Establishment of clover-rich field margins as a forage resource for bumblebees *Bombus* spp. on Romney Marsh, Kent, England

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SUMMARY

Arable field margins were created by natural regeneration or sowing with a legume seed mixture in 2001 on farmland at Romney Marsh. Establishment of bumblebee *Bombus* spp. forage plant species was monitored using frame quadrats from 2001-2004. Natural regeneration margins produced low species richness of forage plants, with a sward dominated by creeping thistle *Cirsium arvense* or bristly ox-tongue *Picris echioides*, 'weed' species, which are unlikely to be favoured by the farmer or used extensively as forage plants by bumblebees. In the sown margins, the abundance of red clover *Trifolium pratense* and alsike clover *T.hybridum* was extremely high one year after margin establishment (almost 100% ground cover combined), but *T.hybridum* declined rapidly two to three years after sowing. The subsequent invasion of the clover-dominated margins by perennial grass species in 2003 and 2004, suggests that legume swards may need to be re-sown every three years due to the poor persistence of *Trifolium* spp.

BACKGROUND

During the last 20 years, there has been a rapid decline in the numbers of bumblebees *Bombus* spp. in the UK (Edwards & Williams 2004), the reasons for which are not fully understood. Three hypotheses have been suggested by Williams (1986, 1988, 1989): i) the specialisation of bumblebees to particular species of wild flower leading to localisation of bees to specific habitats where these plants persist; ii) the necessity to undertake sub-optimal foraging as a result of a reduction in habitat quality and habitat loss; and iii) agricultural improvement of land (artificial fertiliser input, spraying of biocides and conversion of species-rich pasture to arable or improved grassland). There is potential to introduce crops such as red clover *Trifolium pratense* or to establish clover-rich field margins under Government programmes such as Environmental Stewardship (an agri-environment scheme which provides funding to farmers and other land managers in England who deliver effective environmental management on their land). Such leguminous crops could potentially provide important forage sources for bees (Edwards & Williams 2004).

The genus *Trifolium* (Leguminosae) is one of the most important agricultural forage crops in northern Europe. *T.pratense* is considered a useful protein crop but little research has been conducted to examine its merits for nature conservation. It may also be an important component of semi-natural grassland, providing a rich nectar source for long-tongued bumblebee species. Of the major forage legumes grown, extensive agricultural research has been performed on white clover *Trifolium repens* and *T.pratense*. The wide adaptation

and genetic plasticity of *T.pratense* makes it one of the easiest legumes to establish. However, care must be taken during establishment to ensure success, and pollination strategy has to be considered; *T. pratense* has a complex self-incompatibility mechanism and requires long-tongued bumblebees as pollinators.

Initially, the management regime must be fairly robust. *T.pratense* does not respond well to multiple cutting or defoliation by grazing ruminants, is sensitive to timing and level of application of fertiliser, and has specific requirements concerning weed control. The intensity of management of single cultivar stands can therefore be high. However, management must not affect the overall requirements of invertebrates such as bumblebees and it could be envisaged that a management plan implemented for *T.pratense*-dominated swards for nature conservation could depend on low intensity agricultural systems (Ratcliffe & Thompson 1988). This approach would be a departure from normal agricultural production as fostered by a myriad of funding options during the 1980s and 1990s (Alcock 1992; Midmore *et al.* 1998).

This paper details the establishment of clover-rich field margins on farmland at Romney Marsh over a 4-year period, and reports data concerned with dynamics of forage plants suitable to assist the development of stable bumblebee populations.

ACTION

Study site: The experiment was established on arable farmland at Scotney Court Farm on Romney Marsh, Kent (OS grid ref: TQ 9920), southeast England. The soil at the study site is loamy clay which is relatively lime-rich with a high groundwater table. The climate is relatively dry with annual rainfall totalling <700 mm and an average annual temperature of approximately 11^{o}C.

