# Kinder Scout *Sphagnum* Trials: 2018 Update Report

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# 1. Summary


In 2015, two trials were set up: the *Sphagnum* propagule trial and the dense plug plant trial. The aim of the *Sphagnum* propagule trial was to compare the establishment, survival and growth of different *Sphagnum* propagule types on revegetated bare peat. The aim of the dense plug plant trial was to evidence how quickly comprehensive *Sphagnum* cover can be achieved.

In the *Sphagnum* propagule trial, four headwater micro-catchments were treated with one of four different *Sphagnum* propagule types; beads, gel, clumps and plugs. A fifth micro-catchment received no treatment and provides a control. In the dense plug plant trial, 36,550 *Sphagnum* plugs were planted to deliver comprehensive *Sphagnum* cover within 3 years.

In the *Sphagnum* propagule trial, changes in the percentage cover of *Sphagnum* within quadrats has been observed for all propagule types.

In the *Sphagnum* dense plug plant trial changes in the percentage cover of *Sphagnum* within quadrats has been observed on both hag tops and undulating ground.

The cover of individual *Sphagnum* species was also assessed. Eleven species of *Sphagnum* were identified.

Key findings from these trials include:

- Based on *Sphagnum* coverage, the most successful propagule type is plugs, followed closely by clumps, then gel, and lastly beads, which showed limited success.
- Based on *Sphagnum* coverage and cost, the most successful propagule type is clumps, followed by gel, plugs and beads.
- Topography has a dramatic effect on the growth of *Sphagnum* plugs.
- Topography also affects the *Sphagnum* species present.

## 2. Introduction

In 2015, as part of the Peatland Restoration project (Crouch et al 2015), an opportunity arose to trial a number of different *Sphagnum* propagule types, including BeadaGel™ (*Sphagnum* gel), BeadaHumok™ (*Sphagnum* plugs), BeadaMoss™ (*Sphagnum* beads) and translocated *Sphagnum* clumps, on the north Edge of Kinder Scout, Peak District. Two trials were set up: the *Sphagnum* propagule trial and the dense plug plant trial. The rationale for monitoring these different *Sphagnum* propagule types is that no definitive 'optimal' solution has been proven, nor have the relative 'success' of the different *Sphagnum* propagules been robustly tested in a 'real-life' scenario. To date only lab trials, small scale field trials or less robust 'opportunistic' monitoring of landscape scale delivery have been carried out. Table 2-1 lists the species mix for the *Sphagnum* gel, plugs and beads.

**Table 2-1: Species mix for *Sphagnum* beads, slime and plugs**

| Species of *Sphagnum* | % of total mix |
|---|---|
| *fallax* | 30-50% |
| *palustre* | 20-40% |
| *papillosum* | 20-40% |
| *capillifolium* | 10% |
| *cuspidatum* | 10% |
| *fimbriatum* | 5-10% |
| *subnitens* | 5-10% |
| *denticulatum* | ~1% |
| *squarrosum* | ~1% |
| *russowii* | ~1% |
| *tenellum* | ~1% |
| *magellanicum* | ~1% |

## 3. Aims and Objectives

The aim of the *Sphagnum* propagule trial was to compare the establishment, survival and growth of different *Sphagnum* propagule types on revegetated bare peat. The aim of the dense plug plant trial was to evidence how quickly comprehensive *Sphagnum* (i.e. 100%) cover can be achieved.

## 4. Study sites

Both trials are located on the north Edge of Kinder Scout, within the Ashop River catchment, in the Upper Derwent Valley, Derbyshire (Figure 4-1). The Ashop catchment is 2,705 ha in size, of which 2,406 ha (89%) is classified as moorland. Moorland is defined as land located within the Rural Payments Agency (RPA) Moorland Line (England) dataset which is available to download from the MAGIC website. https://magic.defra.gov.uk/Dataset_Download_Summary.htm

