Companion crop establishment of short-lived perennial forage crops in Saskatchewan

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Jefferson, P. G., Lyons, G., Pastl, R. and Zentner, R. P. 2005. **Companion crop establishment of short-lived perennial forage crops in Saskatchewan**. Can. J. Plant Sci. **85**: 135–146. Short-lived perennial forages may provide producers with a cash hay crop as a viable option to diversify annual grain rotations. Little or no information on alternative annual crops for companion crop establishment of forages is available for Saskatchewan conditions. We evaluated field pea (*Pisum sativum*), canola (*Brassica napus*), and Westerwolds ryegrass (*Lolium westerwoldicum*) as companion crops over 3 yr (1998–2000) at three Saskatchewan sites: Swift Current (Brown soil zone), Saskatoon (Dark Brown) and Nipawin (Dark Gray). We also compared three short-lived, vigourous grass species in mixture with two alfalfa (*Medicago sativa*) cultivars or monoculture. Combinations of precipitation and temperature variables combined with companion crop plant density and biomass explained 90% of the variation in forage yield loss relative to no companion crop forage yield. We conclude that companion crops can be used with low yield reductions at Nipawin, but that all three companion crops significantly reduced forage yield at Swift Current. Forage seedling density was reduced under companion crops but the decline in forage seedling density did not explain the reduction in forage yield. We speculate that yield components rather than plant density must have been affected by companion crop competition. Intermediate wheatgrass (*Elytrigia intermedia*) produced higher forage yield than Dahurian wildrye (*Elymus dahuricus*) or slender wheatgrass (*Elymus trachycaulus*). Grass-alfalfa mixtures produced higher forage yield than grass monoculture. Economic returns were superior if no companion crop was used to establish the forages at Swift Current and Saskatoon; but, at Nipawin economic returns were generally higher with companion crop establishment. The feasibility of companion crops for establishment of short-lived perennial forages in Saskatchewan thus depends on soil zone, with their use best suited to the more humid regions.

Key words: Forage yield, plant density, weather, economics

Jefferson, P. G., Lyons, G., Pastl, R. et Zentner, R. P. 2005. **Les plantes associées dans les cultures de vivaces fourragères de courte pérennité en Saskatchewan**. Can. J. Plant Sci. **85**: 135–146. Pour les agriculteurs, les vivaces fourragères de courte pérennité pourraient devenir une option valable comme culture fourragère monnayable pour diversifier les assolements annuels de céréales. Pourtant, on ne sait rien ou pas grand-chose des cultures annuelles qui faciliteraient l'établissement de plantes associées dans les conditions particulières de la Saskatchewan. Les auteurs ont évalué l'utilité du pois de grande culture (*Pisum sativum*), du canola (*Brassica napus*) et du ray-grass de type Westerworlds (*Lolium westerwoldicum*) comme plantes associées pendant trois ans (de 1998 à 2000) à trois endroits de la Saskatchewan : Swift Current (sols bruns), Saskatoon (sols brun foncé) et Nipawin (sols gris foncé). Ils ont aussi comparé trois vigoureuses espèces de graminées de courte pérennité mélangées à deux cultivars de luzerne (*Medicago sativa*) ou cultivées seules. La fluctuation des précipitations, les écarts de température, la densité du peuplement de plantes associées et la biomasse de ces dernières expliquent 90 % de la variation du rendement fourrager par rapport à celui obtenu en l'absence de plantes associées. Ils en concluent que les plantes associées pourraient être utilisées sans grandes pertes de rendement à Nipawin, mais que les trois espèces examinées réduisent sensiblement le rendement fourrager à Swift Current. Les plantes associées diminuent la densité des plantules fourragères, mais cette baisse n'explique pas la diminution du rendement fourrager. Les auteurs supposent que ce sont des composantes du rendement plutôt que la densité du peuplement qui sont affectées par la concurrence des plantes associées. L'agropyre intermédiaire (*Elytrigia intermedia*) donne un meilleur rendement fourrager que l'élyme de Daourie (*Elymus dahuricus*) ou l'agropyre à chaumes rudes (*Elymus trachycaulus*). Les mélanges de luzerne et de graminées produisent un meilleur rendement que la monoculture de graminées. À Swift Current et à Saskatoon, les fourrages rapportent davantage quand on les cultive sans plantes associées; à Nipawin cependant, on assiste généralement à la situation inverse. L'utilité des plantes associées pour l'établissement de vivaces fourragères de courte pérennité en Saskatchewan dépend donc de la zone de sols, l'usage de ces plantes convenant davantage aux régions plus humides.

Mots clés: Rendement fourrager, densité du peuplement, climat, économique

The Saskatchewan beef cow (*Bos taurus*) herd has grown from 0.8 to 1.2 million animals in the past decade (Statistics Canada 2002). At the same time, the land area devoted to introduced forage species for hay and pasture production increased to 1.17 million ha (Saskatchewan Agriculture, Food and Rural Revitalization 2001; Statistics Canada 2002). However, the increase in forage area has not supplied sufficient forage during drought years, most recently in

Abbreviations: **DM**, dry matter; **DWG**, Dahurian wildrye; **evap**, evaporation; **IWG**, intermediate wheatgrass; **ppt**, precipitation; **SWG**, slender wheatgrass

2001 and 2002, when the sale and movement of forage feeds across the province increased dramatically. The rising demand for hay and its recent high market value have stimulated interest among grain producers to grow forage hay as a cash crop to enhance farm income and diversify their cropping options. However, traditional long-lived perennial forage crop species, which are often slow to establish and usually persist for many years, can reduce subsequent grain crop yields in the semiarid Brown soil zone (Kilcher and Anderson 1963; Campbell et al. 1990). Short-lived grass species that establish quickly and produce forage for 1 to 3 yr may provide producers with a viable forage hay option that might fit well into their existing annual grain rotations.

Producers concerned with low economic returns during the forage establishment year often want to use companion crops to establish forages. Previous research in the Brown soil zone at Swift Current reported a significant decline in forage production when cereal companion crops were used to establish dryland forages (Kilcher and Heinrichs 1960). In contrast, in the more moist Black soil zone of Saskatchewan, forage yield losses due to companion crop establishment were usually negligible (Waddington and Bittman 1983). This difference between soil zones suggests that competition for limited soil water reduces forage seedling density in the drier Brown soil zone sites, such as at Swift Current, making companion cropping less successful. However, new annual crops, such as field pea (*Pisum sativum*) and canola (*Brassica napus*), have not been tested as companion crops for the establishment of grasses with high seedling vigour. Westerwolds ryegrass (*Lolium westerwoldicum*) has been used successfully as a companion crop to establish alfalfa (*Medicago sativa*) in the midwestern USA (Sulc et al. 1993). This annual forage can produce high forage yields in the subhumid region of northeastern Saskatchewan (Chen et al. 2002), but is very competitive with irrigated timothy (*Phleum pratense* L.) seedlings, reducing subsequent timothy yield by 41% (Jefferson et al. 2000). Westerwolds ryegrass has not been evaluated as a companion crop for dryland forage establishment in Saskatchewan.

