Cross-Canada comparison of the productivity of fodder galega (*Galega orientalis* Lam.) with traditional herbage legumes

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Fairey, N. A., Lefkovitch, L. P., Coulman, B. E., Fairey, D. T., Kunelius, T., McKenzie, D. B., Michaud, R. and Thomas, W. G. 2000. **Cross-Canada comparison of the productivity of fodder galega (*Galega orientalis* Lam.) with traditional herbage legumes.** Can. J. Plant Sci. **80**: 793–800. A study was conducted across Canada to compare the herbage productivity of fodder galega (*Galega orientalis* Lam.) to that of traditional forage legumes, in order to assess its agricultural potential. Trials were established at latitudes ranging from 45 to 56°N with longitudes from 52°W (St. John's, Newfoundland) to 120°W (Dawson Creek, British Columbia). Herbage productivity was monitored for a maximum of 3 production years. The establishment characteristics of Gale fodder galega were comparable to those of Apica and Beaver alfalfa (*Medicago sativa* L.) and Altaswede red clover (*Trifolium pratense* L.), and somewhat superior to those of Dawn Alsike clover (*T. hybridum* L.) and Leo trefoil (*Lotus corniculatus* L.). Anik alfalfa (*M. falcata* L.) was far less uniform and vigorous in its establishment than any of the other species. The average annual dry matter yield of fodder galega ranked third among the seven legumes when averaged over the nine sites; it produced 5545 (SE 95) kg ha^{-1} compared to 3931 (SE 72) kg ha^{-1} for Dawn alsike clover, the lowest-yielding crop, and 6673 (SE 114) kg ha^{-1} for Apica alfalfa, the highest-yielding. The cumulative dry matter yields indicated that Gale galega is at least as well adapted across Canada as the other legumes, except possibly at Saskatoon where the *M. sativa* alfalfas were far superior to all the other legumes in their ability to establish and thrive. The performance characteristics of Gale fodder galega indicate that it has considerable agricultural potential as an additional, perennial, herbage legume for many regions of Canada, except in the semi-arid continental climate of the central Prairies where its growth may be limited by high air temperature and/or insufficient soil moisture.

Key words: Fodder galega, *Galega orientalis* Lam., goat's rue, herbage production, forage legume

Fairey, N. A., Lefkovitch, L. P., Coulman, B. E., Fairey, D. T., Kunelius, T., McKenzie, D. B., Michaud, R. et Thomas, W. G. 2000. **Comparaison de la productivité du galéga fourrager (*Galega orientalis* Lam.) au Canada avec celle des légumineuses fourragères d'usage courant**. Can. J. Plant Sci. **80**: 793–800. Nous avons conduit à divers endroits de l'est et de l'ouest du Canada une étude comparative de la productivité du galéga fourrager (*Galega orientalis* Lam.) par rapport à celle des légumineuses fourragères d'exploitation courante. Les essais étaient installés sous des latitudes allant de 45 à 56°N et des longitudes de 52°O (St-Jean, Terre-Neuve) à 120°O (Dawson Creek, Colombie-Britannique). La productivité fourragère était observée sur un maximum de 3 années d'exploitation. Au plan de l'installation (levée, survie) l'espèce se comparait favorablement aux cultivars Apica et Beaver de luzerne (*Medicago sativa*) et Altaswede de trèfle rouge (*Trifolium pratense* L.), avec une légère supériorité sur le trèfle hybride Dawn (*T. hybridum* L.) et sur le lotier corniculé Leo (*Lotus corniculatus* L.). La luzerne Anik (*M. falcata* L.) était de loin moins homogène et vigoureuse dans l'année d'installation que toutes les autres espèces comparées. Pour les neuf emplacements confondus, le rendement annuel moyen en matière sèche du galéga se classait au troisième rang parmi les sept légumineuses étudiées: il était de 5 545 (ET 95) kg ha^{-1} contre 3 931 (ET 72) kg ha^{-1} pour le trèfle hybride Dawn, l'espèce la moins productive, et 6 673 (ET 114) kg ha^{-1} pour la luzerne Apica, l'espèce la plus productive. D'après les rendements en matière sèche cumulatifs, le galéga fourrager Gale peut se cultiver aussi bien que les autres légumineuses partout au Canada, excepté peut-être en Saskatchewan où le luzerne *M. sativa* l'emportait de loin sur toutes les autres légumineuses par ses qualités d'installation, de croissance et de longévité. Grâce à ses belles performances, la nouvelle culture offre de grandes possibilités agronomiques comme légumineuse fourragère vivace d'appoint dans beaucoup de régions du Canada, sauf dans les conditions climatiques continentales semi-arides des Prairies centrales où sa croissance risque d'être restreinte par les hautes températures de l'air ou par le manque d'humidité du sol (ou par les deux en combinaison).

