Seeding patterns and companion grasses affect total forage yield and components of binary red clover–grass mixtures

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Lafrenière, C. and Drapeau, R. 2011. **Seeding patterns and companion grasses affect total forage yield and components of binary red clover–grass mixtures**. Can. J. Plant Sci. **91**: 91–97. Red clover (*Trifolium pratense* L.) is the most popular seeded legume for forage production in northern Quebec and Ontario because of the poorly drained soils that prevail in these regions. The objective of this experiment was to determine which seeding patterns [mixed within a row (MR), single alternate rows (1+1), or double alternate rows (2+2)] and which companion grasses (smooth bromegrass, *Bromus inermis* L.; tall fescue, *Festuca arundinacea* Schreb.; orchardgrass, *Dactylis glomerata* L.; or timothy, *Phleum pratense* L.), in association with red clover, were best for sustaining the total forage yield of a red clover–grass mixture and how these factors affect red clover and grass components. Test plots were established at Kapuskasing, ON, and Normandin, QC. At each site, two independent seedings were performed and harvested over 3 yr following the seeding year. Total dry matter (DM) yield and contribution of red clover grasses and weeds to total forage yield were measured. The MR pattern gave higher yield over both alternate seeding patterns by nearly 0.5 Mg DM ha^{-1} at the Normandin site and 1.0 Mg DM ha^{-1} at the Kapuskasing site. Neither the seeding pattern nor the companion grass species improved significantly the contribution of red clover to total forage yield beyond the second production year even though there were differences between sites. Environmental conditions, principally high precipitation in the fall, and maturity stage at harvest resulted in major differences between sites. Results from this experiment showed that tall fescue and orchardgrass could be good alternatives to timothy or bromegrass in association with red clover given that plots were still productive in the third production year and invasion by weeds was lower.

Key words: Red clover, timothy, smooth bromegrass, tall fescue, orchardgrass, seeding pattern, yield

Lafrenière, C. et Drapeau, R. 2011. **Les patrons de semis et les graminées associées affectent le rendement fourrager total et les composantes des mélanges binaires de trèfle rouge**. Can. J. Plant Sci. **91**: 91–97. Le trèfle rouge (*Trifolium pratense* L.) est la légumineuse la plus utilisée pour la production fourragère dans les régions du nord du Québec et de l'Ontario en raison du drainage inadéquat des sols de ces régions. L'objectif de cet essai était de vérifier lequel des trois patrons de semis [mélangés sur le même rang (MR), en rangs alternés simples (1+1) et en rangs alternés doubles (2+2)] et lesquelles des quatre graminées compagnes (brome inerme, *Bromus inermis* L.; fétuque élevée, *Festuca arundinacea* Schreb.; dactyle pelotonné, *Dactylis glomerata* L.; ou fléole des prés, *Phleum pratense* L.) en association avec le trèfle rouge sont les meilleurs pour maintenir un rendement fourrager élevé dans un mélange binaire de légumineuse-graminée et comment ces facteurs influencent les composantes trèfle rouge et graminées du mélange. Les parcelles ont été implantées à Kapuskasing, ON et Normandin, QC où deux semis indépendants ont été réalisés et récoltés pendant trois années consécutives à chacun des sites. Les rendements saisonniers en matière sèche (MS) et la contribution au rendement du trèfle rouge, des graminées et des mauvaises herbes ont été mesurés. Le patron de semis MR a donné les rendements fourragers les plus élevés comparativement aux deux patrons de semis en rangs alternés avec près de 0,5 Mg MS ha^{-1} pour le site de Normandin et 1,0 Mg DM ha^{-1} pour le site de Kapuskasing. Les patrons de semis ou encore les graminées compagnes n'ont pas permis d'augmenter de façon substantielle la contribution au rendement du trèfle rouge au-delà de la deuxième année de production bien qu'il y ait eu des différences entre les sites. Les conditions environnementales, principalement les précipitations automnales, les stades de maturité à la récolte peuvent expliquer les différences entre les sites. Les résultats de cet essai ont démontré que la fétuque élevée et le dactyle peuvent être de bons substituts à la fléole des prés et au brome en mélange avec le trèfle rouge. Les rendements fourragers de ces graminées ont été élevés lors de la troisième année de production et celles-ci ont permis de diminuer l'envahissement des mauvaises dans les peuplements.

