Farmer-directed on-farm experimentation examining the impact of companion planting barley and oats on timothy-alfalfa forage establishment in central Newfoundland

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Spaner, D. and Todd, A. G. 2004. **Farmer-directed on-farm experimentation examining the impact of companion planting barley and oats on timothy-alfalfa forage establishment in central Newfoundland.** Can. J. Plant Sci. **84**: 217–221. Oats (*Avena sativa* L.) or barley (*Hordeum vulgare* L.) sown at increasing seeding rates of 23, 45 and 68 kg ha^{-1} with a timothy *(Phleum pratense* L.)-alfalfa (*Medicago sativa* L.) mixture (harvested at cereal soft dough) resulted in increasing forage yields containing decreasing alfalfa, crude protein, P and Ca percentage in the planting year. Barley out-yielded oats by 11% in the planting year. Oats or barley sown at seeding rates up to 68 kg ha^{-1} do not impede underseeded forage establishment or forage production in the subsequent year in central Newfoundland. The implications of farmer-directed on-farm experimentation are discussed.

Key words: *Hordeum vulgare* L., *Avena sativa* L., *Phleum pratense* L, *Medicago sativa* L., underseeding

Spaner, D. et Todd, A. G. 2004. **Expériences menées par les agriculteurs à la ferme pour vérifier l'incidence du compagnonnage de l'orge et de l'avoine sur l'établissement des peuplements fourragers de fléole et de luzerne dans le centre de Terre-Neuve**. Can. J. Plant Sci. **84**: 217–221. Lorsqu'on sème de l'avoine (*Avena sativa* L.) ou de l'orge (*Hordeum vulgare* L.) à un taux croissant de 23, 45 et 68 kg par hectare avec un mélange de fléole (*Phleum pratense* L.) et de luzerne (*Medicago sativa* L.) pour les récolter au stade pâteux mou des céréales, le rendement fourrager augmente et les fourrages contiennent une proportion de moins en moins grande de luzerne, de protéines brutes, de P et de Ca l'année de la plantation. Le rendement de l'orge dépasse celui de l'avoine de 11 % la première année. Semer de l'avoine ou de l'orge jusqu'à concurrence de 68 kg par hectare ne nuit pas à l'implantation du peuplement fourrager ni à la production de fourrage l'année suivante dans le centre de Terre-Neuve. Suit une discussion sur l'utilité des expériences menées par les agriculteurs à la ferme.

Mots clés: *Hordeum vulgare* L., *Avena sativa* L., *Phleum pratense* L., *Medicago sativa* L., semis sous couverture

Central Newfoundland has a short summer with broadly similar growing conditions to those in northern Quebec and northern Ontario. The frost-free period is roughly 100 d and growing degree days (5°C), and precipitation received between May and September average 1300 and 440 mm, respectively (Gordon 1993). In regions with a short growing season, spring cereals [oats, barley, wheat (Triticum aesitivum L.) and/or triticale (Tritosecale)] are commonly grown for fresh-cut or ensiled forage feed. Those crops are grown in pure stands or as companion crops in the establishment year of a perennial legume-grass pasture. Growing barley or oats in the year of forage establishment is a common agronomic practice in short-season regions, but is generally not recommended to growers by extension workers in Newfoundland. Using companion crops to establish perennial forages has many inherent benefits including weed suppression, erosion control and high forage yields in the establishment year (Wiersman et al. 1999).

Companion planting creates competition for water, nutrients and light, which may or may not reduce the forage yield of the companion-planted cereal crop in the planting year (Rees et al. 1999; Brink and Marten 1986a), or the alfalfa and /or timothy crop in the production year (Brink and Marten 1986b). In the United States, Brink and Marten (1986a), Simmons et al. (1995), and Nickel et al. (1990) examined alfalfa establishment-year forage yield and quality with either oat or barley companion crops, and with no companion cereal controls. Nickel et al. (1990) reported oats were less competitive than barley when companion planted, while Simmons et al. (1995) reported semi-dwarf and conventional height barley and oat cultivars were comparable in yield performance and competitive ability. Brink and Marten (1986a) suggested that the environment was more important than cereal species or cultivar for the determination of establishment year forage quality. All three research groups reported establishment year forage yields were higher when a companion cereal crop was used, and all reported declining forage quality as cereals matured to later growth stages.