Margin establishment: Two continuous margins (each 6 m wide) were established, both subdivided into three plots (which had different cutting regimes in the establishment year) for each of the two treatments: margins established using natural regeneration (control), or by sowing with a commercial legume-companion grass seed mix. The seed mix comprised: 23% meadow fescue *Festuca pratensis*, 13% sheep's fescue *Festuca ovina*, 10% crested dog's-tail *Cynosurus cristatus*, 10% chewings fescue *Festuca rubra* ssp. *commutatus*, 10% slender red fescue *F.rubra* spp. *littoralis*, 10% timothy *Phleum pratense*, 5% smooth meadow-grass *Poa pratensis*, 5% common bent *Agrostis capillaris*, 5% late flowering red clover *T.pratense*, 4% common vetch *Vicia sativa*, 2% alsike clover *Trifolium hybridum*, 2% birds-foot trefoil *Lotus corniculatus*, and 1% early flowering red clover *T.pratense*. The seed mixture was similar to the 'WM2 Pollen and Nectar mix' but was modified by the removal of yellow (lesser) trefoil *Trifolium dubium* and sainfoin *Onobrychis viciifolia* as they were deemed unsuitable for the soil type.

The sites were ploughed (previous crop winter wheat; stubble incorporated), rolled and the seedbed was left for flushing of ephemeral agricultural weeds. They were then recultivated and a fine seedbed prepared before sowing of the legume plots in early April 2001, at a rate of 10 kg/ha. The unsown natural regeneration plots were cultivated using the same methods as the legume plots.

Field margin management: Each of the two treatments had three different management regimes applied in the first year: cut three times, cuttings left; cut three times, cuttings removed; cut six times, cuttings left. Therefore there were six plots (for both treatments combined) for each margin and they were randomly allocated along each of the two continuous margins. In subsequent years after establishment (2002, 2003 and 2004), each plot was cut in late summer and the cuttings removed.

Bumblebee forage plants: The establishment and maintenance of bumblebee forage plants, especially clovers, was monitored using a 30 m transect which diagonally intersected each of the six plots on each of the two continuous margins. In early August 2001, 2002, 2003 and 2004, 30, 50 x 50 cm (0.25 m^2) frame quadrats were positioned centrally at 1 m intervals along each transect. The number of frame squares (25 squares in each quadrat, 1 square = 4% ground cover) covered by every forage plant in each quadrat was recorded. Where a forage plant only covered part of a square, this was counted as 1 square. It was possible to have greater than 100% ground cover in each quadrat due to overlapping sward layers. The same surveyor (TG) conducted the monitoring in each year.

Statistical analysis: All species richness and percentage cover data was square root

transformed before analysis to correct for non normality. Species richness data (mean number of species per quadrat), and mean percentage cover values (data averaged per quadrat) for *T. pratense*, *T. repens*, and two non sown weed species, creeping thistle *Cirsium arvense*, and bristly ox-tongue *Picris echioides*, were analysed using a 3-way ANOVA (data combined for replicates) with margin type (natural regeneration or sown legume mixture), cutting regime in the establishment year and year as the factors. These analyses allow the significant factors for forage plant cover/species richness to be established.

CONSEQUENCES

Species richness of bumblebee forage plant species: The legume-grass seed mix- sown margins had much higher species richness of bumblebee forage plants in all four years compared to those margins established by natural regeneration (Table 1). However, forage plant richness was not affected by the mowing regime in the establishment year. Species richness peaked in 2002 in both natural regeneration and legume mixture field margins, followed by a subsequent decline in 2003 and 2004 (Fig. 1).

Table 1. F values for 3-way ANOVAs conducted for forage plant richness and the percentage cover of four forage species for bumblebees.

