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Hedgerow management experiment relevant to agri-environment schemes: cutting regime impacts species richness of basal flora and Ellenberg indicator profiles

David P. B. Stanbury[1,2], Oliver L. Pescott[1], Joanna T. Staley[1*]

[1] UK Centre for Ecology and Hydrology, Maclean Building, Benson Lane, Wallingford, Oxfordshire, OX10 8BB

[2] School of Biological Sciences, University of Reading, Whiteknights, Reading, RG6 6AS UK

*Corresponding author: Joanna T Staley jnasta@ceh.ac.uk

Highlights

- Hedge plant communities are key conservation indicators of hedgerow condition.
- Plant communities were assessed at four sites after six years of cutting regimes.
- Cutting to allow incremental growth slightly reduced species richness of basal flora.
- Plant communities under incremental cutting also indicated slightly more fertile conditions.
- Hedge cutting regimes under agri-environment schemes can alter plant assemblages.

Abstract

Hedgerow plant communities, including herbaceous species growing in the hedge base, are important conservation indicators of hedgerow habitat condition. The effects of management have the potential to alter the species richness and composition of hedgerow plant communities, but this has not previously been tested experimentally. A novel field experiment was used to test the effects of hedgerow management on hedgerow basal flora. Hedgerow cutting treatments, including relaxed cutting regimes funded under agri-environment schemes, were applied in replicated blocks at four sites in lowland UK. After six years of experimental cutting treatments the hedgerow plant communities were surveyed, both directly under the woody hedgerow vegetation and immediately adjacent to the hedges. For hedgerow plots cut in autumn, a reduced intensity cutting regime (incremental cutting) resulted in an average reduction of one species and a small shift towards plants typical of less fertile conditions, compared to cutting back to a standard height and width. Hedgerow plots cut in late winter had a plant community typical of slightly shadier conditions, compared with those cut in autumn. Hedgerow cutting management can thus alter the richness and composition of plant communities, over relatively short timescales. These results are discussed in the context of longer term trends in hedgerow plant communities across northern Europe, and conservation management funded under agri-environment schemes.

Keywords: agri-environment scheme; Ellenberg; fertility; hedgerow basal flora; shading; species richness;

Introduction

Hedgerows have been defined as a “more or less continuous line of woody vegetation that is or has recently been subject to a regime of cutting” (Barr and Gillespie 2000; Petit et al. 2003). Hedgerows are an important habitat, providing resources and a refuge for plant and animal species in otherwise intensively managed agricultural landscapes in Europe (Carlier and Moran 2019; French and Cummins 2001; Graham et al. 2018; Roy and de Blois 2008; Van Den Berge et al. 2018; Wehling and Diekmann 2009), and elsewhere in the world including North America (Morandin et al. 2016) and China (Yu et al. 1999). Due to their key role in agricultural landscapes, hedgerows are recognised as a priority habitat for conservation in Europe (JNCC 2012) and protected by legislation in several countries (Baudry et al. 2000). The hedgerow basal flora, which consists of the plant species under the hedge canopy and immediately next to the hedge, is an important conservation indicator of hedgerow habitat condition in the UK (Department for Environment, Food and Rural Affairs 2012). Despite this recognition, the vegetation of many hedge bottoms in several northern Europe countries including lowland Britain is impoverished and species poor, largely due to nutrient and pesticide contamination, and inappropriate management or neglect (Critchley et al. 2013; Litza and Diekmann 2017, 2019; Van Den Berge et al. 2019; Wilson, 2019).