Mots clés: Trèfle rouge, fléole des prés, brome inerme, fétuque élevée, dactyle pelotonné, patron de semis, rendement

There are many reasons to use legume–grass mixtures. One of them is to decrease the need for commercial nitrogen fertilizers. Symbiotic N fixation by legumes can add to the soil a significant amount of N that is then

Abbreviations: **MR**, mixed within a row; **1+1**, single alternate rows; **2+2**, double alternate rows; **SEM**, standard error of the mean used by the companion grass (Brophy et al. 1987; Warembourg et al. 1997). It has been demonstrated that symbiotic N transferred to tall fescue (*Festuca arundinacea* Schreb.) from white clover (*Trifolium repens* L.), red clover (*Trifolium pratense* L.) and birdsfoot trefoil (*Lotus corniculatus* L.) increases linearly with the proportion of legumes in the mixture (Mallarino et al. 1990), indicating that a high legume component in mixtures would be desirable. Thus, it is a prerequisite that the legume species in the mixture be adapted to the soil conditions. In northern Quebec and Ontario, a large proportion of the soils are poorly drained. Alfalfa (*Medicago sativa* L.) is a highly productive legume, but not well adapted to poorly drained soils. Consequently, red clover continues to be a widely used legume in these regions owing to its higher tolerance to wet and acid soils compared with alfalfa (Smith et al. 1985).

Grass species and seeding patterns are among the factors that may have an impact on the proportion of legumes in a mixture. In the central United States of America smooth bromegrass (*Bromus inermis* L.), timothy (*Phleum pratense* L.) and reed canarygrass (*Phalaris arundinacea* L.) were less competitive with alfalfa than was orchardgrass (*Dactylis glomerata* L.) under a three- or four-cut regime (Wolf and Smith 1964; Smith et al. 1973; Sheaffer et al. 1990). Under a three-cut regime, Sheaffer et al. (1990) found that smooth bromegrass, reed canarygrass and orchardgrass proportions in binary mixtures with alfalfa averaged 15, 16 and 54%, respectively, after 2 production years. Under a two-cut regime in northern Quebec, Darisse and Drapeau (1982) observed that, in alfalfa mixtures, the timothy component varied from 21 to 35% and the smooth bromegrass component varied from 5 to 32% in the third production year depending on the seeding year. In the same study, the timothy and smooth bromegrass proportions in red clover mixtures were similar for the first and second production years, with 20% for the first and 45 to 50% for the second, and varied from 50 to 65% for the third production year.

Seeding patterns were also reported to influence the grass and legume proportions in mixtures (Chamblee and Collins 1988). Chamblee and Lovvorn (1953) reported that alfalfa growth with orchardgrass was lower in alternate-row mixtures than in broadcast or mixed-within-a-row seeding. Similarly, Tewari and Schmid (1960) observed a greater alfalfa proportion in mixtures with bromegrass and timothy when the species were mixed within a row compared with when they were seeded in alternate rows. In a study that used alfalfa-grass mixtures (i.e., orchardgrass and reed canarygrass) with seeding patterns allowing different proportions of alfalfa and grasses [two rows of alfalfa with one row of grass (2:1), and one row of alfalfa between two rows of grasses (1:2)], the alfalfa contribution to the mixture decreased with the 1:2 seeding pattern. By the third production year, however, the alfalfa component was above 87% for both seeding patterns (Mooso and Wedin 1990).

There is currently no information available on the impact of seeding patterns on red clover–grass mixtures. Information is also lacking on grass species that can be associated with red clover in northern latitudes of Quebec and Ontario. Moreover, a new red clover cultivar that was found to be more winter-hardy in Atlantic Canada (i.e., AC Charlie) was released in 1994 (Choo et al. 1994). The aim of this study was therefore to fill a need by looking into which associated grasses and which seeding patterns are best for sustaining the total forage yield of red clover–grass mixtures and how these factors affect red clover and grass components productivity.

MATERIALS AND METHODS

The study was conducted at the Agriculture and Agri-Food Canada research farms in Normandin, QC (lat. 48°51′N, long. 72°32′W, elevation 137 m), and Kapuskasing, ON (lat. 49°25′N, long. 82°30′W, elevation 218 m). At the Normandin site, the plots were established on a Labarre clay loam with a pH of 6.2. At the Kapuskasing site, the plots were established on a Hearst silty clay with a pH of 7.1.