Dahurian wildrye (*Elymus dahuricus* Turcz. ex Griseb.) (DWG) is a short-lived caespitose grass developed from plant introductions obtained from Central Asia and subsequently released in Canada in 1989 (Alderson and Sharp 1994). It is known to persist for 3 yr in dryland seedings at Swift Current, and was proposed for inter-seeding with Russian wildrye [*Psathyrostachys juncea* (Fisch.) Nevski] to improve productivity of new pastures because Russian wildrye takes 2 yr to become fully established (Lawrence et al. 1990). Dahurian wildrye is also recommended for mixtures with other saline-tolerant grasses to promote rapid stand establishment and ground cover (Saskatchewan Agriculture, Food and Rural Revitalization 2003). It is easy to terminate and thus has good potential for inclusion in annual grain rotations (Saskatchewan Forage Council 1997).

Intermediate wheatgrass [*Elytrigia intermedia* (Host) Nevski] (IWG) is a well-known forage grass that has been used for dryland forage seeding for more than 50 yr in western Canada. There are contradictory reports in the literature regarding the longevity of this species. It may be a short-lived species (Alberta Agriculture 1981) or a long-lived species (Lawrence 1983). Careful grazing or haying management of IWG has been shown to extend its persistence (Lawrence 1983).

Slender wheatgrass [*Elymus trachycaulus* (Link) Gould ex Shinners] (SWG) is a native species to Canada that is often included in mixtures with other native grasses because it has excellent seedling vigour and stand establishment characteristics (Alberta Agriculture 1981). Recent research from Alberta has suggested that current seeding rates of SWG are too high because it tends to dominate the other species in the first few years (Hammermeister and Naeth 1999) due to its high seedling vigour.

The forage yield and quality advantages of including alfalfa in a mixture with grasses is well-known (Van Keuren and Matches 1988). However, some producers are concerned about the risk of frothy bloat when the alfalfa component exceeds 50% of the forage mass in newly seeded forage stands plus the cost of terminating the alfalfa stand prior to seeding the next annual crop (Bullied et al. 1999). The excellent seedling vigour of alfalfa often produces mixtures that are dominated by alfalfa (> 80% alfalfa in the first year). One alternative would be to use an annual or short-lived alfalfa cultivar developed from non-winter hardy germplasm. Nitro alfalfa is a non-winter hardy cultivar that was developed as an annual plow-down (or green manure) legume for Minnesota conditions (Sheaffer et al. 1989). It had a 65% survival rate after two winters at Brandon, Manitoba (Goplen 1989), but suffered complete stand loss after three winters. This characteristic could make it valuable in short rotations where alfalfa stand termination is a problem. Research in Manitoba indicates that herbicides are equally effective as tillage for alfalfa stand termination (Bullied et al. 1999). If producers achieve increased forage production and forage quality benefits from growing a short-lived alfalfa cultivar and, at the same time, are able to avoid costly tillage stand termination prior to seeding the next crop, then this could provide agronomic benefits and economic advantages for Saskatchewan producers.

The objective of this project was to determine, under Saskatchewan conditions, the establishment success (risk) and first year forage production of three high seedling vigour forage grasses (Dahurian wildrye, intermediate wheatgrass, and slender wheatgrass), as affected by soil zone (Brown, Dark Brown, and Dark Gray soil zone), companion crop (canola, field pea, Westerwolds ryegrass vs. none), and alfalfa mixture (Beaver, Nitro vs. none).

MATERIALS AND METHODS

Three sites in Saskatchewan were chosen for this study, one in each major soil zone. The first site was located at the Semiarid Prairie Agricultural Research Centre at Swift Current (50°16′N lat., 107°43′W long., 824 m elev.) on a Swinton loam, a Brown Chernozem (Ayres et al. 1985). The second site was located at the Agriculture and Agri-Food Canada Research Centre near Saskatoon (52°10′N lat., 106°43′W long., 504 m elev.) on a Sutherland clay loam, a

Table 1. Seeding dates, companion crop harvest dates, and established forage harvest dates for three sites and 3 yr in Saskatchewan. Canola and field pea companion crops were harvested for grain and ryegrass and no companion crop treatments were harvested for forage yield

Establishment year	Site[z]	Seeding date	Companion crop and harvest dates		Forage crop harvest dates
1998	Swift Current	May 13	None	August 07	1999 15 June
			Canola	August 05	
			Pea	August 04	
			Ryegrass	August 06	
	Saskatoon	June 01	All	July 21	1999 June 24, August 27
	Nipawin	May 19	All	August 14	1999 July 10 , September 02
1999	Swift Current	May 19–20	None	August 25	2000 July 24
			Canola	August 20	
			Pea	August 19	
			Ryegrass	August 24	
	Saskatoon	May 25	None	August 27	2000 June 27
			Canola	September 13	
			Pea	September 13	
			Ryegrass	August 27	
	Nipawin	May 20	None	August 27	2000 July 27, August 25
			Canola	September 09	
			Pea	August 27	
			Ryegrass	August 27	
2000	Swift Current	May 18	None	August 16	2001 July 25
			Canola	August 14	
			Pea	August 11	
			Ryegrass	August 14	
	Saskatoon	June 21	All	September 11	2001 June 21
	Nipawin	June 01	All	September 23–24	2001 July 03, August 10

[z]Swift Current is located in the Brown soil zone, Saskatoon in the Dark Brown soil zone, and Nipawin in the Dark Gray soil zone.

Dark Brown Chernozem (Head 1979). The third site was located at the Newfield Seeds Limited research and demonstration farm near Nipawin (53°16′N lat., 104°0′W long., 372 m elev.) on a White Fox Nipawin fine sand loam to clay loam, a Dark Gray Chernozem (Canada Soil Survey Committee 1978). The locations also represent a range of elevation, precipitation, and water deficits during the growing season with Swift Current normally being the driest and Nipawin the wettest environment.

