Effect of Sowing Date and Defoliation Timing on Seed Production of Hairy Vetch, Crimson Clover and Serradella in New Zealand.

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ABSTRACT

Autumn-sown hairy vetch (*Vicia villosa* Roth.) responded favourably to spring defoliation under good growing conditions, producing large amounts of dry matter in early spring, but unfavourably under more stressful conditions. Spring sowings of hairy vetch produced seed yields similar to those from optimum combinations of autumn sowing date and spring defoliation treatment, which varied between years. Crimson clover (*Trifolium incarnatum* L.) and serradella (*Serradella* spp.) must be sown before May in order to establish well. Defoliation later than early September severely reduced crimson clover seed yield. Spring defoliation had no effect on serradella seed yield. The serradella cultivar Grasslands Koha established better and produced more seed than the cultivar Grasslands Spectra. Flooding was extremely detrimental to annual legume seed production, particularly when it occurred after defoliation.

***Additional index words:* *Ornithopus* spp, *Trifolium incarnatum*, *Vicia villosa*, establishment, vegetative growth, seed yield.**

INTRODUCTION

The annual legumes hairy vetch (*Vicia villosa* Roth.) and serradella (*Ornithopus* spp.) have potential for revegetating conservation sites and for planting in radiata pine forests in sand country in New Zealand. Crimson clover (*Trifolium incarnatum* L.) has a potential amenity and wild flower use (Douglas, 1993). AgResearch Grasslands has selected two cultivars of serradella, Grasslands Koha (*Ornithopus sativus* Brot.) and Grasslands Spectra (*O. sativus x O. compressus* L.), and one cultivar each of crimson clover and hairy vetch, for seed increase and release. Apart from the experience of growing small areas for nucleus seed production or agronomic evaluation, there have been no detailed field trials conducted on the seed production of these annual legumes in New Zealand.

Crimson clover needs to be sown six weeks before the first frosts in the USA to establish well and produce winter forage (Knight and Hollowell, 1973). Serradella sown in mid-April in the northern part of New Zealand produced only 3000 kg dry matter ha^{-1} by August (Taylor, Hughes and Hunt, 1979). In Australia, serradella must be sown early and well established before winter, otherwise it will grow very poorly (M. Bolland, pers. comm.). Hairy vetch, however, can be sown later in the autumn than the two other species, as it will germinate and establish at night temperatures as low as 5°C (Elkins, Hoveland and Donnelly, 1966). At temperatures above 21°C, hairy vetch germinates poorly. The first objective of this research was to examine the effects of time of autumn sowing on seed production of hairy vetch, crimson clover and serradella, and in particular, to see how late in the autumn the legumes could be sown and still establish successfully.

Many autumn-sown annual legumes can be grazed or harvested for forage in the late winter and spring, with the paddocks then being closed to produce seed. Early spring mowing of crimson clover had little effect on seed yields and was found to decrease lodging, delay flowering and reduce the bulk of vegetation at harvest (Knight and Hollowell, 1962; Rampton, 1969). However, mowing after flowering began severely reduced seed yields (Knight and Hollowell, 1962). Serradella makes very rapid spring growth, and considerable leaf senescence can occur in dense, uncut canopies (Taylor *et al.*, 1979). Serradella has very good regrowth ability, and early spring grazing before the first flowers appear in October (Taylor *et al.*, 1979) may reduce the bulk of vegetation at harvest, making processing easier, without decreasing seed yields. The second objective of this research was to examine the effects of early spring defoliation on the regrowth and subsequent seed yield of crimson clover, hairy vetch and serradella.

With many annual forage plants, sowing in the spring and harvesting seed at the end of the first summer is another option available to growers if autumn sowing conditions are not favourable (Hare and Rolston, 1989). Crimson clover requires vernalization before stem elongation and flowering will occur (Knight and Hollowell, 1973). Spring-sown crimson clover will grow well during the first summer but will not flower until the second. Hairy vetch will flower without vernalization (de Ruiter and Taylor, 1979), but flowering is considerably delayed and seed yields from spring-sown plants are often negligible, despite flowering (Douglas and Foote, 1985). However, when sown in very early spring, hairy vetch can produce seed by the following autumn (Douglas and Foote, unpubl. data). Serradella requires vernalization to flower profusely (de Ruiter and Taylor, 1979), even though

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flowering has occurred from early spring sowings (Fu, 1992). If sown early in the spring, both hairy vetch (Douglas and Foote, 1985) and serradella (M. Bolland, pers. comm.) may produce harvestable seed by the end of the first summer, but crimson clover will not (Knight and Hollowell, 1973). The third objective of this research was to examine the effects of time of spring sowing on seed production of hairy vetch and serradella.

