The impact of underseeding forage mixtures on barley grain production in northern North America

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Spaner, D. and Todd, A. G. 2003. **The impact of underseeding forage mixtures on barley grain production in northern North America**. Can. J. Plant Sci. **83**: 351–355. Livestock farmers in Newfoundland grow most of their required forage, yet must import most feed grain. Growing barley (*Hordeum vulgare* L.) in the year of forage establishment may allow for the incorporation of grain production into local cropping schemes. We examined the effect of barley grain production over an establishing timothy (*Phleum pratense* L.)-clover (*Trifolium pratense* L.; *T. hybridum* L.) forage sward in a 4-yr study near St. John's. The experiment compared two barley varieties (differing in plant height), three barley seeding rates and the effect of a forage under-story on grain production in the establishment year, and forage production in the subsequent year. Increasing barley seeding rate from 125 to 375 plants m^{-2} resulted in a linear increase in spikes m^{-2}, which led to a linear increase in barley yield. Pure-stand grain yields did not differ from those undersown to forage mixtures. The production of barley grain in the establishment year did not alter forage yield in the subsequent year (at any barley seeding rate or cultivar archetype). The barley crop did alter forage species composition in that higher seeding rates resulted in 15% less timothy in the forage production year. Barley undersown at a rate of 375 seeds m^{-2} with a timothy-clover mixture can be produced successfully in Newfoundland.

Key words: *Hordeum vulgare* L., alsike clover, red clover, underseeding, companion planting, Newfoundland

Spaner, D. et Todd, A. G. 2003. **Semis sous couverture d'un mélange fourrager et incidence sur la production d'orge dans le nord de l'Amérique du Nord**. Can. J. Plant Sci. **83**: 351–355. Les éleveurs de Terre-Neuve cultivent presque tous les fourrages dont ils ont besoin. Néanmoins, ils doivent importer la majeure partie de leurs céréales fourragères. En cultivant l'orge (*Hordeum vulgare* L.) l'année de l'établissement du peuplement fourrager, on pourrait intégrer la production céréalière aux productions végétales locales. Les auteurs ont examiné l'impact de la culture d'orge sur l'établissement d'un peuplement de phléole (*Phleum pratense* L.) et de trèfle (*Trifolium pratense* L.; *T. hybridum* L.) lors d'une étude de quatre ans près de St. John's. Dans le cadre de cette expérience, ils ont comparé deux variétés d'orge (de hauteur différente), trois densités de semis ainsi que l'incidence du sous-étage fourrager sur la production grainière l'année de l'établissement et sur la production fourragère, l'année subséquente. Quand on passe de 125 à 375 plants d'orge par mètre carré, le nombre d'épis par mètre carré augmente linéairement, ce qui se traduit par un accroissement linéaire de la production céréalière. Le peuplement pur avait un rendement grainier similaire à celui des peuplements avec sous-étage fourrager. La production d'orge l'année de l'établissement du peuplement n'affecte pas le rendement fourrager l'année suivante (peu importe la densité des semis ou l'archétype du cultivar). La culture d'orge modifie toutefois la composition du peuplement fourrager puisqu'une densité plus élevée du semis réduit la quantité de phléole de 15 % dans les fourrages récoltés l'année suivante. La culture d'un sous-étage d'orge sur peuplement de phléole et de trèfle est réalisable à Terre-Neuve à raison de 375 graines par mètre carré.

Mots clés: *Hordeum vulgare* L., trèfle d'alsike, trèfle rouge, culture sous couverture, compagnonnage, Terre-Neuve

Livestock farmers in Newfoundland use most available land for forage production, and forage is the most important crop in the province in terms of both production and land area used (Statistics Canada 1997). The local production of feed grains is negligible (Spaner et al. 2000a) and imported feed is the largest single farm-operating expense (Statistics Canada 1997).

