Establishment and production of common sainfoin (*Onobrychis viciifolia* Scop.) in the UK. 1. Effects of sowing date and autumn management on establishment and yield

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Summary

The effects of sowing date and autumn management of sainfoin (*Onobrychis viciifolia* Scop.) were investigated over 3 years in the UK. Replicated plots were sown between April and September in 2003 and 2004. Autumn management treatments were early and late cutting carried out in the establishment year and in subsequent years. Dry matter (DM) yields were measured over 3 years. One harvest was taken from April to July sowings in the establishment year and three harvests in each of the following years. DM yields from sowings in April and May were 2·8 and 3·3 t DM ha^{-1}, respectively, in the establishment year, which were higher ($P < 0{\cdot}001$) than from sowings in June and July. Sowings from April to July yielded 10·9–12·5 t DM ha^{-1} in the first full-harvest year, and 9·5–11·5 t DM ha^{-1} in the following year. Sowings in August and September only gave 5 t DM ha^{-1} $year^{-1}$. Early-autumn cutting of an established sward reduced yields of sainfoin at the second harvest in the first and second full-harvest years. Sowing in May had the lowest proportion of weed species (0·06) in the establishment year, and sowing in July had the highest (0·53). Crude protein concentration increased as the seasons progressed from 149·8 to 230·1 g kg^{-1} DM.

Keywords: sainfoin, sowing date, autumn management, establishment, regrowth, yield

Introduction

Sainfoin (*O. viciifolia* Scop.) is grown in many parts of the world including western Asia, Europe, western USA and Canada (Miller and Hoveland, 1995; Frame *et al.*, 1998; FAO, 2006). In Europe, a decline in the area of sainfoin, along with other temperate legumes, has occurred. Rochon *et al.* (2004) concluded in a review that the general decline in the use of forage legumes in Europe was in part because of the expansion of grass production based on cheap inorganic nitrogen fertilizers since the early 1970s. Borreani *et al.* (2003) explained its decline in Italy as a result of agricultural structural changes and the gradual disappearance of livestock farms in hilly areas. In the UK, sainfoin was grown mainly on the limestone and chalk land of southern England and the low rainfall areas of East Anglia (Bland, 1971), although the area currently sown to sainfoin is small (Hill, 1997). It was grown for hay, with the aftermaths providing grazing for lambs, and it was often sown in a mixture with a non-aggressive companion grasses, such as meadow fescue (*Festuca pratensis*) or timothy (*Phleum pratense*), to suppress weed species (Bland, 1971; Sheldrick *et al.*, 1995; Frame *et al.*, 1998). The use of sainfoin in mixtures is described in the second paper in the series (Liu *et al.*, 2008).

Agronomic problems may be the main cause of decline in the area of sainfoin grown, because, compared with lucerne (*Medicago sativa*), sainfoin has lower yields and poorer persistence, lower amounts of nitrogen (N) fixation and, in particular, has lower rates of regrowth after a first cut (Doyle *et al.*, 1983; Frame *et al.*, 1998). Under experimental conditions, however, yields of sainfoin of 14–16 t DM ha^{-1} have been achieved (Sheehy *et al.*, 1984), which are comparable with other temperate legume crops in the UK.

Sainfoin has some nutritional advantages in comparison with other forage legumes, most notably due to the presence of condensed tannins in its leaves, which reduces the risk of bloat in ruminant livestock (Waghorn *et al.*, 1990; McMahon *et al.*, 1999). Condensed tannins have also been shown to limit proteolysis during ensiling (Albrecht and Muck, 1991; Salawu *et al.*, 1999) and to reduce nematode parasitism in sheep

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(Athanasiadou *et al.*, 2000). Feeding sainfoin to lambs has also been shown to provide equivalent levels of performance to feeding lucerne (Karnezos *et al.*, 1994).