MATERIALS AND METHODS

The trials were conducted from 1993 to 1995 at the AgResearch Grasslands Aorangi farm, Manawatu, North Island, New Zealand (40°S) on a weakly leached, slowly accumulating, poorly drained, recent gley soil developed from quartzo-feldspathic silty alluvium (Kairanga silt loam). Rainfall was recorded at a meteorological station approximately 1000 m from the trial sites. Each trial was conducted on a different site from the previous year's trial.

Autumn sowings

Crimson clover (Grasslands selection), hairy vetch (Grasslands selection) and serradella (two cultivars, Grasslands Koha and Grasslands Spectra) were sown in separate randomised blocks with three sowing dates, three weeks apart (26 March, 16 April and 7 May 1993; 29 March, 19 April and 10 May 1994), and with three (serradella 1993) or four (crimson clover and hairy vetch 1993 and all legumes 1994) replications. In the spring, main plots were split for defoliation to near ground level (1993: no defoliation, 8 September, 6 October; 1994 crimson clover and hairy vetch: no defoliation, 12 October, 2 November; 1994 serradella: no defoliation, 2 November, 23 November).

Each main plot measured 24 m x 3 m and was split into three 8 m x 3 m subplots for defoliation, except in 1994 for crimson clover and one replication of hairy vetch which were split into 1 m by 3 m subplots due to substantial stand loss from two episodes of flooding in spring 1994. The seed was drilled by an 'Aitchison Seedmatic' drill into well cultivated soil, in eight 30-cm-wide rows at 12 kg ha^{-1} for crimson clover (germination 85%), 13 kg ha^{-1} (1993) and 20 kg ha^{-1} (1994) for hairy vetch (germination 75%), 10 kg ha^{-1} for Serradella cv. Grasslands Koha (germination 80%) and 16 kg ha^{-1} for Serradella cv. Grasslands Spectra (germination 50%). Germination tests were performed prior to sowing in 1993. All seeds were innoculated with the appropriate *Rhizobium* spp.

During the winter the legumes were sprayed to control broadleaf weeds and grass : crimson clover with 2,4-DB (2.4 kg ai ha^{-1}) and haloxyfop (0.2 kg ai ha^{-1}), hairy vetch with 2,4-DB (1.6 kg ai ha^{-1}), haloxyfop (0.2 kg ai ha^{-1}) and bentazone (1.2 kg ai ha^{-1}), and serradella with linuron (0.5 kg ai ha^{-1}) and haloxyfop (0.2 kg ai ha^{-1}). On 19 November 1993 hairy vetch plots were sprayed with propiconazole (0.625 kg ai ha^{-1}) to control a disease (blackspot) caused by the fungus *Ovularia sphaeroidea*. No data were taken to evaluate the success of this treatment, and it was not repeated in 1994 because disease incidence was lower without spraying in 1994 than it had been with spraying in 1993.

Plants in six 1 m-long sections of row per plot were counted three weeks after sowing. At spring defoliation three 1 m-long sections of row were cut from each plot that was to be defoliated for dry matter analysis, and the remainder of the plot was cut to ground level with a rotary lawnmower. The defoliated vegetation was left on the plots in 1993 as it was finely cut, well mulched by the rotary lawnmower and did not cover remaining plants. Vegetation was cut with a sickle bar mower and removed by hand raking in 1994. Flowers were counted only on the crimson clover plots on 15 November 1993 (three 0.25 m^2 areas per plot). Seed harvesting of autumn-sown legumes varied according to species and year: crimson clover was harvested between 10 to 15 December 1993 and on 9 December 1994, hairy vetch between 9 to 24 February 1994 and on 3 February 1995, and serradella between 14 to 27 January 1994 and 25 January to 13 February 1995. At seed harvest of the first year's trials, six 0.25 m^2 areas of crimson clover, five 0.25m^2 areas of serradella and two 1m^2 areas of hairy vetch were cut by hand from each plot, placed in hessian bags and ambient air dried before threshing. In the second year, harvest areas were 0.9 m^2 for crimson clover and 1.0 m^2 for hairy vetch and serradella. After threshing, the seed was cleaned and 1000-seed weight (TSW) measured for hairy vetch and crimson clover seed (200 seeds per plot the first year, 400 seeds the second). All seed weights were corrected to 12% seed moisture content. Serradella seeds were not dehulled and so TSW was not determined.

Plant establishment data were analysed as randomised blocks and all other data were analysed as split plots. Treatments with no yield were omitted from the analysis of sowing date, defoliation timing, and cultivar main effects, but are presented in the interactions. Because the interactions were often significant, the sowing date x defoliation timing and cultivar x sowing date interactions are presented in all tables for consistency. Because of stand loss in part of one replication due to flooding, missing plot techniques were used to analyze the yield data for serradella sown in autumn 1994. All differences are reported at the $P < 0.05$ level of significance.