The tests at each location were established on cereal crop stubble. The experimental design was a split-split plot with four replications. Companion crops were main plot treatments, grass species were sub-plot treatments, and alfalfa mixtures were sub-sub-plot treatments. Sub-sub-plot dimensions were 6 × 1.8 m at Swift Current and Nipawin and 6 × 2.4 m at Saskatoon. Prior to planting, all plots received glyphosate [*N*-(phosphonomethyl)glycine] at 2.4 L ha^{-1} in early spring for pre-seeding weed control. Row spacing was 30 cm, but the companion crops and forages were seeded in separate rows so there was 15 cm between forage seedlings and the companion crop plants. This mimics the common on-farm practice of seeding the companion crop alone immediately followed by forage seeding. Separate trials were repeated on adjacent areas at each site in 1998, 1999, and 2000.

The seeding rates for the companion crops were: 151 kg ha^{-1} for Highlight field pea, 4.5 kg ha^{-1} for Coronet canola, and 5.6 kg ha^{-1} for Aubade Westerwolds ryegrass. The forage crop seeding rates varied among the sites according to the provincial recommendations for each soil zone (Saskatchewan Agriculture, Food and Rural Revitalization 2003). At Swift Current, Saskatoon and Nipawin, respectively, the seeding rates were: 4.5, 7.8, and 12.3 kg ha^{-1} for Arthur Dahurian wildrye and Chief intermediate wheatgrass; 2.2, 4.5, and 6.7 kg ha^{-1} for Revenue slender wheatgrass. The seedings rates for Beaver and Nitro alfalfa were 2.2 and 3.4 kg ha^{-1} at all three sites.

Prior to seeding, all plots received 34-17-0 fertilizer applied at 168 kg ha^{-1} to supply 57 kg N ha^{-1} and 28 kg P_2O_5 ha^{-1} . In addition, at the Nipawin site in October 1998, fertilizer was applied at 77 kg N ha^{-1} and 11 kg K_2O ha^{-1} . All pea and alfalfa seed was inoculated with an appropriate commercial *Rhizobium* inoculant prior to seeding. No fertilizer was applied in the year after establishment. This latter practice is common among forage producers because young forage stands are generally considered to be using residual fertility and often do not respond to the addition of fertilizer until 3 or more years after establishment (Saskatchewan Agriculture, Food and Rural Revitalization 2002b).

Seeding dates are shown in Table 1. Seeding depth for forage and canola was 19 mm, and 75 mm for field pea.

No in-crop herbicides were used for weed control in the establishment year with the exception of Nipawin in 1999. In 1999 at Nipawin, bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) was applied at 1.25 L ha^{-1} to Westerworlds ryegrass and no companion crop treatments only. However, spray drift resulted in herbicide damage to the canola companion crop when it was at the stem elongation growth stage. In the year after establishment, herbicides were applied as follows: at Saskatoon, bromoxynil was applied at 1.25 L ha^{-1} in 1999, 2000 and 2001, with a second application required in 2000; in 1999, 2,4-DB [4-(2,4-dichlorophe-

Table 2. Summary of selected input costs used for economic analysis

Input item	Cost		Units
Seed			
Canola (including seed treatment)	2.62		$ kg^{-1}
Pea (including inoculant)	0.40		$ kg^{-1}
Westerwolds ryegrass	1.98		$ kg^{-1}
Dahurian wildrye	4.95		$ kg^{-1}
Intermediate wheatgrass	3.85		$ kg^{-1}
Slender wheatgrass	4.95		$ kg^{-1}
Alfalfa (including inoculant)	3.85		$ kg^{-1}
Fuel			
Diesel	0.61		$ L^{-1}
Gasoline	0.65		$ L^{-1}
Fertilizer			
N	0.66		$ kg^{-1}
P_2O_5	0.58		$ kg^{-1}
K_2O	0.29		$ kg^{-1}
Herbicides[z]			
2,4-DB	31.67		$ kg^{-1}
Bromoxynil	73.82		$ kg^{-1}
Glyphosate	25.00		$ kg^{-1}
Labor	9.00		$ h^{-1}
Interest	8.00		%
Machine operations	*Cash costs and labor*	*Fixed cost*	
Sprayer	2.41	4.10	$ ha^{-1}
Fertilizer spreader	2.69	3.20	$ ha^{-1}
Zero-till seeder	11.70	17.50	$ ha^{-1}
Swathing	4.16	5.61	$ ha^{-1}
Haybine	9.63	21.67	$ ha^{-1}
Round baling[y]	10.37	23.49	$ ha^{-1}
Bale hauling[y]	7.05	10.49	$ ha^{-1}
Harvest and transport - pea[y]	30.74	26.58	$ ha^{-1}
Harvest and transport - canola[y]	30.74	24.81	$ ha^{-1}

[z]Costs for all herbicides are per unit of active ingredient.
[y]Costs are shown for a grain or forage yield of 2500 kg ha^{-1}.

noxy)butanoic acid] was applied at 1.8 L ha^{-1} at Swift Current; at Nipawin, bromoxynil at 1.0 L ha^{-1} was applied in spring to the established forage stands. Companion crop plant and forage seedling densities were determined by counting plant numbers in two random row segments (1 m length) in each plot at 4, 8, and 12 wk after seeding. Seedling density data were averaged over the three dates. Forage plant counts were determined in a similar manner in the spring following the establishment year.

Companion crop dry matter forage yields (control and Westerwolds ryegrass) were determined at 10% alfalfa flowering and the seed yields of canola and field pea companion crops were determined at maturity of the respective crops. At Swift Current, forage yield was determined by harvesting 5 × 0.6 m area of each sub-sub-plot with a flail forage harvester. A 300 g subsample of forage was weighed, dried at 60°C in a forced-air oven for approximately 48 hours, and then re-weighed to calculate dry matter (DM) yield. Field pea and canola grain yield was determined by harvesting a 5 × 0.9 m area of each sub-sub-plot with a Wintersteiger plot combine (Wintersteiger Inc., Austria). Another sub-sample (0.3 m^2) of canola and pea crops was harvested by hand, dried and weighed to determine total companion crop biomass at maturity.

At Saskatoon, 5 × 1.2 m area per sub-sub-plot was harvested and weighed with a sickle-bar forage harvester for Westerwolds ryegrass and no companion crop to determine forage yield. A sub-sample of forage was weighed, dried at 60°C and re-weighed to determine DM concentration. The biomass yield of field pea and canola companion crops was determined by harvesting and weighing a 5 × 1.2 m area per sub-sub-plot with the sickle-bar forage harvester. A small sub-sample of the crop was weighed, dried at 60°C and re-weighed to determine DM concentration. The remaining harvested material was allowed to air-dry in the field and then seed yield determined by threshing the crop in a stationary Hege thresher. The grain was then cleaned and weighed to determine field pea and canola grain yield.