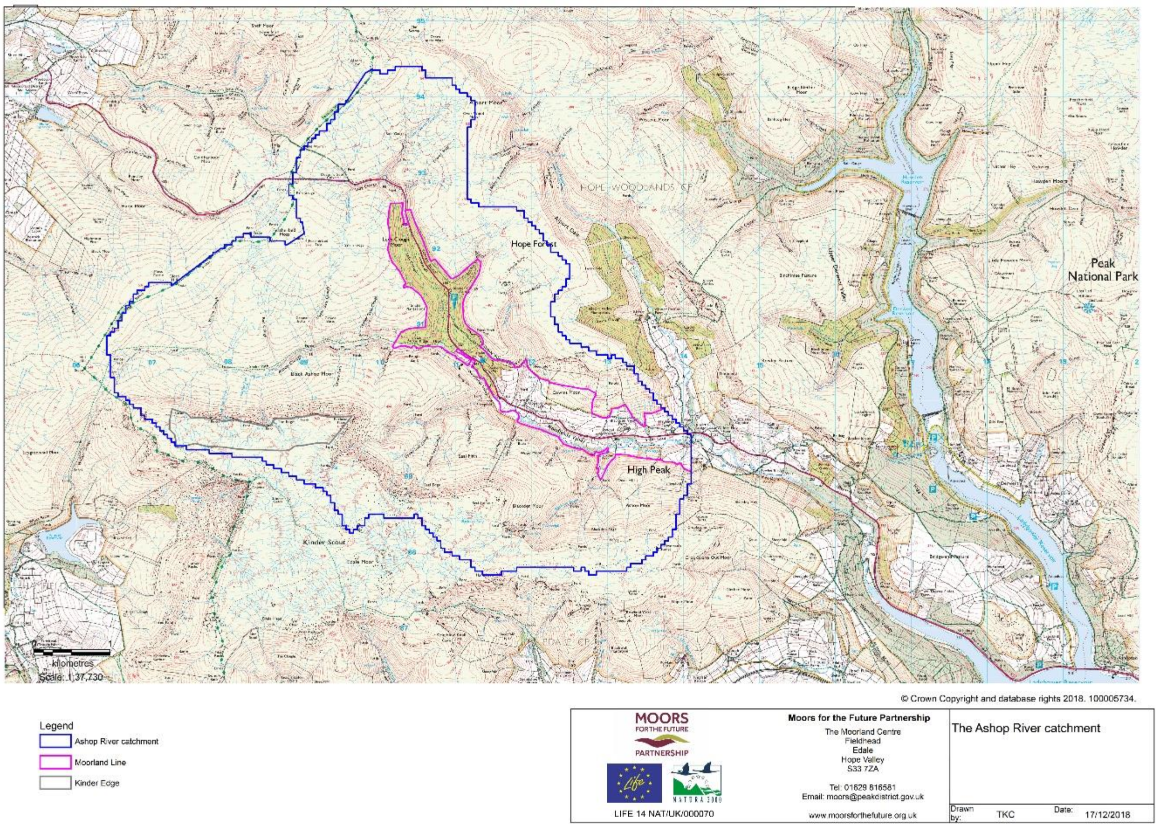


**Figure 4-1: The River Ashop catchment**

Initial bare peat revegetation was completed on the Edge under an Environmentally Sensitive Areas (ESA) Scheme and the Making Space for Water project (Pilkington et al 2015). The Peatland Restoration project continued bare peat revegetation through the application of heather brash, lime and fertiliser; installed additional timber and stone dams in gully systems; and applied *Sphagnum* propagules into the developing sward.

Heather brash is used to halt the erosion of the bare peat in the short term. To ensure that this continues, vegetation must be re-established. This is achieved through the application of lime, seed and fertiliser. Gully blocking reduces the flow of peat sediment along erosion channels, reducing the loss of peat downstream and aiding the recovery of a characteristically high water table, helping to re-wet degraded areas (Buckler et al 2013). This work was completed between February 2011 and July 2013.

## 5. Methodology

*Sphagnum* propagules were applied to the Edge between 6th and 20th March 2015. The two trials were set up, and baseline data recorded between 12th March and 7th April 2015.

## 5.1. Application one – *Sphagnum* propagule trial

Four headwater micro-catchments (1 ha) were treated with one of four different *Sphagnum* propagule types; beads, gel, clumps and plugs. A fifth micro-catchment received no treatment and provides a control. These applications were replicated three times (area 1, area 2 and area 3). Ten quadrats were located within each of the micro-catchments (Figure 5-1). Quadrats were located on flat ground to reduce the likelihood of *Sphagnum* propagules washing down the catchment during heavy rain events. *Sphagnum* propagules were applied to quadrats by the surveyors, not by the contractors. This ensured that each quadrat received a standard amount of propagules. This application took place between 6th and 20th March 2015.

