



## - CHAPTER 3 -

# MATERIALS AND PRACTICAL CONSIDERATIONS

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I hear it said yon land is poor,  
In spite of those rich cowslips there-  
And all the singing larks it shoots  
To heaven from the cowslips' roots.  
But I, with eyes that beauty find,  
And music ever in my mind,  
Feed my thoughts well upon that grass  
Which starves the horse, the ox, and ass.

**Davies W. H.** (1870-1940) From *Cowslips and Larks*.

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### SUMMARY

1. Twenty-five species were used in the primary research scheme. The majority of these species are found in mesotrophic and calcareous grassland communities within five miles of the research location. Most of these plants are also commonly used in grassland creation and restoration schemes. The species were chosen as a representative spectrum of life history/established strategy and scarcity.
2. The author grew all the 9-cm pot transplants, and High Value Horticulture Ltd donated the 2-cm seedling transplants. Unfortunately HVH only had plug material available for 15 of the 25 species used, thus 10 species were only planted as 9-cm pot plants. For the 9-cm transplants, most of the seed was sown in April 1993, although four species were sown later, in July. At the time of planting, the majority of the pot plants were of flowering size at approximately 1 year old. The plug plants at time of collection were two months old, supplied in modular trays, each plug approximately 2-cm in diameter with root volumes of 22-ml.
3. Prior to creating the experimental set-up, the swards of all four plots were mown to approximately 50-mm in height. Within each subplot, 12-m x 25-m central areas were demarcated with 60-cm wooden posts, in order that the parameters of the planting areas could be relocated. Again for ease of relocation, between the 12-m sides of this area, 1-m spacings were denoted with a blue plastic pipe pushed into the ground and then sprayed around using glyphosate herbicide.
4. Pre-treatment prior to transplant inoculation required the creation of competition-free gaps in order to assess the prophylactic efficacy of artificial competition exclusion zones. These *safe-sites* had to be created before the transplants were inserted into the plots. The most efficient way to create competition-free inoculation gaps of specific diameters was through broad-spectrum herbicide. Gaps of 30-cm, 15-cm, and 0-cm (i.e. no gap), were formed using glyphosate herbicide sprayed over plastic stencils with the required diameters. The gap sizes were randomised throughout each subplot.
5. During late March/April 1994, 12 individuals of 25 perennial herbaceous species were planted into the central areas of each subplot, amounting to 300 transplants per subplot spaced at 1-m apart. The scheme per subplot was therefore developed as 12 rows of the 25 species randomly located within each row i.e. one instance of each species per transplant row. The dual-size transplants were randomly allocated across each subplot i.e. for each dual species; six 9-cm transplants and six plug plants were randomly allocated within each subplot.
6. The hay-cutting period was roughly scheduled for mid-end of July for a number of reasons. Hay was traditionally taken at this time; July hay allows some seed-set and dispersal, as well as providing a longer period of development for invertebrates such as butterflies; the hay is still saleable as a conservation forage crop. However, as with all farming systems, the year-by-year 'fine-tuning' is dictated by weather conditions. The specific date for hay cutting is reliant on a period of dry weather of at least 4-5 days in which the hay can be cut, turned (usually twice), baled, picked up, and stacked in a barn. Weather conditions also have implications for annual grazing regimes. For example, due to poaching damage, very wet weather can delay the onset of putting grazing stock out in spring, or reduce the autumn grazing period.
7. Mowing was the most simple management treatment. Subplots were cut to a height of approximately 5-cm, 2-3 times in the autumn, and again 2-3 times in the spring depending on the weather conditions. A 3.5 Hp rotary mower was used with a grass-box to collect the cuttings. The cow grazing followed a typical regional dairy farming regime. Approximately 45 lactating Friesian cows were rotated around the fields, and access to the subplots dictated by sward conditions i.e. height, poaching and fouling levels. Sheep grazing was organised on a 'put-and-take' system whereby animals were moved to 'lay-back land' once the sward had been grazed adequately. Two sheep were placed in each treatment subplot, equivalent to 0.34 Livestock units (LU) for 5 weeks per subplot per annum. All the subplots were fenced with Flexinet and single strand electric fencing to allow simultaneous treatment.

**Keywords:** mesotrophic grassland; established strategy; restoration; 9-cm transplant; plug transplant; subplot; relocation; competition-free gap; glyphosate; inoculation; hay cut; mowing; cow grazing; sheep grazing.

## INTRODUCTION

Within each of the following chapters, methodological accounts are given for each specific experiment. However, in order to minimise a certain degree of repetition, and to provide more details concerning the structural designs of the central experimental treatments – particularly concerning materials, transplant inoculation and sward management regimes - this Chapter describes general aspects of the methodology. Firstly, ecological profiles are given for the species used in the artificial enrichment experiments in order to discuss the primary rationales behind plant species selection (Grime 1979; Grime *et al* 1988). Secondly, the horticultural aspects of experimental stock provision are described, both in the context of propagation by the author and supply by external sources. Thirdly, the primary inoculation methodologies are described with reference to restoration practicalities and associated problems. Fourthly, methodological aspects are discussed in relation to sward management, particularly with regard to mowing versus grazing regimes.

## THE EXPERIMENTAL SPECIES

### Ecological synopses

Twenty-five species were used in the primary research scheme. The majority of these species are found in mesotrophic and calcareous grassland communities within five miles of the research location (Green *et al* 1997). Most of these plants are also commonly used in grassland creation and restoration schemes (Wells *et al* 1989; NPK Landlife 1994; Luscombe & Scott 1994; Dixie & Bisgrove 1996; Hopkins *et al* 1999). The species were chosen as a representative spectrum of life histories/established strategies (Grime 1979; Stace 1991). *A priori* assessment of the ecology of each species (Grime *et al* 1988) suggested that they could be used as indicators (phytometers *sensu lato* Cavers & Harper 1967) of the resistance of grasslands with different agricultural improvement levels to invasion and colonisation, and therefore restoration potential. Thus, at one end of the scale, *Primula veris*, *Malva moschata* and *Geranium pratense* were chosen for their apparent robustness in competitive swards (Bisgrove & Dixie 1994; Hopkins *et al* 1997), and *Scabiosa columbaria* and the two *Campanula* species for their relatively high sensitivity to, and intolerance of, fertile grassland situations (Verkaar *et al* 1983; Grime *et al* 1988; Mitchley 1988; Hopkins *et al* 1997). The main ecological characteristics of each of the 25 species used are summarised in **Table 3.1**.