In the context of UK agriculture, sainfoin may have the potential for increased use in the future based on its attributes of nitrogen (N) fixation and that it has several nutritional advantages, including preventing bloat in ruminants (Sheldrick *et al.*, 1995; Frame *et al.*, 1998). Its future use is limited by the lack of sound agronomic information. The traditionally accepted practice is that sainfoin should be sown between April and July (Bland, 1971; Sheldrick *et al.*, 1995) with some evidence that sowing in April and May gives better establishment than in June or July (Bland, 1971), possibly because June and July sowing may coincide with soil moisture deficits in dry years resulting in poor emergence. Sheldrick (2000) suggests that sowing of perennial legumes in late summer gives rise to fewer problems with weed ingression. Sainfoin exhibits a rapid growth in spring and produces about 0·70 of its annual yield at the first harvest but regrowth is slow relative to lucerne. Growth and regrowth in sainfoin depends on carbohydrates stored in the taproot and crown (Frame *et al.*, 1998). This emphasizes the importance of appropriate cutting intervals and autumn management. In the present study, it was hypothesized that the sowing date and timing of the autumn cut could be important for winter survival and the vigour of the following year's yield. The objectives of this study, therefore, were to investigate the optimum sowing dates and a strategy for autumn cutting management for sainfoin sown in monoculture.

Materials and methods

Site and treatments

The experimental site was located in Piggery Field, Coates Manor Farm (51° 42′N, 02° 01′W; 135 m asl) at the Royal Agricultural College, Cirencester, UK. The soil is a shallow, stony and well-drained clay loam, classified as Sherborne series (Findlay *et al.*, 1984; Conway, 2006). The soil depth was <30 cm overlying Jurassic limestone, and the stone content was 0·10–0·30. The soil pH was 7·5, and the phosphorus, potassium and magnesium contents in the soil were 49·1, 100·1 and 343·6 mg L^{-1} respectively.

The experiment had a split-plot design with three replicates. Six sowing dates (mid-April, mid-May, mid-June, mid-July, mid-August and mid-September) constituted the main treatments with treatment plots of 2 m × 4 m, and early-autumn and late-autumn cutting treatments as the sub-plots. The same treatments were imposed in two establishment years in 2003 and 2004. Measurements were made in 2 years following establishment as well as in the establishment year in 2003 and for 1 year following establishment as well as in the establishment year in 2004.

Establishment and management of swards

The previous sward of perennial ryegrass, red clover and white clover was sprayed with an application of glyphosate [N-(phosphonomethyl) glycine] (Roundup Gold; Monsanto, Cambridge, UK), and the site ploughed after 2 weeks. The area was power-harrowed before sowing. The seed rate of cv. Cotswold Common (Cotswold Seeds Ltd, Moreton-in-Marsh, UK) was 90 kg ha^{-1} of hulled seed, aiming to establish a target population of <150 plants m^{-1}. Germination rate of the seed was 0·88. Seeds were broadcast by hand and then raked into the soil to about 1·0 cm and rolled immediately.

Herbicide [MCPA + MCPB] (Bellmac Plus; United Phosphorus, Warrington, UK) was used to control broad-leaved weeds post-emergence when the first trifoliate leaf of sainfoin had emerged. Carbetamide (Carbetamex; Makhteshim Agan Ltd, Thatcham, UK) was used to control grass weeds and chickweed (*Stellaria media*) in the autumn of the establishment year and in December of each subsequent year. In accordance with the fertilizer recommendations for forage legumes of MAFF (2002), phosphorus was applied as 30 kg ha^{-1} P_2O_5 in August of the establishment year and 20 kg ha^{-1} P_2O_5 after the first harvest in the first and second full-harvest years. Potassium was applied as 30, 40 and 20 kg ha^{-1} K_2O after each harvest of each year.

Harvests and measurements

A 25 cm × 25 cm quadrat was used as the sampling unit to record plant populations, and two quadrats were recorded in each subplot. In the establishment years, the population of the April–July sowing was measured in August, and the August and September sowings in mid-October. In subsequent years, measurements of plant population were taken after the first harvest. One harvest was taken in the establishment year, and three harvests were taken in the subsequent first and second harvest years (Table 1). Before each harvest, measurements of herbage yield were made with two 50 cm × 50 cm quadrats placed at random in each plot. In the establishment year of 2003, the yield of weed species was measured in the establishment year but, in the establishment year of 2004, was not measured, as the presence of weed species was considered to be insignificant. Complete plot harvests were carried out immediately after sampling with a BCS 610 Power Scythe (Tracmaster Ltd, Burgess Hill, UK) with plants

Table 1 Harvesting dates in establishment years 2003 and 2004 and in subsequent first and second full-harvest years. The harvest dates for the early-autumn and late-autumn cutting treatments are also given.