Spring sowings

Hairy vetch (Grasslands selection) and two cultivars of serradella (Grasslands Koha and Grasslands Spectra) were sown in separate randomised blocks with three sowing dates, three weeks apart in 1993 (1 September, 22 September and 13 October), and four weeks apart in 1994 (14 October, 14 November, and 14 December), with four replications in all cases except for serradella in 1993, (three replications). Plots measured 25 m by 3 m for hairy vetch and 10 m by 3 m for serradella in 1993 and 20 m x 3 m for both species in 1994. The seed was drilled into lightly cultivated soil which had been previously sprayed with glyphosate in August. Both species were sown in 30-cm-wide rows at rates of 20 kg ha^{-1} for hairy vetch, 10 kg ha^{-1} for Grasslands Koha and 16 kg ha^{-1} for Grasslands Spectra. To control broadleaf weeds, hairy vetch was sprayed with bentazone (in October, November and December 1993; in November and December 1994) and serradella with linuron (in November and December 1993; in December 1994).

Plants in six 1-m-long sections of row per plot in the first year, and five 1.2 m-long sections of row in the second year, were counted three to six weeks after sowing for hairy vetch and three to nine weeks after sowing for serradella. Seed was hand harvested from two 1 m^2 areas per plot between 15 February and 4 March 1994 for serradella and on 4 March 1994 for hairy vetch, and processed as for the autumn trials. In 1995, seed was hand harvested in March from one 1 m^2 area per plot for the first two sowings of hairy vetch only, as no seed was produced in the third sowing of hairy vetch and any of the serradella sowings. All data were analysed as randomised blocks with three sowing dates for hairy vetch, and three sowing dates x two cultivars for serradella.

RESULTS

Meteorological data

Autumn temperatures were near normal in both years, while temperatures in June were colder in the second year than the first, although still near normal (Table 1). Autumn rainfall was near normal in the first year, but was 26% below normal during March through April of 1994 (127.4, 95.8, and 130.1 mm for 1993, 1994, and the 20-year mean, respectively). Total spring rainfall was above normal in both years. However, the excess moisture that fell in November and December of 1993 (60% above normal) followed below normal rainfall for July through October. In the second year, above normal rainfall occurred in both September and November (77 and 208% above normal), and was followed by drier than normal conditions in December. Due to surface drainage patterns surrounding the test site in the second year, runoff from neighbouring fields from the 25-29 September and 14-15 November storms (66 and 82 mm total each storm) accumulated on the plots, with standing water up to 300 mm deep covering the plants for five days in both cases. Plot areas under water during these floods included all of the autumn-sown hairy vetch and crimson clover, and portions of one replication of the autumn-sown serradella. Spring sowings were located on higher ground and were not submerged, although the soil was badly crusted by the November storm which commenced immediately after sowing.

Autumn sowings - seedling establishment

Sowing in May 1993 significantly reduced establishment of crimson clover and serradella compared to sowing three or six weeks earlier (Table 2). May sowing of serradella resulted in a nearly complete stand failure. In 1994, plants from the April sowings of all three legumes generally established better than those sown three weeks earlier or three weeks later. However, in all cases plant populations from the March and April sowings were sufficient to produce satisfactory ground cover by the following spring. There were no differences in seedling numbers between the March and May sowings in 1994 for crimson clover, hairy vetch and serradella. However, plant numbers for crimson clover, hairy vetch and Grasslands Koha serradella from the May 1994 sowings were significantly lower than numbers from the April sowings. In both years Grasslands Koha serradella established better than Grasslands Spectra, producing an average of 56% more seedlings. This difference was most pronounced in the March sowing of the first year where Grasslands Koha produced more than twice as many plants as Grasslands Spectra (169 vs. 81 plants m^{-2}).

Autumn sowings - spring growth

The two years differed dramatically in patterns of early spring legume growth. In 1994, the first defoliation

Table 1. Monthly total rainfall and average 9 am 10-cm depth soil temperature for 1993, 1994 and 1995, and the 20-year means for the field site.

	Soil Temperature (°C)				Rainfall (mm)			
	20-yr mean	1993	1994	1995	20-yr mean	1993	1994	1995
January	17.3	16.1	18.4	18.2	63.4	55.6	30.8	51.4
February	16.8	15.9	18.7	18.4	57.0	40.4	13.0	56.0
March	15.1	14.4	14.7	16.5	63.2	68.6	50.6	178.0
April	12.0	11.4	12.5		61.9	58.8	45.2	
May	9.1	9.9	13.5		75.5	80.0	92.0	
June	7.1	8.9	7.5		88.3	131.2	110.6	
July	6.5	6.6	6.6		89.8	13.6	85.4	
August	7.6	7.2	8.3		81.3	53.0	75.0	
September	9.7	8.9	9.7		71.9	75.2	139.6	
October	11.7	11.9	12.0		76.8	59.4	75.2	
November	13.9	13.1	14.9		67.6	124.4	183.0	
December	16.0	15.6	17.6		80.4	81.8	38.6	
Total					877.1	842.0	939.0	

Table 2. Effect of date of autumn sowing on plant numbers three weeks after sowing of crimson clover, hairy vetch and serradella.