Mots clés: Galéga fourrager, *Galega orientalis* Lam., rue des chèvres, production fourragère, légumineuse fourragère

The plant family, Leguminosae, includes the genus *Galega* whose common name includes plants known as goat's rue. This genus contains two known species, *Galega officinalis* L., an ornamental and medicinal plant that occurs as a weed in South America, New Zealand and central Europe, and *Galega orientalis* Lam. a perennial legume which, since 1972, has been developed in Estonia as a new fodder crop (Raig 1982, 1994). The agronomic potential of *G. orientalis* has been well documented for temperate regions such as Estonia (Nômmsalu 1994; Raig 1982, 1994) and the Nordic countries (Varis 1986). In 1993, the Estonian Research Institute of Agriculture and Land Improvement made a proposal to the International Seed Testing Association to include this species in their list of field and fodder crops under the name "fodder galega" (Raig 1994). This common name was chosen to avoid confusion with that of *G. officinalis*, a plant that is toxic to ruminant livestock because of the presence of several alkaloids including vasicine and galegine (Raig 1994). According to Varis (1986) and Nômmsalu (1993), *G. orientalis* does not contain sufficient alkaloids to be toxic to ruminant livestock. Benn et al. (1996) detected two hemiterpenoid guanidines (smirnovine and its (*Z*)-4-hydroxy derivative) in the vegetative matter of fodder galega grown in Canada but the concentration of smirnovine was no greater than that isolated from plants grown in Estonia, i.e. 0.2%; smirnovine is the conjugated form of galegine and appears to be much less toxic than galegine itself.

Fodder galega is a perennial, winter-hardy, tap-rooted, leguminous herb that can spread and propagate vegetatively by underground stolons. The aboveground vegetation has a high concentration of protein. Vegetative matter is produced over a long growing season, with growth beginning and seed maturing at least 2 wk earlier than alfalfa (Raig 1982) or red clover (Varis 1986). Furthermore, fodder galega, its symbiotic nitrogen fixation, and associated nitrogen-fixing bacteria (*Rhizobium galegae*) are tolerant of moderately acid soils (at least to pH 4.5) although harsh winters may reduce bacterial numbers in the soil (Lindström et al. 1985). The herbage is best utilised directly by livestock as greenfeed or conserved as silage, hay, haylage or dehydrated meal for subsequent feeding, while the nectar from the flowers of a seed crop is excellent for honey production by bees (Raig 1994). In his assessment of the agronomic and botanical characteristics of fodder galega, Raig (1994) speculated about the crop's suitability as an alternative to alfalfa for Canadian agriculture because of the climatic similarities with northern Europe and the Nordic countries. The present study was conducted at several sites across Canada to compare the productivity of fodder galega to that of traditional legume forage crops, in order to make a provisional assessment of its agricultural potential as an additional, perennial, herbage legume.

MATERIALS AND METHODS

The study was conducted at nine sites across Canada with latitudes in the range of 45 to 56°N; four of these sites were in the Peace region of northwestern Canada and the others

Table 1. Physical characteristics, long-term (1961–1990) environmental conditions, and experimental information for the study sites