Establishment year	Establishment year		First full-harvest year				Second full-harvest year			
	Harvest 1	Harvest 2	Harvest 1	Harvest 2	Harvest 3		Harvest 1	Harvest 2	Harvest 3	
					Early	Late			Early	Late
2003	12 August	30 September	30 May	19 July	16 September	1 November	29 May	3 July	12 Sept.	–
2004	–	16 September	29 May	13 July	12 September	–	–	–	–	–

cut at about 5 cm above the soil surface. Main plots were subdivided into 2 m × 2 m subplots in September for the autumn management treatments (early- vs. late-autumn cutting).

Laboratory analyses

Samples were brought directly into the laboratory to measure the yield of dry matter (DM) of herbage. Sainfoin plants and weeds were separated and then dried at 100°C for 24 h. After weighing the plant samples to determine DM yields, samples from the first subsequent harvest year following establishment in 2003 were ground using a mill (Glen Creston Ltd, Twickenham, UK) with a 0·75 mm screen and stored in sealed plastic bags before the determination of crude protein (CP) and neutral-detergent fibre (NDF) concentrations. CP concentration was determined by the Kjeldahl method and NDF concentration by the Fibre-Bag method, both of C. Gerhardt UK Ltd, Brackley, UK.

Statistical analysis

Data were analysed as a split-plot design with sowing dates as the main treatments and autumn cutting as subtreatments using GenStat 7 (Payne *et al.*, 2003). Multiple comparisons of treatment means were performed by applying the Fisher's least significant difference test when significance was found. Differences were determined at the $P \leq 0{\cdot}05$ level of significance.

Results

Meteorological data

Rainfall and temperature data were recorded during the experiment at the weather station of the Royal Agricultural College. Rainfall and average monthly temperatures in 2003–2005 are given in Table 2.

Table 2 Meteorological data at the site of the experiment, Cirencester, UK, in 2003–2005.

	Precipitation (mm)			Mean air temperature (°C)		
	2003	2004	2005	2003	2004	2005
January	72·6	99·4	33·5	4·4	5·1	4·6
February	24·8	32·1	22·8	3·2	4·9	3·7
March	30·6	65·5	71·8	6·8	6·5	6·8
April	46·5	76·6	54·7	9·6	9·5	9·3
May	58·5	57·5	45·3	12·4	13·3	11·9
June	69·4	43·2	36·3	16·2	16·6	15·8
July	80·8	47·1	32·3	17·3	17·2	17·0
August	10·2	114·0	34·5	19·6	17·6	17·0
September	12·5	48·8	36·0	15·0	15·2	14·7
October	43·2	135·1	90·2	8·9	10·6	12·2
November	10·4	37·7	70·1	7·8	7·5	5·9
December	84·2	52·1	67·9	5·0	4·7	3·7

Effects of sowing date

Sowing date had significant effects on DM yield (Table 3). Yields of DM in the establishment years varied between 0 and 4·63 t DM ha^{-1}. Sowing in May of the establishment year in 2003 produced the greatest annual DM yield, and sowings in April and May 2003 produced two cuts in the establishment year of 2003 but only one in the establishment year of 2004. Sowing in July gave a small yield in the establishment year of 2003 but none in the establishment year of 2004. Sowing in August and September produced no measurable DM yield in either establishment year.

Yield of DM peaked in the first full-harvest year (Table 3). There was no difference in the DM yield of the first full-harvest year from sowings between April and July, but DM yields from sowings in August and September were lower. The same pattern was found for sanfoin established in 2003 and 2004 (Table 4). There were no yield differences between sowings in April to August in the second harvest year. Overall, sainfoin cv. Cotswold Common produced substantial DM yields at the first cut in both the full-harvest years studied. First cuts accounted for 0·66 and 0·56 of the annual DM yields in the first and second full-harvest years respectively.