Most information on cereal grain production in Newfoundland dates to the 1960s (Rayment 1968), although our research group recently began reporting modern agronomic data (Spaner et al. 2000a, b, 2001a, b). We reported six-row barley (*Hordeum vulgare* L.) as the highest yielding, most well adapted, cereal grain in Newfoundland (Spaner et al. 2000a). The optimum barley seeding date for barley was early May, with a soil pH requirement between 5.4 and 6.0. Chapais six-row barley was the highest yielding cultivar among those tested in Newfoundland (Spaner et al. 2000a), and has exhibited pan-Canadian adaptation when compared with all available barley cultivars (Kong et al. 1994). A 4-yr study examining the effect of seeding rate and N fertilization rate on pure-stand Chapais barley indicated that increasing seeding rates from 200 to 380 seeds m^{-2} did not alter final grain yield (Spaner et al. 2001a). Early seeding may allow for lower seeding rates due to increased tillering in the vegetative phase.

Livestock farmers in Newfoundland grow most of their forage requirements, yet import most of their feed grain. Growing barley in the year of forage establishment may allow for the incorporation of grain production into local cropping schemes. Companion crops create competition for

Table 1. Planting and harvest dates, precipitation and growing degree day (5°C) accumulation during growing season for experiments planted near St. John's (1998–2001)

		Precipitation[z] and Growing Degree Day[z] (5°C) accumulation (GDD) from planting to harvest													
				May		June		July		August		September		Season total	
Year	Planted	Grain harvest	Forage harvest	Precip. (mm)	GDD	Precip. (mm)	GDD	Precip. (mm)	GDD	Precip. (mm)	GDD	Precip. (mm)	GDD	Precip. (mm)	GDD
1998	27 May	14 Sept.	–	79	90	44	208	98	384	56	396	99	236	198	1224
1999	7 May	25 Aug.	6 July	57	177	49	255	70	374	54	383	53	295	173	1484
2000	15 May	1 Sept.	5 July	83	69	76	195	80	334	93	376	75	256	249	1161
2001	–	–	18 July	113	49	39	198	83	328	53	385	264	245	552	1156

[z]Data collected from Environment Canada's Atmosphere Environment Service stations at St. John's West CDA (1998 and 1999), St. John's International Airport (2000 and 2001).

water, nutrients and light, which may or may not reduce the yield of the grain crop in the planting year (Rees et al. 1999), or the forage crop in the following year. Stewart et al. (1980) did not report a barley yield reduction when underseeding with red clover (*Trifolium pratense* L.) in Northern Ireland. Conversely, Rees et al. (1999) reported a marginal (<7%) reduction in grain yield when underseeding barley with either red clover or a triple-mix of timothy *(Phleum pratense* L.), alsike (*T. hybridum* L.) and red clover in New Brunswick. They also reported that underseeding barley with selected forage grasses and legumes increased plant residues and ultimately the organic carbon contributions to the soil. Manipulation of row spacing, row orientation, seeding rate and the use of non-competitive species are some practices used to minimize competition from companion crops (Chastain and Grabe 1988; Nickel et al. 1990).

The first objective of this study was to determine the effect of underseeding barley on the establishment of a triple-mix forage sward of timothy, alsike and red clover. The second objective was to determine the appropriate barley seeding rate, and barley cultivar (plant archetype), to maximize grain production in the seeding year, while minimizing yield reduction of the forage sward in the subsequent year. The overall objective of this work was to refine our understanding of barley production in a cool Maritime climate, with the goal of improving present cropping recommendations.

MATERIALS AND METHODS

We planted three experimental trials near St. John's (47°31′N; 52°47′W) Newfoundland on 27 May 1998, 7 May 1999 and 15 May 2000 (Table 1). Soils were of the well-drained Cochrane series (Orthic Humo-Ferric Podzol) formed on a gravelly medium-textured glacial till (Heringa 1981). Land used for these experiments was first plowed, then disc harrowed prior to planting.