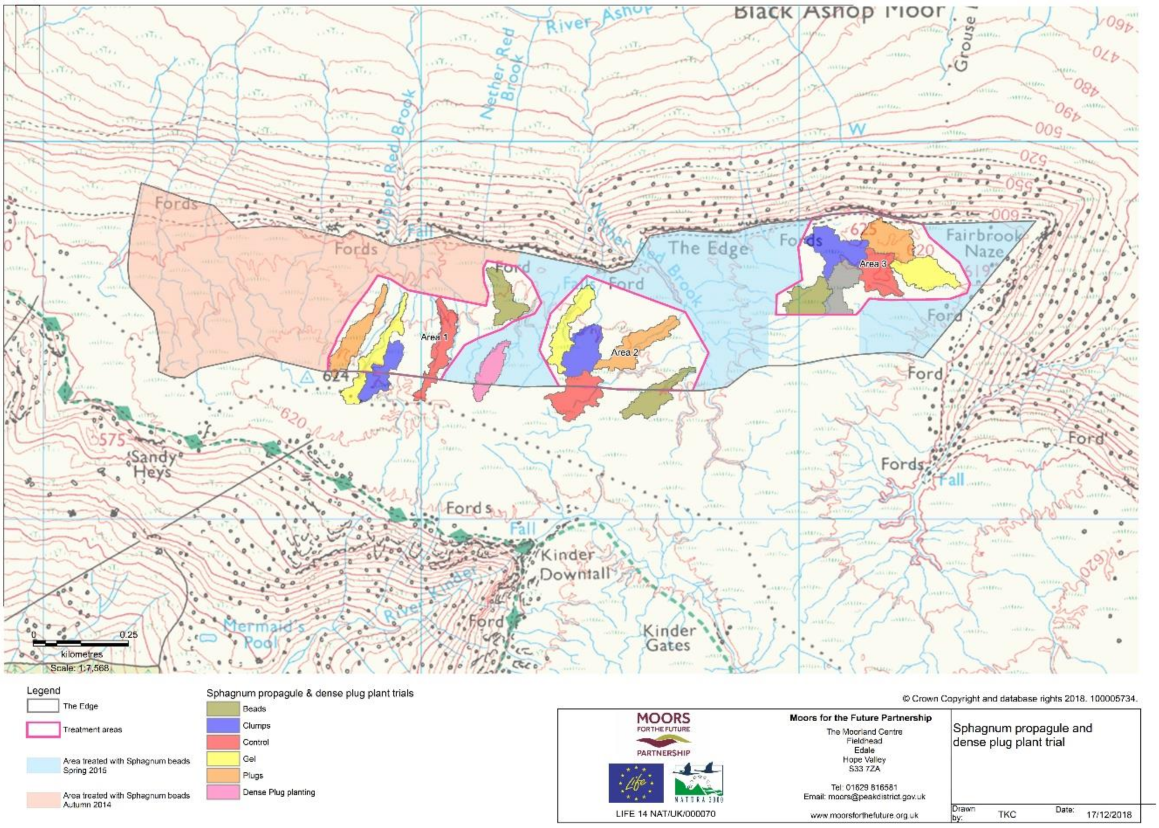


**Figure 5-1: *Sphagnum* propagule and dense plug plant trials**

The quantities of propagules that were applied to each quadrat are presented in Table 5-1. It is worth noting that this is a higher application rate than would be used in restoration; standard application rates are: 35 L beads per ha (0.0035 L per $m^2$); 20 L gel per ha (0.0020 L per $m^2$); 1250 plugs per ha (1 plug per 8$m^2$); and 625 clumps per ha (1 clump per 16 $m^2$). The costs per $m^2$, presented in Table 5-1, are based on the production and application costs presented in

Table 5-2; these costs are applicable to *Sphagnum* production and application for the Peatland Restoration project trials in 2015. Table 5-3 shows the quantities of propagules required for application in quadrats.

**Table 5-1: Quantity of propagules applied to quadrats and cost**

| Propagule type | No. of propagules per quadrat | Vol. of propagules per quadrat | Cost of production (£ / m²) | Cost of spreading (£ / m²) | Total cost (£ / m²) |
|---|---|---|---|---|---|
| BeadaMoss™ | 420 | 0.07 (L) | £1.03 | £0.01 | £1.04 |
| BeadaGel™ | 18 * | 0.072 (L) | £1.03 | £0.01 | £1.04 |
| BeadaHumok™ | 9 | | £6.30 | £4.14 | £10.44 |
| Clumps | 4 | | £1.25 | £1.90 | £3.15 |

* 72ml of BeadaGel™ was applied to each quadrat in 18 x 4ml measures

**Table 5-2: *Sphagnum* production and application costs**

| Propagule type | Production cost | Application cost |
|---|---|---|
| BeadaMoss™ | £14.75 per litre | £60.00 per hectare |
| BeadaGel™ | £12.50 per litre | £60.00 per hectare |
| BeadaHumok™ | £0.70 per plug | £0.46 per plug |
| Clumps | £0.25 per hummock | £0.38 per hummock |

**Table 5-3: Number / volume of propagules applied to quadrats**

| Propagule type | No. / vol. of propagules per m² | No. of quadrats | Total no. / vol. propagules |
|---|---|---|---|
| BeadaMoss™ | 0.07 (L) | 30 | 2.1 (L) |
| BeadaGel™ | 0.072 (L) | 30 | 2.2 (L) |
| BeadaHumok™ | 9 | 30 | 270 |
| Clumps | 4 | 30 | 120 |
| Control | N/A | 30 | N/A |
| Plug plant trial | N/A | 20 | N/A |

## 5.2. Application two – dense plug plant trial

Application two investigated a concentrated application of *Sphagnum* propagules on one of the MS4W micro-catchments. This site (Nogson) has been revegetated, using heather brash, and lime, seed and fertiliser, and gully blocked. Within this catchment 36,550 *Sphagnum* plugs (~5 per m²) were planted to deliver comprehensive *Sphagnum* cover within 3 years. A revegetated and a non-revegetated micro-catchment are available for comparison. This application took place between 6th and 20th March 2015.

Two types of plugs were used; individual *Sphagnum* plugs with peat bases, referred to as 'plugs' (31,750), and plug carpets split into individual 'micro-plugs' without peat bases (4,800). Twenty quadrats were located according to two main criteria: (a) on flat ground to reduce the likelihood of *Sphagnum* propagules washing down the catchment during heavy rain events, and (b) within two categories of topography, such that ten quadrats are located on each of the following (i) undulating ground and (ii) depressions / hollows on hag tops.

The design associated with application one and two is based on 1 ha micro-catchments. Fixed quadrats were set-up within each of the 1 ha micro-catchments to monitor the success of *Sphagnum* propagule development. The quadrats were marked with two wooden stakes located in the south-west and north-east corners. When locating quadrats, areas of existing *Sphagnum* were avoided; this was to ensure that *Sphagnum* within quadrats from applied propagules was not confused with existing *Sphagnum*. Photographs were taken both for monitoring purposes (to illustrate change over time) and to help in locating quadrats should the stakes be lost.