Table 3 Dry matter yield (t ha^{-1}) at successive harvests for April–September sowings in the establishment year of 2003 over three successive seasons.

	Establishment year			First full-harvest year				Second full-harvest year				
	Harvest			Harvest				Harvest				
Sowing date	**1**	**2**	**Annual**	**1**	**2**	**3**	**Annual**	**1**	**2**	**3**	**Annual**	**Mean**
April	1·43	2·22^{b}†	3·65^{b}	9·50^{a}	2·54^{a}	1·17^{a}	13·28^{a}	5·56	1·57^{ab}	2·85^{bc}	9·98^{abc}	8·93^{b}
May	1·20	3·43^{a}	4·63^{a}	9·62^{a}	2·69^{a}	1·28^{a}	13·58^{a}	6·42	1·61^{ab}	3·19^{a}	11·22^{ab}	9·83^{a}
June		1·98^{b}	1·98^{c}	8·58^{a}	2·57^{a}	1·08^{ab}	12·22^{a}	6·12	1·76^{a}	3·78^{a}	11·66^{ab}	8·60^{b}
July		0·78^{c}	0·78^{d}	9·06^{a}	2·56^{a}	1·16^{a}	12·79^{a}	5·98	1·48^{ab}	3·59^{a}	11·05^{ab}	8·48^{b}
August				3·42^{b}	2·21^{a}	0·86^{b}	6·49^{b}	5·25	1·40^{b}	2·75^{bc}	9·4^{bc}	5·30^{c}
September				2·23^{b}	1·78^{b}	1·16^{a}	5·17^{b}	5·37	1·28^{b}	2·43^{c}	9·08^{c}	4·78^{c}
Least significant difference ($P < 0·05$)	0·96	0·29	0·42	1·64	0·50	0·23	1·37	1·58	0·32	0·66	1·93	0·78

†Values in the same column followed by a different superscript letter are significantly different at $P = 0·05$.

Table 4 Dry matter yield (t ha^{-1}) of April–September sowings in the establishment year of 2004 over two seasons.

		First full-harvest year			
		Harvest			
Sowing date	**Establishment year**	**1**	**2**	**3**	**Total annual**
April	2·02^{a}	6·78^{a}†	2·13^{a}	1·65^{a}	10·55^{a}
May	2·01^{a}	5·76^{a}	1·78^{b}	1·04^{b}	8·58^{b}
June	0·97^{b}	5·80^{a}	1·68^{b}	1·10^{b}	8·58^{b}
July		5·24^{ab}	1·57^{bc}	1·37^{ab}	8·18^{b}
August		4·07^{b}	1·34^{c}	1·29^{b}	6·71^{c}
September			1·26^{c}	1·07^{b}	2·33^{d}
Least significant difference ($P < 0·05$)	0·95	1·67	0·31	0·33	1·30

†Values in the same column followed by a different superscript letter are significantly different at $P = 0·05$.

Effect of autumn cutting treatments

The results of the effects of early-autumn (16–30 September) vs. late-autumn (1 November) cutting on DM yield are given in Table 5. There was no significant effect of autumn cutting treatment on the swards established in 2004. There were, however, significant effects at the second harvest in the first and second harvest years of the sward established in 2003. The early-autumn cutting treatment reduced DM yields of the second harvests in both years. The late-autumn cutting treatment resulted in a lower annual DM yield than the early-cutting treatment in the first harvest year, which was attributed to loss of leaf on the late-autumn cutting treatment. However, the late-autumn cutting treatment produced more DM yield than the early-autumn cutting treatment in the second full-harvest year, as the third cut took place at the same time in the final year of the project.

Herbage quality

Table 6 summarizes the CP and NDF concentrations of herbage harvested at each of the three cuts in 2004 for the treatments established in 2003. There was an increase in the CP concentration of herbage as the season progressed. Neither the previous year's sowing date nor autumn management had any significant effect on CP concentration. Sowing date and autumn management also had no significant effect on NDF concentration. Regardless of the sowing date, NDF concentration was lower at harvest 2 compared with harvests 1 and 3.