Hedgerow plant communities have recently been resurveyed in Belgium (Van Den Berge et al. 2019), Northern Germany (Litza and Diekmann 2017, 2019) and the UK (Staley et al. 2013), showing an ongoing interest in changes to hedgerow flora and the role of both hedgerow management and broader agricultural practices in driving these changes. In an assessment of changes in the plant communities growing alongside hedgerows over the period 1978 to 2007 in the UK, a significant increase in competitive species was found, and also in species tolerant of lower light and more able to compete in conditions of higher soil fertility (Carey et al. 2008). A reduction in plant species richness in individual hedgerows was observed between 1978 and 1998, but no change in species richness between 1998 and 2007 (Carey et al. 2008). An assessment of changes to the hedgerow plant communities in Dorset (UK) over a 70-year period (between the 1930s and 2001), showed a loss of diversity in basal plant communities across sites (taxonomic homogenisation or a loss of beta diversity; Staley et al. 2013). Drivers of these changes included recent cutting of hedgerows by a mechanical flail and historic management such as hedge-laying or coppicing, the effects of which differed between groups of plant species, in addition to environmental factors such as eutrophication (Staley et al. 2013). An increase in generalist herbaceous plant species has been observed over a 50-year period in Northern Germany, where it has been attributed to acidification and eutrophication (Litza and Diekmann 2017). An increase in nitrogen-indicating plant species has also been attributed to eutrophication in resurveys of 176 hedgerows in North-west Germany (Huwer and Wittig, 2012) and 54 hedgerow plots in Northern Belgium (Van Den Berge et al. 2019).

Within the UK and other countries in Europe and North America, landowners can receive funding to support management with environmental objectives, through agri-environment schemes (AES). Typical hedgerow management in England (UK) consists of cutting with a mechanised flail every year in early autumn, immediately after harvest, with hedgerows cut back to the same height and width each year (Sparks and Croxton 2007; Staley et al 2016). Cutting with a mechanised flail is also used in some regions of other European countries, but is less common. For example, cutting with a flail is used in parts of France (Bazin and Schmutz 1998), and in the Schleswig-Holstein region of Germany lateral cutting with a flail is permitted once every three years in between less frequent coppicing (Schleswig-Holstein Ministry of Energy Transition 2017).

Agri-environment schemes in England include options for cutting hedges less frequently than every year, and in late winter rather than autumn (Natural England 2013a, b, 2018). Comparable AES hedgerow options are available in some other European countries (Fuentes-Montemayor et al., 2011). In 2009, around 40% of the length of managed hedgerows in England were under AES, and three-quarters of those hedgerows under AES were managed under an option to cut once every two years (Natural England 2009). These AES cutting options were introduced primarily to increase the availability of hedgerow resources for wildlife (e.g. flowers for pollinating invertebrates, berries for overwintering birds and mammals; Natural England 2013b), but have the potential to also alter hedgerow structure and community composition (Staley et al. 2012).

Recent hedgerow cutting with a flail (in the preceding two years) has been shown to affect some groups of hedgerow plants compared to unmanaged hedgerows, potentially through changes to the structure resulting in altered shading and microclimate (Staley et al. 2013). Hedgerow height, width and variability in width, which can be altered by management, have been shown to relate to herbaceous plant richness in a survey in Flanders, Belgium (Deckers et al. 2004). Garbutt and Sparks (2002) resurveyed a species rich, ancient hedgerow in Eastern England with sections that were unmanaged and others that were cut annually and adjacent to an intensively managed arable field, and concluded that no management is not appropriate for maintaining hedgerow floral diversity. However, the studies discussed above were surveys of existing hedges, where the effects of management could co-vary with differences in soil, adjacent agricultural practice or landscape context. The effects of different regimes of hedgerow cutting, and specifically the frequency, timing and intensity of cutting, on hedgerow plant communities have not previously been experimentally tested.

The aim of this study was to test the effects of cutting regimes on hedgerow plant communities, including management under AES options (reduced frequency of cutting and cutting in late winter), the standard cutting management for hedges managed outside of AES (cutting once every year in the autumn) and potential, future hedgerow management options that could be incorporated into AES, including reduced intensity of cutting (cutting for incremental growth; Staley et al. 2016). Cutting treatments were applied to replicated sections of hedgerows (plots) at a multi-site, manipulative field experiment in lowland England for six years (Staley et al. 2018), prior to the hedgerow basal plant community being surveyed. The following null hypotheses were tested: (H_1) the frequency, timing and intensity of hedgerow cutting has no effect on the species richness of plants growing under hedges; (H_2) the frequency, timing and intensity of hedgerow cutting has no effect on cover-weighted attributes of plant species growing under hedges, specifically attributes relating to light and fertility (Ellenberg L and N respectively; Hill et al. 2004).