Todd and Spaner (2003) compared several varieties of barley, wheat, oats and pea (*Pisum sativum* L.)-cereal mixtures for forage yield and quality in Newfoundland and reported that barley headed earliest, yielded most forage, and had lowest crude protein and acid detergent fibre (ADF) concentrations. Lemieux et al. (1987) reported that seeding a barley companion crop (for grain harvest) with timothy, or timothy-clover mixtures, near Quebec City, reduced forage yield 13% in the following year, but had little effect on the quality of that forage. 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 (Nickel et al. 1990). There is no information on cereal seeding rates for companion planting with alfalfa mixtures in Newfoundland.

The objective of this study was to examine the effect of companion planting differing seeding rates of barley and oats on forage yield in the planting year, and on the establishment of a mixed forage sward of timothy and alfalfa in the production year. This study was directed and managed by a farmer interested in applying the results to his farming operation.

Three experimental trials were planted near Bishop's Falls (49°02′N; 55°34′W) Newfoundland in 1998, 1999 and 2000. Soils were of the well-drained Peter's Arm Association (Orthic Humo-Ferric Podzol) formed on a moderately coarse to coarse textured glacialfluvial sand and gravel (Sudom and Van de Hulst 1985). In the fall prior to seeding, fields under perennial legume-grass mixtures for 3 to 6 yr were sprayed with glyphosate. When growing plants subsequently died, limestone and approximately 5000 L of liquid dairy manure ha^{-1} were applied, followed by one plowing and one discing operation prior to winter. Fields were limed to a final target soil pH of 6.8. An additional 5000 L of liquid dairy manure ha^{-1} was applied in the following spring and then disc plowed and harrowed for seedbed preparation. Weeds were controlled through one application of MCPB/MCPA (15:1) at 0.8 kg ha^{-1} a. i. at approximately 200 L ha^{-1}, and approximately 55 kg N ha^{-1} was applied as 34-0-0 following crop emergence in establishment years.

The experiment consisted of six treatments arranged in randomized complete blocks, with two blocks per trial. The six experimental treatments included (1) Chapais barley planted at 23 kg seed ha^{-1}, (2) Chapais barley planted at 45 kg seed ha^{-1}, (3) Chapais barley planted at 68 kg seed ha^{-1}, (4) Nova oat planted at 23 kg seed ha^{-1}, (5) Nova oat planted at 45 kg seed ha^{-1}, and (6) Nova oat planted at 68 kg seed ha^{-1}. All six treatments were companion seeded with Champ timothy planted at a rate of 5.4 kg seed ha^{-1} together with Caribou alfalfa at a rate of 10 kg seed ha^{-1}. The timothy-alfalfa mixture was planted immediately after spring cereals using a field cultipacker seeder. The experiment did not include a no-companion seeded control as the cooperating farmer needed a reasonable forage yield in the year of establishment, and was not willing to plant such a control treatment. Cereals were planted in strips 9.1 × approximately 300 m with a row spacing of 20-cm.