Crop and sowing date[1]	Year 1993 (no. plants m^{-2})	1994
Crimson clover		
March 26-29	156 a[2]	55 b
April 16-19	151 a	166 a
May 7-10	19 b	74 b
Hairy vetch		
March 26-29	22 a	20 ab
April 16-19	18 b	30 a
May 7-10	19 ab	9 b
Serradella sowing date effects		
March 26-29	125 a	42 b
April 16-19	94 a	66 a
May 7-10	3 b	38 b
Serradella cultivar effects[3]		
Grasslands Koha	133 a	60 a
Grasslands Spectra	86 b	38 b
Serradella sowing date x cultivar interaction		
G. Koha - March 26-29	169 a	57 ab
G. Koha - April 16-19	97 b	81 a
G. Koha - May 7-10	3 c	41 bc
G. Spectra - March 26-29	81 b	26 c
G. Spectra - April 16-19	90 b	51 bc
G. Spectra - May 7-10	3 c	36 bc

1 *Sowing dates were 26 March, 16 April, and 7 May in 1993, and 29 March, 19 April, and 10 May in 1994.*
2 *Means followed by the same letter do not differ at $P<0.05$.*
3 *Serradella cultivar main effects do not include data from May 1993 sowing stand failure.*

was delayed until 12 October for crimson clover and hairy vetch, and until 2 November for serradella, waiting for growth to approximately equal that seen by 8 September in 1993 (Table 3). Crimson clover sown in May failed to survive the winter in either year, and serradella sown in May 1993 also failed to survive. Hairy vetch sown in May 1993 did not produce harvestable growth by September, but unclipped plots grew well from October onwards and produced seed.

Legumes sown in March 1993 produced 1.7 to 3.0 times the amount of dry matter at spring defoliation (averaged over the two defoliation dates) compared with those sown three weeks later. In 1994, crimson clover and hairy vetch did not differ between March and April sowings in the amount of dry matter at spring defoliation, although serradella followed the pattern seen in the first year. Delaying spring defoliation by four weeks in 1993 increased dry matter production by 2.3, 3.7, and 2.5-fold for crimson clover, hairy vetch, and serradella, respectively. In 1994, a three week difference in defoliation timing produced no change in crimson clover dry matter, and only increased hairy vetch and serradella dry matter by 1.5 and 1.8-fold. At the late defoliation in 1993 (6 October), only the earliest-sown plots of crimson clover were starting to flower. In 1994, all crimson clover plants that had survived the September flooding had begun to flower by the early defoliation (12 October). In 1994, crimson clover grew very little after the September flood if unclipped, and none at all if clipped.

There was no difference between Grasslands Koha and Grasslands Spectra serradella in spring dry matter production in either year. Interactions occurred in spring dry matter production of serradella between autumn sowing date and spring defoliation timing in both years. In 1993, March sowing of serradella produced 1450 kg ha^{-1} more dry matter in September than April sowing, and 2670 kg ha^{-1} more in October. In 1994, March sowing produced 1560 kg ha^{-1} more serradella dry matter than May sowing at the earlier defoliation, and 2130 kg ha^{-1} more at the later defoliation.

Table 3. Effects of autumn sowing date and spring defoliation timing on crimson clover, hairy vetch and serradella dry matter at spring defoliation.

Sowing date and defoliation timing		Crimson clover		Hairy vetch		Serradella[3]	
		1993	1994	1993	1994	1993	1994
		(kg dry matter ha^{-1})					
Sowing date effects[1]							
March 26-29		5880 a[4]	2340 a	4950 a	3660 a	3080 a	2130 a
April 16-19		3360 b	2450 a	2240 b	3770 a	1020 b	1260 b
May 7-10		—	—	—	610 b	—	290 c
Defoliation timing effects[2]							
early		2830 a	2310 a	1540 b	2180 b	1160 b	860 b
late		6410 b	2480 a	5660 a	3180 a	2950 a	1590 a
Sowing date x defoliation timing interaction							
March	- early defoliation	4110 b	2320 a	2520 bc	3070 a	1880 b	1690 b
April	- early defoliation	1560 c	2300 a	560 c	3300 a	430 c	770 c
May	- early defoliation	—	—	—	160 b	—	130 d
March	- late defoliation	7640 a	2360 a	7380 a	4260 a	4280 a	2580 a
April	- late defoliation	5170 b	2590 a	3920 b	4240 a	1610 b	1750 b
May	- late defoliation	—	—	—	1050 b	—	440 cd

