Short-lived intercrop forages affect long-term yields of alfalfa and wildrye grass mixtures

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Leyshon, A. J., Jefferson, P. G. and Waddington, J. 2002. **Short-lived intercrop forages affect long-term yields of alfalfa and wildrye grass mixtures**. Can. J. Plant Sci. **82**: 67–74. Widely seeded rows (>60 cm) of perennial grasses have exhibited greater long-term yield stability, but allow weed invasion in the first years after establishment. A 9-yr study was conducted at a semiarid site at Swift Current, Saskatchewan, Canada, to determine the effects of intercropping oats (*Avena sativa* L.) and slender wheatgrass [*Elymus trachycaulus* (Link) Gould ex Shinners] between rows of Russian wildrye [*Psathyrostachys juncea* (Fisch.) Nevski], and Altai wildrye [*Leymus angustus* (Trin) Pilger] seeded in 90-cm spacings either alone or in alternate rows with alfalfa (*Medicago sativa* L.). Two rows of oats depressed grass forage production in the year following establishment. Slender wheatgrass intercrops reduced grass forage yield and alfalfa forage yield. However, slender wheatgrass contributed to increased total forage yields while it persisted in the mixture. By the fifth year, it had disappeared from the Russian wildrye plots but persisted 2 more years when intercropped with Altai wildrye. Interseeded companion crops, either annual or short-lived perennials, for forage will give short-term yield gains, but long-lived perennial forages may not recover from the competition in the long-term.

Key words: *Avena sativa, Elymus trachycaulus, Psathyrostachys juncea, Leymus angustus, Medicago sativa,* forage yield

Leyshon, A. J., Jefferson, P. G. et Waddington, J. 2002. **Les cultures fourragères intercalaires de courte durée diminuent le rendement à long terme des mélanges de luzerne et d'élyme**. Can. J. Plant Sci. **82**: 67–74. Les graminées vivaces cultivées en rangs très espacés (plus de 60 cm) donnent un rendement plus stable à long terme, mais elles sont envahies par les adventices au cours des premières années suivant leur implantation. Les auteurs ont entrepris une étude de neuf ans sur un site semi-aride, à Swift Current, en Saskatchewan (Canada), en vue d'établir les conséquences de la culture d'avoine (*Avena sativa* L.) et d'élyme élancé [*Elymus trachycaulus* (Link) Gould *ex* Shinners] entre des rangs d'élyme de Russie [*Psathyrostachys juncea* (Fisch.) Nevski] et d'élyme de l'Altaï [*Leymus angustus* (Trin) Pilger], seuls ou en alternance avec de la luzerne (*Medicago sativa* L.), à un écartement de 90 cm. Deux rangs d'avoine réduisent la production de fourrage de graminées l'année suivant l'implantation. La culture intercalaire d'élyme élancé diminue le rendement fourrager des graminées et de la luzerne, mais il concourt à augmenter le rendement global en fourrages tant qu'il persiste dans le mélange. La cinquième année, l'espèce avait disparu dans les parcelles d'élyme de Russie, mais elle a résisté deux années supplémentaires quand elle était accompagnée d'élyme de l'Altaï. L'emploi de cultures-abris annuelles ou vivaces à vie brève avec les cultures fourragères entraîne une hausse à court terme du rendement, mais il se pourrait que les vivaces fourragères à vie plus longue ne parviennent pas à se remettre de la concurrence des autres espèces.

Mots clés: *Avena sativa*, *Elymus trachycaulus*, *Psathyrostachys juncea*, *Leymus angustus*, *Medicago sativa*, rendement fourrager

Under the semiarid conditions of southwestern Saskatchewan, forage production is primarily limited by the amount and variability of precipitation (Kilcher 1965; Holt and Jefferson 1999). Long-term productivity in this region (Kilcher 1961; Lawrence and Heinrichs 1968; Leyshon et al. 1981) is increased by growing forages in rows spaced 60 cm or more apart. Although higher hay yields can be obtained from these wide row spacings (Leyshon et al. 1990; Jefferson and Kielly 1998), new stands take 3 to 5 yr to reach maximum productivity (Leyshon et al. 1981).

The seeding of perennial forage species on previously fallowed soil is a common agronomic practice in this region, and improves seedling establishment by providing 16 mo of stored soil water and nutrients to the developing seedlings. If perennial forage species, such as Russian wildrye [*Psathyrostachys juncea* (Fisch.) Nevski] and Altai wildrye [*Leymus angustus* (Trin.) Pilger], are slow to establish, then stored soil water and nutrients plus growing season precipitation promote weedy annual plant growth between wide rows in the initial years of a new stand (Holt and Jefferson 1999). Over time, however, competition from perennial forage species eliminates the annual weeds (Holt and Jefferson 1999). Inter-row seedings of annual forage species or short-lived perennial forage species would establish quickly, exhibit higher growth rates in the establishment year and could improve initial forage production. Because these intercrops would be spatially separated from long-lived perennial forage species, we hypothesized that the former would not have a negative effect on the latter.