Trials were seeded as early as possible in the spring (early to mid-May), and planting-year harvests were between 26 Jul. and 05 Aug. in each year, when the cereals were in the soft dough stage. Harvests in the production year were conducted between 21 Jun. and 7 Jul., when alfalfa had generally reached the late-bud stage. At each of the six harvest periods, 10 quadrats (0.5 × 0.5 m) were hand-harvested at approximately 2.5 cm above ground level, along a pre-determined random grid within each of the 12 treatment-block combinations. Plants were separated, cereal tillers counted (in the establishment year), and all plant material was thereafter dried for 3 d at 60°C. The percentage of oats or barley, timothy, alfalfa, weeds and total yield was calculated on a dry matter basis. Dried forage samples were subsequently ground in a Thomas-Wiley mill with a 1-mm sieve, and then analysed for crude protein, P, K, Ca, Mg, ADF and neutral detergent fibre (NDF) using standard methods of AOAC International (Cunniff 1997). After experimental sampling, the forage was cut to windrows, wilted for a number of days, and harvested with large-scale farming equipment. The forage was ensiled and/or fed fresh for normal farm feeding operations. The cooperating farmer harvested a second time in the 1999 seeding year because alfalfa-timothy regrowth was high and he needed the forage. He also cut early (21 Jun.) in the 2001 forage production year, again because forage was needed at that time and weather conditions permitted. Temperature and precipitation data were collected near trial sites during the 4 yr of this study.

Data for all traits were analysed within mixed models (Littell et al. 1996), with the Kenward-Roger method used to determine denominator degrees of freedom. Year and block were considered random effects, with species, seeding rate and species × seeding rate effects considered fixed. Employing such an analysis, year × species, year × seeding rate, and year × species × seeding rate interaction effects are also considered random, and these means are not presented. Least square means are presented throughout (Littell et al. 1996). Seeding rate effects were separated with orthogonal contrasts. We discuss treatment differences only when $P < 0.05$.

Chapais barley companion planted with alfalfa-timothy mixture yielded 11% more forage dry matter than Nova oats in the year of planting, but the two grain forage species did not differ for any forage quality trait (Table 1). Increasing seeding rate from 23 to 68 kg ha^{-1} resulted in a 32% linear increase in forage dry-matter yield (1.41 t ha^{-1}) in the year of planting, and linear decreases in percentage crude protein of 3 g kg^{-1}, P of 0.04 g kg^{-1}, and Ca of 0.13 g kg^{-1} in the harvested forage. Percentage timothy, weeds, K, Mg, ADF and NDF of the harvested forage was not altered by seeding rate in the year of planting (Table 1; data for timothy, weeds and ADF not shown). Species × seeding rate interactions were significant ($P < 0.05$) for cereal tillers m^{-2} and percent alfalfa, but not for any other measured trait. Barley seeding rate treatments resulted in a linear increase of 160 to 330 tillers m^{-2}, while oat seeding rate treatments resulted in a linear increase of 145 to 270 tillers m^{-2}. Increasing barley seeding rates from 23 to 45 to 68 kg ha^{-1} resulted in a quadratic decrease ($P < 0.05$) of 10 to 3 to 1% alfalfa in the harvested forage, while increasing oat seeding rate treatments resulted in a linear decrease ($P < 0.05$) of 6 to 2 to 1% alfalfa in the harvested forage, respectively (data not shown).

Table 1. Effect of companion cereal species and seeding rate on cereal tiller number at harvest, forage quality, and dry weight forage yield in the year of planting for oat and barely grown with a companion planting of timothy-alfalfa in central Newfoundland (1998–2000)

Treatment in planting year	Dry weight forage yield ($t\ ha^{-1}$)	Cereal tillers m^{-2} (no.)	Forage dry weight: Alfalfa	Crude protein	P	K	Ca	Mg	NDF
			($g\ kg^{-1}$)						
Barley seeded with timothy-alfalfa	5.48	250	5	12	0.31	2.38	0.31	0.15	56
Oat seeded with timothy-alfalfa	4.94	205	3	11	0.32	2.38	0.26	0.15	59
Species main effect *F*-test	*	NS	NS	NS	NS	NS	NS	NS	NS
Companion cereal 23 kg ha^{-1}	4.44	150	8	13	0.34	2.61	0.37	0.16	56
Companion cereal 45 kg ha^{-1}	5.34	235	2	10	0.31	2.27	0.26	0.15	58
Companion cereal 68 kg ha^{-1}	5.85	300	1	10	0.30	2.27	0.24	0.15	59
SE diff. (seeding rate)	0.276	10.9	0.8	0.4	0.013	0.148	0.026	0.010	1.3
Seeding rate *F*-test	**	**	**	*	*	NS	**	NS	NS
Seeding rate × species *F*-test	NS	*	*	NS	NS	NS	NS	NS	NS
Contrasts									
Seeding rate linear	**	**	**	**	*	NS	**	NS	NS
Seeding rate quadratic	NS	NS	*	NS	NS	NS	NS	NS	NS

*, ** Main effect or contrast *F*-tests significant at $P < 0.05$ and $P < 0.01$, respectively; NS, not significant ($P \geq 0.05$).