Site	Latitude	Longitude	Soil classification	Annual precipitation (mm)	Minimum monthly air temperature (°C)		Maximum monthly air temperature (°C)		Mean monthly air temperature (°C)		Seeding date	Harvested plot size (m^2)
					January	July	January	July	January	July		
Dawson Creek, British Columbia	55°46'N	120°14'W	Gray Solod/Luvisol	487	−20.8	8.5	−9.1	21.8	−14.9	15.1	1/6/94	3.1
Beaverlodge, Alberta	55°12'N	119°24'W	Gray Solod/Luvisol	468	−18.1	8.9	−9.0	21.6	−13.5	15.3	30/5/94	3.1
Foster's, near Beaverlodge, Alberta	55°10'N	119°23'W	Orthic Gleysol	468	−18.1	8.9	−9.0	21.6	−13.5	15.3	30/5/94	3.1
Fairview, Alberta	56°04'N	118°23'W	Gray Solod/Luvisol	454	−19.4	10.5	−11.3	21.8	−15.3	16.2	2/6/94	3.1
Saskatoon, Saskatoon	52°07'N	106°38'W	Dark Brown Chernozem	347	−22.9	11.7	−12.3	25.4	−17.5	18.6	24/5/95	7.5
Sainte-Foy, Québec	46°47'N	71°18'W	Gleysol	1208	−17.3	13.2	−7.7	24.9	−12.4	19.1	23/6/94	5.0
Truro, Nova Scotia	45°22'N	63°16'W	Humo-Ferric Podzol	1176	−12.0	12.1	−1.6	23.8	−6.7	18.0	24/5/94	7.5
Charlottetown, Prince Edward Island	46°14'N	63°08'W	Humo-Ferric Podzol	1137	−11.3	14.4	−3.3	23.1	−7.2	18.8	25/5/94	6.0
St. John's, Newfoundland	47°34'N	52°43'W	Humo-Ferric Podzol	1580	−7.5	11.0	−0.6	20.5	−4.0	15.8	25/5/94	6.0