A standard amount of *Sphagnum* propagules were applied to each quadrat; however, hummocks were not identical in size, therefore, the length, width, depth and circumference of each hummock were also recorded. Each plug / hummock within a quadrat was numbered and its position within the quadrat recorded in a sketch. Plugs and hummocks were identified to species where possible. A visual estimate of percentage cover was made for all *Sphagnum* propagule types. In addition, the percentage cover of dwarf shrub, cotton grass, other grasses, mosses (including any existing *Sphagnum*), bare peat and standing water, as well as the proximity to nearest standing water / pool outside of the quadrat was recorded. As stated above, existing *Sphagnum* was avoided when placing quadrats.

# 6. Statistical analyses

All statistical tests were carried out in SPSS. A paired t-test was used to investigate differences in the percentage cover of *Sphagnum* between 2015 and 2018. This method assumes that data are normally distributed. In cases where the data was not normally distributed the non-parametric Wilcoxon signed-rank test was used.

# 7. Results

## 7.1. Application one - *Sphagnum* propagule trial

Since the application of *Sphagnum* propagules in 2015, three repeat surveys have been carried out. Changes in the percentage cover of *Sphagnum* within quadrats has been observed for all propagule types (Table 7-1).

**Table 7-1: *Sphagnum* growth from beads, gel, plugs and clumps**

| Survey | No. of quadrats | Mean percentage cover of *Sphagnum* | | | | |
|---|---|---|---|---|---|---|
| | | Control | Beads | Gel | Plugs | Clumps |
| Spring 2015 | 30 | 0.0 | 0.0 | 0.0 | 2.0 | 7.9 |
| Summer 2015 | 30 | | | | 2.6 | 5.7 |
| Spring 2016 | 30 | 0.0 | 0.0 | 0.2 | 5.3 | 12.6 |
| Summer 2018 | 30 | 0.2 | 0.8 | 10.4 | 40.4 | 36.3 |

In 2015, the mean percentage cover of *Sphagnum* in quadrats treated with beads and gel was 0%. By 2018, this had increased to 0.8% for beads and 10.4% for gel (
Figure 7-1). A Wilcoxon signed-rank test showed that this increase was significant for beads (Z = -2.060, p = 0.039) and gel (Z = -4.112, p = 0.000).

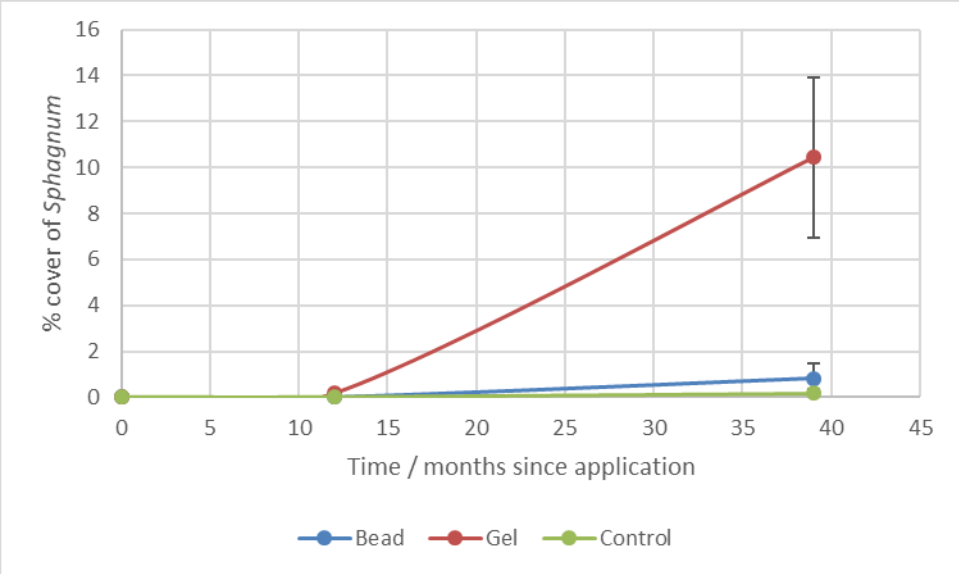


**Figure 7-1: *Sphagnum* growth from beads and gel**

Plugs and clumps, which had a higher initial cover of 2% and 7.9% respectively, also increased by 2018 to 40.4% for plugs and 36.3% for clumps (Figure 7-2). A Wilcoxon signed-rank test showed that this increase was significant for plugs (Z = -4.788, p = 0.000). A paired t-test showed that this increase was significant for clumps (t (29) = -6.436, p = 0.000).