Ingress of weed species in the establishment year

The proportion of weed species in the herbage harvested in the establishment year of 2003 was lower in

Table 5 Dry matter yield (t ha^{-1}) of early-autumn and late-autumn cutting treatments in establishment years of 2003 and 2004.

Establishment year	Full-harvest year	Early-autumn cutting treatment	Late-autumn cutting treatment	Least significant difference ($P < 0.05$)
2003		First		
	Harvest 1	7·20	6·96	0·60
	Harvest 2	2·31[b]†	2·47[a]	0·15
	Harvest 3	1·84[a]	0·30[b]	0·12
	Annual	11·35[a]	9·82[b]	0·78
		Second		
	Harvest 1	5·49	6·08	0·91
	Harvest 2	1·33[b]	1·70[a]	0·18
	Harvest 3	2·90	3·27	0·38
	Annual	9·72[b]	11·05[a]	1·12
2004		First		
	Harvest 1	5·48	5·59	1·06
	Harvest 2	1·62	1·64	0·18
	Harvest 3	1·19	1·32	0·19
	Annual	7·56	7·9	0·78

†Values in the same row followed by a different superscript letter are significantly different at $P = 0{\cdot}05$.

Table 6 Crude protein and neutral-detergent fibre concentrations (g kg DM^{-1}) of sainfoin from the harvests made in first harvest year of the establishment year of 2003.

	Crude protein concentration			Neutral-detergent fibre concentration		
	Harvest 1	Harvest 2	Harvest 3	Harvest 1	Harvest 2	Harvest 3
April	153·5	188·6	214·2	475·8[a]†	372·6[a]	422·8[ab]
May	159·5	191·1	232·2	480·4[a]	374·0[a]	427·1[ab]
June	153·2	186·9	218·3	487·5[a]	378·1[a]	436·3[a]
July	147·7	191·8	219·4	479·1[a]	346·0[b]	437·0[a]
August	148·8	187·2	232·2	440·7[b]	263·9[c]	416·8[ab]
September	150·7	189·2	225·8	434·8[b]	281·1[c]	407·1[b]
Least significant difference ($P < 0.05$)	16·5	5·04	31·7	22·6	15·22	24·3
		Least significant difference ($P < 0.05$)			Least significant difference ($P < 0.05$)	
Early-autumn cut	160·3	6·4		427·2	58·3	
Late-autumn cut	165·0			426·7		

†Values in the same column followed by a different superscript letter are significantly different at $P = 0{\cdot}05$.

the sowing in May (0·06) than in the April, June and July sowings, the July sowing having the greatest proportion of weed species (0·53) (Table 7). Weed species included groundsel (*Senecio vulgaris*), cleavers (*Galium aparine*), fat hen (*Chenopodium album*), common orache (*Atriplex patula*), red dead-nettle (*Lamium purpureum*) and annual sow-thistle (*Sonchus oleraceus*). There was a negative linear correlation between DM yields of sainfoin and weed species in the sward ($P = 0{\cdot}04$, $r^2 = 0{\cdot}74$) at the first cut in the establishment year of 2003.

Plant population

All sowings exhibited a substantial decline in the population of sainfoin plants over the experimental period (Table 8). Sowing date had significant effects on plant populations in all years. For the establishment year of 2003, the DM yield was negatively linearly correlated with the plant population in the first full-harvest year ($P = 0{\cdot}001$; $r^2 = 0{\cdot}82$). There was no such relationship evident in the second full-harvest year, nor for the plant population in the establishment year of 2004.

Table 7 Dry matter (DM) yield (t ha^{-1}) of sainfoin and weed species and the proportion of weed species in April–July sowings of the establishment year of 2003.

	DM yield		Proportion of weed species
	Sainfoin	Weed species	
April	$2{\cdot}22^{b}$†	$0{\cdot}82^{a}$	$0{\cdot}27^{b}$
May	$3{\cdot}43^{a}$	$0{\cdot}22^{b}$	$0{\cdot}06^{c}$
June	$1{\cdot}98^{b}$	$0{\cdot}56^{a}$	$0{\cdot}22^{bc}$
July	$0{\cdot}78^{c}$	$0{\cdot}88^{a}$	$0{\cdot}53^{a}$
Least significant difference ($P < 0{\cdot}05$)	0·29	0·54	0·19

†Values in the same column followed by a different superscript letter are significantly different at $P = 0{\cdot}05$.