Characteristic/plant species tested	**Factor** Margin type	Cutting regime	Year
Forage plant species	29.94*	0.04 NS	6.67*
Trifolium pratense cover	57.15*	0.05 NS	4.98**
Trifolium hybridum cover	34.24*	0.28 NS	5.48*
Cirsium arvense cover	2.18 NS	0.69 NS	5.18*
Picris echioides cover	33.38*	0.24 NS	9.37*

* sig P<0.01; ** sig P<0.05; NS = no significance

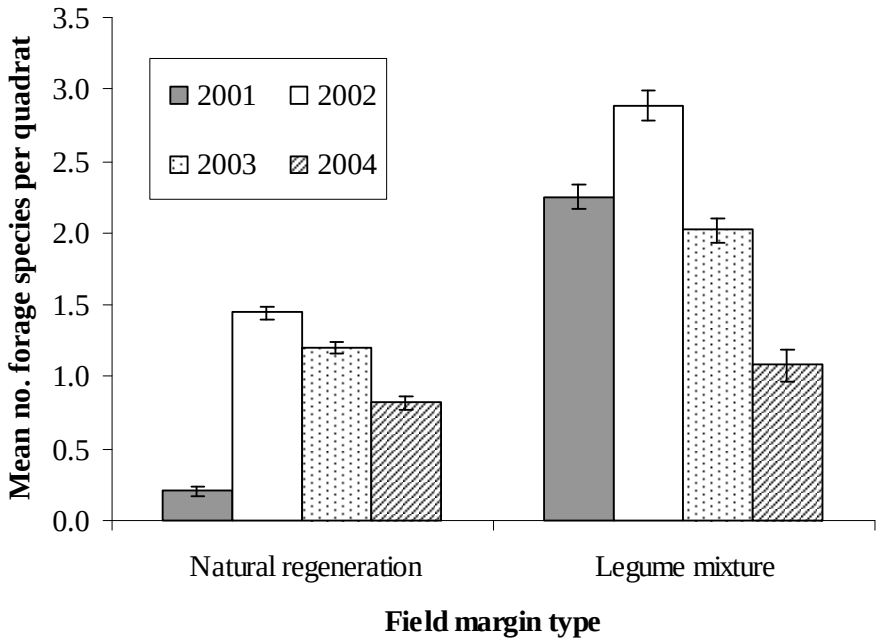

Figure 1. Mean number of bumblebee forage plant species per quadrat over the 4-year monitoring period (2001-2004) (standard error bars shown).

Ground cover of red clover and alsike clover: In the establishment year, there was very little ground cover of either clover species in the field margins (Fig. 2). However, in 2002, one year after establishment, both species combined formed almost 100% cover in the sown plots (Fig. 2; Table 2); their dominance however, allowed very few other forage species to co-exist. In comparison, the cover of both clovers was much lower in natural regeneration plots (Table 1). The abundance of both clover species was not affected by the mowing regime in the establishment year.

In 2003, the dominance of *T.pratense* seemed to increase at the expense of *T. hybridum*, which had much reduced cover in 2003 and 2004 (year significantly affected the cover of both clovers: Table 1). The reasons for this may be because *T. pratense* is more successful at competing for environmental resources, or that *T. hybridum* persists in the sward for only a short time period, after which it needs to be resown to regain substantial ground coverage. The authors also noticed in 2003 and 2004 that the legume margins contained more grass than in 2002 (Fig. 3), which may be a sign of the deterioration of the clover sward.

As expected, there was very little clover present on the natural regeneration plots (Table 2), with only scattered plants recorded. The clover seed was probably accidentally transported onto the natural regeneration plots by machinery. The non sown weeds, *C.arvense* and *P.echioides*, combined formed high ground cover in the natural regeneration plots (Table 2), particularly in 2002 and 2003 (margin type significantly affected the cover of *P.echioides* but not *C.arvense*: Table 1). These plots, which also had relatively low numbers of forage species (Fig. 1), are therefore unlikely to be beneficial to bumblebees in the surrounding agricultural landscape, or to farmers who do not want persistent agricultural weeds on their land. The ground cover of both weed species was low in the sown plots in all four years, which may be due to the dense cover of clover allowing little space for these species to establish. Mowing regime in the establishment year had no significant impact on the ground cover of either weed species (Table 1).