Most of this data is extracted from Hodgson *et al* (1995), though six of these species do not have ecological accounts in Grime *et al* (1988), and were constructed from other sources, notably Clapham *et al* (1987), Stace (1991) and NPK Landlife (1994). Evidence of relative species abundance throughout the County of Somerset was calculated from Green *et al* (1997). Some of the most significant features of the data presented in **Table 3.1** are summarised below:

- The most common terminal habitats for the species list are pasture (52%), wasteland (12%), meadow (8%) and road verge (8%).
- The majority of the species are found on calcareous to neutral soils, centred on the modal class of pH 7 (68%).
- 84% of the species are associated with high floristic species-richness.
- The most common established strategies are: *S* stress-tolerator (44%), followed by *CSR* (24%), and *S/CSR* (12%).
- Proportions within canopy height categories: <10 cm 20%; 10-29 cm 44%; 30-59 cm 12%; 60-99 cm 24%.
- Proportions within month-of-first-flowering categories: April 4%; May 8%; June 52%; July 36%.
- The largest proportion of the species regenerate primarily by seed (28%); seed and vegetative (24%); vegetative and seed bank (16%); and seed bank (16%).
- 40% of the species produce a soil seed bank where a small amount of seed persists for > 1 year.
- When divided into frequency-in-Somerset categories (tetrads occupied /total tetrads): 0-25 (32%); 26-50 (48%); 51-75 (8%); 76-100 (12%).

In **Table 3.01** ecological descriptions are given for each species used in the primary research project (spring transplant inoculation). The information is compiled from accounts in Clapham *et al* (1987), Grime *et al* (1988), Stace (1991) and Hodgson *et al* (1995).

**Table 3.01** Ecological synopses for transplant species.

<i>Briza media</i> L.	A tufted polycarpic perennial grass with a semi-cryptophyte life-form. It is winter green, with major leaf expansion taking place during early spring with the foliage reaching 10-cm. The distinctive flower spikes are produced from June to July and the inflorescence can reach 50-cm in height. The seed is dispersed typically from July to September and no persistent soil seed bank is formed. Regeneration is mainly by seed shed into gaps in the vegetation during autumn. In addition <i>B. media</i> has a limited ability for lateral spread by means of rhizomes. It is a species that is typical of infertile, semi-natural calcareous pastures and older meadows. Due to agricultural intensification and this species' limited ability to colonize newly created habitats, it is generally declining in abundance.
<i>Campanula glomerata</i> L.	An erect downy polycarpic perennial, semi-rosette hemicryptophyte. It is winter green, and usually less than 20-cm, though may reach up to 80-cm in less infertile conditions. The bright purple-blue flowers occur from June to September. Possibly forms soil seed bank persisting greater than one year. Regeneration seems to be from seed as species has limited lateral vegetative expansion potential. It is a species typical of semi-natural grassland, particularly short sheep grazed conditions on calcareous soils.
<i>Campanula rotundifolia</i> L.	A polycarpic perennial, semi-rosette hemicryptophyte with slender rhizomes. It is winter green, with foliage usually less than 30-cm in height. The blue flowers are produced from July to September, and inflorescence may reach and 40-cm. Has the ability to regenerate by slender underground rhizomes, and by seed, which takes advantage of autumn and winter

	regeneration-gap formation. Probably forms a soil seed bank of greater than one year. It is a species of dry grassy places and on fixed sand dunes, usually on poor shallow soils, both acid and alkaline.
<i>Carex flacca</i> Schreber	A glaucous leaved polycarpic perennial, semi-rosette hemicryptophyte. It is winter green, with long-lived foliage, which reaches 30-cm in height and is replaced in the spring. The flower spikes are produced from May to June, with the flowering shoots reaching 60-cm. Fruits are formed from June onwards, and a persistent seed bank is produced. Regeneration is mainly vegetative through the spread of rhizomes, which can create large patches. Seedlings are rarely observed in the field, except after recruitment from the seed bank after scrub clearance. <i>C. flacca</i> is a common sedge of nutrient-deficient soils, notably those of semi-natural calcareous grasslands. It is a declining species due to agricultural intensification.
<i>Centaurea nigra</i> L.	A stout branching polycarpic perennial, semi-rosette hemicryptophyte. New shoots are produced in spring, and the plant eventually reaches up to 60-cm in height. The production of the red-purple flowers occurs from June through to September, and the seed may be shed from July onwards. Regeneration is mostly by seed, though there is the ability for vegetative spread via side shoots. No persistent seed bank is formed. <i>C. nigra</i> is a frequent plant of infertile to moderately fertile grasslands, and is found commonly in older pastures and meadows, especially those formed on limestone soils.
<i>Centaurea scabiosa</i> L.	A stout polycarpic perennial, semi-rosette hemicryptophyte., with woody stock. The leaves usually die back in winter, reshooting in the spring, and attaining 25-cm in height. The flowering shoots may reach 90-cm, and the red-purple flowers are produced mainly between July and August, with the seeds shed from August to November. Regeneration is almost entirely by seeds germinating in the spring. There is no evidence that a seed bank is produced, and this species has little capacity for lateral vegetative spread. <i>C. scabiosa</i> is mainly restricted to calcareous grasslands, particularly where grazing is light and soils are shallow, as well as infertile disturbed habitats.
<i>Filipendula vulgaris</i> Moench	A polycarpic perennial, semi-rosette hemicryptophyte. It is generally winter green. The inflorescence with stem leaves may reach up to 80-cm. The creamy white flowers tinged with reddish purple flowers are produced in a cymose panicle from May to August. Seed probably persists in the soil for less than one year. Regeneration seems to be mainly from seed, though species has limited lateral vegetative expansion potential through the production of ovoid root tubers. It is a species of semi-natural calcareous grassland, particularly grazed short by sheep.
<i>Galium verum</i> L.	A polycarpic perennial hemicryptophyte with slender creeping stoloniferous root stock and unusually deep root system. A winter green herb, which produces a compound panicle of bright yellow flowers between July and August. Foliage and flower stems are typically 30-cm though can reach 100-cm on more fertile conditions. Regeneration seems to be mainly by stolons, though may form a soil seed bank that persists more than a year. It is a species of all but the most acidic semi-natural grassland, and can also be found on hedgebanks and stable dunes.
<i>Geranium pratense</i> L.	A polycarpic perennial hemicryptophyte with stout oblique rhizome. The flowers are bright violet-blue and open between June to September. Growth is between 30 to 80-cm, with flowers borne in pairs on axillary peduncles. Hymenoptera are the main pollination agents and regeneration seems to be mainly by seed, which is assisted by explosive dehiscence. This is a species mainly of meadows, roadsides, usually under moist soil conditions.
<i>Hordeum secalinum</i> Schreber	A slender erect polycarpic perennial semi-rosette hemicryptophyte. Shoots erect or spreading and leaves linear. Leaves are 2 to 5-mm wide and the inflorescence will grow on average between 15 to 70-cm in height. The flower spike is produced between June and July. Regeneration seems to be mainly by seed, which is vectored by hay making and animals through attachment via the bristly, scabrid glumes and awns. It is a species usually associated with semi-natural mesotrophic meadows.
<i>Knautia arvensis</i> (L.) Coulter	A loosely caespitose polycarpic perennial hemicryptophyte. The erect flower stems can reach 100-cm in height and the flower heads are usually bluish-lilac in colour, produced between July and August. It is protandrous and visited by bees and lepidoptera. Regeneration is by seed and stoloniferous stock which gives rise to further leaf rosettes. It is to be found on dryish rough pasture, dry hedgebanks, field borders, roadsides and waste places, usually favouring calcareous soils, but also found on sand.