Discussion

Sowing date had a significant effect on the DM yield of sainfoin (cv. Cotswold Common) under the conditions of the experiment. Sowings from April to July showed consistently higher DM yields than August and September sowings. Although no other published studies were found on the optimum sowing dates for sainfoin, the results of this study are in agreement with previous recommendations for sowing dates in England, i.e. between April and July (Bland, 1971; Spedding and Diekmahns, 1972). The sowing in April 2004 substantially outyielded all other sowing dates for that year. Bland (1971) also suggested that sowings in April and May may achieve better establishment than sowings in June and July. Furthermore, sowings in April and May are early enough to allow for two harvests to be taken in the establishment year, whereas sowings in June and July allow only one.

Yields of DM in the establishment years varied substantially with sowing date. The establishment year of 2003 achieved 0·78–4·63 t DM ha^{-1}. This was similar to the 4·7 t DM ha^{-1} obtained by Fychan and Jones (1997). In the establishment year of 2004, however, yields were much lower (0·97–2·02 t DM ha^{-1}) and were probably adversely affected by the particular weather conditions of that year (Table 2). The months of June and July in 2004 were much drier than in 2003, whereas August was very wet and, on an average, 2°C cooler. Yields of sainfoin measured over 3 years peaked in the first full-harvest year, similar to that found in an experiment carried out at the Grassland Research Institute, Hurley, UK, in 1956 (Spedding and Diekmahns, 1972). In the present experiment, the highest annual yields (12·22–13·58 t DM ha^{-1}) were obtained from sowings in April to July in the first full-harvest year (i.e. 2004) of the establishment year of 2003. Yields in the second full-harvest year declined, apart from the sowings in August and September, which actually increased. These results were similar to that reported by Spedding and Diekmahns (1972) in the UK, Goplen *et al.* (1991) in Canada and Cash *et al.* (1993) in the USA. The first full-harvest-year yields of the April to July sowings of the establishment year of 2004 were in the range of 8·18–10·55 t DM ha^{-1}, much lower than in the previous year, and are likely to be due to dry conditions in June that delayed emergence and encouraged ingress of weed species.

Autumn management of other perennial legumes that have similar morphology and growth habit to sainfoin (e.g. lucerne) should allow an adequate period at the end of the annual growing season for plants to

Table 8 Changes in populations of sainfoin plants (plants m^{-2}) over 3 years in swards established in 2003 and 2004.

	2003			2004	
	Establishment year	First full-harvest year	Second full-harvest year	Establishment year	First full-harvest year
April	$119{\cdot}7^{c}$†	$82{\cdot}7^{c}$	$74{\cdot}7^{c}$	$210{\cdot}7^{a}$	$106{\cdot}7^{b}$
May	$155{\cdot}7^{bc}$	$91{\cdot}0^{c}$	$90{\cdot}7^{abc}$	$122{\cdot}7^{b}$	$84{\cdot}0^{c}$
June	$142{\cdot}7^{bc}$	$87{\cdot}0^{c}$	$82{\cdot}0^{bc}$	$202{\cdot}7^{a}$	$92{\cdot}1^{bc}$
July	$129{\cdot}0^{bc}$	$109{\cdot}3^{c}$	$93{\cdot}0^{ab}$	$184{\cdot}0^{a}$	$128{\cdot}0^{ab}$
August	$198{\cdot}3^{ab}$	$146{\cdot}7^{b}$	$78{\cdot}7^{bc}$	$184{\cdot}0^{a}$	$162{\cdot}7^{a}$
September	$263{\cdot}7^{a}$	$240{\cdot}0^{a}$	$105{\cdot}7^{a}$	–	$93{\cdot}3^{bc}$
Least significant difference ($P < 0{\cdot}05$)	76·6	35·4	16·8	76·4	40·6