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The use of a spring cereal as a companion crop in perennial forage crop seedings has been a long-time agricultural practice to protect seedlings from wind, to reduce soil erosion, and to reduce weeds by competition during the establishment year. Such companion crops also compete with forage seedings for moisture (Kilcher and Heinrichs 1960; Genest and Steppler 1973), for light (Waddington and Bittman 1983), and for nutrients (Dupuis 1983; Bittman et al. 1991). Further, the underseeded forage may affect the companion crop (Nielsen et al. 1981; Waddington and Bittman 1984), and possible allelopathic interactions between the companion crop and the forage crop may be deleterious to the yields of both (Nielsen et al. 1981). Oat companion crops are preferred in the Brown Soil zone of Saskatchewan because the oat forage can be utilized for "green-feed" hay in the establishment year of the perennial species.

Seeding the companion crop between rows of forages may reduce the interspecific competitive effect by providing each species with its own space. Lawrence (1967) found that one or two rows of spring wheat (*Triticum aestivum* L.) seeded between Russian wildrye rows spaced 90 cm apart tended to reduce Russian wildrye yields. Subsequently, Lawrence (1970) found that a single row of wheat seeded between rows of crested wheatgrass [*Agropyron desertorum* (Fisch) Schult.] seeded at 90-cm spacings did not have any long-term effects. It was concluded from these studies that the extra yield from the intercrop compensated for any decreased yields of the perennial grass.

To increase forage production for the first and perhaps second year after the establishment year, Irvine and Lawrence (1982) and Asay and Knowles (1985) proposed the inclusion of slender wheatgrass [*Elymus trachycaulus* (Link) Gould ex Shinners], a short-lived, but rapidly establishing grass, when seeding slow-establishing species. Jefferson and Irvine (1992) found that this practice did not improve total forage production in the first 2 yr after seeding Russian wildrye, and that alfalfa (*Medicago sativa* L.) production was reduced when it was seeded in the same row with slender wheatgrass.

The objective of this study was to determine whether seeding an oat intercrop and a slender wheatgrass intercrop between rows of Russian wildrye or Altai wildrye with or without alfalfa and seeded in 90-cm spacings would increase the overall yield of a new forage stand during its early years and their impact on long-term forage yield.

MATERIALS AND METHODS

In the spring of 1980, a six row forage-plot seeder with individual seed delivery cones for each row was used to seed Swift Russian wildrye and Prairieland Altai wildrye either alone or in alternate rows with Rangelander alfalfa on a previously fallowed soil at the Semiarid Prairie Agricultural Research Centre, Swift Current, Saskatchewan, Canada (50°16′N, 107°44′W, elev: 825 m). A seeding depth of 2 cm was maintained by bands on each disk opener. Seeding rate was 67 pure live seeds per metre of row (Leyshon et al. 1981). Each plot consisted of four rows spaced 90 cm apart and 7 m long. The alfalfa was inoculated with the appropriate *Rhizobium* culture prior to seeding.

At the same time, using other seed delivery cones on the seeder, one of six intercropping treatments was sown in the space between the rows of perennial forage. The intercrops consisted of (a) one row of Harmon oats (*Avena sativa* L.); (b) two rows of oats; (c) one row of Revenue slender wheatgrass; (d) two rows of slender wheatgrass; (e) one row of oats and one row of slender wheatgrass; (f) no intercrop (control). The single row was midway (45 cm) between the perennial forage rows. The two-row arrangements were seeded equidistant (30 cm) from the perennial rows and each other. Oat was chosen because it is the most commonly used companion crop in this area. Slender wheatgrass was used as a short-lived perennial intercrop because it has a 3- to 5-yr life span under a hay-type clipping regime (Jefferson and Irvine 1992). Oat was seeded at a rate equivalent to 17% (one row) and 33% (two rows) of the monoculture oat seeding rate (60 kg ha^{-1}) in this area. The slender wheatgrass was also seeded at the 67 live seeds m^{-1} of row. The experiment was a split-plot design with four replications where the main plots were long-lived perennial grasses (Altai wildrye or Russian wildrye) and the subplots were factorial combinations of alfalfa treatments (present or absent) with the six intercrop treatments. Thus, each main plot consisted of 12 subplots.

The soil is a Swinton loam (Ayres et al. 1985), an Orthic Brown Chernozem (Canada Soil Survey Committee, Subcommittee on Soil Classification 1978). The 113-yr mean annual precipitation is 361 mm and the 38-yr mean annual USDA Class "A" pan evaporation for 1 April to 30 September is 1136 mm.