At Nipawin, field pea and canola companion crop biomass was determined by harvesting and weighing material from 6 × 0.6 m area of each sub-sub-plot. A sub-sample of crop was weighed, dried at 60°C and re-weighed to calculate DM biomass yield. Another sub-sample of the crop was hand-processed to determine grain yield. Forage and seed yield harvest dates for companion crops and forage harvest dates in the year after establishment are shown in Table 1.

Forage yields were determined at the 10% flowering stage of alfalfa in the year following establishment at the three sites for each trial. Forage material was harvested with a flail plot harvester at Swift Current and Nipawin or a sickle-bar forage harvester at Saskatoon from the centre of each plot and weighed. A sub-sample of forage was weighed, dried to a constant weight and re-weighed to determine dry matter percentage. The area harvested was 5 × 0.6 m at Swift Current or Nipawin and 5 × 0.9 m at Saskatoon.

Daily weather data were obtained from nearby meteorological stations reporting to Environment Canada (Environment Canada 2003). Monthly mean temperature and monthly precipitation were obtained for each site-year combination.

An economic analysis was conducted for each experimental unit by totalling all input costs (Table 2) from the establishment year plus the first forage production year (i.e., 2-yr costs) and all revenues from crops produced in the establishment year plus the first forage production year. Costs were based on actual fertilizer and herbicide rates applied at each site, using 2002 input cost levels (University of Saskatchewan 2002). Other input costs (labour and machine operation and depreciation) were based on 2002 custom work rates for seeding and harvesting operations (Saskatchewan Agriculture, Food and Rural Revitalization 2002a). Net returns (i.e., gross revenue from product sales minus production costs) for the 2-yr periods were calculated for three hay price levels: $83, $110, and $137 t^{-1}. The lowest hay price reflects the long-term price of grass-alfalfa hay in Saskatchewan in years of abundant forage supply, while the highest price reflects a price expectation for hay in years of forage shortages. Forage DM yield was converted to typical hay water content (15% water) in calculation of net returns. The prices assumed for canola and pea were held constant at $323 and $191 t^{-1}, respectively. The seed yields for canola at Nipawin in 1999 were estimated from the average ratio of canola seed yield to total biomass obtained from

Table 3. Monthly precipitation and mean temperature at three test sites in Saskatchewan (1998–2000, Nipawin and Saskatoon data from Environment Canada; Swift Current data from Agriculture and Agri-Food Canada weather station)

Site	Year	April	May	June	July	August	September	Total
					precipitation (mm)			
Nipawin	1998	7	14	83	82	24	25	234
	1999	50	33	75	115	48	14	334
	2000	12	61	126	168	68	14	448
30-yr mean		24	50	76	78	60	42	
Saskatoon	1998	7	9	75	31	37	27	187
	1999	15	115	59	80	43	20	332
	2000	41	16	50	83	42	27	259
30-yr mean		24	49	61	60	39	31	
Swift Current	1998	15	38	90	37	35	22	238
	1999	23	90	84	55	15	2	270
	2000	38	65	47	127	13	49	339
119-yr mean		22	44	73	52	43	31	
					temperature (°C)			
Nipawin	1998	6.8	11.6	14.2	18.1	19.0	12.1	
	1999	5.8	10.4	14.7	16.5	17.1	10.1	
	2000	2.5	9.0	13.3	18.0	16.4	10.7	
30-yr mean		2.5	10.4	15.3	17.6	16.2	10.4	
Saskatoon	1998	7.2	13.0	14.5	18.7	20.0	13.2	
	1999	6.5	10.7	14.6	16.4	17.8	10.3	
	2000	4.4	10.5	14.3	18.7	16.8	11.7	
30-yr mean		4.4	11.5	16.0	18.2	17.3	11.2	
Swift Current	1998	7.5	12.6	14.0	20.2	21.0	15.1	
	1999	5.6	9.8	14.0	16.3	18.9	10.9	
	2000	4.9	10.8	13.9	19.0	18.1	12.2	
119-yr mean		4.6	10.9	15.4	18.7	17.6	11.8	

the 1998 and 2000 trials at the site and these estimates were used in the economic analysis.

The data were analyzed as a split-split-plot design using the JMP software (SAS Institute Inc. 1995). Few interactions were statistically significant ($P < 0.05$), so the means of main factors are presented. Stepwise regression (mixed option) analysis with JMP software was used to relate forage yield loss (% of no companion crop) to weather and companion crop variables. Variables were selected for inclusion in the regression procedure at $P = 0.25$ and excluded at $P = 0.10$. Due to different growth characteristics and periods among the three companion crops, separate regression equations were developed for each crop.

RESULTS AND DISCUSSION

Weather

Precipitation varied among the 9 site-years (Table 3); each site had one above-average, one average, and one below-average year for precipitation. At all sites, precipitation in April and May was below-average in 1998.

Temperature in April was above-average at all three sites in 1998 and 1999 (Table 3). Above-average temperature continued for May at all three sites in 1998. June temperatures were slightly below-average in all years, whereas above-average temperatures for July, August and September were reported in 1998 at all three sites. Thus, 1998 can be considered a warm and dry season, while 1999 at Saskatoon and 2000 at Nipawin and Swift Current can be considered wet growing seasons.

Plant Density

Average grass seedling density (seedlings m^{-2}) ranged from a high of 131 at Nipawin in 1999 to a low of 15 at Saskatoon in 2000 (Table 4). While higher grass seedling establishment was expected at the more humid Nipawin site, it was surprising that grass seedling density was lower at Saskatoon than at the normally drier Swift Current site. The differences in seedling density among locations and years reflect, in large part, the differences in early-season (May) precipitation levels. Grass seedling density varied among grass species in 6 of 9 site-year combinations (Table 4). SWG had 22% lower seedling density than DWR or IWG in 5 site-years.

Grass seedling density was affected by alfalfa cultivar in 5 of 9 site-years (Table 4). Mixing either Beaver or Nitro alfalfa cultivar with grass reduced grass seedling density by an average of 12%. At Nipawin in 1999, grass seedling density was lower when seeded with Nitro alfalfa but unaffected when seeded with Beaver alfalfa. The grass seedling density was 118% higher at Nipawin in 1999 compared to 1998 or 2000, reflecting the very favourable weather conditions for germination and survival of the grass seedlings in 1999.