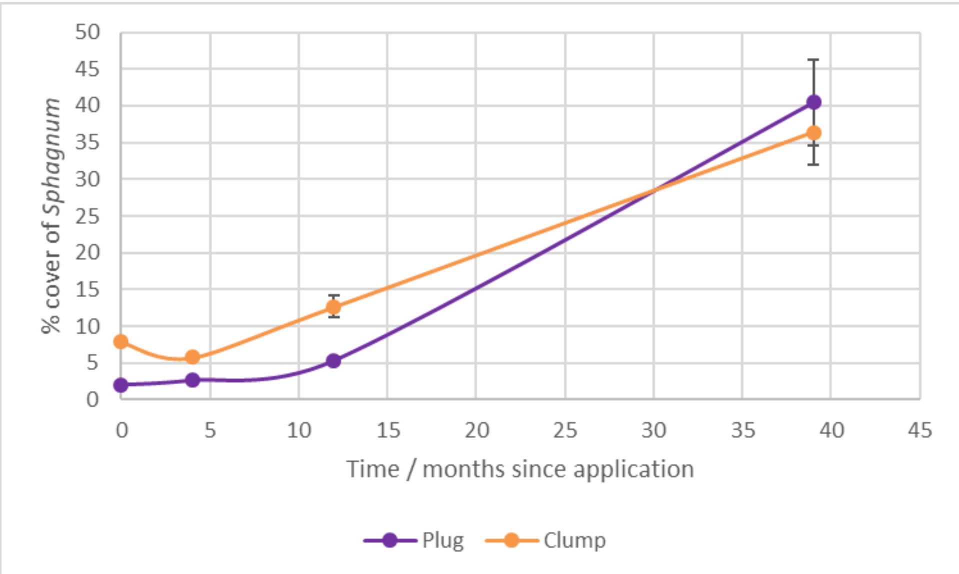


**Figure 7-2: *Sphagnum* growth from plugs and clumps**

The mean percentage cover of *Sphagnum* in untreated control quadrats also increased from 0% in 2015 to 0.2% in 2018 (

Figure 7-1). However, a Wilcoxon signed-rank test showed that this increase was not significant ($Z = -1.000$, $p = 0.317$).

### 7.1.1. Cost benefit comparison

Of the four forms of *Sphagnum*, clumps and plugs were the most successful, in terms of mean percentage cover. In terms of cost (production and application) per quadrat, plugs were the most expensive (£10.44 / m²), followed by clumps (£3.15 / m²) and then beads and gel (£1.04 / m²) (Figure 7-3).

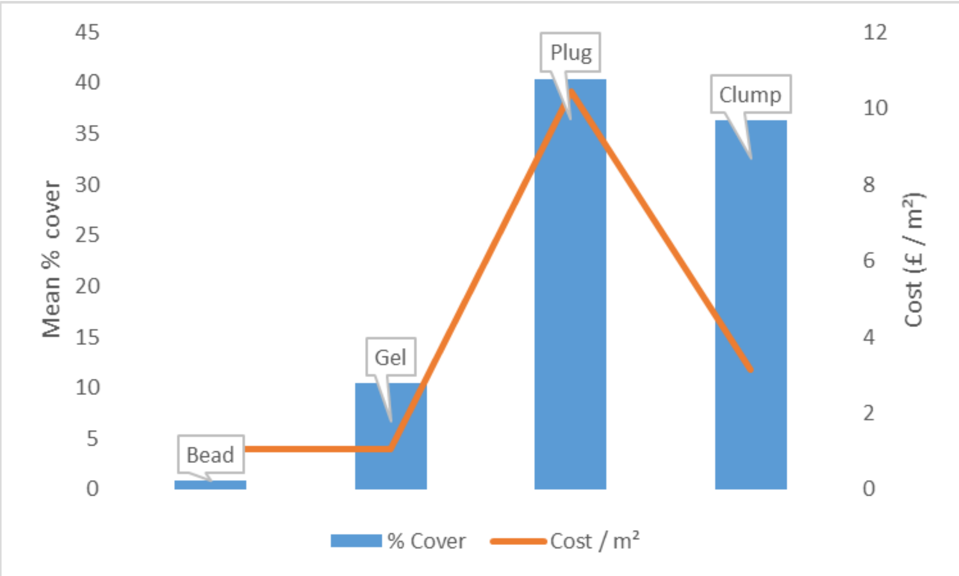


**Figure 7-3: A graph to show mean percentage cover of each propagule type versus cost**

In order to take both measures of success (i.e. *Sphagnum* cover and cost) into account, the cost per 1% (1 cm²) cover of established *Sphagnum* has been calculated, providing a cost-benefit comparison across all propagule types. When both *Sphagnum* coverage and cost is taken into account, the most successful propagule type is clumps (£0.09 per 1 cm² of established *Sphagnum*), followed by gel (£0.10 per 1 cm² of established *Sphagnum*), plugs (£0.26 per 1 cm² of established *Sphagnum*) and beads (£1.30 per 1 cm² of established *Sphagnum*) (Table 7-2).

**Table 7-2: Cost-benefit comparison across all propagule types**

| Propagule | Mean % cover after 3 years | Cost (£ / m²) to treat quadrat | Cost (£) per 1% cover of *Sphagnum* |
|---|---|---|---|
| Beads | 0.8 | 1.04 | 1.30 |
| Gel | 10.4 | 1.04 | 0.10 |
| Plugs | 40.4 | 10.44 | 0.26 |
| Clumps | 36.3 | 3.15 | 0.09 |

## 7.2. Application two - dense plug plant trial

Since the application of *Sphagnum* propagules (plugs) in 2015, four repeat surveys have been carried out (Table 7-3: ***Sphagnum* growth from plugs** and Figure 7-4). In 2015, the mean percentage cover of *Sphagnum* in quadrats located on hag tops was 1.6% and on undulating ground was 1.9%. By summer 2018, this had increased to 11.3% on hag tops and 51.3% on undulating ground. A Wilcoxon signed-rank test showed that this increase was significant for hag tops (Z = -2.668, p = 0.008) and undulating ground (Z= -2.803, p = 0.005).