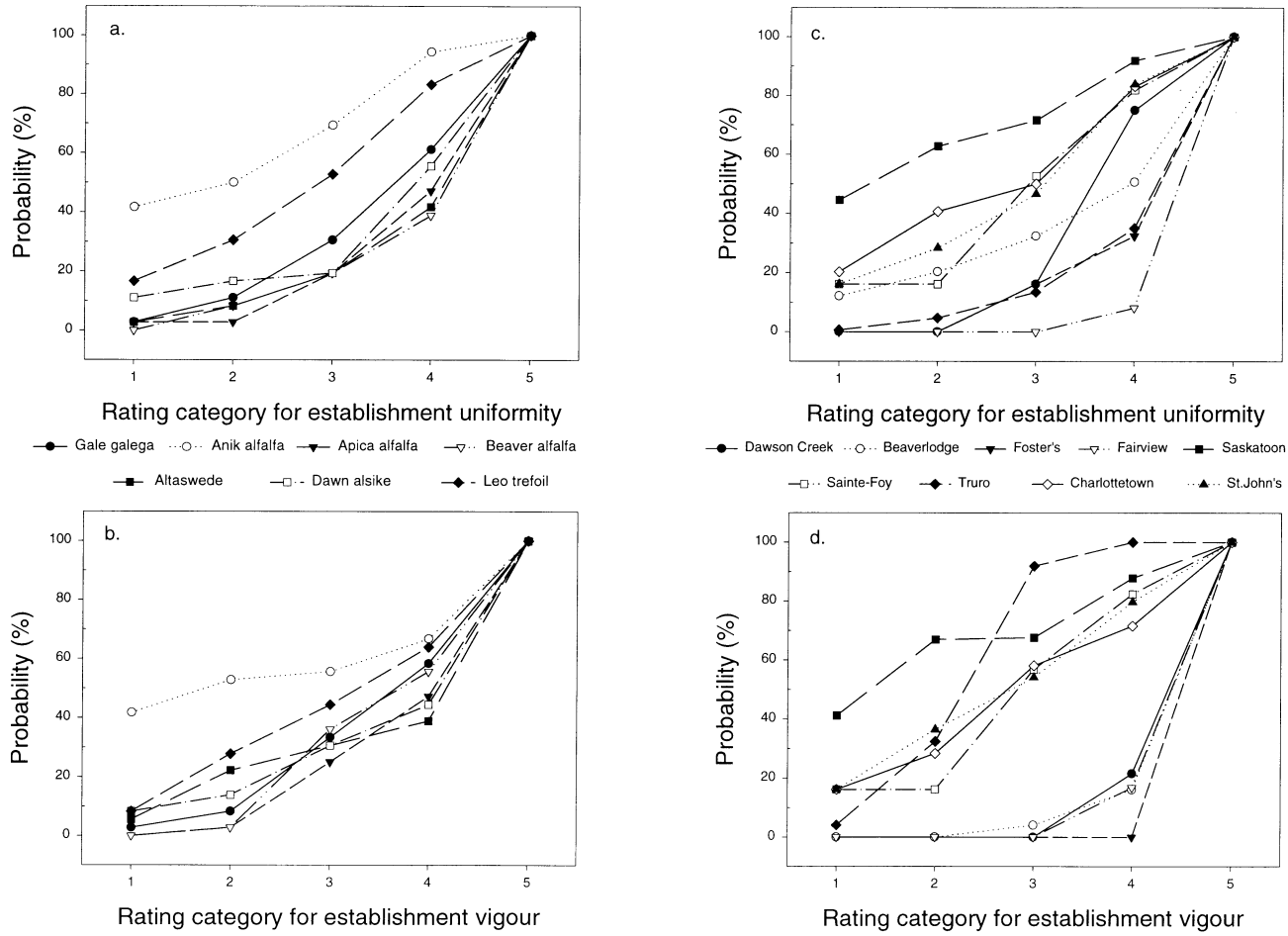

Fig. 1. Establishment characteristics expressed as the cumulative probability of being rated lower than or within a specific category (1 to 5 where 5 is most uniform or most vigorous): a. Uniformity of each legume; b. Vigour of each legume; c. Uniformity at each site; d. Vigour at each site.

were distributed across Canada to as far east as St. John's, Newfoundland. The physical characteristics of each site are summarised in Table 1. A randomised complete block design with four replicates of seven herbage legumes was used at each site. The treatments included six, traditional, herbage legumes and Gale fodder galega, the first recognised variety of *G. orientalis* released in 1987 from a cooperative breeding program of the Estonian Research Institute of Agriculture and the All-Union Institute of Fodder Crops in Moscow (Raig 1994). The traditional herbage legume cultivars were *Lotus corniculatus* L. 'Leo', *Medicago sativa* L. 'Apica' and 'Beaver', *M. falcata* L. 'Anik', *Trifolium hybridum* L. 'Dawn' and *T. pratense* L. 'Altaswede'. Individual plot size differed among sites according to the availability of drilling and harvesting equipment. For each site, the seed of each legume came from the same batch of certified seed, and the seeding density for each legume at each site was standardised at 400 viable seeds m^{-2} in order to ensure the validity of species/variety comparisons. Although the seeding density was standardised, the actual seeding rate for each legume varied according to the thousand-seed weight and the viability of each specific batch of seed. Just prior to seeding, the seed was inoculated with the appropriate *Rhizobium* bacteria, *R. galegae* for fodder galega (Lindström 1989). The seed and inoculant of fodder galega were obtained from Dr. Helmut Raig of the Estonian Research Institute of Agriculture. The trials were sown in 1994 and the growth of the establishment year was removed/harvested to control weeds. The trials were harvested for herbage for a minimum of 2 production years (1995 and 1996) and for a third year (1997) when warranted by the persistence of the seeded legumes. Two or three cuts were harvested per year, depending on the seasonal development of the stands; the first cut was taken when Apica alfalfa was at the early- to mid-flowering stage of development. The site at Saskatoon was re-seeded in 1995 and harvested in 1996 and 1997 because of a drill malfunction in 1994. The harvested area per plot differed among

Table 2. Accumulated analysis of deviance for annual dry matter yield of herbage

Factor term added	df	Deviance	Mean deviance ratio[z]		*F*-probability
			Unadjusted	Adjusted	
Sites	8	45.86995	270.21	82.595	0.0000***
Sites.Reps	27	1.87432	3.27	–	–
Legumes	6	20.25239	159.07	–	0.0000***
Galega vs. other legumes (GvOL)	1	0.40770	19.21	0.103	0.7612NS
Other legumes (OL)	5	19.84469	187.04	–	–
Sites × Legumes	47	20.73446	20.79	–	0.0000***
Sites × GvOL	8	6.84342	40.31	2.402	0.03269*
Sites × OL	39	13.89104	16.79	–	–
Year	2	8.06743	190.09	1.540	0.2612NS
Year × Sites	10	26.18551	123.40	–	–
Year × Legumes	12	2.92787	11.50	–	0.0000***
Year × GvOL	2	0.33519	7.90	0.646	0.5446NS
Year × OL	10	2.59268	12.22	–	–
Year × Sites × Legumes	58	7.47115	6.07	–	0.0000***
Year × Sites × GvOL	10	0.76003	3.58	0.544	0.8500NS
Year × Sites × OL	48	6.71112	6.59	–	–
Residual	399	8.46659			