The experiment consisted of nine treatments arranged in randomized complete blocks, with four blocks per trial. The nine experimental treatments included (1) Chapais barley planted at each of three seeding rates (125, 250, 375 seeds m^{-2}; ≈ 50, 100, 150 kg seed ha^{-1}) underseeded with a forage crop, (2) Leger barley planted similarly, (3) Chapais barley planted in pure-stand at 375 seeds m^{-2}, (4) Leger barley planted in pure-stand at 375 seeds m^{-2} and, (5) a pure-stand forage. The forage companion crop and the pure-stand forage treatment consisted of certified "triple-mix" seed [60% Climax timothy (*Phleum pratense* L.), 20% Marino red clover (*Trifolium pratense* L.), 20% Alsike clover (*T. hybridum* L.)] planted at 28 kg ha^{-1} immediately following barley, using a 1.8-m width cultipacker seeder. Leger barley is a much taller (≈ 20 cm) cultivar than the semi-dwarf Chapais, and this differential was used to determine if plant height affected forage establishment through increased shading. Seeding rates were chosen as 1/2, 1 and 1 1/2 times the recommended sole-crop barley seeding rate of 250 seeds m^{-2} in Newfoundland (Spaner et al. 2001a). Barley was planted with a mechanical double disk plot seeder consisting of 10 seed drills, spaced 20 cm apart. Plot dimensions were 2 × 6 m.

Prior to harvest we trimmed the plots to 5 m and harvested three inner rows for grain yield determination. Weeds were controlled with recommended chemical herbicides, and limestone amelioration raised pH above 5.7 at all sites. At planting, 135 kg ha^{-1} of a 17-17-17 (N-P_2O_5-K_2O) fertilizer was drilled to the side and below the barley seed. Soil test values for P, K, Ca and Mg were all high. No organic soil amendment had been applied for at least 5 years and trial sites followed grass species in rotation.

Barley plant height was measured after stem elongation was compete, from the soil surface to the tip of the spike, excluding awns. Spikes m^{-2} were counted in a 1-m row sample, randomly chosen from along the second row of each plot, immediately prior to combine harvest. Within each plot, 10 spikes were randomly harvested for kernels spike^{-1} determination. Grain weight was determined from a 400 to 800 kernel cleaned sub-sample of harvested grain. Plot yield was recorded immediately following harvest, dried for 3 d at 60°C, and weighed again for calculation of grain moisture at harvest. In 1998 and 1999, lodging on a per-plot basis was rated on a 0–9 scale and subsequently converted to percentage plot lodged. There was no lodging in 2000.

Each year following grain harvest remnant straw was removed from plots. A day following combine harvest, the pure-stand forage plots were cut with a Swift Current flail mower at a plant height of ≈ 5 cm. In the following year, ammonium nitrate fertilizer was broadcast-applied following early spring forage regrowth at a rate of 17 kg N ha^{-1}. When clover was at ≈ 50% bloom we hand-harvested all

Table 2. Effect of cultivar and seeding rate on grain yield, yield components and agronomic traits for Chapais and Leger barley undersown to a mixture of timothy-red clover-alsike clover in eastern Newfoundland (1998–2000)

Treatment	Plant height (cm)	Spikes m^{-2} (No.)	Kernels $spike^{-1}$ (No.)	Kernel weight (mg)	Grain moisture (%)	Grain yield ($t\ ha^{-1}$)
Cultivar						
Chapais	78	230	44	46	25	3.08
Leger	97	230	52	42	26	2.62
Cultivar *F* test	**	NS	*	*	NS	NS
Seeding rate						
125 seeds m^{-2}	88	200	50	43	28	2.62
250 seeds m^{-2}	88	230	49	43	25	2.87
375 seeds m^{-2}	87	260	45	43	24	3.06
Seeding rate (S) *F* test	NS	*	NS	NS	NS	*
S Linear contrast[z]	NS	**	*	NS	*	**
SE[y]	3	25	2	1	1	0.20

[z]Seeding rate quadratic contrasts and seeding rate × cultivar interactions were not significant ($P \geq 0.05$) for all traits.
[y]Standard error of the difference of two least-square seeding rate means.
*, ** Effects or contrasts significant at $P < 0.05$ and $P < 0.01$, respectively; NS, not significant at $P \geq 0.05$.

plants 1-cm above ground level, from within randomly placed 625-cm^2 quadrants within each plot, excluding those plots planted to pure-stand barley in the previous year. Plants were separated, dried for 3 d at 60°C, and the percentage of timothy, clover and weeds calculated on a dry matter basis. Thereafter, we harvested a 3-m^2 (60 cm width × 5 m length) area from within each plot (excluding those plots planted to pure-stand barley in the year previous) with a Swift Current flail mower. A sub-sample was weighed immediately, dried for 3 d at 60°C, and weighed again for forage moisture and subsequent dry-weight yield calculations. Temperature and precipitation data were collected near trial sites during the 4 yr of this study (Table 1).