<i>Leontodon hispidus</i> L.	A polycarpic perennial, rosette hemicryptophyte. The new leaves expand in late spring, and the shoots die back in the autumn. The scapes of golden yellow flowers are produced from June to September. A deep taproot is produced which sustains growth during the dry summer months. May regenerate through clonal growth from branching stock and adventitious roots. Otherwise regenerates by means of wind dispersed seed. Seed probably persists in the soil for less than a year. It is a species of open meadows, pastures and grassy slopes, and can readily establish on unstable substrates such as quarry heaps.
<i>Leucanthemum vulgare</i> Lam.	A polycarpic perennial protohemicryptophyte with slender branched woody stock producing wintergreen flowering and non-flowering leaf rosettes. The white and yellow composite flowers are born on stems from June to August, and can reach 100-cm in height. <i>L.v.</i> is patch forming but has limited capacity for extensive clonal growth. Effective regeneration is by seed which is produced in large quantities, efficiently dispersed through hay making, and can germinate both in autumn and spring. It is a species of open grassy habitats, most abundant on infertile soils with grazing or hay making, or colonist after disturbance such as spoil heaps and road sides.
<i>Lotus corniculatus</i> L.	A decumbent polycarpic perennial protohemicryptophyte. <i>L.c.</i> has a stout stock and is scarcely stoloniferous. Flowers are yellow and mainly produced from June to July, with flower stems reaching 35-cm in height. <i>L.c.</i> does have the potential for clonal expansion especially where seed production is suppressed by grazing. However, regeneration is mainly by seed, and the development of a persistent soil seed bank. <i>L.c.</i> is the most common legume of unproductive semi-natural pastures and meadows, as well as other infertile open grassy habitats.
<i>Malva moschata</i> L.	An erect, tall polycarpic perennial hemicryptophyte, with branching stock producing leafy and flowering shoots up to 80-cm. The flowers are rose-pink and produced during July and August. <i>M.m.</i> has very limited capacity for vegetative spread and regeneration is by seed and the development of a persistent soil seed bank. It is generally avoided by grazing stock and can produce a domineering leaf canopy on more productive unimproved soils. <i>M.m.</i> is a species of grassy places, pastures and hedgebanks on neutral to calcareous soils.
<i>Origanum vulgare</i> L.	A rhizomatous, polycarpic perennial chamaephyte/hemicryptophyte. The erect, branching inflorescence stems can reach up to 80-cm, bearing clusters of small violet-purple flowers. <i>O.v.</i> can form compact clumps, which present a phalanx to neighbouring competition but seems to be an ineffective means of vegetative regeneration. Propagation is therefore by seed, either via those that germinate in spring or become incorporated into a large persistent soil seed bank. It is a species of dry pastures, hedgebanks and scrub, and is restricted to calcareous infertile soils.
<i>Plantago media</i> L.	A polycarpic perennial hemicryptophyte with a rosette growth form and produces short leafless flowering spikes up to 30-cm. Vegetative multiplication from the taproot can be rapid in open communities. <i>P.m.</i> over winters as a small rosette and the white insect pollinated flower scapes appear from early June to late summer. The mean weight of seed is 0.45-mg, and the seeds may germinate throughout spring, summer and autumn. This species is characteristic of calcareous pasture, although it can be found in grassy places on neutral soils.
<i>Primula veris</i> L.	A shortly rhizomatous, polycarpic perennial, wintergreen rosette hemicryptophyte. The rhizome is short, stout, ascending, and is covered with swollen persistent leafbases and bearing many stout roots. The scapes of deep yellow flowers are bourn to a height of 30-cm from April to May. Unusual phenology in that it commences growth during winter, flowers in spring, and reaches peak biomass in summer. Regeneration in stable communities is by very limited branching of rhizome. In more disturbed habitats seed regeneration is more important. <i>P.vs.</i> is a component of species-rich turf, usually over moist calcareous-neutral soils.
<i>Prunella vulgaris</i> L.	A stoloniferous, polycarpic perennial, semi-rosette hemicryptophyte, with short rhizomes. The erect or ascending flowering shoots reach to 3-cm, and bear heads of violet flowers between June and September. <i>P.v.</i> overwinters as rosettes, with shoots elongating in spring. It is capable of regeneration through stoloniferous growth and ramet production, as well as seed and formation of a persistent soil seed bank. Typically, it is found in grassland, woodland clearings and wastes overlying moist moderately fertile soils.