Methods

Experimental design and field sites

Experimental hedgerows on four sites were located on working farms across lowland, southern UK. Mature hedgerows dominated by hawthorn (*Crataegus monogyna*) were present at the Woburn site, Buckinghamshire (planted between 1793 and 1799: 51°580N, 0°370W), and a second site had a hedgerow dominated by mature blackthorn (*Prunus spinosa*) at Waddesdon Estate, Buckinghamshire (Waddesdon blackthorn: 51°500N, 0°530W). The other two sites both contained mixed species hedgerows, one planted under the previous Countryside Stewardship AES in the mid-1990s at the Waddesdon Estate, Buckinghamshire (Waddesdon mixed species: 51°500N, 0°560W) and the second a traditional mixed species hedge growing on a small bank in Yarcombe, Devon (planted 200–300 years ago: 50°510N, 3°030W).

Three experimental treatments were applied in full factorial combination: 1) frequency of cutting (once every 1 vs. 2 vs. 3 years); 2) timing of cutting (early autumn, September vs. late winter, January/February); and 3) intensity of cutting (standard vs. cutting for incremental growth). In cutting for incremental growth, the cutting bar of the flail was raised by approximately 10 cm each time the plot was cut, to leave about 10 cm of wood grown since the previous cut. In comparison, for the standard cutting treatment, hedges were cut at the same height and width each time. Treatments were applied to 20 m long contiguous hedgerow plots, replicated in three randomised blocks at each of the four sites. Hedge cutting treatments were applied using tractor mounted flails. These were operated by local contractors who regularly cut the hedges on each farm, to ensure that the cutting was representative of hedgerow cutting in the wider countryside. All experimental plots were cut prior to the start of the experiment in late winter (January/February 2010). Hedgerow cutting treatments were applied for 6 years from September 2010. The winter cutting treatments were not applied at the Waddesdon blackthorn field site, due to a shortage of suitable hedgerow. Total replication of each factorial combination of the three cutting treatments was thus 12 (for autumn cutting treatments) or 9 (for winter cutting treatments as these were not applied at Waddesdon blackthorn) across the four field sites.

Plant community data collection

Plant community data were collected from each side of each experimental hedgerow plot, with the exception of the Waddesdon blackthorn site and block 1 of the Waddesdon mixed species site, where access wasn't possible due to deep ditches. Two quadrats were marked out on each side of each plot, each 1 m wide × 10 m long, following an approach used previously to characterise hedgerow basal flora for a national survey (Carey et al. 2008). The inner quadrat started at the centre of the hedge and measured 1 m out from the centre in width, so on the wider hedgerows at the Yarcombe site (3-5m width) this sampled plant species growing under the hedgerow itself. At the other sites hedgerows were a more typical width ranging from 1.2–2.8m (Carey et al. 2008), so the inner quadrats included some plants growing in field margins adjacent to the hedgerow woody vegetation. The outer quadrat was immediately adjacent to the inner quadrat, so at all sites except for the wide hedges at Yarcombe, this sampled plant communities growing beside rather than under the hedge (Figure 1). Quadrats were placed approximately 5 m from the start of each hedgerow plot, to avoid edge effects in relation to the adjacent hedgerow cutting treatments. Vegetation cover was surveyed up to a height of 80 cm. Percentage cover of each herbaceous or woody higher plant species within the quadrat was assigned to the nearest 5% when cover was between 5 and 100%, and to the nearest 1% if cover was 1-4%. Species with <1% cover (e.g. a single seedling) were recorded as having a cover of 0.1%.