1 *Sowing dates were 26 March, 16 April, and 7 May in 1993, and 29 March, 19 April, and 10 May in 1994. For all species, May 1993 sowings were not clipped due to loss of stand over the winter.*

2 *Defoliation timing: 1993 early = 8 September; 1993 late = 6 October; 1994 early (crimson clover and hairy vetch) = 12 October, (serradella) = 2 November; 1994 late (crimson clover and hairy vetch) = 2 November, (serradella) = 23 November.*

3 *Because all serradella cultivar effects and cultivar x treatment interactions were nonsignificant, the data were averaged over the two cultivars.*

4 *Means followed by the same letter do not differ at P<0.05.*

Table 4. Effect of autumn sowing date and spring defoliation timing on flowering, seed yield and seed weight of crimson clover.

Sowing date and defoliation timing		Flowers (no.m^{-2}) 1993	Seed yield (kg ha^{-1}) 1993	Seed yield (kg ha^{-1}) 1994	1000-seed weight (g) 1993	1000-seed weight (g) 1994
Sowing date effects[1]						
March 26-29		373 a[3]	550 b	160 a	4.45 a	3.34 a
April 16-19		456 a	1440 a	150 a	4.35 a	3.00 b
May 7-10		0 b	0 c	0 b	—	—
Defoliation timing effects[2]						
no defoliation		605 a	1200 a	300 a	5.01 a	3.39 a
early		549 a	1340 a	4 b	4.15 ab	2.54 b
late		90 b	440 b	0 b	3.69 b	—
Sowing date x defoliation timing interaction						
March	- no defoliation	580 a	830 b	320 a	5.06 a	3.64 a
April	- no defoliation	629 a	1580 ab	290 a	4.97 a	3.21 a
May	- no defoliation	0 c	0 c	0 b	—	—
March	- early defoliation	512 a	830 b	2 b	3.82 c	2.46 b
April	- early defoliation	586 a	1860 a	5 b	4.47 b	2.58 b
May	- early defoliation	0 c	0 c	0 b	—	—
March	- late defoliation	26 bc	0 c	0 b	—	—
April	- late defoliation	154 b	890 ab	0 b	3.69 c	—
May	- late defoliation	0 c	0 c	0 b	—	—

1 *Sowing dates were 26 March, 16 April, and 7 May in 1993, and 29 March, 19 April, and 10 May in 1994. Data for late defoliation in 1994 not included in sowing date main effects because no seed was harvested.*

2 *Defoliation timing: 1993 early, late = 8 September, 6 October; 1994 early, late = 12 October, 2 November. Data for May sowings are not included in defoliation timing main effects because no seed was harvested either year.*

3 *Means followed by the same letter do not differ at P<0.05.*

Table 5. Effect of autumn sowing date and spring defoliation timing on herbage yield at seed harvest, seed yield and seed weight of hairy vetch

Sowing date and defoliation timing		Herbage yield[3] 1994	Seed yield (kg ha^{-1}) 1993	Seed yield (kg ha^{-1}) 1994	1000-seed weight (g) 1993	1000-seed weight (g) 1994
Sowing date effects[1]						
March 26-29		5640 a[4]	530 ab	1230 a	26.5 a	30.9 a
April 16-19		5910 a	660 a	1070 a	28.0 a	31.0 a
May 7-10		2420 b	390 b	320 b	27.4 a	29.1 a
Defoliation timing effects[2]						
no defoliation		6160 a	420 b	1300 a	27.0 a	30.8 a
early		3160 b	640 a	450 b	26.5 a	30.2 a
late		0 c	720 a	0 c	28.4 a	—
Sowing date x defoliation timing interaction						
March	- no defoliation	8000 a	330 de	2080 a	25.4 d	32.3 a
April	- no defoliation	8620 a	500 cd	1500 a	26.5 bcd	30.6 a
May	- no defoliation	1850 b	940 a	330 b	29.1 a	28.4 a
March	- early defoliation	3290 b	640 bc	380 b	26.0 cd	29.4 a
April	- early defoliation	3200 b	640 bc	640 b	27.9 abc	31.3 a
May	- early defoliation	2980 b	210 ef	320 b	25.2 d	29.5 a
March	- late defoliation	0 c	620 bc	0 c	28.2 ab	—
April	- late defoliation	0 c	830 ab	0 c	29.6 a	—
May	- late defoliation	0 c	0 f	0 c	—	—

1 *Sowing dates were 26 March, 16 April and 7 May in 1993, and 29 March, 19 April and 10 May in 1994. Data for late defoliation in 1994 are not included in sowing date main effects because no seed was harvested.*