<i>Salvia verbenaca</i> L.	A polycarpic wintergreen perennial hemicryptophyte, little-branched with slightly aromatic rosette of basal leaves. Flowers are in axillary whorls, blue or lilac, on shoots reaching approximately 80-cm. Regeneration is mostly from seed and has minimal ability for clonal expansion. Probably does not produce a persistent soil seed bank. It is a scarce plant of dry pastures, roadsides and occasionally dunes, usually on calcareous infertile soils.
<i>Sanguisorba minor</i> Scop.	A polycarpic wintergreen perennial, semi-rosette hemicryptophyte with woody stock. Stems are erect, simple or branched above, flowering shoots reaching to 80-cm with globose heads produced between May and August. <i>S.m.</i> seems to have poor regenerative potential as vegetatively it lacks lateral spread, though does produce a dense clump of rosettes on woody root stock. Viable seed production is also limited, and probably does not produce persistent seed bank, thus relies on longevity to sustain populations. It is a component of species-rich, dry and moist grasslands, over relatively infertile calcareous soils.
<i>Scabiosa columbara</i> L.	A monocarpic to polycarpic perennial, semi-rosette hemicryptophyte, wintergreen with a deep tap root. The flat basal rosettes overwinter, and produce flowering shoots up to 70-cm with bluish-lilac flower heads in July and August. It is usually a relatively short-lived plant and has little capacity for lateral spread. Regeneration is through seed, which mostly germinate in the autumn. It probably does not develop a persistent soil seed bank. <i>S.c.</i> is restricted to dry open unproductive calcareous grasslands and banks where grazing or burning maintains short turf.
<i>Silene latifolia</i> Poiret	An annual or short-lived perennial protohemicryptophyte. Produces a thick almost woody stock from which grow a few short non-flowering shoots and erect flowering shoots to 100-cm bearing white dioecious blooms during May to September. Has limited lateral spread ability through short stolons. However does produce copious viable seed which can allow ruderal type population growth. Persistent soil seed bank may be formed. A species of open grassy places, roadsides, field borders, hedgerows and waste places usually on light calcareous or sandy soils.
<i>Stachys officinalis</i> (L.) Trevisan	A polycarpic perennial, semi-rosette hemicryptophyte with a short woody rhizome. It produces a well-marked basal rosette, and erect sparsely leafy stems up to 60-cm bearing clustered heads of bright reddish-purple flowers from June to September. <i>S.o.</i> has the ability for slow but significant lateral vegetative spread, though can also regenerate from spring germinating seed. It does not seem to produce a persistent soil seed bank. Typically <i>S.o.</i> frequents short open turf, hedgebanks, and open woods on mildly acidic to neutral infertile soils.
<i>Succisa pratensis</i> Moench	A polycarpic perennial, wintergreen semi-rosette hemicryptophyte with short vertical rhizomes and long stout roots. Flowering stems may reach 100-cm, producing mauve to dark blue-purple flower heads from June to October. This species is able to sustain very limited vegetative spread through lateral shoots, which can be liberated from the mother plant by stock poaching. Otherwise, regeneration is by seed, which germinates in the spring, and no persistent soil seed bank seems to be produced. <i>S.p.</i> mostly grows in relatively unproductive semi-natural damp pastures, and ungrazed grassland over moderately acidic soils, as well as marshes, fens and damp woods.

### Transplant Cultivation

Over the last decade there has been considerable debate within British wild plant conservation and habitat restoration circles concerning the importance of plant material, and plant material provenance in schemes to create or enrich vegetation (Mitchley 1988; Akeroyd 1994; Hopkins *et al* 1997; Everett 1999; Flora Locale 2000; Kendle & Rose 2000). To date, there is little evidence to suggest that genetic provenance of a species can deleteriously affect the local genotypic stock either by dissipating genetic diversity, or actually usurping the local population through competitive vigour. The few data at present suggest that the local environmental variables select more significantly than minor

variations in genetic make-up (Jones & Hayes 1999). With reference to population differentiation, van Andel (1998) considers that risk of reduced fitness and reduced performance due to not using locally adapted genotypes should be considered less important than the actual absence of a species at a restoration site. It is possible that the use of locally adapted stock may in fact be less beneficial than using mixed material, as mixed stock contains a range of *hedge-betting* variability (van Andel 1998). Considering that the great majority of the British countryside is *contaminated* with genetically modified species through intensive plant breeding, the local purity of inoculation material applied to highly disturbed environments seems relatively insignificant. However, taking the precautionary principle, within resource limitations, the *local-is-best* policy seems to be a coherent one. For the present study, with experimental transplant cultivation starting in 1993-4, rapidly sourcing adequate seed material for growing on was of utmost priority. Although it is preferential to use seed from the most local source (Flora Locale 2000), because of timing, limited external commitment, and thus the uncertain future of the project, local collection was not undertaken. However, all the seed used in the experiments came from British provenances guaranteed by the merchants - Emorsgate Seeds, High Value Horticulture Ltd, and NPK Landlife. While most of the seed was from British but non-Somerset sources, the *Carex flacca* and *Prunella vulgaris* seed were collected from Plot 5, the reference community.

The author grew all the 9-cm pot transplants, and High Value Horticulture Ltd<sup>1</sup> donated the 2-cm seedling transplants. Unfortunately HVH only had plug material available for 15 of the 25 species used, thus 10 species (*Briza media*, *Carex flacca*, *Filipendula vulgaris*, *Hordeum secalinum*, *Leontodon hispidus*, *Origanum vulgare*, *Plantago media*, *Salvia verbenaca*, *Sanguisorba minor* & *Succisa pratensis*) were only planted as 9-cm pot plants. The experimental comparison of pot versus plug transplant survivorship could not therefore be applied to this set of species. The following accounts thus refer to the cultivation of the 9-cm transplants. Most of the seed was sown in April 1993, although four species were sown later, in July. *Stachys officinalis* and *Silene latifolia* were also grown later on in order to maximise the number of species available for the research. *Campanula rotundifolia* was grown later because the previous tray of seedlings sown in

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<sup>1</sup>High Value Horticulture Ltd, *Really Wild Flowers*, The Shop, The Street, Sutton Waldron, Blandford Forum, Dorset DT11 8NZ.

April was heavily predated upon by molluscs invading the polytunnel, therefore leading to an insufficiency of material to grow-on. *Carex flacca* seed was gathered in July from the local unimproved grassland (Plot 5) as it was unavailable from the seed merchants and also gave an opportunity to use locally indigenous material.

To increase germination rates, pre-treatments were applied to species with seed known to have germination inhibition features. The *Primula veris* seeds were vernalised by placing them in the freezer with moist sand for three weeks (NPK Landlife 1994). The hard testas of *Geranium pratense* and *Lotus corniculatus* seed were treated with light scarification using sandpaper. Otherwise, the method for germination was the same for all the species. The seeds of each species were sown into standard polypropylene (35 x 23 cm) seed trays (Morgan 1999) containing coconut fibre (coir) general-purpose commercial potting compost, which had added fertiliser. Apart from the very small seeded species (e.g. *Campanula rotundifolia*), the seeds were then covered by a thin (5 mm) layer of further compost. Soil moisture was maintained with overhead irrigation pipes, though initially with a watering can and rose. The trays were then placed on the Mypex floor of an unheated polytunnel. Opening and closing the entrances regulated the temperature of the tunnel. Once the seedlings had produced approximately 3 or 4 true leaves, they were removed and planted into standard full-length 9-cm diameter polypropylene pots, of volume approximately 300-ml, with the same compost as the seed trays and racked-up in Empot plastic potholders. When the plants were sufficiently grown-on, they were taken out of the polytunnel and placed on 2-m x 6-m open air bays laid out using Mypex. They were then watered from above using a hose and sprinkler. As is usual with wild species, germination was generally spread out over an extended period, which was especially the case with *Geranium pratense*, *Knautia arvensis* and *Centaurea scabiosa*. The seedlings of these species were therefore pricked out and placed in pots as and when they were individually large enough.