Data analysis

Species richness, cover-weighted average Ellenberg light (L) and fertility (N) attributes were calculated per quadrat. Ellenberg attribute values follow those in Hill et al. (2004). These three response variables were calculated both for all species recorded in each quadrat, and for the non-woody species only (defined as herbaceous in Hill et al., 2004). The effects of hedgerow management treatments were tested using generalised linear mixed-effect models (GLMMs) for species richness, with a Poisson error structure, and linear mixed effect models (LMERs) for the two Ellenberg attributes. A nested random term was used in each model to reflect the experimental design: Site/Block/Plot. Quadrat position (inner/outer; see Figure 1) was included as a fixed effect in each model, along with the management treatments: cutting time, cutting frequency and cutting intensity, and the two way interactions between each of the three management treatments. Non-significant interaction terms were removed from each model. All analyses were carried out in R (R Core Development Team 2019) version 3.5.3 using the lme4 (Bates et al. 2015) and LMERTest (Kuznetsova et al. 2017) packages. Following analyses, over-dispersion was tested for in the GLMMs (Faraway 2015). The R code used and output of final models is in the electronic supplementary material.

Results

One hundred and twenty-four plant species were recorded, of which 111 were non-woody species. Species richness, both of all plants surveyed and non-woody plants, was most strongly affected by the hedgerow type / site and quadrat position. No over-dispersion was detected in the GLMMs. On average, there were more than double the number of species per quadrat at the Waddesdon blackthorn dominated hedge compared with the more recently planted Waddesdon mixed species hedge on the same estate in Buckinghamshire, with species richness also high at the mixed species Yarcombe site in Devon (Table 1). Species richness was nearly double in outer quadrats compared with inner hedgerow quadrats which were placed more under the woody hedgerow foliage (Figure 1), both for all hedgerow plant species and the non-woody species (Table 1).

The hedgerow management treatments had smaller effects on species richness than site or quadrat position. Species richness was slightly greater for hedgerow plots cut to a standard height and width, compared to those cut to allow incremental growth, both for all plants and for non-woody species (Tables 2 and 3). In addition, just for the non-woody subset of plant species, there was an interaction between the intensity and timing of hedgerow cutting (Figure 2). Non-woody plant species richness was not affected by cutting intensity for hedgerow plots cut in late winter, but plots cut in autumn had on average one additional species if cut to a standard cutting intensity compared with cutting to allow incremental growth (Table 3; electronic supplementary material page 7).

The cover-weighted mean Ellenberg L attributes of all and non-woody plant species were also most strongly affected by hedgerow type / site and the quadrat position, though differences between sites were relatively small (Tables 1 and 3). Ellenberg L was smallest at the Yarcombe site, indicating a plant assemblage slightly more typical of shady conditions, and largest at the more recently planted Waddesdon mixed species hedge (Table 1). Ellenberg L was larger in outer quadrats compared with the inner hedgerow quadrats (Table 1), indicating an assemblage typical of less shady conditions in the outer quadrats, which at most sites were not directly under the woody hedgerow species. Ellenberg L average attribute for all plant species was slightly reduced on hedgerow plots cut in late winter rather than autumn, and was affected by an interaction between the timing and frequency of cutting (Tables 2 & 3). For hedges cut every year, the average Ellenberg L attribute was reduced for plant communities under hedges cut in late winter, compared to autumn. However, the effect of cutting timing was not apparent for hedgerows cut less frequently, once every three years. The Ellenberg L attribute for non-woody species followed a similar pattern in relation to hedgerow management treatments (Tables 2 and 3), though in both cases the differences between treatments were small.