2 *Defoliation timing: 1993 early, late = 8 September; 6 October; 1994 early, late =12 October, 2 November. Data for May sowings in 1993 are not included in defoliation timing main effects because no seed was harvested for the late defoliation.*

3 *Herbage yield at seed harvest was not recorded in 1993.*

4 *Means followed by the same letter do not differ at $P<0.05$.*

Autumn sowings - seed production

In 1993, crimson clover produced an average of 890 kg ha^{-1} more seed when sown in April than in March (Table 4). While the difference between sowing dates was most visually striking with late defoliation (890 vs. 0 kg ha^{-1}), the magnitude of the difference between sowings was relatively similar for the other defoliation treatments (difference between sowings equalled 750 and 1030 kg ha^{-1} for no defoliation and early defoliation). Both early and late defoliation reduced crimson clover seed weight, and late defoliation also greatly reduced flowering. Yields in 1994 were much lower than in 1993 because of injury from the flooding, averaging only 25% of the first year's yield in unclipped plots and less than 1% when defoliated. Seed weights in 1994 were lower than in 1993, and were reduced further by defoliation.

Hairy vetch seed yields were increased by spring defoliation in 1993 and decreased by it in 1994 (Table 5). The two years differed dramatically in early spring growth by the hairy vetch, with March sowings producing 7380 kg ha^{-1} of dry matter by 6 October in 1993 but only 3070 kg ha^{-1} by 12 October in 1994 (Table 3). The highest yielding treatment in 1993 was the undefoliated May sowing, while the second highest was the late defoliation of the April sowing (Table 5). These two treatments also produced the heaviest seed. In 1994, undefoliated March and April sowings produced the most seed, averaging 1370 kg ha^{-1} more than the undefoliated May sowing and the early defoliation of all three sowings. Plants in the late defoliated plots had only regrown approximately 100 mm when flooded 12 days later in the mid-November storm, and suffered 100% mortality. The larger plants in the undefoliated and early-defoliated plots suffered less than 50% mortality from the same flood. The fungal disease blackspot *(Ovularia sphaeroidea)* treated with propiconazole in 1993 was observed again in 1994. However, it progressed more slowly in 1994 and was not treated with fungicide.

Seed yield of Grasslands Koha serradella exceeded that of Grasslands Spectra by an average of 24% in 1993 and 59% in 1994, with a similar margin between cultivars for total dry matter at harvest in 1994 (Table 6). Total dry matter at seed harvest was not measured in 1993. May sowing produced no seed in the first year, and only 410 kg ha^{-1} in the second. March and April sowings did not differ in 1993, but March sowing outyielded April sowing by 49% in 1994, with the difference in yield between these sowing dates being significant for Grasslands Spectra but not Grasslands Koha. Defoliation timing had no effect on seed yield in either year. The seed yield advantage of Grasslands Koha over Grasslands Spectra in 1994 was less with March sowing (240 kg ha^{-1}, not significant) than with either April or May sowing (1120 and 740 kg ha^{-1}).

Table 6. **Effect of cultivar, autumn sowing date and spring defoliation timing on herbage yield at seed harvest and seed yield of serradella.**

Cultivar, sowing date and defoliation timing	Herbage yield[3] (kg ha^{-1}) 1994	Seed yield 1993	Seed yield 1994
Cultivar effects			
Grasslands Koha	4840 a[4]	1450 a	1880 a
Grasslands Spectra	3020 b	1170 b	1190 b
Sowing date effects[1]			
March 26-29	6460 a	1250 a	2510 a
April 16-19	4340 b	1170 a	1680 b
May 7-10	990 c	0 b	410 c
Defoliation timing effects[2]			
no defoliation	3850 ab	1270 a	1530 a
early	3490 b	1440 a	1480 a
late	4450 a	1220 a	1600 a
Cultivar x sowing date interaction			
G. Koha - March	6970 a	1380 ab	2630 a
G. Koha - April	5700 a	1520 a	2240 a
G. Koha - May	1860 bc	0 c	780 bc
G. Spectra - March	5960 a	1120 b	2390 a
G. Spectra - April	2980 b	1220 ab	1120 b
G. Spectra - May	110 c	0 c	40 c

1 *Sowing dates were 26 March, 16 April and 7 May in 1993, and 29 March, 19 April and 10 May in 1994.*
2 *Defoliation timing: 1993 early, late = 8 September, 6 October; 1994 early, late =2 November, 23 November. Data for May 1993 sowings are not included in cultivar or defoliation timing main effects because no seed was harvested. All defoliation timing interactions were nonsignificant.*
3 *Herbage yield at seed harvest was not recorded in 1993.*
4 *Means followed by the same letter do not differ at P<0.05.*

Table 7. **Effect of spring sowing date on plant number, seed yield and seed weight of hairy vetch.**