Because the polytunnel was newly erected on an area of grassland, as already intimated, there were initial problems with predation from molluscs - particularly *Cepaea* spp., *Helix aspersa* and *Derocerus reticulatum*. *Campanula glomerata* and *Campanula rotundifolia* were particularly badly affected, with even fairly well established *C. rotundifolia* plants still being stripped of leaves and shoots by the molluscs. It was therefore necessary to use slug pellets to prevent more wholesale damage of the stock. Initially ‘nature-friendly’

pellets were used, though unfortunately this was not an effective enough control. It was therefore necessary to resort to the typical metaldehyde pellets, which did reduce the predation to an acceptable level. The pellets were, however, only used within the confines of the poly-tunnel. Once large enough to place outside, none of the species were seriously affected by mollusc predation in the Mypex bays.

At the time of planting, the majority of the pot plants were of flowering size at approximately 1 year old. Typically, certain species were particularly well developed, forming dense root systems and foliage. *Leucanthemum vulgare*, *Centaurea* spp., and *Knautia arvensis* formed the largest plants. This meant that by the time of planting some material was pot-bound, and/or had placed roots outside of the container, into the Mypex flooring. Some of these roots had to be severed for removal, and this could have had the repercussion that once inserted into the swards, these individuals suffered a greater degree of drought stress than those which remained confined within the pot.

The plug plants were collected from HVH at the end of April 1994, supplied in modular trays, each plug approximately 2-cm in diameter with root volumes of 22-ml. All the plants except *Stachys officinalis*<sup>2</sup> had been grown from February 1994. The plugs were grown in coir compost, which included Vitax slow-release fertilizer granules. They were also treated to a fortnightly application of foliar feed, though the plants used in the research were collected from HVH just prior to their next dosage. The usual procedure for the commercial production of the plugs is to heavily feed them prior to despatch so as to stimulate rapid growth in the initial establishment phase (Bisgrove & Dixie 1993). For reasons of experimental comparison, this treatment was not required for the plugs used in this project.

## INOCULATION METHODS & PRACTICALITIES

### Inoculation methodology

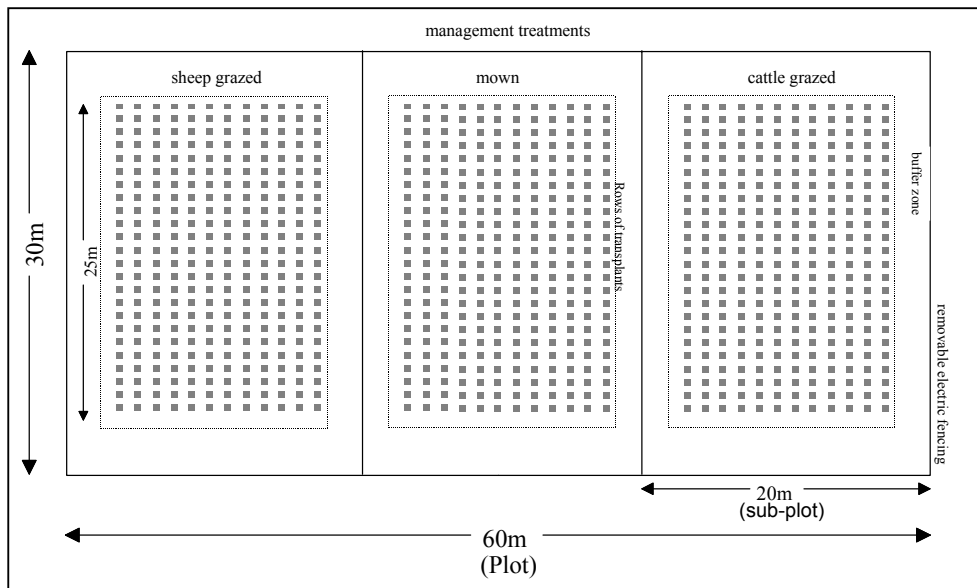
The four experimental treatment plots (Plots 1-4) were each divided into three subplots, as described in **Chapter 2**. It was essential to the whole project that the position of each transplant, or planting position was relocatable in subsequent years (Wells *et al* 1989). In order to achieve this, great effort was made to make each tier of the plot design easy

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<sup>2</sup> The only available specimens of this species had been grown from September 1993.

to re-find. Prior to creating the experimental set-up, the swards of all four plots were mown to approximately 50-mm in height (Luscombe & Scott 1994). Within each subplot 12-m x 25-m central areas were demarcated with 60-cm wooden ‘stobs’, in order that the boundaries of the planting areas could be relocated. Between the 12-m sides of this area, 1-m spacings were denoted with a blue plastic pipe pushed into the ground and then sprayed around to a 30-cm diameter using glyphosate herbicide (Frame 1981). It was essential that the planting area sides were parallel and that the row spacings were matched on both sides of the planting row. This ensured that the planting rows were all 1-m apart along their whole length.

**Figure 3.01** Experimental plot plan showing management treatment subplots with spring transplant inoculation design.



Pre-treatment prior to transplant inoculation required the creation of competition-free gaps in order to assess the prophylactic efficacy of artificial competition exclusion zones. These *safe-sites* had to be created before the transplants were inserted into the plots. The most efficient way to create competition-free inoculation gaps of specific diameters was through broad-spectrum herbicide. Gaps of 30-cm, 15-cm, and 0-cm (i.e. no gap), were formed using glyphosate herbicide sprayed over plastic stencils with the required diameters. The transplants were inserted when mineral soil became exposed. The transplants were therefore planted into the subplot swards in late March/April 1994 (Luscombe & Scott 1994). Into each central zone of these subplots were inserted 12

individuals of 25 perennial grassland species, amounting to 300 transplants per subplot spaced at 1-m apart (see **Figure 3.01**). The scheme per subplot was therefore developed as 12 rows of the 25 species randomly located within each row i.e. one instance of each species per transplant row (Boyce 1994). As mentioned previously, two sizes of transplant were used in the experiment in order to assess the importance of inoculate size on the establishment of transplants. Also, as detailed above, plug transplants were only available for 15 species. Thus 10 species were inserted into each of the subplots as only 9-cm pot inoculates, and 15 species were introduced as equal numbers of the two sizes of transplant. The dual-size transplants were randomly allocated across each subplot i.e. for each dual species; six 9-cm transplants and six plug plants were randomly allocated within each subplot.

### **Practicalities**

#### *Gap creation*

The most obvious methods of creating artificial competition-free gaps of regular diameter was either through turf scraping (skreefing) (Morgan 1999), digging out the required areas of turf, or using a broad-spectrum herbicide (Bullock *et al* 1995; Davies *et al* 1999; Luscombe & Scott 1994; Pakeman *et al* 1998; Wells 1983). Due to the large number of competition-free gaps that had to be created throughout the four plots (1200 15-cm and 1200 30-cm gaps), use of herbicide seemed to be the most efficient option, as it was more effective than scraping, and less time-consuming than turf removal. However, it must be noted that turf cutting unlike herbicide, will essentially guarantee removal of both above- and below-ground vegetation, and also a significant proportion of the soil seed bank (Bullock *et al* 1995). The competition reducing dynamics of herbicide versus turf removal is a point of further research, though elements of this question are addressed in **Chapter 10**.