The average Ellenberg N attributes also differed between hedgerow sites, with the highest value (indicating species more typical of fertile conditions) at the hawthorn-dominated Woburn site and the lowest at the mixed species hedge at Waddesdon. Ellenberg N was larger on average for plants in the inner quadrat, compared with those growing in the outer positioned quadrat (Tables 1 and 3). For non-woody species only there was an effect of cutting intensity; Ellenberg N was slightly increased for plants growing under hedgerow plots cut to allow incremental growth, compared with those cut to a standard height and width (Tables 2 and 3). The hedgerow management treatments did not have any significant effects on Ellenberg N when calculated for the entire assemblage of plant species, though the trend in relation to cutting treatments was similar to those found for non-woody species.

Discussion

The current experimental study shows that cutting regime management can affect hedgerow plant communities over a relatively short time scale of six years. The small effects of hedgerow cutting management shown here over six years are likely to increase with time, and have broad relevance for the majority of hedges in the UK that are managed through cutting with a flail, as well as hedgerows in some regions of other European countries.

Cutting in autumn to allow incremental growth reduced the number of herbaceous (non-woody) plant species by an average of one, compared to cutting hedgerows back to a standard height and width. This may be due to increased shading under the slightly larger and taller hedges cut to allow incremental growth. Fewer species were also found in the inner quadrats, which were more shaded than the outer quadrats. In addition, the plant community under hedges in the current study cut every year in winter had a slightly reduced Ellenberg L attribute compared to those cut in autumn, indicating that cutting in winter led to a more shade-tolerant assemblage of plant species. The Van Den Berge et al. (2019) survey of hedges in Belgium found an increase in plant species richness over forty years, with an increase in more light-demanding species, which they attribute partly to an increase in gaps within hedges, resulting in more edge habitat. In contrast, Litza and Diekmann (2017) found a reduction in species richness since the 1960s in German hedges, mainly due to the loss of forest herb species, linked primarily to eutrophication.

A previous survey of 357 hedgerow sites in Dorset (south-west UK) found hedges that had historically been coppiced or had no management had increased species richness (an average increase of 2.9 – 4.1 species) over a time scale of 70 years, while hedges that had been managed through hedge-laying had an increase in the richness of a subset of species that indicate high conservation value (Staley et al. 2013). Rejuvenation management methods such as coppicing or hedge-laying are now used for only a minority of hedges in the UK (Staley et al. 2015), while some of the hedgerow cutting treatments tested here such as cutting every one or two years in autumn are the most common methods of hedgerow management (Staley et al. 2016).

Non-woody plant communities growing in hedgerow bases were indicative of slightly more fertile conditions in plots cut to allow incremental growth in the current study, compared to those cut back to a standard height and width. The previous surveys discussed above have found an increase over time in hedgerow species typical of more fertile conditions, probably due to eutrophication (Litza and Diekmann 2017; Van Den Berge et al. 2019). In contrast, the cutting treatments in this study were applied to relatively short sections of hedgerow, which differ only in the hedgerow management treatment, and not in relation to broader agricultural practices within a site. Plant communities in the inner hedgerow quadrats were also more typical of fertile conditions than those in outer quadrats, though the difference in average Ellenberg N between both quadrat positions and management treatments were small (Table 1). The quadrat position effect may be due to the amount of woody hedgerow material being returned to the soil when hedges are cut with a flail, which is likely to be greater in inner quadrats that more directly under the woody hedgerow vegetation.

This study has demonstrated the value of experimental work to test the effects of cutting management on hedgerow plant communities, in addition to previously demonstrated effects of management on the provision of resources by hedgerows for other wildlife. Cutting to allow incremental growth has been shown to increase the abundance and diversity of Lepidoptera larvae (Staley et al. 2016), egg abundance of the Brown hairstreak butterfly (*Thecla betulae*, a priority conservation species; Staley et al. 2018), and the production of woody hedgerow flowers for pollinating insects and hedgerow berries for over-wintering wildlife (Staley et al. 2019). The current study shows a small reduction in the species richness of plants growing under hedges cut to allow incremental growth, and plant communities that are typical of slightly more fertile conditions, compared to those growing under hedges cut back to a standard height and width. While the effects shown are relatively small after six years of hedgerow cutting treatments, they are likely to increase over longer timescales. Restoration objectives for hedgerow plant communities include decreasing average fertility attributes and increasing species richness (Critchley et al. 2013). Our results suggest neither of these objectives may be attained through the use of reduced intensity cutting, in contrast to the positive effects of reduced intensity cutting found previously for invertebrate taxa and provision of resources for other wildlife.