However, between summer and autumn 2018, a decrease in the cover of *Sphagnum* on hag tops was observed, but not found to be significant (Wilcoxon signed-rank test, Z = -0.460, p = 0.646).

**Table 7-3: *Sphagnum* growth from plugs**

| Survey | No. of quadrats | Mean percentage cover of *Sphagnum* | | |
|---|---|---|---|---|
| | | Hag top | Undulating ground | Total |
| Spring 2015 | 20 | 1.6 | 1.9 | 1.8 |
| Summer 2015 | 20 | 1.7 | 2.8 | 2.2 |
| Spring 2016 | 20 | 2.0 | 4.5 | 3.3 |
| Spring 2017 | 20 | 5.6 | 14.0 | 9.8 |
| Summer 2018 | 20 | 11.3 | 51.3 | 31.3 |
| Autumn 2018 | 20 | 6.0 | 52.8 | 29.4 |

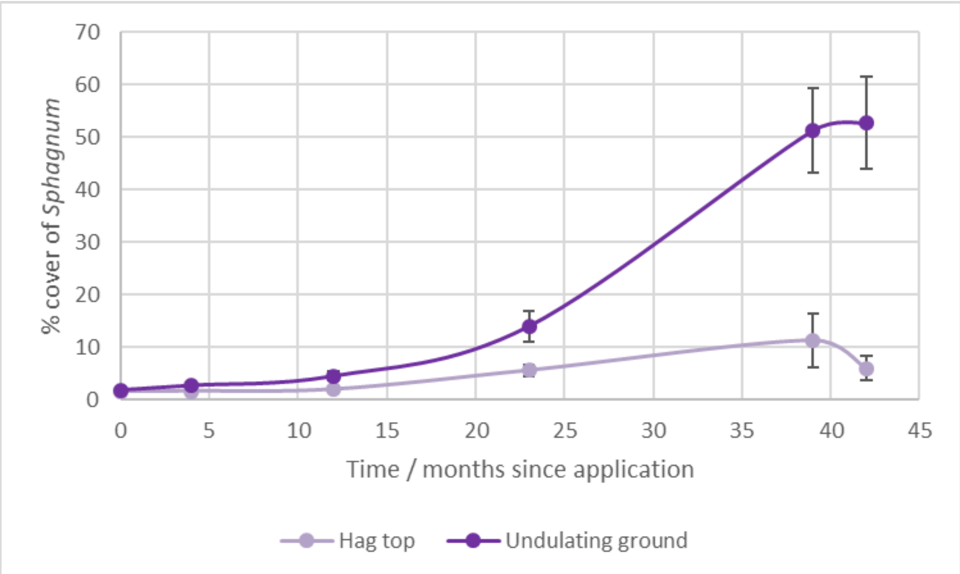


**Figure 7-4: *Sphagnum* growth from plugs located on hag tops and undulating ground**

During the autumn 2018 survey, the cover of individual *Sphagnum* species was also assessed. Eleven species of *Sphagnum* were identified (Figure 7-5). On hag tops, the most dominant species included, *S. palustre* (47.8%), *S. fallax* (28.5%), *S. capillifolium* (14.7%) and *S. papillosum* (8.4%). On undulating ground, the most dominant species included *S. fallax* (49.5%) and *S. palustre* (43.7%).

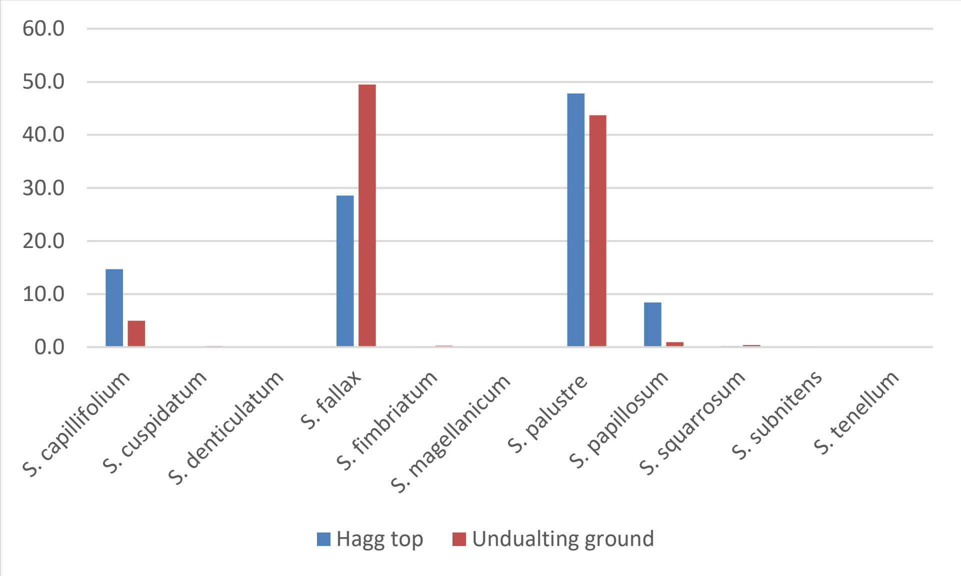

**Figure 7-5: *Sphagnum* species present in 2018**

## 8. Discussion

The *Sphagnum* propagule trial was used to investigate the growth of *Sphagnum* from propagules in four forms; beads, gel, plugs and translocated *Sphagnum* clumps, over a period of three years and three months. Plugs were the most successful propagule type in terms of percentage cover, with *Sphagnum* achieving a mean percentage cover of 40.4%. This was closely followed by clumps, with *Sphagnum* achieving a mean percentage cover of 36.3%. The establishment of *Sphagnum* from beads and gel was much lower, with *Sphagnum* achieving a mean percentage cover of 0.8% and 10.4% respectively.