The gaps used in the project had to be of specific diameters, and created with the minimum of ‘collateral’ damage to the non-target sward i.e. as limited spray drift and smearing as possible (Bisgrove 1988). This was adequately achieved by cutting the bases off polypropylene flowerpots of the required diameters. These were then attached to long cane handles so that they could be moved efficiently without contact with the glyphosate residue. The pot thus acted as a stencil with sides so that drift was prevented. The application was undertaken using a standard garden sprayer with lance

and pressurized reservoir. The calibration of planting positions was maintained with a plastic rope marked at the spray (and insertion points) with coloured tape.

#### *Planting implements*

A number of different tools were assessed as to their efficacy for creating specific sized divots into which the transplants could be inserted. For the 2-cm plug transplants, Really Wild Flowers had developed a special ‘plug-shaped’ long-handled dibber with a foot grip to force it into the ground. This generally worked efficiently. However, creating planting holes for the 9-cm pot transplants was much more of a problem, particularly owing to the stony ‘corn-brash’ soil. Spade and trowel digging were too time-consuming. Garden-centre bulb-planters were not robust enough and easily bent when forced into the ground by foot pressure as found by Bisgrove (1988). An auger was not available, and for speed of hole formation a special 9-cm slot-making device had to be designed by a local agricultural engineer using hardened steel (Thompson 1993). This implement had to be sharp enough to cut into the turf and soil; strong enough to prevent bending against stones; and designed in order that the turf plug could be ejected without resort to scraping the soil out. Thus, with this device, planting holes could be rapidly ‘punched’ into the swards. After a number of prototypes, a workable implement was created out of a scrap tractor piston casing, with one end sharpened into the cutter, and box steel for shaft and handle. The piston itself was redesigned to push out the turf plug using a footplate.

#### *Transplant damage by non-grazing stock*

Though soil fertility and grass competitive dominance were viewed as the main factors affecting transplant survival, invertebrate (primarily mollusc) predation (Bisgrove 1988; Hanley & Fenner 1997), activities of the domestic grazing animals, and wild vertebrate animals were also judged as probable influences on survivorship. However, an unforeseen problem was disturbance by foxes *Vulpes vulpes*, badgers *Meles meles*, and especially by rabbits *Oryctolagus cuniculus* and corvids *Corvus* spp. during the initial two-month period after planting. Foxes and badgers were clearly implicated in the early destruction of some of the pot transplants. It was clear that given an obsessive individual chancing upon a newly planted area, they could possibly destroy a whole tranche of transplants. The prime motivation for destroying the transplants was probably the pursuit of worms and molluscs lodged in the easily ‘diggable’ compost. However, in this study, the destruction by fox and badgers was probably relatively low. Rabbits and corvids were, however, a more persistent

and intractable problem. In the spring planting of 1994, rabbits were active in all but Plot 1, and especially in Plot 3, which was close to a rabbit burrow located in a nearby hedge bank. Digging in Plot 3 destroyed approximately 30% of the initial planting. No real reason for this activity was apparent as the transplants, though often ripped to pieces, were not noticeably eaten. The reason may lie in the fact that the compost was simply easy to dig. Any plant with compost showing was at risk, and the plants in large gaps were especially targeted, probably because they were most conspicuous (Bisgrove 1988). Corvids could be equally destructive, particularly flocks of jackdaws *Corvus monedula* and rooks *Corvus frugilegus*, which after the spring planting, took to probing in the plots and pulling out rows of plugs. In addition, throughout the study, the corvids constantly pulled out the blue marker piping, some of which was found fifty to one hundred metres away. This behaviour was both intriguing and irritating. There was no apparent foraging value in this activity!

Although the behaviour of the above animals can be considered as a ‘natural’ factor in the survival of the transplants, this was not the experimental rationale taken, not at least for the immediate post-planting period. The core objective of the project was to assess the competitive dynamics of the plant communities in relation to botanical restoration techniques, not the damage inflicted to inoculants by observant mammal and bird opportunists! Therefore, in the first month after planting, transplants were replanted if pulled out, and initially, replaced if destroyed. Disturbance leading to transplant destruction by rabbits etc after the initial period was deemed acceptable. Perhaps the central issue is scale. The loss of a few transplants to foxes could be part of the everyday survival of all the plants in the sward. However, whole- scale destruction whereby transplants are specifically targeted due to their initial visibility could have completely skewed the project results. This problem became acute with the autumn planting of 1996 when large flocks of jackdaws and rooks targeted Plot 2, probably because it was the field with the clearest sight-lines, open and away from hedges so they could watch for predators such as sparrow hawks and foxes. The soil was very moist after consistent rain and the corvids were probing for worms and larvae. They also found the compost easy to dig up and the plugs were pulled out *en masse* over a period of 5 weeks for no apparent gain. Approximately 18.7% of transplants were destroyed in this way. Where possible, plants were replanted, and destroyed plants replaced until an ‘acceptable’ level of destruction was reached. Flexinetting eventually had to be placed over the plants in Plot 2 because of the

persistence of the foraging corvids. Plot 3 was little affected by corvids, but, as with the spring planting of 1994, the rabbit damage was acute. Approximately 14.9% of transplants were dug up, 88% of which were 9-cm pot plants. Although some showed signs of their shoots having been nibbled, most were not obviously eaten.

A cause for concern is the role played by the insertion gaps in the destruction by rabbits. Both 15-cm and 30-cm spray gaps had significantly higher ( $\chi^2_2=11.41$ ,  $P<0.01$ ) destruction of transplants than the 0-cm gaps. Clearly, the gaps provide both a high visibility target for the rabbits, and a ready-formed scrape judging by the piles of pellets. In this situation, gaps can have a very negative effect on initial transplant survivorship. This observation suggests that where a rabbit colony is present, their disturbance activities can be very detrimental, particularly, if a particular plant species is selected. Combine rabbit-effects with those of corvids, foxes and badgers, and a whole scheme of grassland enrichment using transplants may be jeopardised. It is ironical that Plot 1, which should be the most hostile environment for the transplants in plant competition terms due to the soil fertility, was virtually unscathed by rabbit/corvid destruction because it is located next to the house and thus has most human disturbance.