In the establishment or seeding year, oat forage was harvested at the soft dough stage. Only oat rows were sampled and none of the other forage species were cut. Ranchers can often follow the same practice by setting the cutting height of their forage harvesting equipment above the top of perennial forage plants. In some years, however, the alfalfa seedlings may be tall enough to be harvested. In succeeding years, the centre two rows of the long-lived perennial forages (Altai wildrye or Russian wildrye and alfalfa) in each plot were cut separately, using the Swift Current forage plot harvester (Thompson 1972) set to collect all plant material above a 7- to 8-cm height. The slender wheatgrass intercrop between the two centre rows was sampled separately, but on the same day as the other forages. Two cuts were taken to estimate forage yield in 1982 and 1983, one in early June, the second in mid-August when there was sufficient regrowth. In 1981 and 1984–1988, only one cut was made each year. At the first cut, grasses had headed and alfalfa was at the late bud stage of development. At the second cut, all species were vegetative. Only total annual dry matter yields are reported.

Heteroscadasticity of error variance among years in the forage yield data was confirmed by Bartlett's test (Steel and Torrie 1980). Because of this, the results were analysed separately for each year after transforming the data values to natural logarithms (Steel and Torrie 1980). Total forage yield over 9 yr was similarly transformed to natural logarithms. Differences between treatments were tested with Fisher's protected LSD based on error variances from orig-

Table 1. Winter and seasonal precipitation at Swift Current, Saskatchewan

Year	Previous winter (Sept.–March)	Spring (April–May)	Summer (June–Aug.)
		(mm)	
1980 (establish)	92	17	178
1981	128	54	173
1982	113	93	203
1983	121	84	143
1984	72	30	100
1985	153	44	81
1986	127	136	99
1987	166	39	196
1988	54	37	138
108-yr mean	127	65	167

inal data scale variables as calculated for split-plot designs by Steel and Torrie (1980). For presentation, means were back-transformed while standard errors were calculated from original data scale ANOVA error variances.

RESULTS

Precipitation during the Experiment

Growing season precipitation is the principal environmental factor affecting dryland forage production in southwestern Saskatchewan. Although precipitation in the establishment year was below the long-term mean for the previous winter and April and May (Table 1), all the seeded crops established well, probably because the average amount of rain fell during the summer. The following 3 yr received average or above average rainfall. Particularly in 1982, growing season rainfall was well above average, but included a snowfall event in late May. Precipitation in spring of 1984, 1985, 1987 and 1988 was lower than average, but was punctuated by a very wet May in 1986. Summer precipitation was low in 1984-86, and higher than average in 1987.

Oats Yields

Two rows of oats between the perennial forage rows produced 903 kg ha^{-1} of dry matter, significantly ($P < 0.01$) more than the 625 kg ha^{-1} from one row of oats or the 628 kg ha^{-1} from oats seeded with a row of slender wheatgrass (data not shown).

Total Forage Yield

The slender wheatgrass intercrop treatments produced more total forage than control or oats intercrops during 1981 to 1983 (Tables 2 and 3). This coincided with the period of highest slender wheatgrass forage production (Table 4). From 1984 to 1987, there was no effect of intercrops on total forage yield. However, in 1988 the total forage yield of all intercrop treatments was less than that of the control treatment.

Total forage production was greater for mixtures including alfalfa in all 8 yr (Tables 2 and 3). Only in 1987 was the grass × alfalfa interaction significant for total forage yield. The yield advantage due to alfalfa was less for Altai wildrye than Russian wildrye mixture in 1987. The presence of alfalfa in these dryland mixtures improved total forage yield response to “wetter” growing seasons in 1982 and 1986.

When combined over all 9 yr, slender wheatgrass intercrops produced more total forage yield than the control (Tables 2 and 3). The oat and slender wheatgrass intercrop produced 28% more forage from 1980 to 1988, primarily due to the oat yield in 1980 and the slender wheatgrass contribution to total forage yield from 1981 to 1985. As expected, alfalfa mixtures produced more total forage than grass monocultures.

Slender Wheatgrass Forage Yield

The slender wheatgrass intercrop treatments differed in 1981 when the two rows of slender wheatgrass produced more slender wheatgrass forage than the other intercrops (Table 4). For brevity, the significant main effects and interactions from the ANOVA are also presented in Table 4. The slender wheatgrass forage yields peaked in 1982 and declined annually thereafter. By 1985, low levels of slender wheatgrass forage were measured and completely disappeared by 1987. This is consistent with previous observations that slender wheatgrass has a 3- to 5-yr life span (Jefferson and Irvine 1992).