[z]The mean deviance of each factor term is its deviance divided by its df. The denominator for calculating the unadjusted ratio is the mean deviance of the residual factor. An adjusted ratio is given for factor terms where the use of the residual mean deviance is inappropriate; in these cases, the denominator for the ratio is the mean deviance of the factor term in the row immediately below the factor being assessed, i.e., the appropriate error term.

sites and ranged from 3.1 to 7.5 m^{-2} (Table 1). The soil fertility status at each site was adjusted with applications of lime, P, K and S according to soil analysis requirements and local management practices; N fertiliser was not applied during the production years.

An assessment of the uniformity and vigour of stand establishment was made in the fall of the establishment year; each characteristic was rated visually using an ordinal scale of 1 to 5 where 5 was most uniform or most vigorous. At each harvest, the total plot fresh weight was recorded and a sub-sample of 3–500 g was weighed, oven-dried, and reweighed for the determination of dry matter yield.

Genstat 5, Release 4.1, (Lawes Agricultural Trust 1993, 1997) was used for all statistical analyses. Each variate was analysed using a generalised linear model (McCullagh and Nelder 1989) with an error distribution and link function appropriate for the variate (Lefkovitch 1993). To allow for the possibility of unequal variability due to differing plot sizes, scatter diagrams of the deviance-standardised residuals against fitted values were examined in detail. For all reported analyses, no obvious systematic trends in mean values or in variability were revealed by the scatter diagrams. The dry matter yield variates were analysed assuming a constant coefficient of variation by specifying a gamma distribution and a logarithmic link. The ratings of establishment uniformity and vigour were analysed using the procedure of Lefkovitch (1991) which involved binomial analyses (with a logit link) to compare the cumulative frequency of occurrence of a specific rating within each of the first four rating categories against the respective cumulative frequency within category 5, the highest rating category. Tests of significance for the yield variates referred the ratio of mean deviances to the *F*-distribution and, for the ratings, the deviance was referred to the chi-squared distribution. Probabilities of less than 5% are considered to be significant. The means reported for each response variate are the natural averages of the means predicted by the fitted model.

RESULTS AND DISCUSSION

The results of the analyses of the ratings of establishment uniformity and establishment vigour were similar to each other (Fig. 1). They indicate that the establishment characteristics of Gale fodder galega are generally comparable to those of Apica and Beaver alfalfa, Altaswede red clover and Dawn Alsike clover, somewhat superior to those of Leo trefoil, and that Anik alfalfa is far less uniform and vigorous in its establishment than any of the other species (Fig. 1a and b). The slow establishment characteristics of Anik alfalfa, a yellow-flowered cultivar of *M. falcata*, have been noted repeatedly in the Peace region (D.T. Fairey and J.A.C. Lieverse 1999, personal communication) since its registration as a cultivar (Pankiw and Siemens 1976). In general, with the exception of the Saskatoon site, establishment uniformity and vigour were better at the sites in western Canada than at those in central and eastern Canada; establishment at the Saskatoon site was considerably less uniform and vigorous than at any other site (Fig. 1c and d).

As was to be expected with a study of this nature, the site and year of production, in conjunction with the legume species, had a significant influence on crop productivity. Although there was a significant difference among the legumes for the annual dry matter yield of herbage, the productivity of fodder galega was comparable to that of the other legumes (Table 2). The average annual dry matter yield of fodder galega, when averaged over the nine sites, ranked third out of the seven legumes; it produced 5545 (SE 95) kg ha^{-1} compared with 3931 (SE 72) kg ha^{-1} for Dawn alsike clover, the lowest-yielding legume, and 6673 (SE 114) kg ha^{-1} for Apica alfalfa, the highest-yielding. The productivity at the individual sites (Fig. 2) indicates