Following the above discussion, it is worth noting some practical observations on planting methodology:

- Pots should be dug well down and displaced soil packed around compost surface, not only to wedge the plant in firmly, but also to cover any exposed compost to camouflage it from digging animals.
- Plugs should be firmly pinched-in to prevent them from being tugged out by corvids.
- Gaps created around transplants may reduce neighbour competition from the surrounding sward, but may also make the transplants conspicuous targets for animal disturbance and thus have a very deleterious effect.
- Sites close to hedges or woods are less likely to be attacked by rabbits and corvids due to the lack of clear sight lines for predator detection.
- Areas close to human disturbance are also relatively safe, though nocturnal digging by rabbits, foxes and badgers may still be a problem.
- If resources permit, it is advisable to budget for some destruction of transplants in the early establishment period, and have enough stock to replace those that are destroyed.
- More active (and expensive) methods may have to be employed, such as temporary fencing to make sure some plants survive long enough to establish anchoring roots, and for the pot compost to be mixed with soil by worms (i.e. less detectable).
- Though not tested in this study, the compost type used for the transplants may be of significance. A soil-based compost such as John Innes may be less appealing or obvious to digging animals.

- In any similar schemes where transplants are used for restoration purposes, the abundances and proximities of digging animals to the site should be assessed. Especially as the damage inflicted can have a significant effect on overall survivorship, to the point where it may not be viable to use certain species, or even to attempt the scheme of planting at all.

## SWARD MANAGEMENT TREATMENTS

Plot location and basic plot architecture have been mostly illustrated in **Chapter 2**. However it is necessary to describe further details of plot structure in relation to the defoliation management treatments. The plots were primarily designed to allow three management treatments to be applied to each grassland area. In order to allow stock grazing, and particularly cow grazing, the experimental structure was always going to be a compromise between necessary practicalities and analytical strictures. The subplots had to be both accessible for grazing and to exclude animals when necessary. Electric fencing was therefore the most malleable, temporary and practical system for experimental purposes, and the plots were fenced-up accordingly, although the wooden corner stakes were permanent. Paddocks smaller than that employed in the experiment could not be effectively used for the dairy herd as the cows would be inhibited by the confined space, and therefore the swards would not be effectively grazed. Excluding cow grazing from the experiment would probably have allowed more randomisation in the design, and mowing would have been the most easily manipulatable treatment, for say, a Latin Square set-up (Fowler *et al* 1998). However, to have avoided the use of dairy cows would have lessened the applicability of the results, not only for Lusty Hill Farm with a century of dairy management history, but also most of the surrounding farms in this part of the West Country (SSDC 1998; Whyte 1997). As indicated previously, three management treatments were applied to the plots: mowing; cattle grazing; and sheep grazing. The types (i.e. sequence) of treatments for each plot were allocated randomly. The basic regime consisted of two periods of management treatment; one in the spring; and the other in the autumn (aftermath) (MacDonald 1994), with a hay cut in-between (Smith & Jones 1991). This was the traditional dairying system in Somerset before WWII (Tanner 1857; Fraser 1991; Gibson 1998).

### *Hay cutting*

The hay-cutting period was roughly scheduled for mid-end of July for a number of reasons. Before WW2 and widespread mechanisation, this would have been the most usual

month in which hay could be harvested, due to late spring grazing, sward phenology and moisture content of the crop for storage, and the likely chance of a window of stable high-pressure weather conditions for harvesting (Smith & Jones 1991). For nature conservation, this period is also generally preferred, as opposed to modern farming, which requires the crop to be taken as soon as possible, usually in mid-June (Kirkham & Wilkins 1994). Taking the hay in July allows some seed-set and dispersal (Jefferson 1999; Smith *et al* 1996), as well as providing a longer period of development for invertebrates such as butterflies (Younger & Smith 1994). In addition, the hay is still saleable as a conservation forage crop unlike hay taken in August. **Figure 3.02** demonstrates the basic management periods.

**Figure 3.02** Annual time-line for management treatments. Bars indicate periods for specific cropping treatments (sheep grazing, cow grazing, mowing), with universal July hay cut.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						hay cut					

However, as with all farming systems, the year-by-year ‘fine-tuning’ is dictated by weather conditions (Jefferson 1999). The specific date for hay cutting is reliant on a period of dry weather of at least 4-5 days (Kirkham & Wilkins 1994), in which the hay can be cut, turned (usually twice), baled, picked up, and stacked in a barn. Weather conditions also have implications for annual grazing regimes. Wet spring weather can delay the onset of putting grazing stock out due to possible poaching risks, and in the autumn, for example, a drought such as in 1995, can set back the aftermath grazing to October due to the lack of sward regrowth. **Table 3.02** shows the actual grazing and hay cutting dates for the experiment 1994-1999. The first hay cut in 1994 was taken later than desired (20<sup>th</sup> August) as it was feared that the transplants might not have been established enough by July to prevent them being tugged from the ground by the tractor PTO driven drum mower.

**Table 3.02** The actual periods of management treatments as undertaken from 1994-99.

Year	Spring treatments start	Spring treatments end	Hay cut	Autumn treatments start	Autumn treatments end
1994	Transplantation		20 <sup>th</sup> August	27 <sup>th</sup> September	25 <sup>th</sup> October
1995	1 <sup>st</sup> May	20 <sup>th</sup> May	20 <sup>th</sup> July	4 <sup>th</sup> October	29 <sup>th</sup> October
1996	21 <sup>st</sup> April	10 <sup>th</sup> May	22 <sup>nd</sup> July	23 <sup>rd</sup> September	24 <sup>th</sup> October
1997	19 <sup>th</sup> April	12 <sup>th</sup> May	9 <sup>th</sup> August	2 <sup>nd</sup> October	6 <sup>th</sup> November
1998	1 <sup>st</sup> May	22 <sup>nd</sup> May	9 <sup>th</sup> August	16 <sup>th</sup> October	14 <sup>th</sup> November
1999	26 <sup>th</sup> April	20 <sup>th</sup> May	26 <sup>th</sup> July	20 <sup>th</sup> September	13 <sup>th</sup> November

It is worth noting that for small grasslands, managed primarily for nature conservation, it is often difficult to find agricultural contactors that will cut and bale a crop within a specified time period. Few conservation organisations have the machinery to cut and bale their own hay crops. This is readily apparent with a small nature reserve such as LHF. Little ‘jobs’ such as Lusty Hill Farm (annual crop less than 1000 small bales) are bottom of the list when harvesting weather occurs, and delay increasingly entails the threat of bad weather. This has recently become even more critical as ‘small’ bale production has now given way to round bale and ‘big’ bale machinery, so that contactors that can and will deal with small bales from small cropping areas are fewer and fewer, with previously simple contracts now increasingly restricted to specialists (Davies & Davies 1998).