Champ timothy, Baylor smooth bromegrass, Kay orchardgrass and Courtenay tall fescue were seeded in association with AC Charlie red clover at rates of 7, 10, 9, 10 and 7 kg ha^{-1}, respectively, according to the recommendations of the Conseil des productions végétales du Québec (1989). The red clover was inoculated with *Rhizobium leguminosarum* bv. *trifolii* prior seeding. Plots consisting of 10 rows spaced 18 cm apart and measuring 6 m in length were seeded at a depth of 1 cm using a rod-row V-belt seeder. Three seeding patterns were used: grass and legume mixed within the same row (MR), grass seeded in single rows alternating with single rows of the legume (1+1), and grass and legume seeded in double alternating rows (2+2). A factorial arrangement of 12 treatments (four companion grasses × three - seeding patterns) replicated four times in a randomized complete block design was used. Two independent but identical seedings were established at each site. Seeding was performed on 1995 Jun. 05 and 1996 May 17 at the Normandin site and on 1995 Jun. 01 and 1996 Jun. 12 at the Kapuskasing site.

Prior to seeding at the Normandin site, 23 kg N ha^{-1}, 100 kg P ha^{-1} and 100 kg K ha^{-1} were applied according to soil analysis. In the fall of the seeding year and the following year, 37.5 kg P ha^{-1} and 75 kg K ha^{-1} were applied to maintain soil fertility. At the time of seeding at the Kapuskasing site, the plots received 46 kg P ha^{-1} and 60 kg K ha^{-1} according to soil analysis. During the production years, 45 kg P ha^{-1} and 22.5 kg K ha^{-1} were applied in the spring to maintain soil fertility. A cut was carried out in mid-July to control annual weeds in the establishment year. No herbicide was applied at either site.

During the production years, forage was harvested twice when the red clover was at the 10 to 60% flowering stage. For the first harvest, this stage was reached between Jun. 29 and Jul. 11 at the Kapuskasing site and between Jun. 18 and Jul. 2 at the Normandin site, depending on the year. The stage of maturity of grasses at harvest varied from early to late anthesis at both sites. For the second harvest, the red clover was harvested at the 25 to 50% flowering stage. This stage was reached between Aug. 19 and 28 at the Kapuskasing site and between Aug. 02 and 20 at the Normandin site. For that harvest, all grasses were at the vegetative stage except for timothy, which was at the heading stage.

Prior harvesting, one 0.25-m^2 quadrat (1×0.25 m) was sampled to determine the botanical composition of each plot. The quadrat was placed perpendicularly to the rows to ensure that six rows of a representative spot in the plot were sampled. The sample was divided into three components: red clover, seeded grass and weeds. The contribution of each component to the total forage yield on a dry matter (DM) basis was determined by measuring its weight after drying at 55°C to a constant weight. At harvest, the yield of each experimental plot was determined by measuring the fresh weight of the harvested forage, cut at a height of 5 cm, in a 0.61×5 m area. A flail harvester (Swift Machine and Welding Ltd., Swift Current, SK) was used. The DM content was determined on a 500-g fresh sample of forage, which was dried at 55°C to a constant weight.

Experimental data were collected for every independent seeding over 3 yr following the seeding year. At the Kapuskasing site, however, the spring of 1995 was dry (Table 1), and forage establishment was weak. The plots were therefore harvested only in 1996, because they were invaded by weeds by the second production year. Consequently, data for the first production year are the average of 4 yr, data for the second and third year production years are the average of 3 yr, and data for the third production year are the average of 3 yr. Data normality was assessed using the UNIVARIATE procedure of SAS (SAS Institute, Inc. 2002). Homogeneity of variance was verified through the analysis of residuals. Data were analyzed using the MIXED procedure of SAS (SAS Institute, Inc. 2002). The sites, treatments (companion grasses, seeding patterns) and production years were considered fixed effects, whereas the replicates and seeding years were considered random effects (Table 2). For factors where an overall difference was significant ($P \leq 0.05$), means were compared using Tukey's test.