Hedgerow management under AES therefore has the potential to affect the composition of plant assemblages growing in the hedgerow base. Balancing the responses of different taxa to hedgerow cutting effects will need to be considered in the development of future management, including hedgerow options funded under AES. To date, AES hedgerow management prescriptions have mainly been set at a national level. The varying responses to cutting regimes shown by hedgerow plants and invertebrates support the use of more local or regional management prescriptions, guided by the presence of priority species and other local conservation goals.

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Data Availability

Raw data from this study are available at https://doi.org/10.5285/cfeceb7e-b6b5-4f40-a1bc-c25f38deeb9f.

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Tables and figure

Legends

Figure 1: a) Layout of experimental hedgerow blocks and plots at the Waddesdon mixed species site. Factorial combinations of treatments manipulating the frequency (once every 1 vs. 2 vs. 3 years), timing (A = autumn, September vs. W = winter, January or February), and intensity (S = cut back to standard height and width vs. I = incremental growth, cut to allow 10 cm of recent growth to remain on sides and top) of hedgerow cutting were applied. Reproduced and modified from Staley et al. (2018), Figure 1, with permission of John Wiley and Sons. b) Example placement and dimensions of the four inner and outer quadrats (dashed grey outlines) used to survey hedgerow flora, on each side of an experimental hedgerow plots (solid grey outline). Width of the hedge varied with site and cutting treatments, so overhang of woody foliage into quadrats differed between hedgerow plots. Each of the quadrats surveyed in a hedgerow plot was 1m wide, 10m long and 0.8m tall.

Figure 2: Species richness (mean ± standard error) of non-woody plants per 10 × 1 m quadrat growing under hedges subject to management treatments: cutting intensity (standard vs. incremental); cutting timing (autumn vs. late winter); and cutting frequency (once every 1 vs 2 vs 3 years).

Table 1: Species richness (mean), Ellenberg L (mean ± standard error) and Ellenberg N (mean ± standard error) average attributes of all plant species and non-woody species per 10 × 1 m quadrat at four sites and in Inner position = quadrats placed from the middle of the hedge to 1

m from the hedge centre or Outer position = the 1 m adjacent to the inner quadrat (see Figure 1b).

Table 2: Species richness (mean), Ellenberg L (mean ± standard error) and Ellenberg N (mean ± standard error) average attributes of all plant species and non-woody species per 10 × 1 m quadrat under hedges subject to management treatments: cutting intensity (standard vs. incremental); cutting timing (autumn vs. late winter); and cutting frequency (once every 1 vs 2 vs 3 years).

Table 3: Mixed effects model outputs for all hedgerow management treatments, interactions between treatments retained in the final models, and quadrat position, on species richness (GLMM; Z statistics), cover-weighted average Ellenberg L and Ellenberg N attributes (LMER; t statistics), of all plants and non-woody plant species. P = probability of Z or t statistic.

Table 1

		Site				Quadrat position	
		Woburn	Waddesdon blackthorn	Waddesdon mixed species	Yarcombe	Inner	Outer
Species richness	All plant species	8.36	16.39	7.35	14.02	7.91	13.21
	Non-woody species	7.94	14.94	5.68	12.20	6.58	11.95
Ellenberg L	All plant species	6.30 ± 0.047	6.30 ± 0.082	6.57 ± 0.034	5.99 ± 0.053	5.97 ± 0.041	6.58 ± 0.023
	Non-woody species	6.32 ± 0.047	6.31 ± 0.083	6.70 ± 0.027	6.01 ± 0.056	6.04 ± 0.045	6.60 ± 0.023
Ellenberg N	All plant species	7.08 ± 0.027	6.83 ± 0.068	6.26 ± 0.067	6.86 ± 0.037	6.93 ± 0.033	6.60 ± 0.044
	Non-woody species	7.14 ± 0.029	6.88 ± 0.076	6.31 ± 0.071	6.93 ± 0.039	7.03 ± 0.034	6.62 ± 0.045