Sowing date effects[1]	Plant numbers (no. m^{-2}) 1993	Plant numbers (no. m^{-2}) 1994	Seed yield (kg ha^{-1}) 1993	Seed yield (kg ha^{-1}) 1994	1000-seed weight (g) 1993	1000-seed weight (g) 1994
Early sowing	34.7 a[2]	35.8 a	980 a	1940 a	27.2 a	26.0 a
Mid-sowing	36.3 a	18.6 b	990 a	1350 a	26.8 a	25.4 a
Late sowing	28.9 a	32.6 a	900 a	0 b	27.1 a	—

1 *Sowing dates were 1 September, 22 September and 13 October in 1993, and 14 October, 14 November and 14 December in 1994.*
2 *Means followed by the same letter do not differ at P<0.05.*

Spring sowings - seedling establishment

Time of spring sowing did not affect the establishment of hairy vetch in 1993, but stands were poorest for the 14 November sowing in 1994 because of severe crusting of the soil from heavy rainfall just after sowing (Table 7). Serradella establishment was improved by delayed sowing in both years (Table 8). In 1993, serradella plant numbers increased as sowing was delayed from 1 September to 22 September, while in 1994 emergence was poor until the final sowing date, 14 December. Grasslands Koha serradella produced 2.5-times as many plants as Grasslands Spectra at the earliest sowing in 1993 and 3.8-times as many at the latest sowing in 1994. However, Grasslands Koha experienced a total stand failure at the 14 November 1994 sowing, with only 1.0 plant m^{-2} successfully emerging through the crusted soil. The cultivars did not differ significantly for the other sowings.

Table 8. Effect of cultivar and spring sowing date on plant number, seed yield and seed weight of serradella.

Cultivar and sowing date	Plant numbers (no. m^{-2}) 1993	1994	Seed yield (kg ha^{-1}) 1993	1994
Cultivar effects				
Grasslands Koha	54.2 a[2]	31.6 a	1880 a	0 a
Grasslands Spectra	45.5 a	17.6 b	1400 b	0 a
Sowing date effects[1]				
Early sowing	38.7 b	17.6 b	1940 a	0 a
Mid-sowing	59.8 a	7.6 b	1890 a	0 a
Late sowing	51.1 ab	49.0 a	1090 b	0 a
Cultivar x sowing date interaction				
G. Koha - early sowing	55.0 a	17.2 bc	2420 a	0 a
G. Koha - mid-sowing	60.7 a	1.0 c	1840 ab	0 a
G. Koha - late sowing	46.8 a	77.4 a	1370 bc	0 a
G. Spectra - early sowing	22.4 b	18.1 b	1450 b	0 a
G. Spectra - mid-sowing	58.9 a	14.2 bc	1940 ab	0 a
G. Spectra - late sowing	55.2 a	20.6 b	810 c	0 a

1 *Sowing dates were 1 September, 22 September and 13 October in 1993, and 14 October, 14 November and 14 December in 1994.*
2 *Means followed by the same letter do not differ at $P<0.05$.*

Spring sowings - seed production

Time of spring sowing had no effect on hairy vetch seed yields and seed weight with the exception of the 14 December sowing in 1994, which failed to produce seed before the arrival of autumn rains in 1995 (Table 7). Sowing date did affect serradella seed yields in 1993, with the two September sowings outyielding the October sowing by an average of 820 kg ha^{-1}. Grasslands Koha serradella produced an average of 34% more seed than Grasslands Spectra in 1993, with most of the advantage occurring at the earliest sowing. All spring sowings of serradella in 1994 were apparently too late to vernalize, as the plants only sparsely flowered and produced no harvestable seed before arrival of cool, wet autumn weather, (Table 8).

DISCUSSION

Crimson clover and serradella were far more sensitive than hairy vetch in establishing at soil temperatures below 10°C (May and early September, 1993) and at low soil moisture content (autumn 1994). Crimson clover and serradella sown in May 1993 failed to persist into the spring, whereas hairy vetch not only survived but, when undefoliated, produced more seed than from the earlier sowings (Table 5). However, hairy vetch sown in May 1993 produced less seed than the earlier sowings when defoliated, and none at all with late defoliation. These plots behaved more like spring-sown hairy vetch in that they only started to grow in October, were fairly sparse, and did not exhibit any signs of disease. The study confirms the findings of Elkins *et al.* (1966) who showed that hairy vetch will establish at low temperatures (down to 5°C) and the observations of Bolland (pers. comm.) who reports from Western Australia that serradella must be well established before winter, otherwise it will grow poorly.