RESULTS AND DISCUSSION

The seeding pattern had a significant effect ($P \leq 0.001$) on total forage yield. This response differed between the sites and the production years as indicated by a significant interaction ($P \leq 0.001$) between sites, seeding patterns and production years (Table 2). In general, the total forage yield of the MR seeding pattern was superior to those of the 1 + 1 and 2 + 2 seeding patterns at both sites (Table 3). At the Normandin site, the MR seeding pattern produced its highest yield in the first production year, with an annual average total forage yield of 6.6 Mg DM ha^{-1}, and yielded 5.3 Mg DM ha^{-1} in the third production year (Table 3). The total forage yields of both alternating seeding patterns, 1 + 1 and 2 + 2, were comparable in all three production years ($P > 0.05$) (Table 3). Nevertheless, the difference in total forage yield observed between the MR seeding pattern and the alternating seeding patterns was less than 0.5 Mg DM ha^{-1} in all 3 yr (Table 3). At the Kapuskasing site, similar results were observed for the second and third production years. For these years,

Table 1. Mean temperature (°C) and precipitation (mm) at both sites during the growing season

	Mean temperature (°C)						Precipitation (mm)					
Month	1995	1996	1997	1998	1999	Avg.[z]	1995	1996	1997	1998	1999	Avg.
Kapuskasing												
May	9.3	5.7	5.6	10.7	11.9	8.2	47.1	31.3	40.7	47.5	95.5	64.2
June	17.5	16.7	16.4	14.9	16.6	14.3	56.0	74.0	102.9	86.6	85.8	75.7
July	18.0	16.1	17.3	17.5	19.3	17.0	129.5	93.0	112.0	89.2	115.9	90.9
August	18.5	17.5	15.2	17.2	15.6	15.7	41.2	48.2	83.2	77.0	46.0	82.6
September	9.5	12.6	11.4	11.8	13.0	10.6	118.1	74.3	81.4	123.7	90.8	87.5
October	5.1	4.3	5.0	5.2	3.4	4.4	163.5	102.7	97.5	39.5	168.8	71.0
Total							555.4	423.5	517.7	463.5	602.8	471.9
Normandin												
May	8.6	7.1	6.5	12.2	12.6	8.9	133.0	67.1	78.0	89.4	43.0	71.8
June	15.4	15.5	15.0	15.5	16.3	14.6	62.3	62.9	74.4	126.0	69.0	82.3
July	18.4	16.9	17.5	17.0	17.2	17.0	36.9	211.2	64.2	52.0	138.5	108.7
August	16.7	16.2	14.6	15.9	15.7	15.5	38.0	69.6	101.2	54.0	104.7	87.6
September	9.0	12.4	10.9	11.1	14.5	10.7	56.9	135.5	82.3	79.0	104.0	90.6
October	7.3	3.7	4.3	5.5	3.0	4.7	69.4	111.2	49.3	23.8	73.7	61.9
Total							396.5	657.5	449.4	424.2	532.9	502.9

[z]Avg., average of 82 yr at the Kapuskasing site and 63 yr at the Normandin site.

Table 2. Analysis of variance (F value) for total forage yield and contribution of red clover and grasses to total forage yield

				Contribution to total forage yield (Mg DM ha^{-1})					
Source of variation	df[z]	Total forage yield (Mg DM[y] ha^{-1})		Red clover		Grass		Weed	
Companion grasses (G)	3	4.17	**	0.85	NS	17.21	***	38.21	***
Seeding patterns (SP)	2	6.47	***	1.58	NS	2.54	NS	9.54	***
G × SP	6	0.32	NS	0.16	NS	0.24	NS	0.91	NS
Sites (S)	1	0.21	NS	3.75	*	12.81	***	80.75	***
S × G	3	0.07	NS	0.12	NS	1.49	NS	7.38	***
S × SP	2	1.83	NS	0.01	NS	1.37	NS	2.45	NS
S × G × SP	6	0.10	NS	0.06	NS	0.11	NS	0.15	NS
Error a	168								
Production year (PY)	2	250.73	***	2073.9	***	204.38	***	355.48	***
G × PY	6	2.09	*	6.28	***	6.34	***	19.94	***
SP × PY	4	6.83	***	7.45	***	2.73	*	1.38	NS
G × SP × PY	12	1.40	NS	2.92	***	0.83	NS	1.42	NS
S × PY	2	71.89	***	664.68	***	41.53	***	10.81	***
S × G × PY	6	0.49	NS	11.42	***	4.19	**	4.48	**
S × SP × PY	4	6.62	***	10.46	***	1.11	NS	0.02	NS
S × G × SP × PY	12	1.41	NS	5.11	***	0.14	NS	0.11	NS
Error b	240								

[z]df, degrees of freedom.
[y]DM, dry matter.
*, **, ***, significant at $P \le 0.05$, $P \le 0.01$, and $P \le 0.001$, respectively; NS, not significant ($P > 0.05$).

the average total forage yield from MR was nearly 1.0 Mg DM ha^{-1} higher than the total forage yield from the alternating seeding patterns, but this was not observed for the first production year (Table 3).