Table 2

Hedgerow	**Cutting intensity**	**Standard**						**Incremental growth**					
management	**Cutting timing**	**Autumn**			**Late Winter**			**Autumn**			**Late Winter**		
treatment	**Cutting frequency**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Species richness	All plant species	11.93	11.38	11.15	9.56	9.94	10.12	10.73	10.50	10.68	9.41	10.56	10.32
	Non-woody species	10.60	10.00	10.05	8.47	8.73	8.71	9.30	9.05	9.30	8.09	9.26	9.21
Ellenberg L	All plant species	6.29 ± 0.081	6.44 ± 0.069	6.30 ± 0.083	6.04 ± 0.14	6.43 ± 0.067	6.32 ± 0.11	6.22 ± 0.089	6.36 ± 0.091	6.16 ± 0.10	6.13 ± 0.11	6.27 ± 0.099	6.32 ± 0.090
	Non-woody species	6.33 ± 0.084	6.47 ± 0.067	6.33 ± 0.086	6.11 ± 0.14	6.46 ± 0.068	6.38 ± 0.12	6.27 ± 0.088	6.40 ± 0.094	6.22 ± 0.11	6.20 ± 0.13	6.29 ± 0.10	6.36 ± 0.10
Ellenberg N	All plant species	6.63 ± 0.010	6.70 ± 0.11	6.74 ± 0.092	6.78 ± 0.082	6.82 ± 0.12	6.87 ± 0.10	6.84 ± 0.090	6.79 ± 0.11	6.78 ± 0.095	6.74 ± 0.10	6.77 ± 0.086	6.80 ± 0.096
	Non-woody species	6.69 ± 0.11	6.74 ± 0.11	6.79 ± 0.097	6.82 ± 0.085	6.85 ± 0.12	6.93 ± 0.11	6.89 ± 0.093	6.85 ± 0.12	6.87 ± 0.10	6.80 ± 0.11	6.83 ± 0.091	6.86 ± 0.099

Table 3

	Species richness				**Ellenberg L**				**Ellenberg N**			
	All plants		**Non-woody**		**All plants**		**Non-woody**		**All plants**		**Non-woody**	
	Z	**P**	**Z**	**P**	**t**	**P**	**t**	**P**	**t**	**P**	**t**	**P**
Quadrat outer	16.9	< 0.001	18.23	< 0.001	16.58	<0.001	14.1	<0.001	-8.64	<0.001	-10.58	<0.001
Cutting intensity standard	1.98	0.048	2.48	0.013	1.29	0.2	1.1	0.27	-1.84	0.068	-2.1	0.038
Cutting timing late winter	0.82	0.41	1.25	0.21	-2.06	0.042	-1.8	0.074	-0.26	0.79	-0.38	0.7
Cutting frequency 2-year cycle	0.38	0.7	0.28	0.78	1.94	0.054	1.77	0.079	0.44	0.66	0.42	0.68
Cutting frequency 3-year cycle	0.31	0.76	0.46	0.65	-0.3	0.76	-0.28	0.78	0.94	0.35	1.17	0.24
Cutting intensity standard × cutting time late winter	-1.68	0.093	-2.04	0.042					1.88	0.064	1.9	0.061
Cutting timing × cutting frequency 2-year cycle					0.94	0.35	0.66	0.51				
Cutting timing × cutting frequency 3-year cycle					2.26	0.025	2.05	0.043				