†Values in the same column followed by a different superscript letter are significantly different at $P = 0{\cdot}05$.

accumulate root reserves in the autumn (Jones, 1955; Bosworth, 2006). In this study, early-autumn (September) cutting in the establishment year increased DM yield in the first full-harvest year of the establishment year of 2003, although this was not the case for the establishment year of 2004 (Table 5). This was attributed to the reduced yield of the late-autumn cutting treatment taken in November 2003, when excessive loss of leaves resulted in a poor recovery of the plant material. The late-autumn cutting treatment significantly outyielded the early-autumn cutting treatment in the second full-harvest year, giving an additional 1·33 t DM ha^{-1} (Table 5). Similar findings have been reported from studies with lucerne; e.g. Jones (1955) showed that November cutting resulted in higher root weights and greater root diameters than the roots of plants cut in August and September, and that plants cut in September subsequently yielded less than those cut in August or October. The optimum timing of autumn cutting of sainfoin is clearly a topic that justifies further study, particularly as the effects of increases in ambient temperature may extend the length of the growing season and necessitate further changes in management practice.

Weed ingress was a significant feature of the experiment. The proportion of weed species in the DM of the sowings in April–July 2003 at the first cut of the establishment year varied from as little as 0·06 of the harvested herbage for the May-sown treatment to 0·53 in the case of the July-sown treatment. The proportion of weed species of the sowing in April (0·27) was similar to the value of 0·25 reported by Fychan and Jones (1997) for a sainfoin sward sown on 1 May 1997. A negative linear relationship between DM yield of sainfoin and weed species at the first harvest in the 2003 establishment emphasizes the importance of adequate control of broad-leaved weed species. Frame *et al.* (1998) noted that the practice of sowing sainfoin with a non-aggressive companion grass, such as meadow fescue (*F. pratensis*) or timothy (*P. pratense*), can reduce weed ingress; undersowing with spring barley may also achieve this.

In this study, a density of 120–264 plants m^{-2} was achieved from the monthly sowings in the establishment year of 2003 (Table 8). This had declined to 75–106 plants m^{-2} by the second full-harvest year. A population of 123–211 plants m^{-2} was achieved from the 2004 establishment, which was similar to the results of Fychan and Jones (1997). This declined to 84–163 plant m^{-2} in the following year. For the 2003 establishment, there was a negative linear correlation between DM yield and plant population. The sowings in August and September established large numbers of plants that were individually low yielding, and had a low winter survival rate. The sowings from April to July established lower plant populations compared with that in August and September, but they had a higher a winter survival rate and higher individual plant yields. On the other hand, there was no linear relationship between yield and plant population in the second full-harvest year, nor for the swards established in 2004 in their first full-harvest year.

Crude protein concentration of sainfoin herbage increased as the season progressed (Table 6) from 149·8 g kg^{-1} DM at the first cut to 230·1 g kg^{-1} DM at the third cut. This may be partly explained by the increased proportion of leaf in the herbage as the season progresses. Fagan and Rees (1930) reported proportions of leaf increasing from 0·43 on 26 May at the first growth, to 0·65 on 12 July, and to 0·90 on 11 August on sainfoin regrowths. NDF concentration of herbage also varied according to the growth stage of the crop. The herbage from the second harvest, and herbage from the August- and September-sown plots, had the lowest values. At the first harvest, when the early sown plots were in early flower, the August- and September-sown plots were still at the early bud stage. Autumn management did not affect CP or NDF concentrations of herbage.

Conclusions

Sowings from April to July gave similar yields of sainfoin of about 9·0 t DM ha^{-1}. The first full-harvest-year yields varied from 8·18–13·58 t DM ha^{-1}. The most reliable month for sowing appeared to be April, and August and September proved to be unsuitable sowing times, producing less herbage in subsequent years compared with April–July sowings. Early-autumn (September) cutting reduced the yield of second cuts in the following year. Late-autumn (November) cutting led to a reduced yield and an increase in NDF concentration because of leaf loss. Sowing dates between April and July had no effects on CP or NDF concentrations of herbage. Autumn management did not affect the CP or NDF concentrations of herbage in the following year.

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