Species × seeding rate interaction was not significant ($P \geq 0.05$) for all measured forage traits in the production year (Table 2). Species main effect was significant ($P < 0.01$) only for percent NDF, where forage initially companion-planted with barley had 1 g kg^{-1} lower NDF than with oats, which may not be biologically significant. Companion planting oats or barley at rates increasing from 45 to 68 kg ha^{-1} resulted in a 9% increase in timothy-alfalfa in the production year, but did not alter any forage quality trait (Table 2).

Klebesadel and Smith (1960) noted that companion crops cause moisture stress and shading of small forage seedlings, especially when the companion crops were allowed to mature prior to grain harvest. It is assumed that increased competition for water and plant nutrients associated with underseeding has a negative influence on the development of a grain crop (Nickel et al. 1990). In the present study, barley and oat were harvested in the soft dough stage, about 1 mo before grain maturation. This, in combination with adequate moisture in the growing season for the Newfoundland agro-ecoregion, may have diminished the temporal competition of the timothy-alfalfa sward on the companion cereal crop and vice versa.

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 (Nickel et al. 1990). Nickel et al. (1990) reported oats to be a less competitive companion crop than barley. Lemieux et al. (1987) reported that seeding a barley companion crop (for grain harvest) with timothy, or timothy-clover mixtures, near Quebec City reduced forage yield 13% in the following year, but had little effect on the quality of that forage. In the present study, barley companion-planting resulted in higher planting-year yields than companion-planted oats. These results are in agreement with those reported by other research groups (Brink and Marten 1986a; Simmons et al. 1995). Nevertheless, there was a greater percentage of alfalfa in the establishment year in the lowest seeding rate of the barley companion crop than with oats. Percent timothy in the forage harvested in the planting year was not altered by any treatment. Similarly, forage establishment was not impeded when companion planted with barley or oats at any of the seeding rates studied. Results from the present experiment indicate that an oat or barley seeding rate of 68 kg ha^{-1} may be employed in central Newfoundland when companion planting with a forage mixture of timothy-alfalfa. The decision process for the choice of seeding rate of the companion-planted cereal will involve a producer-inferred balance between higher yields at higher cereal seeding rates, with a decline in crude protein percentage as forage yields increase in the year of seeding.

A Note on Farmer-directed On-farm Experimentation

On-farm systems research within the framework of the Consultative Group of International Agricultural Research Centres initially began in response to the differential societal impact of the Green Revolution in some regions of the Developing World (Whyte and Boynton 1983). Researchers in North America are undertaking more on-farm research in response to different needs and interests: (1) to foster closer relationships with farmers, (2) to demonstrate cultivars and technologies directly to the farming community and (3) to maintain research activity with shrinking resources.

Our experiment was undertaken as the result of all three of the above-mentioned imperatives. We needed to work on-farm to attract both financial and research support from the farming community. This experiment was undertaken at the suggestion of one of the more successful local dairy farmers (Mr. Art Gill) who had adopted many improved grain production technologies (Spaner et al. 2000; 2001). Mr. Gill wanted to know the best cereal species and cereal seeding rate for use in companion cropping for forage establishment. Because there was no information for Newfoundland, we suggested he seed at three rates with both oats and barley in one field with all six treatments replicated twice. We also suggested that he repeat the experiment for 3 successive years, each time using a new 20-ha field.