The success of *Sphagnum* plugs and clumps may be due to the larger plant mass being better able to withstand extreme fluctuations in environmental conditions, e.g. desiccation and waterlogging, and crowding by other vegetation (Caporn et al 2018). The size of *Sphagnum* plants in micro propagated material varies widely, from 1-5 mm moss fragments within beads to the fully developed (20-40 mm) plants in the gel and plugs. The larger and faster growing *Sphagnum* plugs can establish more quickly and cover ground sooner than the juvenile plants within beads and gel (Caporn et al 2018).

When the *Sphagnum* propagule trial was set up an attempt was made to apply an equal amount of clumps and plugs to quadrats. Despite this, the initial mean percentage cover of clumps (7.9%) was higher than that for plugs (2%). Clump and plug quadrats were re-surveyed four months after planting, and while the percentage cover of plugs had increased (2.6%), clumps had decreased (5.7%). This may suggest that more stress is caused to *Sphagnum* propagules that are harvested and transplanted than to *Sphagnum* propagules that are transferred from greenhouse to field sites. Clumps and plugs continue to grow well, with plugs achieving a slightly higher percentage cover than clumps. This may be due to the planting design; as plugs were smaller, nine plugs were planted per quadrat, compared to four clumps per quadrat. This means that if one plug is lost from a quadrat it would only reduce the amount of *Sphagnum* remaining by ~11%, compared to 25% for clumps. Furthermore, nine plugs provide more sources for *Sphagnum* to spread out from (lateral growth) than four clumps.

The dense plug plant trial has also investigated the growth of *Sphagnum* from propagules in the form of plugs. In this trial, half of the quadrats were located on undulating ground and half on hag tops. Over the same period (three years and three months), *Sphagnum* within quadrats located on undulating ground achieved a mean percentage cover of 51.3%, compared with 11.3% for *Sphagnum* located within quadrats on hag tops.

In a similar trial (Caporn et al 2018) compared the growth of different forms of *Sphagnum* (beads, gel and plugs) on a low-land cut-over peatland. This trial applied approximately the same density of beads (400 $m^2$) as the current trial, but a higher density of gel (3 L $m^2$) and plugs (30 $m^2$). *Sphagnum* was applied into a low-density sward of naturally regenerating *Eriophorum angustifolium*. *Sphagnum* growth was assessed by recording percentage cover of gel and area cover of plugs. *Sphagnum* cover from gel reached 56% just 16 weeks after application, increasing to 95% cover after 2 years. *Sphagnum* plugs increased from 10.2 $cm^2$ to 76.5 $cm^2$ after 2 years. This 650% increase is consistent with results from the dense plug plant trial in which percentage cover of plugs located on undulating ground increased by 637% after 2 years. Caporn et al (2018) did not present the results for beads but states that the increase in cover for beads was slower than for gel or plugs.

Research on *Sphagnum* restoration of lowland raised bogs suggests that a high water table and some form of protection against desiccation (e.g. straw mulch or nurse crop) is required for successful *Sphagnum* establishment (Quinty & Rochefort 2003, Groeneveld et al. 2007 cited in Caporn et al. 2018). According to Caporn (2018), it is less certain whether a high water table is essential on blanket bog. This is because blanket bog occurs in areas of high precipitation and cloud cover (Rydin & Jeglum 2013, cited in Caporn et al. 2018); therefore, moisture arriving from above may compensate for a poor supply of water from below (Caporn et al. 2018).

In the dense plug plant trial, *Sphagnum* has survived on hag tops but the growth has been much slower than on undulating ground. Hag tops are likely to have a lower water table than the surrounding undulating ground and also offer less protection from desiccation. This suggests that moisture from precipitation and cloud cover is sufficient for *Sphagnum* to survive and grow slowly but much faster growth is observed when *Sphagnum* is located in areas likely to have a higher water table. Furthermore, an additional survey, carried out during September 2018, showed a decrease in the percentage cover of *Sphagnum* on hag tops since the previous survey. This is likely to be a result of the warm, dry and largely sunny summer, which according to the Met Office (2018) was provisionally the equal warmest on record for the UK. *Sphagnum* located on undulating ground did not seem to be affected in the same way.

The dense plug plant trial also investigated the cover of individual *Sphagnum* species. Eleven species of *Sphagnum* were identified. On hag tops, the most dominant species included, *S. palustre*, *S. fallax*, *S. capillifolium* and *S. papillosum*. On undulating ground, the most dominant species included *S. fallax* and *S. palustre*.

In another trial, Rosenburgh (2015, cited in Caporn et al. 2018), investigated the growth of different species of *Sphagnum* beads associated with different peatland substrates and times of year. The *Sphagnum* species used in this trial were *S. capillifolium*, *S. cuspidatum*, *S. fallax*, *S. fimbriatum*, *S. palustre* and *S. papillosum*. In this trial, despite poor establishment of beads overall, *S. fallax* was the most successful species, followed by *S. cuspidatum*, *S. papillosum*, *S. palustre*, *S. fimbriatum*. *S. cappilifolium* failed to grow.