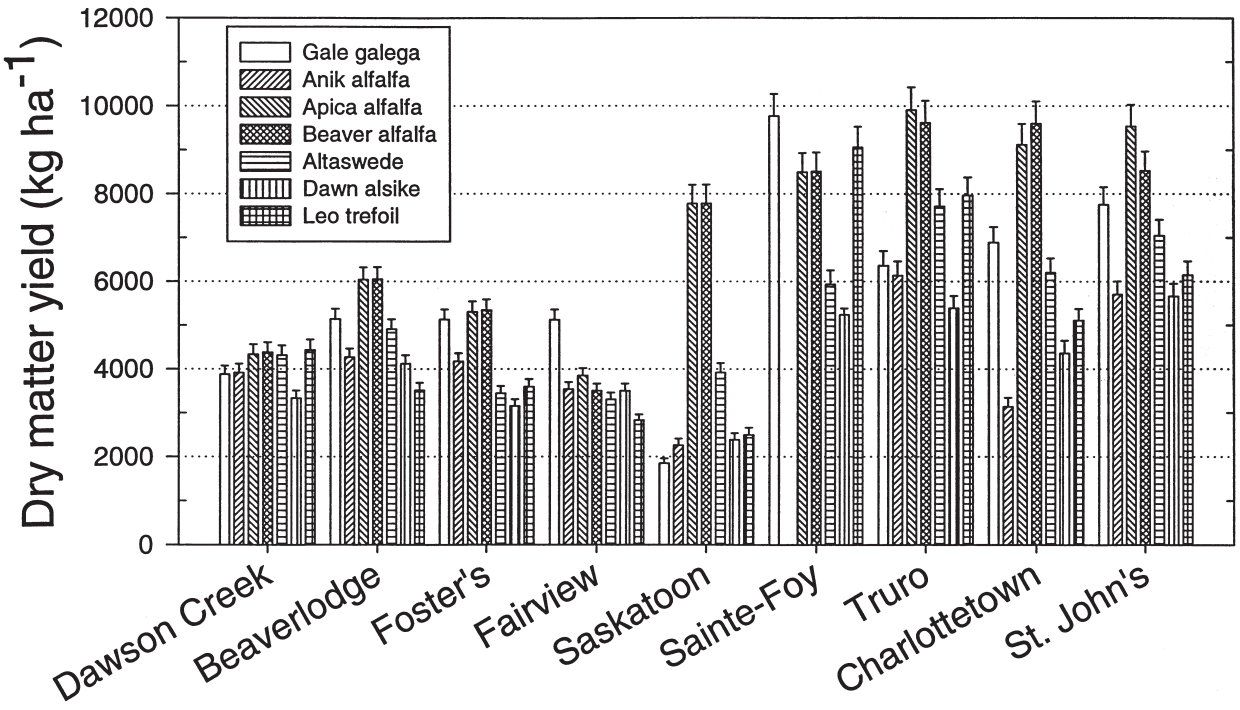

Fig. 2. Average annual dry matter yield of herbage for each legume at each site (vertical lines above bars are SE).

that fodder galega ranked first at two sites (Fairview and Sainte-Foy), third at four sites (Beaverlodge, Foster's, Charlottetown and St. John's), fifth at Truro, sixth at Dawson Creek where differences among legumes were small (3877 [SE 200] kg ha^{-1} for Gale galega compared to 4437 [SE 238] kg ha^{-1} for Leo trefoil, the highest-yielding legume at the site), and seventh at Saskatoon where Apica and Beaver alfalfa produced twice as much herbage as any of the other legumes and Gale galega was comparable to Anik alfalfa, Dawn Alsike clover and Leo trefoil. The superior performance of *M. sativa* alfalfa over fodder galega was also reported from trials conducted in Denmark after establishment with a companion crop of barley; the yields of organic matter, crude protein and feed units for cattle were similar for the two legumes in the establishment year but, in subsequent production years, the fodder galega produced 76, 69 and 62% as much as the alfalfa of these respective components when harvested twice per year, and 55, 59 and 57%, respectively, when harvested three times per year (Møller et al. 1997).

The cumulative dry matter yield of each legume, over 2 or 3 yr of production for each site and averaged over sites (Fig. 3), indicates that Gale galega is at least as well adapted as the other legumes that are traditionally grown across Canada, except possibly at Saskatoon where Apica and Beaver alfalfa were far superior to all the other legumes in their ability to establish and thrive under the prevailing growing conditions. Among the trial sites, Saskatoon, with its semi-arid continental climate, has the lowest annual precipitation and the highest maximum air temperature in July (Table 1). The *M. sativa* alfalfas appear better adapted to these conditions than any of the other forage legumes, possibly because of their superior rooting depth.