Conclusion and recommendations for field margin establishment: Results of this 4-year study indicate that those field margins left to regenerate naturally after initial preparation by ploughing and rolling, resulted in vegetation comprising almost entirely of persistent, common agricultural weeds, which are neither likely to be a good forage resource for bumblebees or welcomed by farmers. However, thistles which became established are of some value as a nectar-provider for ubiquitous bumblebee species such as red-tailed bumblebee *Bombus lapidarius* (Benton 2000). The seed bank at Scotney Court Farm would appear to be impoverished due to years of arable cropping and spraying with herbicides, this is a situation that is representative of most lowland arable land in England. Therefore in this context, naturally regenerating margins probably have very little value as a means of providing forage resource for bumblebees.

Table 2. Mean % cover of four bumblebee forage plant species on the field margins in 2002 (one year after establishment) (maximun cover in brackets).

	Plant species			
Treatment/mowing regime in 2001	*Trifolium hybridum**	*Trifolium pratense**	*Cirsium arvense*	*Picris echioides*
Natural regeneration				
3 cuts, cuttings left	0	0	10 (60)	49 (100)
3 cuts, cuttings removed	0	1 (8)	24 (96)	30 (80)
6 cuts, cuttings left	1 (20)	1 (68)	9 (80)	51 (100)
Legume mixture				
3 cuts, cuttings left	33 (92)	60 (100)	3 (20)	2 (24)
3 cuts, cuttings removed	31 (100)	58 (100)	1 (16)	4 (32)
6 cuts, cuttings left	34 (100)	70 (100)	6 (48)	1 (12)