Alfalfa seedling density was affected by grass species in only 2 of 9 site-years (Table 4) and these differences were small. Alfalfa cultivar affected alfalfa seedling density in 7 of 9 site-years (Table 4). Beaver alfalfa had 18% higher seedling densities on average than Nitro alfalfa. Nitro alfalfa had higher seedling density (20%) than Beaver alfalfa only at Nipawin in 2000.

Table 4. Grass or alfalfa seedling density in three establishment years at three sites in Saskatchewan as affected by grass species or alfalfa cultivar

		Grass species				Alfalfa cultivar			
Year	Site	DWR	IWG	SWG	$LSD_{0.05}$	Beaver	Nitro	None	$LSD_{0.05}$
		grass (seedlings m^{-2})							
1998	Nipawin	58	38	52	–	58	45	76	4
	Saskatoon	28	27	23	4	26	25	27	–
	Swift Current	43	43	29	4	37	37	41	–
1999	Nipawin	115	123	156	7	135	126	133	7
	Saskatoon	25	20	22	3	24	22	22	–
	Swift Current	69	48	34	5	48	49	53	5
2000	Nipawin	63	57	59	5	58	55	65	4
	Saskatoon	15	17	14	–	16	16	15	–
	Swift Current	50	50	42	4	47	45	52	4
		alfalfa (seedlings m^{-2})							
1998	Nipawin	17	12	17	–	15	15	–	–
	Saskatoon	23	22	24	–	37	31	–	3
	Swift Current	23	23	26	–	38	34	–	1
1999	Nipawin	14	15	16	–	26	18	–	2
	Saskatoon	23	20	21	–	33	31	–	–
	Swift Current	35	31	35	–	55	46	–	5
2000	Nipawin	26	26	26	–	35	42	–	4
	Saskatoon	17	17	19	1	28	25	–	2
	Swift Current	34	31	34	2	53	47	–	3

These results suggest that forage seedling density was primarily affected by environmental conditions during the establishment year, especially at time of seeding. This is similar to results reported for spring wheat in the semiarid prairies (Campbell et al. 1990). Grass species and alfalfa cultivar in the mixture also influenced seedling density, but to a lesser degree than environmental conditions. These findings also agree with previous studies (Kilcher and Heinrichs 1960; Waddington and Bittman 1983).

Forage (alfalfa + grass) seedling density was affected by the companion crop in 6 of 9 site-years (Table 5); in the other 3 site-years (two at Saskatoon and one at Swift Current) there was no effect of companion crop on forage seedling density. The lowest forage seedling densities were observed in 5 site-years when Westerwolds ryegrass was used as the companion crop. At Swift Current in 1999 forage seedling density was lowest with a field pea companion crop. Seedling density under canola companion crops was generally similar to that with no companion crop.

Companion crop plant density varied among site-years (Table 5). Westerwolds ryegrass had high plant density at Nipawin in 1999, reflecting the favourable environmental conditions for high DWR, IWG, and SWG seedling densities. Canola crops had the highest plant density in 4 site-years, field pea in 3 site-years, and Westerwolds ryegrass in 2 of 9 site-years.

Companion Crop Yield

Companion crops differed in biomass yield in 7 of 9 site-years (Table 5). In 6 site-years, field pea produced the highest biomass yield, while Westerwolds ryegrass produced the highest biomass yield at Nipawin in 1999. The biomass yield of ryegrass at Nipawin in 1999 was similar to the yields of this forage species reported at Melfort (Chen et al. 2002).

The seed yields of canola averaged 1.64, 0.42, and 0.89 Mg ha^{-1} at Nipawin (only 2 yr), Saskatoon, and Swift Current, respectively. The average seed yields of field pea at the respective locations were 1.75, 0.59, and 1.93 Mg ha^{-1} (Table 5). Generally, field pea produced more grain yield than canola. The high yields of field pea at Swift Current in 1999 and 2000 reflect the above-average precipitation received at the site in these 2 yr. The canola yields obtained at Nipawin were higher than the 10-yr (1992–1 993 to 2001–2002) average yield reported for this region (1.33 Mg ha^{-1}, Saskatchewan Agriculture, Food and Rural Revitalization 2001), while those obtained at Saskatoon and Swift Current were lower than the regional average yields (1.38 and 1.24 Mg ha^{-1}, respectively). The yields of field pea obtained in our tests were also lower at Nipawin and Saskatoon than the 10-yr provincial average (1.99 Mg ha^{-1}, Saskatchewan Agriculture, Food and Rural Revitalization 2001).

Companion Crop Effects on Forage Crops

Companion crops reduced subsequent forage yields in 6 of 9 site-years (Table 6). At Nipawin the yield reduction averaged 21% in 2001 (compared to no companion crop), at Saskatoon the reduction was 20% in 1999 and 92% in 2000, and at Swift Current the reduction, which occurred in all 3 study years, averaged 39%; however, the impacts differed among companion crops. At Saskatoon in 1999 and Nipawin in 2001, Westerwolds ryegrass reduced forage yield more than canola or pea. At Saskatoon in 2000, the

Table 5. Forage (grass + alfalfa) seedling density as affected by companion crop and companion crop plant density, biomass, and seed yield as affected by companion crop for three years at three sites in Saskatchewan

		Companion crop					Companion crop			
Year	Site	None	Canola	Pea	Ryegrass	$LSD_{0.05}$	Canola	Pea	Ryegrass	$LSD_{0.05}$
		forage (seedlings m^{-2})					crop (plants m^{-2})			
1998	Nipawin	100	75	92	25	12	31	46	53	6
	Saskatoon	54	50	51	41	6	76	52	46	10
	Swift Current	66	67	55	62	–	91	56	69	20
1999	Nipawin	187	170	117	110	43	–	17	193	43
	Saskatoon	46	45	44	40	–	42	52	40	4
	Swift Current	90	93	71	82	10	138	60	68	5
2000	Nipawin	91	87	91	72	10	32	42	33	8
	Saskatoon	37	34	28	34	–	30	45	26	4
	Swift Current	80	87	80	77	6	73	63	58	6
		biomass (Mg ha^{-1})					seed (Mg ha^{-1})			
1998	Nipawin	5.91	6.76	5.46	6.88	–	1.48	2.18	–	–
	Saskatoon	–	1.51	2.27	1.03	0.23	0.19	0.35	–	0.04
	Swift Current	2.56	2.47	2.85	1.66	0.40	0.21	0.64	–	0.11
1999	Nipawin	3.01	5.09	3.18	6.05	2.34	–	0.58	–	–
	Saskatoon	2.82	4.92	6.86	4.50	0.85	0.96	0.98	–	–
	Swift Current	2.11	7.24	7.56	3.28	1.30	1.56	2.86	–	0.54
2000	Nipawin	2.47	3.21	4.04	3.75	0.52	1.79	2.48	–	–
	Saskatoon	2.72	2.89	3.24	2.92	–	0.11	0.45	–	–
	Swift Current	4.41	5.18	6.50	4.51	1.16	0.91	2.28	–	0.34