Bogs dominated by *S. fallax* are less favoured in conservation terms in the UK (JNCC 2009, cited in Caporn et al 2018). Within MFFP, there have been some concerns that due to the proportion of *S. fallax* contained within the plug (30-50%), this species would dominate, at the expense of other more favoured species. While *S. fallax* is the dominant species on undulating ground, *S. palustre* is also doing well, and on areas less favourable for *S. fallax* a number of species are establishing. If concerns remain about the dominance of *S. fallax* then it may be possible to reduce the proportion of this species in the mix.

## 8.1. Cost-benefit considerations

Of the four forms of *Sphagnum*, clumps and plugs were the most successful, in terms of mean percentage cover. In terms of cost (production and application) per quadrat, plugs were the most expensive, followed by clumps and then beads and gel.

When both measures of success (i.e. *Sphagnum* cover and cost) are taken into account, the most successful propagule type is clumps, followed by gel, plugs and beads. It should also be noted that as percentage cover of *Sphagnum* continues to increase over time, the cost per 1% cover will decrease. The evidence thus far suggests that this is likely to happen more quickly for clumps and plugs than for beads and gel.

However, there are still a number of important considerations to take into account. The mean percentage cover of *Sphagnum* from beads is the lowest at just 0.8%; however, there is some anecdotal evidence of *Sphagnum* establishment outside of quadrats. While this could be attributed to natural recovery, it may also be possible that, despite locating quadrats on flat ground, beads have washed out of quadrats and down the catchment during heavy rain events. However, this observation is not exclusive to catchments treated with beads. There is one observation of *Sphagnum* growth outside of quadrats in catchments treated with gel and eight observations of *Sphagnum* growth outside of quadrats in catchments treated with plugs. Further research (e.g. into the relationship between stream network and location of *Sphagnum*) could be carried out to investigate whether the *Sphagnum* observed outside of quadrats is likely to have come from within the quadrats or whether it is simply natural recovery.

Gel was much more successful than beads. However, gel was applied using a syringe to ensure that the gel made contact with the peat and did not get caught on the vegetation where it would have been prone to drying out. This application method was very time consuming and is not appropriate for application over a large area. If gel is to be used, careful consideration must being given to the method of application to ensure that it allows the gel to make contact with the peat and is practical over a large area. For example, a prototype planting machine has been produced for applying BeadaGel™. This machine cuts grooves into the surface vegetation to ensure that *Sphagnum* gel makes contact with the peat surface (Caporn et al 2018).

The mean percentage cover of *Sphagnum* from plugs (40.4%) and clumps (36.3%) was similar. However, to achieve this with plugs costs 2.9 times more. Consequently, where there is a source of *Sphagnum* from which to harvest and transplant this option may be preferred. However, despite plugs being more expensive than clumps they do offer a number of benefits, for example, only a small amount of donor *Sphagnum* material is required; a 'clean' *Sphagnum* culture, free of potential disease can be generated; the species composition can be adjusted; and they are potentially available in large quantities. These benefits also apply to other forms of micro propagated *Sphagnum* (i.e. beads and gel).

## 9. Conclusion

In 2015, two trials were set up: the *Sphagnum* propagule trial and the dense plug plant trial. The aim of the *Sphagnum* propagule trial was to compare the establishment, survival and growth of different *Sphagnum* propagule types on revegetated bare peat. The aim of the dense plug plant trial was to evidence how quickly comprehensive *Sphagnum* cover can be achieved. In the *Sphagnum* propagule trial, four headwater micro-catchments were treated with one of four different *Sphagnum* propagule types; beads, gel, clumps and plugs. A fifth micro-catchment received no treatment and provides a control. These applications were replicated three times. In the dense plug plant trial, 36,550 *Sphagnum* plugs were planted to deliver comprehensive *Sphagnum* cover within 3 years.

A number of conclusions can be drawn from these trials.

- Based on *Sphagnum* growth, over a period of three years and three months, the most successful propagule type is plugs, followed closely by clumps, then gel, and lastly beads, which showed limited success.
- When both *Sphagnum* coverage and cost is taken into account, the most successful propagule type is clumps, followed by gel, plugs and beads.
- As the percentage cover of *Sphagnum* continues to increase over time, the cost per 1% cover will decrease. This may justify the higher initial cost for plugs, which appear to result in a greater extent of *Sphagnum* over time.
- If, based on initial cost, gel is to be used, consideration must being given to the method of application to ensure that it allows the gel to make contact with the peat and is practical over a large area.
- Topography (i.e. hag top versus undulating ground) has a dramatic effect on the growth of *Sphagnum* plugs, suggesting that moisture from precipitation and cloud cover is sufficient for *Sphagnum* to survive and grow slowly but much faster growth is observed when *Sphagnum* is located in areas with a higher water table and better protection from desiccation.
- Topography also affects *Sphagnum* species; the most dominant species on hag tops was *S. palustre* and on undulating ground was *S. fallax* and *S. palustre*.

- Further research into the relationship between stream network and location of *Sphagnum* could be carried out to investigate whether the *Sphagnum* observed outside of quadrats is likely to have come from within the quadrats or whether it is simply natural recovery.

# 10. Reference list

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