* sown in legume mixture margins in 2001

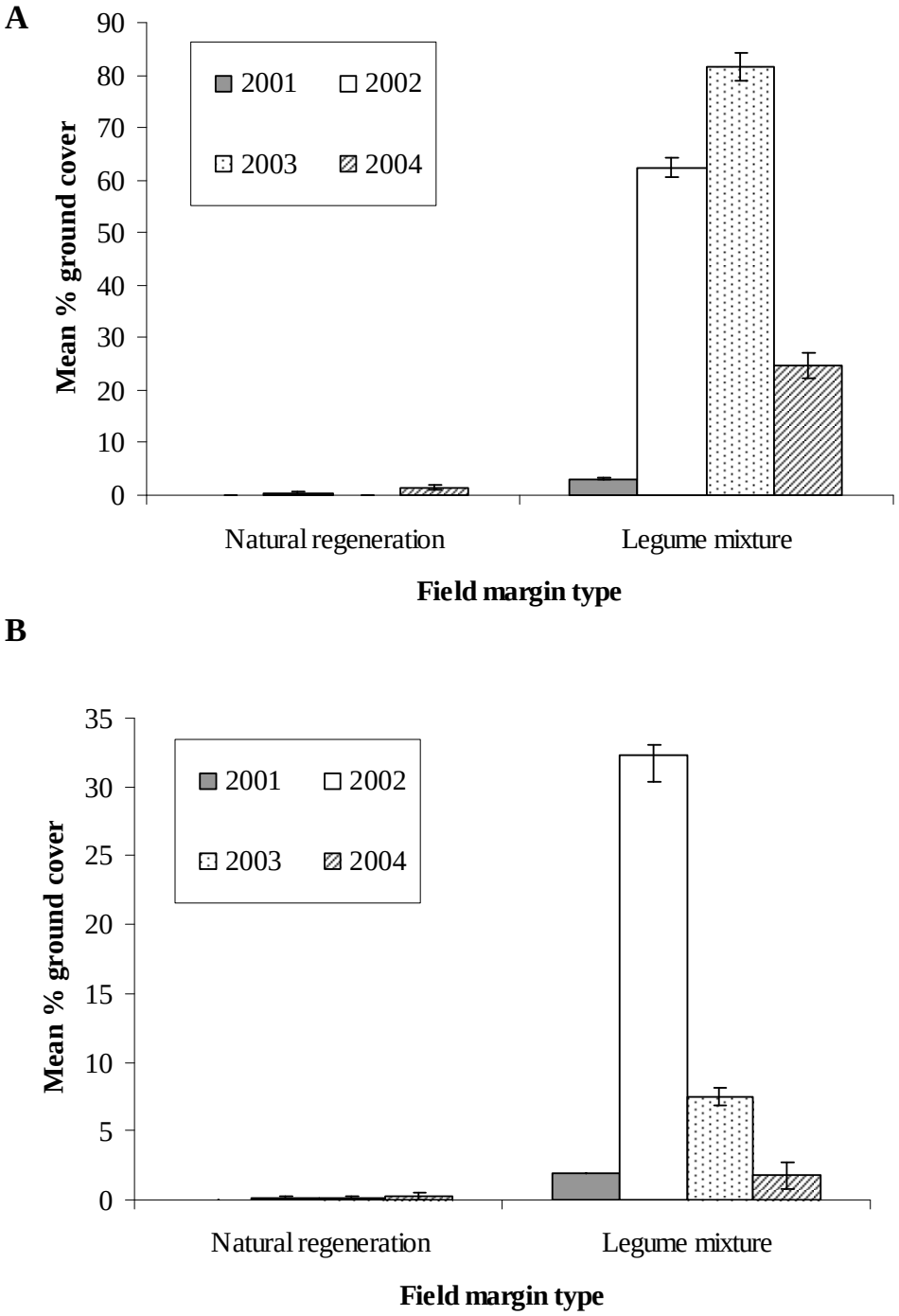

Figure 2. Mean percentage ground cover of red clover *Trifolium pratense* (A) and alsike clover *Trifolium hybridum* (B) over the 4-year monitoring period (2001-2004) (standard error bars shown).

Figure 3. A legume mixture-sown field margin in August 2002 (one year after sowing - note the dominance of clover - top) and August 2003 (two years after sowing - note the invasion by tall grasses - bottom).

The sown plots had almost 100% cover of *T.hybridum* and *T.pratense* in 2002 (one year after establishment), which would have provided a valuable forage resource for the local bumblebee population that includes the carder bumblebee *Bombus humilis*, an uncommon species in the UK now mostly found in southern England. Indeed, in a study of field margins on Romney Marsh, a 300-fold increase in bumblebee numbers was recorded on clover-rich margins (Edwards & Williams 2004). The dense clover cover also allowed very few agricultural weed species to become established, therefore providing adequate weed

suppression for the farmer. However, by 2003, *T.pratense* had become dominant in the legume margins, with *T.hybridum* much less common, indicating that the former species may out-compete it or that *T.hybridum*, a short-lived perennial, was dying back and was unable to persist through self-seeding under the prevailing dense sward conditions. This aspect of clover population dynamics needs further research.

The legume mixture plots were invaded by various nitrophilous, vigorous perennial grasses, such as false oat-grass *Arrhenatherum elatius*, in 2003 and 2004, and this could have contributed to the reduction in abundance and cover of bee forage species (Fig. 3). It may be that short-lived perennial clover species, such as *T.hybridum*, only persist for one or two years in the sward. Therefore, re-sowing of margins may have to occur on a fairly regular basis (perhaps every three years), which would make this option quite expensive. It may also be possible to establish field margins suitable for bumblebees by spreading clover-rich hay, this might be a more cost effective solution than buying expensive seed mixtures (Allcorn *et al.* 2006).

Each experimental treatment incorporated three different mowing regimes in the establishment year. However, the mowing regime had no significant impact on the cover of all forage species combined or that of either *Trifolium* species. This may have been due to the poor germination of many forage species in 2001 which meant that they did not attain sufficient growth (and therefore height) to be seriously defoliated by cutting. For example, in the August 2001 survey, most clover plants were < 10 cm in height and would have been under the cutting height of the mower (about 9 cm from the ground), therefore it is unlikely that mowing in the establishment year had much effect on the abundance of clovers in this experiment. Management of the margins one or two years after establishment when clover plants are much taller (30-50 cm height) is likely to be of more importance with a late cut (August/September) allowing most forage species to flower and set seed.

ACKNOWLEDGEMENTS

Thanks are extended to the farm manager at Scotney Court Farm, Simon Ashworth, for establishment and maintenance of the field margins over the three years. Thanks also to Natural England (formerly English Nature) for funding this study which formed part of a larger project on bumblebees on Romney Marsh.

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