The results obtained with the MR seeding pattern are similar to those observed in other studies with alfalfa (Chamblee and Lovvorn 1953; Tewari and Schmid 1960; Sheaffer and Marten 1992). In contrast, Kilcher and Heinrichs (1958) found, in western Canada, that the alfalfa component of a mixture was higher with alternate-row seeding than with mixed-within-a-row seeding. According to these authors, that difference occurred because alternate-row seeding reduces interspecies competition for water resources. In the present experiment, water was not a problem during the production years (Table 1).

In an experiment with alfalfa-grass mixtures, Sheaffer and Marten (1992) demonstrated that the MR and broadcast seeding patterns produced the highest total forage yields among all seeding patterns tested. These results were explained by a greater contribution of alfalfa to total forage yield with these two seeding

Table 3. Effect of seeding patterns on total forage yield and contribution of red clover, grasses and weed to total forage yield for each production year and site

		Total yield (Mg DM ha^{-1})			Contribution to total forage yield (Mg DM ha^{-1})								
					Red clover	Grass	Weed	Red clover	Grass	Weed	Red clover	Grass	Weed
Site	Seeding pattern[y]	PY1[x]	PY2	PY3	PY1			PY2			PY3		
Kapuskasing	1+1	7.1	5.8*b*	6.5*b*	5.2	1.7*bc*	0.1	1.8*b*	3.7*a*	0.3	–[w]	–	–
	2+2	7.3	5.2*c*	6.1*b*	5.6	1.6*c*	0.1	1.9*b*	3.0*b*	0.3	–	–	–
	MR	7.4	6.4*a*	7.3*a*	5.5	1.8*ab*	0.1	2.6*a*	3.6*ab*	0.2	–	–	–
	SEM[v]	1.9	0.2	0.4	1.1	0.4	0.05	0.3	0.5	0.06			
Normandin	1+1	6.2*b*	5.4*b*	5.0*b*	4.0*b*	1.8	0.5*a*	1.6*b*	2.9	0.9*a*	0.7*b*	2.6*b*	1.8*a*
	2+2	6.2*b*	5.5*b*	4.9*b*	3.9*b*	1.8	0.6*a*	1.6*b*	2.9	0.9*a*	0.6*b*	2.4*b*	1.8*a*
	MR	6.6*a*	5.9*a*	5.3*a*	4.6*a*	1.8	0.3*b*	2.4*a*	2.9	0.7*b*	0.9*a*	2.9*a*	1.4*b*
	SEM	0.3	0.1	0.7	0.2	0.2	0.03	0.1	0.2	0.1	0.1	0.3	0.1

DM, dry matter.
[y]1+1, single alternate row; 2+2, double alternate rows; MR, mixed within a row.
[x]PY, production year.
[w]Not determined because no red clover plants remained.
[v]SEM, standard error of the mean.
a–c Means followed by a different letter in a column within a given site are significantly different according to Tukey's test ($P \le 0.05$).

patterns. In the present experiment, it was observed that the MR seeding pattern generally produced the highest red clover dry matter yields among all seeding patterns (Table 3). It may explain total forage yield differences between seeding patterns as statistical differences observed for grass productivity were not biologically very important (Table 3). These results also suggest a protection effect for red clover with MR seeding pattern as red clover productivity was higher at both sites, excepted the first production year at the Kapuskasing site (Table 3). In fact, grasses and red clover on the same row may offer a physical barrier to the laying bare of red clover plants compared with other seeding patterns. Protection effect by timothy had been reported by Belzile (1987) when red clover and timothy were seeded in mixtures compared with a pure stand of red clover. According to the author, the effect was observed when winter survival conditions were difficult no matter what the snow cover thickness.