Although crop establishment was more uniform and vigorous at the more westerly sites (Fig. 1c and d), the annual and cumulative productivity over years was generally greater at the more easterly sites (Fig. 3) where precipitation is more plentiful (Table 1). The reverse trend was evident as far as persistence of production was concerned, as it was possible to retain three of the four sites in the Peace region for a third production year. The trials at the eastern sites were discontinued after 2 production years because of a decline in stand persistence and quality (weed invasion). In Atlantic Canada, root-rot pathogens are a common cause of stand deterioration in most forage legume species, and fodder galega appears to be no exception. It is also notable that, at Sainte-Foy, the Anik alfalfa failed to establish well enough to produce any harvestable herbage and the Dawn Alsike clover did not persist into the second production year. The lack of persistence of Alsike clover into a second production year has long since precluded the use of the species in central and eastern Canada. While the trials in this study were not retained for an adequate time to provide a meaningful assessment of long-term persistence, it is notable that plots of Gale fodder galega seeded at Beaverlodge and near the Dawson Creek site have persisted for more than 5 yr (N.A. Fairey 1999, unpublished data). Furthermore, plots of fodder galega at Sainte-Foy have persisted for at least 4 yr and have also revealed that the species is more tolerant than alfalfa to poor drainage and water-sat-

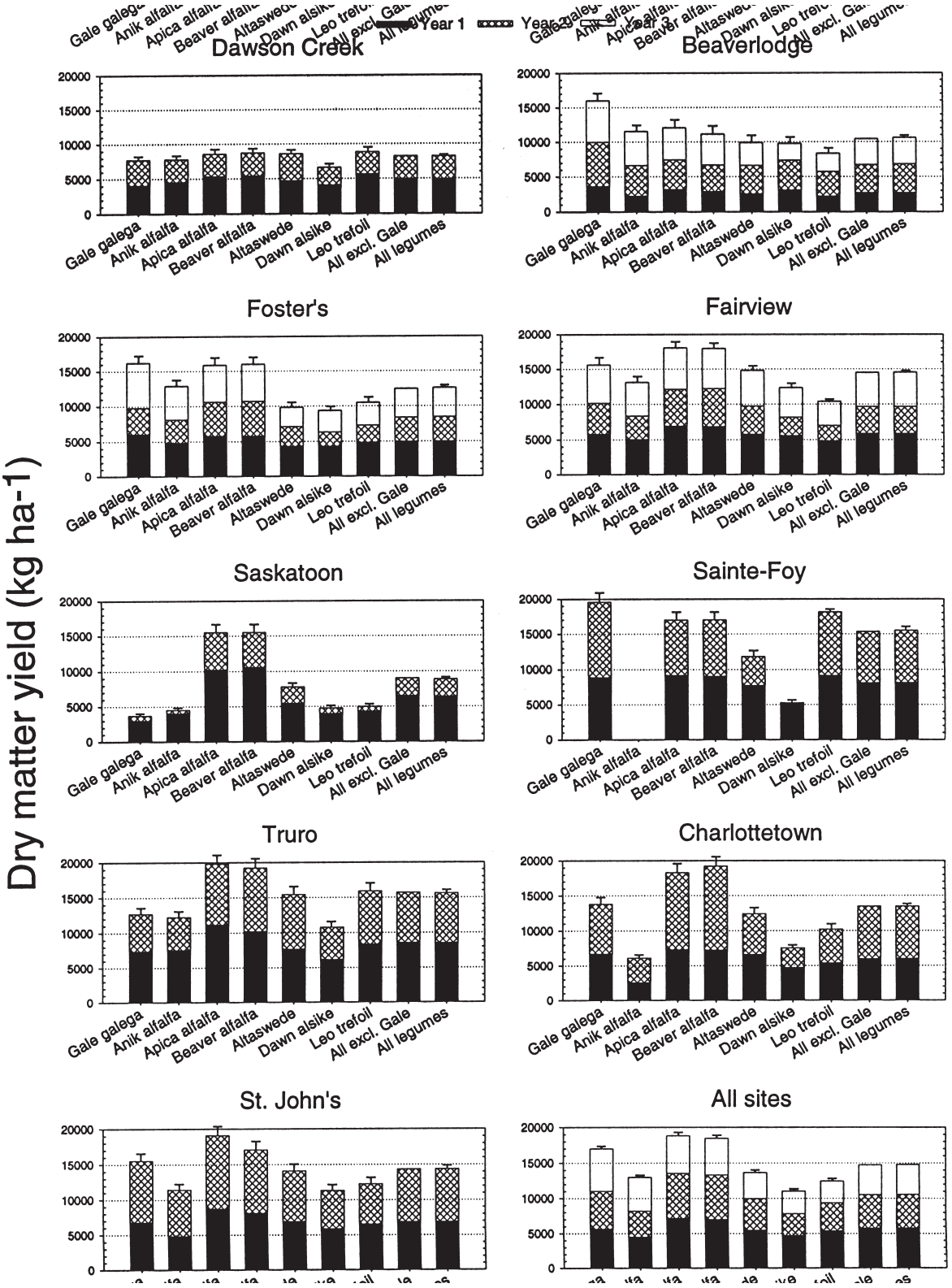

Fig. 3. Annual and cumulative dry matter yield of herbage over production years, at each site and averaged over all sites, for each legume, for all legumes excluding Gale galega, and for all legumes (vertical lines above bars are SE for the cumulative yield over years).

urated soils. These observations are in agreement with trial results from Finland (Varis 1986) and Estonia (Raig 1994), which have documented the very persistent and perennial productivity of fodder galega.

The nutritional quality of the herbage produced by fodder galega is comparable to that of alfalfa (Varis 1986; Nômmsalu 1994), but apparently has a higher concentration of hemicellulose than that of other forage legumes such as red and white clover, yellow lupin and some vetches (Møller and Hostrup 1996). Furthermore, provisional indications are that its bloat-inducing potential is much lower than that of alfalfa (W. Majak, personal communication, 1999). Herbage quality comparisons of fodder galega and alfalfa grown at Sainte-Foy have indicated that galega has an