The successful seed production of spring-sown hairy vetch, where yields sometimes exceeded those of autumn sowings, makes the option of spring sowing attractive in this species. In the more stressful growing conditions of spring 1994, seed yields of undefoliated March and April sowings exceeded those of October and November sowings by an average of only 140 kg ha^{-1}. Under the more favourable growing conditions of 1993, spring sowings averaged 230 kg ha^{-1} more seed than the best treatment for the March and April sowings, i.e., late defoliation, and an average of 490 kg ha^{-1} more than the poorer treatments, i.e., early or no defoliation. The large bulk of dry matter produced from March and April sowings in 1993 was a disadvantage in that a fungal pathogen (*Ovularia sphaeroidea*) spread throughout the herbage and fewer seeds were produced. No fungal disease was observed on spring-sown hairy vetch. Slower disease progression in 1994 than in 1993 was probably a result of the more open canopy associated with less hairy vetch dry matter production at the same calender date in 1994 compared to 1993. Indeed, we defoliated hairly vetch about one month later in 1994 than in 1993, waiting for the accumulation of approximately similar amounts of dry matter. In Italy, lower density sowings of hairy vetch, (70 seeds m^{-2}), have produced more seed than higher density sowings, (100 seeds m^{-2}) (Martiniello and Ciola, 1993). Our hairy vetch sowing rate of 20 kg ha^{-1} corresponded to their lower sowing rate. Clipping in September is a useful management practice for autumn-sown hairy vetch that is growing vigorously. However, if growth is limited by late sowing or adverse weather, clipping may reduce seed yield.

Spring sowings of serradella were successful in 1993 but not 1994. In the first year, the spring sowings averaged 330 kg ha^{-1} more seed than the March and April sowings. None of the spring sowings of serradella produced seed in 1994, despite the similarity in calendar date between the earliest sowing in 1994 (14 October) and the latest sowing in 1993 (13 October).

If autumn sowings encounter favourable growing conditions, the large bulk of vegetation produced during early spring can be removed without reducing seed yields of hairy vetch and serradella. While we used clipping to remove this vegetation, rapid grazing at an appropriate stocking rate would probably give similar results, as long as the soils were not too wet and compaction was avoided. Removal of vegetation can be safely conducted later in the spring with serradella than with hairy vetch. Indeed, serradella requires warmer weather for rapid vegetative growth than hairy vetch, naturally leading to later grazing or clipping dates. The amount of dry matter produced by September by the annual legumes was impressive in 1993 but not in 1994. Under growing conditions in which large amounts of forage are produced, spring grazing followed by closing for seed is an attractive management option.

Seed yield of crimson clover, however, was severely affected by spring defoliation, particularly those plants sown earliest and defoliated in October. Knight and Hollowell (1962) also found that mowing after flowering severely reduced crimson clover seed yields. Martinello and Ciola (1993) found that hairy vetch and crimson clover did not regrow following cutting in early spring (crimson clover) and late spring (hairy vetch). Both legumes were cut when 5 to 10% of the plants were flowering. Defoliation after the start of flowering has decreased yields in many other legumes (*Lotus uliginosus* Schkuhr., Hare, 1985; *L. corniculatus* L., Anderson and Metcalfe, 1957; *Medicago sativa* L., Kowithayakorn and Hill, 1982; *Trifolium subterraneum* L., Rossiter, 1961; *T. pratense* L., Dade, 1966; and *T. ambiguum* M. Bieb., Steiner, 1992). Crimson clover is extremely sensitive to stress during early spring growth, and should neither be planted in areas subject to flooding nor defoliated later than early September.

Grasslands Koha serradella produced significantly more seed than Grasslands Spectra, both from autumn and spring sowings. Grasslands Spectra serradella is a cross between pink and yellow serradella *(Ornithopus sativus x compressus)* and Grasslands Koha is a pink (or French) serradella *(O. sativus)*. Grasslands Spectra has far more hardseededness than Grasslands Koha, but this was taken into account when sowing, in that the sowing rate of Grasslands Spectra was 60% higher than for Grasslands Koha. Even though Grasslands Koha established better than Grasslands Spectra when autumn-sown, there was no difference between the two cultivars in dry matter production at spring defoliation. However, there was a difference in dry matter between the cultivars at seed harvest in 1994, which correlated with the difference in seed yield, indicating that Grasslands Koha is more vigorous than Grasslands Spectra in growth from November through January.

CONCLUSIONS

Hairy vetch can reliably produce seed from both spring and autumn sowings, whereas spring-sown serradella requires early sowing and good growing conditions to produce seed. Crimson clover and serradella establish very poorly when sown at soil temperatures below 10°C or at low soil moistures. Hairy vetch establishes better than the other legumes under such conditions. Hairy vetch can be defoliated in early spring and serradella in later spring without decreasing seed yield. Indeed, hairy vetch seed yield may be increased by spring defoliation when excessive vegetation is present. Crimson clover seed yields are reduced if plants are cut in October, particularly those which are starting to flower. Standing water is extremely detrimental to annual legumes, particularly after defoliation.

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