Data for all traits except barley lodging were analysed within mixed models, applying appropriate corrections for heterozygous error variances between years (Littell et al. 1996). Year and block were considered random effects, with cultivar, seeding rate and cultivar × seeding rate effects considered fixed. Least square means are presented throughout (Littell et al. 1996). Barley lodging did not occur in 2000 and these data were analysed by year for the first two trial years only. Seeding rate effects were separated with orthogonal contrasts. We discuss treatment differences only when $P < 0.05$.

RESULTS

Leger was 20 cm taller, produced 8 more kernels $spike^{-1}$, which weighed 8 mg $kernel^{-1}$ less than Chapais over the three trial years (Table 2). Mean grain yields of the two cultivars were statistically similar (Table 2). However, when analysed by year, Chapais yielded 870 and 430 kg ha^{-1} more ($P < 0.05$) grain than Leger in 1998 and 2000, respectively, while yields were similar in 1999 (data not shown). Grain yield rose linearly with seeding rate, increasing 10% when the rate was raised from 125 to 250 seeds m^{-2}, and an additional 7% when this was increased to 375 seeds m^{-2}. This yield increase occurred largely as a result of a linear increase in spikes m^{-2} with higher seeding rates (Table 2). Experimental mean barley lodging was 78 in 1998, 21% in 1999 and 0% in 2000. Lodging in 1998 was the result of a severe early-September storm, a not uncommon occurrence in the autumnal hurricane season in Newfoundland. Leger lodged 20 and 29% more than Chapais in 1998 and 1999, respectively (data not shown).

We included pure-stand treatments of both cultivars planted at the highest seeding rate (375 seeds m^{-2}) and compared this with barley planted at the same seeding rate and underseeded to timothy-red clover-alsike clover. Underseeding barley to triple-mix forage did not affect grain yield, plant height or any primary yield component trait (Table 3).

The production of barley grain in the establishment year did not alter forage yield in the forage production year at any barley seeding rate, although it did alter species composition (Table 4). At the higher barley seeding rates (250 and 375 seeds m^{-2}) there was 15% less timothy and about 15% more clover in the first cut of the forage production year. Similarly, barley seeded at the lowest rate (125 seeds m^{-2}) altered forage composition but to a lesser degree. Weed population was not altered by any treatment.

DISCUSSION AND CONCLUSIONS

Lemieux et al. (1987) reported that seeding a barley companion crop with timothy, or timothy-clover mixtures, near Québec City precluded forage harvest during the establishment year, reduced forage yield 13% in the following year, but had little effect on the quality of that forage. Klebesadel and Smith (1960) noted that lodging of a companion crop is a major disadvantage during the establishment of small-seeded legumes, and often results in poor forage establishment. They also noted that companion crops cause moisture stress and shading of small forage seedlings, especially when allowed to mature to grain harvest. Leger barley was selected as a representative tall cultivar, in juxtaposition with the semi-dwarf Chapais. Leger was about 20 cm taller and exhibited more than 20% greater lodging than Chapais (in 2 of 3 yr), but this did not cause any discernable effect on timothy-clover forage establishment in the production year. The yield of the forage mixture (under either barley cultivar) in the forage production year was the same as for the pure-stand forage mixture. This result reflects some of

Table 3. Mean plant height, yield components and grain yield for Chapais and Leger barley planted at 375 viable seeds m^{-2} in pure-stands or undersown with timothy-red clover-alsike clover in eastern Newfoundland (1998–2000)

Treatment	Plant height (cm)	Spikes m^{-2} (No.)	Kernels spike^{-1} (No.)	Kernel weight (mg)	Grain yield (t ha^{-1})
Chapais pure-stand	79	280	44	47	3.43
Chapais underseeded	79	260	42	47	3.38
Leger pure-stand	96	270	50	40	3.00
Leger underseeded	95	250	48	40	2.75
Contrasts					
Underseed (U) vs. pure-stand (P)	NS	NS	NS	NS	NS
Chapais U vs. Chapais P	NS	NS	NS	NS	NS
Leger U vs. Leger P.	NS	NS	NS	NS	NS
SE[z]	4	20	2	1	0.24

[z]Standard error of the difference of two least-square seeding rate means.
*, ** Contrasts significant at $P < 0.05$ and $P < 0.01$, respectively; NS, not significant at $P \geq 0.05$.