equal or higher concentration of crude protein, a higher concentration of neutral-detergent fibre, and a similar concentration of acid-detergent fibre. A reliable and economic supply of good quality seed is also required for successful cultivation of a new species; at the Beaverlodge site, initial investigations into the seed-producing capability of fodder galega have resulted in seed yields of 203 (SE 24) and 851 (SE 102) kg ha^{-1} (@12% moisture) in the first and second production years, respectively (N.A. Fairey, 1999 unpublished data). These herbage quality and seed-producing characteristics, together with the broad adaptation and comparative herbage yields reported in this study, support the contention of Raig (1994) that fodder galega may be worth considering as an additional herbage-legume crop for Canadian agriculture.

The erect growth of fodder galega, in conjunction with it being a persistent, winter-hardy perennial with a tap-root and the ability to spread by underground stolons, suggest that it would be more suitable for conservation as dehydrated forage or silage, or for direct-cutting and utilisation as greenfeed, than for pasture. Future studies in Canada with fodder galega should investigate: 1) Its acceptability for the production of dehydrated forage for export purposes, particularly considering the possible advantages of its early spring growth and early maturity (as much as 14 d or more earlier than alfalfa) for lengthening the time-period over which high-quality dehydrated forage may be harvested; 2) Its persistence/longevity and herbage quality under different types of crop management and with various companion grasses; 3) The agronomic practices required for optimising seed yield in conjunction with the utilisation of its early-flowering capability to extend the period of nectar availability for honeybees and/or other pollinating insects, particularly in the Peace region; 4) Its suitability for the pasturing of ruminant livestock.

CONCLUSIONS

The average annual dry matter yield of fodder galega ranked third among the seven legumes when averaged over the nine sites; it produced 5545 (SE 95) kg ha^{-1} compared with 3931 (SE 72) kg ha^{-1} for Dawn alsike clover, the lowest-yielding crop, and 6673 (SE 114) kg ha^{-1} for Apica alfalfa, the highest yielding. In this provisional investigation, the performance characteristics of Gale fodder galega indicate that it has considerable agricultural potential as an additional, perennial, herbage legume for many regions of Canada, except possibly in the central Prairies with its semi-arid, continental climate.

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