Table 6. Effect of companion crop in the previous year on forage DM yield at cut 1 and cut 2[z] for the three sites in Saskatchewan from 1999 to 2001

			Companion Crop in establishment year					
Year	Harvest	Site	None	Canola	Pea	Ryegrass	Prob.>F	$LSD_{0.05}$
			(Mg ha^{-1})					
1999	Cut 1	Nipawin	6.73	6.46	6.40	6.59	NS	–
		Saskatoon	5.15	4.19	4.17	3.12	*	1.01
		Swift Current	1.24	0.82	0.72	0.92	**	0.25
	Cut 2	Nipawin	1.45	1.30	1.53	1.58	NS	–
		Saskatoon	2.57	2.41	2.26	2.35	NS	–
2000	Cut 1	Nipawin	2.49	2.44	2.45	2.16	NS	–
		Saskatoon	2.79	1.77	1.07	1.51	**	0.58
		Swift Current	5.06	2.56	3.33	3.36	**	0.49
	Cut 2	Nipawin	2.18	2.43	1.92	2.20	NS	–
2001	Cut 1	Nipawin	5.12	4.1	3.78	3.08	**	0.58
		Saskatoon	0.60	0.62	0.39	0.50	NS	–
		Swift Current	1.77	1.03	0.99	0.99	**	0.14
	Cut 2	Nipawin	3.90	3.40	4.03	2.97	**	0.32

[z]Cut 2 was harvested only when regrowth was sufficient.
*, **Indicate probability values 0.05 and 0.01, respectively; NS, not significant.

reduction due to field pea was greater than that of canola or ryegrass. At Swift Current in 2000, the reduction due to canola was greater than that of field pea or annual ryegrass. In 2 other site-years, all three companion crops reduced forage yield to a similar degree. These mixed responses likely reflect edaphic and/or environmental conditions that favoured one companion crop more than another at that site-year.

It is commonly assumed that competition from a companion crop will reduce forage seedling density during the establishment year and that subsequent forage yield is correlated to forage plant density (Kilcher and Heinrichs 1960).

However, the correlations between forage seedling density and forage yield varied among sites. There was a significant correlation between first cut forage yield (Table 6) and forage seedling plant density (Table 5) at Nipawin ($r = -0.63$, $P < 0.05$, $n = 12$) and Saskatoon ($r = 0.89$, $P < 0.01$, $n = 12$) but not at Swift Current ($r = 0.54$, $P > 0.05$, $n = 12$). The negative correlation coefficient at Nipawin can be attributed to year differences. Forage seedling density and yield were correlated at Saskatoon but not at Swift Current. May precipitation was below average in 2 of 3 yr at Saskatoon and this may have contributed to low forage seedling density at this site (see below). The evidence from this study does not support the assumption that forage seedling density is important to subsequent forage production. We speculate that companion crop competition negatively impacts other forage yield components, such as leaf number or size, tiller number, tiller size, height of reproductive tillers, or the ratio of reproductive tillers to vegetative tillers. Competition from durum wheat (*Triticum turgidum* L.) reduced leaf area, leaf number, tiller number and dry weight of Russian wildrye grass seedlings in a growth room experiment (Jefferson and Muri 1995). Similar responses to companion crop competition by DWR, IWG, and SWG in this experiment would explain the yield loss that we observed.

Variation among site-years in weather and companion crop variables accounted for 96, 91, and 90% of the variation in forage yield loss due to canola, field pea, and Westerwolds ryegrass companion crops, respectively (Table 7). May precipitation was consistently the first or second most important variable for all three regression equations. Companion crop density was the most important variable for canola and pea, while companion crop biomass was second most important variable for ryegrass. Companion crop density or biomass are indicators of the competitive nature of the companion crop. May precipitation likely increases companion crop density or biomass and causes increased competition effects on the forage seedlings. Similarly, June precipitation would increase ryegrass biomass and cause increased competitive effects on forage seedlings. September precipitation increases ryegrass regrowth and extends competitive effects on the forage seedlings into the autumn. Environmental factors that increase the growth of annual ryegrass will contribute to reduced forage seedling establishment (Jefferson et al. 2000). The biological explanation of September temperature effect on canola companion crops or July temperature effect on pea companion crops are less obvious. We can conclude from these relationships that canola and field pea can be used as companion crops for forage establishment in regions with cool spring temperatures and reliable spring rain (i.e., Black or Dark Gray soil zones).

Our results demonstrate that the impact of companion crop forage establishment varies with the soil zone in Saskatchewan. Producers in the Dark Gray soil zone can choose to use canola, pea, or ryegrass companion crops to establish Dahurian wildrye, intermediate wheatgrass or slender wheatgrass with a one in three chance of incurring a slightly reduced forage yield. However, producers in the Brown soil zone should not use companion crops to establish these grasses due to the consistent and large reductions in subsequent forage yield. The latter results confirm the earlier research findings of Kilcher and Heinrichs (1960) regarding the detrimental effects of using companion crops to establish forages in the drier regions of the province.

Table 7. Results of stepwise regression analysis of the relationship between forage yield loss due to canola, field pea, or Westerwolds ryegrass companion crops at three sites for three years in Saskatchewan

Companion Crop	Variables selected to explain % forage yield loss[z]	Step	Sequential Sums of Square	R^2 statistic
Canola	CCdensity	1	1355	0.96**
	Mayppt	2	677	
	SepTmn	3	297	
Field Pea	CCdensity	1	1664	0.91**
	Mayppt	2	432	
	CCseed	3	401	
	JulTmn	4	215	
Ryegrass	Mayppt	1	740	0.90**
	CCbiomass	2	647	
	Sepppt	3	222	
	Junppt	4	99	

[z]% forage yield loss was calculated as the difference between yield established with no companion crop and those established with canola, field pea, or ryegrass companion crops expressed as a percent of the no companion crop yield.
** Significant at $P < 0.01$
Variables are: Mayppt = precipitation in May (mm); Junppt = precipitation in June (mm); Sepppt = precipitation in September (mm); JulTmn = mean July temperature (°C); SepTmn = mean September temperature (°C); CCdensity = companion crop plant density (# m^{-2}); CCseed = companion crop seed yield (kg ha^{-1}); CCbiomass = companion crop biomass (kg ha^{-1}).