There are limitations to on-farm research: (1) Most management decisions are constrained by practical considera-

Table 2. Effect of companion planting barley and oats at three seeding rates on forage composition, quality, and dry weight forage yield in the year following establishment of timothy-alfalfa in central Newfoundland (1999–2001)

Treatment in planting year	Forage dry weight								Dry weight forage yield
	Timothy	Alfalfa	Crude protein	P	K	Ca	Mg	NDF	
	(g kg^{-1})								(t ha^{-1})
Barley seeded with timothy-alfalfa	55	43	17	0.29	2.98	0.71	0.19	49	4.59
Oat seeded with timothy-alfalfa	64	34	16	0.28	2.76	0.66	0.19	50	4.59
Species main effect *F*-test	NS	NS	NS	NS	NS	NS	NS	**	NS
Companion cereal 23 kg ha^{-1}	61	37	16	0.30	2.90	0.63	0.18	50	4.46
Companion cereal 45 kg ha^{-1}	59	39	16	0.30	2.76	0.72	0.18	49	4.46
Companion cereal 68 kg ha^{-1}	58	39	16	0.30	2.90	0.70	0.18	50	4.84
SE diff. (Seeding rate)	1.9	1.9	0.4	0.005	0.065	0.034	0.008	0.5	0.152
Seeding rate *F*-test	NS	NS	NS	NS	NS	NS	NS	NS	*
Seeding rate linear contrast[z]	NS	NS	NS	NS	NS	NS	NS	NS	*

[z]Seeding rate × species *F*-test and seeding rate quadratic contrasts were not significant ($P \leq 0.05$) for all traits presented.
*, ** Main effect or contrast *F*-tests significant at $P < 0.05$ and $P < 0.01$, respectively; NS, not significant ($P \geq 0.05$).

tions. For example, Mr. Gill harvested a second time in the 1999 seeding year because cereal and alfalfa-timothy regrowth was high and he needed the forage. This lowered the timothy percentage in the first-cut of the forage production year. He cut early in the 2001 forage production year, altering the forage composition of that harvest to favour alfalfa. It is probable that these management decisions negated any statistical significance between treatments (especially species companion planted) for forage composition in the production year, which may have been found in a controlled on-station experiment. The experiment did not include a no-companion seeded control as Mr. Gill needed a reasonable forage yield in the year of establishment, and was not willing to plant such a control treatment. Management practices need to be realistic for the study to be useful to farmers, although altering methodology may complicate interpretation. (2) Farmers use large machinery, plant large areas and can not easily set seeding rates to exact numbers of plants per hectare, but rather seed at pre-determined weights per hectare. Thus, fewer oat seed per hectare were planted than barley (1000-kernel weight of Chapais barley of 42 g versus 34 for Nova oat) as the farmer planted based on kilograms of seed per hectare, not plant number per hectare. The large size of the experiment results in more within-plot variation. We attempted to reduce experimental error with a large number of samples. However, there is a balance between statistical precision (Littell et al. 1996) and practical concerns, which may not be overcome on such a large scale. The use of large field equipment, which results in tire compaction and in some unharvested forage left over winter may, however, provide more realistic research results than through the use of small-plot experimental equipment. (3) This experiment was conducted on one farm and therefore the statistical inference space for these data is, strictly speaking, this farm (Littell et al. 1996). The agronomic research community has been conducting on-station research trials for many years, employing ideal and impractical agronomic strategies (Whyte and Boynton 1983), and extrapolating our results to real farms. Mr. Gill's skill in conducting multi-treatment trials was quite high, and we felt that replicating the experiment on other farms simply to conform to the idea of statistical inference space was not an attractive alternative. Because of a research funding agreement Mr. Gill continued the experiment for the third year, so as to provide greater scientific validity to our experiment, even though he felt that he had learned all he wanted after 2 yr. Mr. Gill is now employing the results from this experiment. Farmers will work with researchers if they can see the practical benefits of their efforts. While the researcher conducting farmer-directed on-farm experimentation gives up much control of the experimental protocol, the results are immediately applicable to farmers. Despite the limitations of this approach, we are convinced that the results presented provide a practical and realistic guideline for farmers in a similar climate and wishing to employ similar agronomic practices.

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