The various companion grasses produced significant differences ($P \leq 0.01$) between the red clover–grass mixtures in terms of total forage yield. The response was the same for each site ($P > 0.05$), but different for each production year, as shown by a significant interaction between companion grasses and production years ($P \leq 0.05$) (Table 2). During all production years, the red clover–tall fescue mixture had the highest total forage yield compared with the other mixtures, with mean values of 7.3, 6.3 and 6.8 Mg DM ha^{-1} for the first, second and third production years, respectively (Table 4). All the other mixtures produced similar yields in the first production year, (average of 6.7 Mg DM ha^{-1}). For the second and third production years, red clover–timothy and red clover–bromegrass had similar total yields (average 5.6 Mg DM ha^{-1} and 6.2 Mg DM ha^{-1}, respectively) red clover–orchardgrass having the lowest total yield (average 5.4 Mg DM ha^{-1}) (Table 4). Results observed in this experiment for smooth bromegrass and timothy corroborate those of Darisse and Drapeau (1982), who found that timothy and smooth bromegrass provided similar total forage yields in mixtures with red clover.

Table 4. Total forage yield of binary mixtures of red clover and grasses in 3 production years. Data are the average of two sites and three seeding patterns

	Total forage yield (Mg DM[z] ha^{-1})		
Binary mixtures	PY[y]1	PY2	PY3
Red clover–bromegrass	6.6*b*	5.5*b*	6.2*b*
Red clover–tall fescue	7.3*a*	6.3*a*	6.8*a*
Red clover–orchard grass	6.6*b*	5.3*c*	5.4*c*
Red clover–timothy	6.7*b*	5.7*b*	6.1*b*
SEM[x]	0.8	0.2	0.7

[z]DM, dry matter.
[y]PY, production year.
[x]SEM, standard error of the mean.
a–c Means followed by a different letter in a column are significantly different according to Tukey's test ($P \leq 0.05$).

The effect of companion grass on total forage yield for binary red clover mixtures is probably more related to the productivity of grass species as red clover productivity decreased rapidly over the production years. Nevertheless, significant interactions were observed between sites, production years and each component of the mixture namely red clover, grass and weed (Table 2).

Overall, red clover dry matter productivity decreased dramatically from the first to the second production year at both sites. In the third production year, red clover productivity was very low (Table 5). In the first production year red clover productivity of most binary mixtures accounted for more than 70% of total forage dry matter yield at both sites. However, red clover productivity of red clover-tall fescue and red clover-orchardgrass mixtures were lower at the Normandin site with 62 and 55%, respectively (Table 5). By the second production year, the contribution of red clover to the dry matter yield varied from 26 to 51% and from 25 to 37% for the Kapuskasing and Normandin site, respectively, depending on the companion grass. The most important difference between sites was observed with red clover–smooth bromegrass mixture, where red clover productivity was particularly high at the Kapuskasing site compared with the other binary mixtures (Table 5). It is recognized that red clover is competitive with smooth bromegrass especially in heavy soil (Michaud and Allard 2005), which was the case at the Kapuskasing site with a silty clay soil. In the third production year, the contribution of red clover to the dry matter yield was negligible excepted with tall fescue, where red clover still produced 21% of total dry matter yield.

In this experiment, the contribution of red clover to the dry matter yield with timothy or smooth bromegrass, decreased more rapidly than what was observed by Darisse and Drapeau (1982). In another study, Barnett and Posler (1983) in Kansas observed that the red clover still contributed over 45% of the total yield by the third production year, but the companion grasses tested were not the same as in the present experiment. Discrepancies can also likely be explained by differences in environmental conditions between these studies. Soil water status, resulting from precipitation and soil drainage, is an important factor for the winter survival of red clover, as plants can easily be laid bare if there is too much water in the soil at the first frost. Unfortunately, dead plants were not counted in the spring, but they were observed. A study by Darisse and Drapeau (1982) was conducted in a tile-drained soil, a fact that might partially explain why their results were better than those obtained in the present study. The soil texture and probably the drainage were different in all these experiments.

Given that a binary mixture of red clover–tall fescue produced the highest dry matter yield, the superior

Table 5. Effect of companion grass on contribution of red clover, grass and weed to total forage yield of red clover binary mixtures for each production year and site