Effect of Grass Species

Among the grass species, IWG produced the highest forage yield at first cut in all 9 site-years in the year after forage establishment (Table 8). Dahurian wildrye and SWG generally produced similar first cut yields. Regrowth (cut 2) forage yield of IWG was less than DWR or SWG at 3 of 4 site-years where there was sufficient regrowth for a second cut.

A significant companion crop × grass species interaction occurred in 3 of 9 site-years (data not shown). The interaction resulted from changes in the rank order of the grass species among the three companion-crop-established treatments. The no companion crop treatment consistently resulted in highest forage yield with all three grasses.

Effect of Alfalfa Cultivars

Alfalfa cultivar significantly influenced first cut forage yields at Saskatoon and Swift Current but not at Nipawin (Table 9). Beaver alfalfa mixtures consistently produced more first cut forage yield than Nitro alfalfa. In several cases, Nitro alfalfa mixtures produced similar forage yield to grass alone. At second harvest, Nitro alfalfa mixtures produced more forage than grass alone in 2 site-years. Stand counts indicated that few Nitro alfalfa plants survived after the establishment year, which was lower persistence than was observed in Brandon (Goplen 1989). A useful short-

Table 8. Effect of grass species on forage DM yield from 1999 to 2001 at three sites in Saskatchewan

Year	Harvest	Site	Grass species: Dahurian wildrye	Intermediate wheatgrass	Slender wheatgrass	Prob.>F[z]	$LSD_{0.05}$
			($Mg\ ha^{-1}$)				
1999	Cut 1	Nipawin	5.73	7.34	6.57	**	0.72
		Saskatoon	3.98	4.41	4.08	*	0.32
		Swift Current	0.66	1.27	0.85	**	0.16
	Cut 2	Nipawin	1.52	1.53	1.35	NS	–
		Saskatoon	2.60	1.96	2.64	**	0.16
2000	Cut 1	Nipawin	2.24	2.84	2.07	**	0.32
		Saskatoon	1.84	2.10	1.42	**	0.21
		Swift Current	3.49	3.91	3.33	**	0.27
	Cut 2	Nipawin	2.33	2.05	2.11	*	0.19
2001	Cut 1	Nipawin	3.91	4.37	3.77	*	0.40
		Saskatoon	0.54	0.61	0.44	**	0.08
		Swift Current	0.91	1.64	1.04	**	0.13
	Cut 2	Nipawin	3.80	3.37	3.56	*	0.33

*, ** Indicate probability values 0.05, and 0.01, respectively; NS, not significant.

Table 9. Effect of alfalfa cultivar on forage DM yield at two cuts from 1999 to 2001 at three sites in Saskatchewan

Year	Variable	Site	Alfalfa cultivar: Beaver	Nitro	None	Prob.>F[z]	$LSD_{0.05}$
			($Mg\ ha^{-1}$)				
1999	Cut 1	Nipawin	6.58	6.05	6.48	NS	–
		Saskatoon	5.08	3.46	3.93	**	0.37
		Swift Current	1.31	0.63	0.84	**	0.16
	Cut 2	Nipawin	2.02	1.17	1.22	**	0.20
		Saskatoon	3.52	2.08	1.61	**	0.19
2000	Cut 1	Nipawin	2.31	2.38	2.47	NS	–
		Saskatoon	1.82	1.55	1.98	**	0.12
		Swift Current	4.30	3.32	3.10	**	0.24
	Cut 2	Nipawin	2.42	2.14	2.00	NS	–
2001	Cut 1	Nipawin	3.94	3.97	4.15	NS	–
		Saskatoon	0.72	0.47	0.38	**	0.07
		Swift Current	1.22	1.08	1.29	**	0.07
	Cut 2	Nipawin	4.40	3.41	2.92	**	0.26

** Indicate probability value 0.01; NS, not significant.

rotation alfalfa cultivar would survive for 1 to 2 yr after establishment and contribute to forage production in a manner similar to Beaver alfalfa, then the plants would die prior to the next annual crop. Neither Beaver nor Nitro alfalfa appear to fit this need. There was a significant companion crop by alfalfa cultivar interaction for 6 site-years at first cut and 2 site-years at second cut (data not shown). The interaction can be attributed to rank order changes in forage yield among the three companion crops.

Beaver alfalfa plants would persist for longer than desirable for "short-rotation" forage production and could dry the soil profile which would reduce subsequent grain crop yields (Campbell et al. 1990). No-till alfalfa stand termination by herbicides at 2 to 3 yr has advantages in sub-humid climatic conditions (Bullied et al. 1999) and should be compared agronomically and economically to stand termination by tillage which is the current common practice in the semi-arid region of the Prairies.

Economic Returns

Net returns (2-yr totals) were higher ($P < 0.05$) when the forages were established with no companion crop at Swift Current (Brown soil zone) and Saskatoon (Dark Brown soil zone); but, at Nipawin (Dark Gray soil zone) net returns were generally similar ($P > 0.05$) with or without companion crop establishment (Table 10). However, when forage price was low or medium and when canola was used as the companion crop at Nipawin, net returns were higher from

Table 10. Two-year production costs and net returns for companion crops by soil zone in Saskatchewan

Site/companion crop	Soil zone	Total cost	Forage price Low	Forage price Medium	Forage price High
		($ ha^{-1})	Net returns		
Swift Current	Brown				
None		379	92	250	407
Canola		358	71	118	164
Field pea		447	80	133	187
Westerwolds ryegrass		404	1	136	271
Mean		397	61	159	257
$LSD_{<0.05}$		14	51	65	80
Saskatoon	Dark Brown				
None		481	54	232	410
Canola		471	–52	42	137
Field pea		523	–161	–77	6
Westerwolds ryegrass		498	–60	86	232
Mean		493	–55	71	196
$LSD_{<0.05}$		11	48	56	65
Nipawin	Dark Gray				
None		603	306	609	912
Canola		608	474	686	898
Field pea		685	342	554	766
Westerwolds ryegrass		664	317	643	971
Mean		640	360	623	887
$LSD_{<0.05}$		16	68	81	97

Table 11. Two-year production costs and net returns for grass species by soil zone in Saskatchewan

