28 & 38 days. Results (Fig. 2) show no significant decrease in viability up to 18 days, with a slight reduction at 28 & 38 days. It is clear from this that periods of drought after planting beads should have little effect on the eventual establishment, provided there is sufficient moisture available after the drought for growth of *Sphagnum*. Such drought periods should be avoided if possible because there was a noticeable delay in growth once water was applied.

Field trials: Trials on degraded bog

A series of permanent 0.5 x 0.5 m quadrats planted with *Sphagnum* propagules were set up on two sites in the South Pennines (Black Hill & Holme Moss Mast) March and May 2009 (reported here). Each plot had 90 propagules placed on it, equal to 400 per m^2. Three replicate quadrats were established on each visit and an additional three replicate quadrats per site were placed with chopped heather brash scattered on top of the *Sphagnum*. Quadrats were placed at random in three blocks within the Mast (bare) and Black Hill (restored) sites.

RESULTS

Plots were examined in detail in autumn 2011. All growing pieces were marked with thin canes for future monitoring and counted.

Black Hill (restored) site:

There was considerable variation in the number of pieces growing and this was most dependant on the topography on a very localised basis. The driest sites had the lowest numbers, in some cases none visible (3 of 12 plots). The wettest sites had the highest counts. One site had 62 pieces growing, which is 69% of those planted (Fig. 3).

Fig. 2: Percentage beads surviving at 20 weeks after planting with periods of drought: 0,11,18,28 & 38 days.

In Table 1 it can be seen that on average, ‘dry’ sites had only 1% survival, but ‘wet’ sites had 39%, an average overall of 20%.
There was no significant difference in brash versus non-brash: 20% versus 21%
March plots were slightly better 26% on average than the May 15% planting.

Fig. 3: A forest of canes marking 62 visible *Sphagnum* plants of the original 90 propagules planted.

Table 1. Count of visible *Sphagnum* plants at October 2011 from planting March & May 2009

Survival beads	Black Hill restored	Mast site bare
'Dry' sites	1% + - 0.4	1% + - 0.2
'Wet' sites	39% + - 3.0	12% + - 1.4
Mar planting	26% + - 4.5	3% + - 0.4
May planting	15% + - 3.3	4% + - 1.5
Brash	21% + - 4.7	7% + - 1.2
Non-brash	20% + - 3.3	5% + - 0.9

Mast (bare) site:

One or two pieces were found slightly downhill of the marked plots, so some ‘wash-off’ seems likely, unfortunately once outside the plot area the lack of brash and presence of a small gulley means they could have washed a considerable distance.
It can bee seen from Table 1 that all figures for the Mast (bare) site are lower than for Black Hill (restored site). On the more favourable (‘wet’) sites an average of 12 % was seen, with a maximum of 17%.

CONCLUSIONS/DISCUSSION

Previous monitoring has shown that S*phagnum* beads can establish and grow into significant robust pieces (Fig. 4) that can survive harsh winters and even the moderately severe drought in spring 2010. The results presented here shows that given sufficient time a very large percentage of beads (BeadaMoss™) can become apparent over 2 years after planting.

Fig. 4: Established sphagnum from bead approx 2 years.

The Mast site plots had on previous visits to the site yielded very few visible growing beads, so *Sphagnum* is still continuing to appear (grow to be visible) year on year. It had been assumed that all *Sphagnum* had been either, blown away, washed away or simply dried and died. It is presumed now, that they have grown but had been buried or covered with wind blown black peat and obscured from view. *Sphagnum* establishment from beads on vegetation stabilized surfaces, like Black Hill, was evident more quickly than on the bare peat

(Mast site). However, even on bare peat in areas/ground conditions previously thought too severe, *Sphagnum* beads can colonise with a good degree of success, given time.

Further field trials and application to intact vegetation

In early trials, BeadaMoss™ *Sphagnum* successfully established in the moorland environment, and recent, more extensive trials to examine topographic, hydrological and microclimate effect have been set up in blanket bog (bare peat, restored and intact vegetation) and lowland raised bog situations. Many of these trials are on-going but early results show their ability to survive and grow, in competition with dense cotton grass (*Eriophorum* spp.) dominated vegetation, allowing the possible introduction of *Sphagnum* into intact vegetation to re-establish the bio-diversity (Fig. 5). This also confirms that the main reason S*phagnum* is not already growing in abundance is that there is a deficiency of natural propagules.

In Table 2 we list the trials set up over the past 3-4 years in a wide range of locations and differing ground conditions. Many of these will be monitored and reported in the future.

Table 2. Field trials of BeadaMoss™ set up in last 3-4 years

Field Trials Sphagnum BeadaMoss™			
Trial	Date set up	Location	Details
First 0.5 x 0.5 quadrat trials	June'08-May'09	Black Hill & Holme Moss	S. fallax 2 substrate+/-brash
Larger scale plots	Nov'08-May'09	Black Hill	S. fallax & S. palustre
Species trials bare/treated	Nov'09-May'11	Black Hill & Holme Moss	S. fallax, palustre, cuspidatum, fimbriatum, papillosum
Toughened beads	Nov'09-May'11	Black Hill	4 species
Intact Cotton Grass plots	Nov'09-May'11	Holme Moss	S. fallax & palustre intact veg.
Topography trial	Nov'09-May'11	Black Hill	5 species undulating terrain
Beads & Mulch	May 2010.	Holme Moss	mulch
Helicopter trial	June 2010.	Holme Moss	1 Ha trial of planting method
Intact Molinia	Oct 2010.	Butterly Moor	Mown Molinia beads applied
Raised bog - ex-forestry	Nov 2010.	Fenns & Whixall	bog
Cut-over bog - old	May 2011-	Wedholme Flow	grass
Cut-over bog - fresh	May 2011-	Bolton Fell	grass
Dovestones species intact veg/	June 2011.	Dovestones	6 species intact vs restored
Kinder species cotton grass	Aug 2011.	Kinder Scout	Planted cotton grass

The survival rate of BeadaMoss™ even in fairly severe conditions means that a good *Sphagnum* cover can be achieved over large areas, by seeding with beads at a relatively low application rate. The real possibility of restoring a fully functioning *Sphagnum* bog back to the Peak District and other degraded areas is therefore becoming a reality.

Fig. 5: BeadaMoss™ planted in Nov 2010 are beginning to establish in the ‘depths’ of the cotton grass on intact vegetation site (Photo Oct 2011).

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