Figure 1

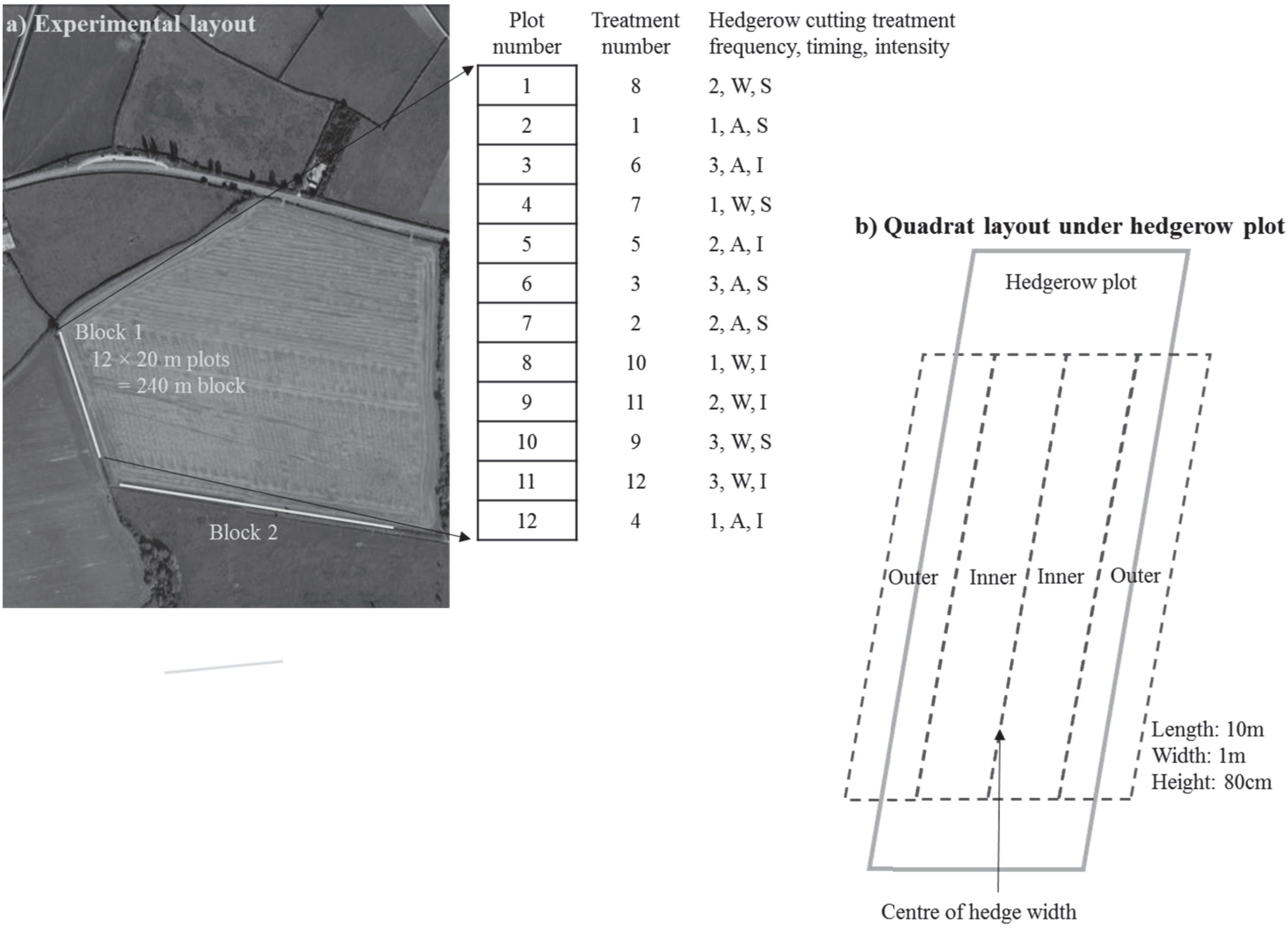

Figure 2