Site/grass species	Soil zone	Total cost	Forage price Low	Forage price Medium	Forage price High
		($ ha^{-1})	Net returns		
Swift Current	Brown				
Dahurian wildrye		401	51	147	242
Intermediate wheatgrass		404	79	186	292
Slender wheatgrass		386	53	146	238
$LSD_{<0.05}$		4	16	20	24
Saskatoon	Dark Brown				
Dahurian wildrye		503	–66	60	187
Intermediate wheatgrass		493	–56	70	195
Slender wheatgrass		484	–42	83	207
$LSD_{<0.05}$		5	17	22	27
Nipawin	Dark Gray				
Dahurian wildrye		647	317	573	828
Intermediate wheatgrass		649	398	670	943
Slender wheatgrass		624	364	626	889
$LSD_{<0.05}$		7	25	33	41

companion crop establishment. Producers frequently cite higher net returns in the establishment year from companion crops as the primary reason to use this technique in forage establishment. However, by extending the economic analysis into the second year to account for subsequent losses in forage yield, our findings do not generally support this notion. At Swift Current the use of companion crops reduced the 2-yr net returns by an average of \$41, \$121, and \$200 ha^{-1} at the low, medium, and high forage prices, respectively. At Saskatoon, the use of companion crops reduced the 2-yr net returns by \$145, \$215, and \$285 ha^{-1} at the respective forage prices. The use of companion crops at Nipawin increased the 2-yr net returns by \$72 ha^{-1} at the low forage price and by \$19 ha^{-1} at the medium forage price, but at the high forage price their use reduced average net returns by \$33 ha^{-1}. By comparison, under conditions when water is non-limiting, Jefferson and Zentner (1994) reported that economic returns in the establishment year were highest when alfalfa was grown with an oat (*Avena sativa* L.) companion crop that was harvested for hay, but when evaluated over a 3-yr period, they found little difference among direct-seeded and the companion crop methods

Table 12. Two-year production costs and net returns for grass-legume mixtures by soil zone in Saskatchewan

Site/alfalfa cultivar in mixture	Soil zone	Total cost	Forage price Low	Forage price Medium	Forage price High
		($ ha^{-1})	Net returns		
Swift Current	Brown				
Grass - Beaver		412	80	189	298
Grass - Nitro		400	40	134	227
Grass alone		380	64	155	247
$LSD_{<0.05}$		3	12	15	19
Saskatoon	Dark Brown				
Grass - Beaver		523	−14	136	285
Grass - Nitro		495	−92	21	135
Grass alone		462	−58	55	169
$LSD_{<0.05}$		3	11	15	19
Nipawin	Dark Gray				
Grass - Beaver		671	388	667	947
Grass - Nitro		649	315	570	824
Grass alone		600	376	632	889
$LSD_{<0.05}$		7	30	36	43

for establishing alfalfa on irrigated areas in southwestern Saskatchewan.

Among the companion crops evaluated in our current study, net returns at the Swift Current site were highest for canola and field pea when forage prices were low, similar for all three companion crop options at the medium forage price, and highest for Westerwolds ryegrass when forage price was high (but as indicated above, all were generally less profitable than the no-companion crop treatment) (Table 10). At Saskatoon, net returns were highest for canola and Westerwolds ryegrass at the low and medium forage prices, and at the high forage price ryegrass was best. At Nipawin, the canola companion crop ranked highest for the low and medium forage price scenarios, with Westerwolds ryegrass being the best choice when forage price was high. This improvement in relative economic returns from Westerwolds ryegrass with increasing forage price reflects the fact that the ryegrass (together with lesser amounts of grass and alfalfa) was being harvested as hay in the establishment year compared to the other companion crop treatments for which only the grain was harvested.

The effect of grass species selection on the 2-yr net returns also varied among soil zones (Table 11). In the Brown and Dark Gray soil zones, IWG produced the highest net returns ($27 to $52 ha^{-1} more at Swift Current, and $57 to $84 ha^{-1} more at Nipawin than other grass species), while SWG and IWG produced similar and the best economic returns in the Dark Brown soil zone ($14 to $17 ha^{-1} more at Saskatoon than DWG). The economic performance of DWG was generally lowest at all sites.

Grass plus Beaver alfalfa mixtures produced the highest economic returns at all three soil zone sites, while the Nitro alfalfa mixtures produced the lowest economic returns (Table 12). This is because Beaver alfalfa was persistent in all site-years, but Nitro alfalfa exhibited few plants that lived after the seeding year. The 2-yr net economic benefit from including Beaver alfalfa with the grass species averaged $24 to $51 ha^{-1} in the Brown soil zone (compared to the grass alone treatment), $44 to 116 ha^{-1} in the Dark Brown soil zone, and $12 to $58 ha^{-1} in the Dark Gray soil zone. These results are consistent with the forage productivity of this mixture compared to grass plus Nitro alfalfa or grass alone treatments.

CONCLUSIONS

This study examined the agronomic and economic merits of using canola, field pea, and Westerwolds ryegrass as companion crops to establish three short-lived grass species (Dahurian wildrye, intermediate wheatgrass, and slender wheatgrass), grown alone or in mixture with Beaver or Nitro alfalfa. The study was conducted at three locations in Saskatchewan. At Nipawin, in the Dark Gray soil zone, the companion crops had small impact on the subsequent short-rotation forage yields, and consequently, net returns were generally similar with or without companion crop establishment (and in a few cases higher when companion crops were used). But in the Dark Brown soil zone at Saskatoon and in the Brown soil zone at Swift Current, the use of companion crops had large negative effects on seedling growth, subsequent forage yields, and economic performance.

We demonstrated that companion crops had a negative effect on forage seedling density but this effect did not explain the reduction in forage yield. Current forage seeding and land conversion incentive programs, run by conservation agencies and governments, use forage plant density to gauge establishment success and trigger payments to producers. This approach does not include any estimate of productivity, which, as we have shown, can vary greatly due to seeding year management and weather conditions.

Intermediate wheatgrass exhibited higher forage productivity and net returns than SWG or DWR, and was generally consistent across all three sites. Beaver alfalfa produced more forage and economic earnings in mixture with grasses than did Nitro alfalfa. Nitro lacked sufficient winter hardiness to survive more than one Saskatchewan winter and the resulting yield of Nitro alfalfa-grass mixtures was generally similar to grass monoculture. Additional research is needed to address concerns about negative effects of alfalfa in dryland crop rotations.

We conclude that short-lived, high seedling vigour grasses can be utilized in short-rotation forage stands and that the use of companion crops should be recommended on a soil zone basis.

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