#### *Mowing*

Logistically, and practically, mowing was the easiest management treatment and one often applied to urban conservation and amenity grasslands for this reason (Wells 1971; Green 1980; Anderson 1995; Fenner & Palmer 1998; Parr & Way 1988). Grazing stock is technically far harder to manipulate for defoliation experiments, and thus often avoided (Gilbert & Anderson 1998; Flora Locale 2000). A 3.5 Hp rotary mower was used with a grass-box to collect the cuttings. This was undertaken once the sward had grown approximately above 10-cm in height. The sward was then cut back to 5-cm. This meant in practice that the mown subplots were cut 2-3 times in the autumn, and again 2-3 times in the spring depending on the weather conditions, especially in the autumn. Mild weather conditions could mean that the grass would grow continually until November requiring a higher cutting frequency. Similarly, mild late winter weather meant that the sward was too high to collect and remove in one go during the first spring defoliation treatment. Therefore, the first spring cut was undertaken without grass box, and then after a few days of ‘withering’ the arisings were collected with a second cut using both mower and grass box.

#### *Dairy cow grazing*

Personal observations of cow foraging behaviour on Lusty Hill Farm suggest that they pursue a pattern of grazing following a hierarchy or sequence of species selection. There are very few species within the sward matrix that the cows will not eat e.g. *Cirsium* spp. and *Urtica dioica*. On introduction to a new pasture, they preferentially eat all grass species except *Bromus hordeaceus*, and some *Trifolium repens*, but attempt to avoid most

other herbs at first. With increased grazing pressure they are forced to graze less palatable species such as *Ranunculus bulbosus* and *Ranunculus acris*. Their grazing behaviour therefore produces a mosaic structure when grazing extensively, which reduces the dominance of grasses (Fisher *et al* 1994; Putman *et al* 1991) and may enhance the competitive position of forbs. This is the pattern left after the spring grazing period before the fields are shut up for hay. However, vegetation patterns generally develop in accordance with grazing intensity (van den Bos & Bakker 1988; Gibson 1997). The field surrounding Plot 2, Wheatstubble, is managed as pasture, and grazed throughout spring and summer. By the end of June, with continuous rotational grazing, most of the sward has been grazed evenly, and both grams and forbs reduced to the same height. The pattern of avoidance is then organised around unpalatable/inedible species such as *Cirsium arvense* and the sward surrounding dung pats (Parish & Turkington 1990; Putman *et al* 1991). When allowed to graze in grasslands with more heterogeneous structure/productivity, the cows seem to graze the shorter swards preferentially. This usually means that the short diverse patches dominated by finer-leaved grasses such as *Festuca rubra* and *Cynosurus cristatus* are grazed in preference to the more highly productive patches dominated by coarser grasses such as *Dactylis glomerata*, *Arrhenatherum elatius*. With time this pattern is reinforced with the less productive areas becoming over-grazed and the more productive areas becoming under-grazed, developing into tussocks. As we have found at Lusty Hill Farm, manipulating grazing stock in an attempt to restore diversity to agriculturally improved grassland seems to be very difficult. The benefit of taking a mid-summer hay crop is that the selective-avoidance mosaics created by the grazing stock are levelled so preventing the reinforcement of deleterious sward structures. The cow grazing management was aligned with the guidelines of Gibson *et al* (1987), Mountford *et al* (1993), Crofts & Grayson (1999) and typical regional dairy farming practices. In essence, the grazing regime was continuous throughout the treatment periods (Bacon 1990). However, the animals were rotated from subplot to subplot. For the cows, this fitted in with the usual management of dairy cattle, whereby they are constantly moved - the movement of which was controlled by the local farmer. Approximately 45 cows were rotated around the fields, and access to the subplots was dictated by the condition of the sward i.e. height, poaching and fouling levels. The herd was made up of typical commercial breeds, mainly Friesian with a smaller number of Friesian x Holstein cows.

### *Sheep grazing*

The sheep breed chosen was the Wiltshire Horn, considered to be an ‘at risk’ breed by the Rare Breeds Survival Trust (RBST 1991). Ewe lambs were bought from a breeder with a registered flock after enquiries with the Rare Breeds Survival Trust, and further evidence from conservation bodies such as the Dorset Trust. The Wiltshire Horn is a white faced, short-wool breed and therefore needs no shearing. Furthermore, it is one of the traditional breeds of the region, and is both biddable, hardy and has strong foraging ability (RBST 1991). Because of these characteristics, this breed is increasingly being used for conservation as a good ‘easy-care’ sheep that can give economic returns (Small 1994; Alderson & Small 1997). The only problem encountered with this breed is the speed of hoof-horn growth when grazed on relatively productive grassland with soft ground, such as on the present study site. The horn therefore grows rapidly and is not worn down. To prevent the sheep going lame and contracting hoof-rot, their hooves have to be trimmed twice a year (Simpson & Gee 1997), unlike our flock of Soays, which rarely need tending to. Also, the Wiltshire Horn was developed in the medieval period as a large mutton sheep (65 kg+), and difficult to handle even if they are relatively biddable and trained to come to a bucket of ‘sheep-nuts’. In order to gather the animals for transit, they had to be rounded up into a permanently fenced pen, with the additional use of 100-m of Flexi-netting and at least three people to herd. Once corralled, the use of a ‘sheep-crate’ was necessary to make manipulation possible for hoof trimming and worming.

Observations of Wiltshire Horn grazing/foraging behaviour suggest that they are periodically selective grazers. That is, they graze the sward relatively evenly, but graze certain species at certain times, and palatability is a more relative concept for this sheep breed than for dairy cows. Unlike cows, they will preferentially eat flower heads, often ‘snacking’ on specific species (Oates & Bullock 1997). This can be a problem for vernal species such as *Primula veris* as in the spring grazing period; the sheep may often target the flower heads, eating the entire potential seed source in one session. Similarly, whereas the cows would usually avoid the flower scapes of *Ranunculus* spp, the sheep often single out these species for preferential defoliation. Sheep grazing commenced a little later than the cattle treatment due to difficulties acquiring the stock. The sheep grazing was organised on a ‘put-and-take’ system (Mountford *et al* 1993; Bullock *et al* 1994) whereby animals were moved to ‘lay-back land’ (Simpson & Gee 1997) once the sward had been grazed relatively evenly to approximately 5 to 10-cm. As

the sheep remained continuously on the subplots during the grazing periods they form their own partial avoidance mosaics around defecation and urine patches. Two sheep were placed in each treatment subplot as, after observation, this was deemed adequate for this sheep breed to allow them to graze in ‘flocking behaviour’ rather than stressed behaviour (Gibson *et al* 1987). The grazing regime roughly equated to 0.34 Livestock units (LU) for 5 weeks per subplot per annum (Crofts & Grayson 1999). All the subplots were fenced with Flexinet and single strand electric fencing to allow all the sheep grazed subplots to be treated simultaneously.

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