Table 4. First-cut dry-matter forage yield and composition in the production year following pure-stand or undersown with Chapais and Leger barley in eastern Newfoundland (1999–2001)

Treatment in planting year	First-cut dry-matter forage yield (t ha^{-1})	Forage dry-matter composition		
		Timothy (%)	Clover (%)	Weeds (%)
Pure-stand timothy-clover (1)	4.94	31	64	5
Timothy-clover seeded with 125 barley seeds m^{-2} (2)	5.23	21	75	4
Timothy-clover seeded with 250 barley seeds m^{-2} (3)	4.99	15	81	4
Timothy-clover seeded with 375 barley seeds m^{-2} (4)	5.03	15	82	3
Contrasts				
Seeding rate linear[z]	NS	**	*	NS
Treatment 1 vs. 2	NS	**	*	NS
Treatment 1 vs. 3	NS	**	**	NS
Treatment 1 vs. 4	NS	**	**	NS
SE[y]	0.25	3	4	2

[z]Seeding rate quadratic contrasts were not significant ($P \geq 0.05$) for all traits.
[y]Standard error of the difference of two least-square seeding rate means.
*, ** Contrasts significant at $P < 0.05$ and $P < 0.01$, respectively; NS, not significant at $P \geq 0.05$.

the known benefits of including species mixtures in multiple cropping systems (Francis 1989). The reduction of timothy in the harvested forage crop in the production year as barley seeding density increased may have been the result of a lower competitive ability of timothy, or a greater competitive ability in the clovers (Walton 1983). Also, barley and timothy occupy both the same functional and spatial niches, whereas clover has a slightly different spatial and more different functional niche.

Nickel et al. (1990) suggested that increased competition for water and plant nutrients associated with underseeding has a negative influence on the development of the grain crop. Nevertheless, there have been conflicting reports in the literature. Stewart et al. (1980) did not report a barley yield reduction when underseeding with red clover in Northern Ireland; however Rees et al. (1999) reported a marginal reduction of barley grain yield when underseeding with either red clover or a triple-mix of timothy, alsike and red clover in New Brunswick. In the present study, we found no negative effects of underseeding on grain yield in Newfoundland at high planting rates of 375 seeds m^{-2} [Advisory Committees on Cereal, Protein, Corn and Forage Crops (ACCPCFC) 1991].

Manipulation of row spacing, row orientation, seeding rate and the use of non-competitive species are some of the practices used to minimize competition from companion crops (Chastain and Grabe 1988; Nickel et al. 1990). In our trials, forage establishment was not impeded by barley seeding rates from 125 to 375 plants m^{-2}, indicating that at these seeding rates, in conjunction with the relatively low yield potential of barley grown in eastern Newfoundland (Spaner et al. 2001 a), there was limited competition with the establishing forage. Hay and Walker (1994) summarized many cereal grain seeding rate trials, and concluded that yield increases to a plateau value at moderate densities, and that a significant reduction in yield occurs only at very high densities. We previously established optimum barley seeding rates of 250 ± 50 seeds m^{-2} in pure-stand seeding rate experiments in eastern Newfoundland (Spaner et al. 2001 a). Such values are somewhat less than the 250–450 seeds m^{-2} recommended for the Maritime provinces (ACCPCFC 1991) but are similar to experimental results in western Canada (Jedel and Helm 1995; Lafond and Derksen 1996) for pure-stand barley. Results from the present study indicate that similar, or higher, seeding rates may be employed in eastern Newfoundland when companion cropping with an establishing forage sward of timothy-clover mixtures. We conclude that it is both feasible and desirable to include barley seeding rates of up to 375 seeds m^{-2}, harvested as grain, in the establishment year of a timothy-clover forage sward in Newfoundland.

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