	Contribution to total forage yield (Mg DM[z] ha^{-1})								
	Red clover	Grass	Weed	Red clover	Grass	Weed	Red clover	Grass	Weed
Binary mixtures		PY[y]1			PY2			PY3	
Kapuskasing									
Red clover–bromegrass	5.3	1.7*b*	0.1	2.8*a*	2.4*c*	0.3	–[x]	–	–
Red clover–tall fescue	5.5	2.1*a*	0.1	1.9*bc*	4.3*a*	0.2	–	–	–
Red clover–Orchardgrass	5.5	1.5*b*	0.1	1.4*c*	3.8*ab*	0.2	–	–	–
Red clover–timothy	5.4	1.5*b*	0.2	2.2*ab*	3.3*b*	0.3	–	–	–
SEM[w]	1.1	0.4	0.05	0.3	0.4	0.06	–	–	–
Normandin									
Red clover–bromegrass	4.5*a*	1.1*b*	0.5*a*	2.1*a*	2.2*b*	1.4*a*	0.7*b*	2.4*bc*	2.2*a*
Red clover–tall fescue	4.2*a*	2.2*a*	0.4*b*	2.1*a*	3.5*a*	0.5*c*	1.2*a*	3.5*a*	0.9*b*
Red clover–orchardgrass	3.3*b*	2.4*a*	0.3*b*	1.3*b*	3.4*a*	0.4*c*	0.5*b*	2.7*b*	1.2*b*
Red clover–timothy	4.5*a*	1.3*b*	0.5*a*	2.0*a*	2.4*b*	1.1*b*	0.7*b*	2.0*c*	2.4*a*
SEM	0.2	0.2	0.3	0.1	0.2	0.1	0.1	0.4	0.1

[z]DM, dry matter.
[y]PY, production year.
[x]Not determined because no red clover plants remained.
[w]SEM, standard error of the mean.
a–c Means followed by a different letter in a column within a given site are significantly different according to Tukey's test ($P \leq 0.05$).

contribution of tall fescue to total dry matter yield among all companion grasses was observed only in the first production year at the Kapuskasing site and in the third production year at the Normandin site. In all other production years, tall fescue productivity was higher than those of smooth bromegrass and timothy, but similar to orchardgrass (Table 5). On the other hand, the productivity of the red clover component with tall fescue was similar to or higher than what was observed for any other mixtures in the experiment with the exception of the red clover–smooth bromegrass mixture at the Kapuskasing site in the second production year (Table 5). Thus, the higher total dry matter yield of the red clover–tall fescue mixture might be related to both components of the mixture and not only to the grass component.

The total forage yield of red clover–orchardgrass produced the lowest dry matter yield among all mixtures by the second production year. However, unlike to tall fescue, orchardgrass impaired red clover productivity as soon as the first production year at the Normandin site and by the second production year at the Kapuskasing site compared with other binary mixtures tested in this experiment (Table 5). In the first production year, higher productivity of orchard grass compensated for the lower contribution of red clover to total forage yield of this mixture compared with red clover–smooth bromegrass and red clover–timothy. In subsequent production years, higher total dry matter yield from red clover–smooth bromegrass and red clover–timothy mixtures was produced by the contribution of weeds to total dry matter yield. In the second production year, the contribution of weeds to total forage yield was over 20% for these mixtures compared with less than 10% for red clover–orchardgrass and red clover–tall fescue mixtures at the Normandin site (Table 5). In the third production year, the contribution of weeds to total forage yield for these mixture was over 40%, while red clover–orchardgrass increased to 27% and red clover–tall fescue to 16% (Table 5). Weed invasion was negligible at the Kapuskasing site, probably because plots were harvested later and precipitation was more important in July than at the Normandin site (Table 1). This situation probably favored rapid regrowth after harvest, thus limiting weed invasion in the plots. These results suggest that companion grasses differed in their ability to fill spaces in the stand, with orchardgrass and tall fescue being more aggressive than timothy and smooth bromegrass.

CONCLUSION

Under northern conditions in Quebec and Ontario, binary mixtures of red clover and grass seeded in the same row produced higher yields during 3 production years. The red clover–tall fescue mixture produced the highest total forage yields during all the production years, whereas red clover–orchardgrass yields gradually decreased, to produce the lowest total forage yields by the second production year, and those of mixtures with smooth bromegrass and timothy were intermediate. Neither the seeding pattern nor the companion grass species significantly improved the contribution of red clover to total forage yield beyond the second production year, confirming that red clover is a short-lived legume. Environmental conditions, principally high precipitation in the fall, and maturity stage at harvest resulted in differences between the sites. In these northern regions, red clover may be used to establish a grass stand. These results show that tall fescue and orchardgrass would be alternative choices to timothy or bromegrass, given that plots were still productive in the third production year and invasion by weeds was lower.

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