Table 2. The ANOVA mean square values for natural-log-transformed forage yield of two wildrye grasses grown with or without alfalfa and with six short-lived intercrops for eight years at Swift Current, Saskatchewan

	df	1981	1982	1983	1984	1985	1986	1987	1988	Total
Replication	3	0.51	0.88	0.59	1.51	1.34*	0.71	0.41	0.51	0.68
Grass (G)	1	0.00	0.50	0.40	0.43	0.57	0.35	4.11**	1.67*	0.40
Error A	3	0.06	0.21	0.25	0.30	0.11	0.15	0.11	0.11	0.11
Alfalfa (A)	1	35.76***	18.22***	11.85***	6.30***	1.05*	8.86***	3.16***	3.15***	7.00***
Intercrop (I)	5	7.03***	1.90***	0.38*	0.09	0.22	0.14	0.15	0.21*	0.18*
A × G	1	0.00	0.00	0.00	0.24	0.10	0.19	1.45***	0.21	0.02
A × I	5	3.44***	0.87***	0.05	0.16	0.16	0.06	0.05	0.08	0.07
G × I	5	0.14	0.04	0.08	0.25	0.32	0.18	0.01	0.06	0.04
A × G × I	5	0.05	0.90	0.06	0.12	0.06	0.09	0.08	0.07	0.04
Error B	66	0.15	0.14	0.12	0.16	0.17	0.09	0.07	0.09	0.07
CV %		6.2	5.2	4.8	6.2	6.6	4.3	4.1	4.5	2.9

*, **, *** Significant at $P = 0.05$, $P = 0.01$ and $P = 0.001$, respectively.

Table 3. Total forage yield following establishment of Russian and Altai wildryes with intercrops of oats and slender wheatgrass with or without alfalfa. Oat intercrop yields from 1980 are included in 9-yr total yield

	Year								1980-1988
	1981	1982	1983	1984	1985	1986	1987	1988	Total
Intercrop					(kg ha^{-1})				
None	333[z]	971	1219	592	611	1227	633	902	6729
Oats – 1 row	297	972	1351	544	503	1072	503	703	6998
Oats – 2 row	210	924	1137	575	427	1047	488	674	6968
Slender wheatgrass + oats	826	1766	1603	608	546	1256	519	655	8618
Slender wheatgrass – 1 row	863	1724	1638	645	519	1222	538	756	8077
Slender wheatgrass – 2 row	1122	1875	1559	524	514	1270	574	741	8323
SEM	91	140	151	78	74	128	53	87	654
$LSD_{0.05}$	184	282	302	–	–	–	–	174	1309
Mixture									
Russian wildrye	263	789	921	441	488	780	324	512	5348
Russian wildrye + alfalfa	941	1876	1884	667	644	1580	596	808	9449
Altai wildrye	286	906	1060	457	446	979	627	732	6263
Altai wildrye + alfalfa	989	2177	2114	842	516	1613	705	958	10445
SEM	59	123	146	65	60	125	48	58	848

[z]Means were back transformed for presentation. SEM values were calculated from original scale variable ANOVA mean squares.

Table 4. Slender wheatgrass yield when used as an intercrop with Russian or Altai wildrye with or without alfalfa

	Year					
Intercrop	1981	1982	1983	1984	1985	1986
Intercrop			(kg ha^{-1})			
Slender wheatgrass + oats	475[z]	888	702	122	19	32
Slender wheatgrass – 1 row	402	854	673	158	10	8
Slender wheatgrass – 2 row	692	1080	776	159	21	30
SEM	80	99	82	37	19	93
$LSD_{0.05}$	163	–	–	–	–	–
P > F - Intercrop	<0.01	0.06	NS	NS	NS	NS
Mixture						
Russian wildrye	603	827	418	44	2	2
Russian wildrye + alfalfa	439	817	732	158	6	4
Altai wildrye	648	1261	987	253	121	150
Altai wildrye + alfalfa	392	899	816	254	61	143
P > F Grass	NS[y]	0.08	<0.01	<0.01	0.01	0.02
P > F Alfalfa	<0.01	0.04	<0.01	<0.01	NS	NS
P > F G × A	NS	0.06	<0.01	<0.01	0.03	NS
SEM	165	222	174	78	37	189
CV (%) (log transform)	7.2	4.1	3.9	11.0	52.4	84.9

[z]Means were back transformed for presentation. Significance probability and CV values are on transformed variables. SEM values were calculated from original scale variable ANOVA mean squares.
[y]NS indicates $P > 0.10$.

The effects of wildrye species and alfalfa mixture on slender wheatgrass forage yield changed over time (Table 4). In 1981 and 1982, the competition effect of alfalfa reduced slender wheatgrass yield compared to grass monoculture. By 1983 and 1984, the grass × alfalfa interaction was significant because Russian wildrye alone was more competitive on slender wheatgrass than Russian wildrye plus alfalfa, which was more competitive than Altai wildrye with or without alfalfa. In 1985 and 1986, there was very little slender wheatgrass in the Russian wildrye treatments compared to Altai wildrye.

Grass Forage Yield

The use of intercrops reduced wildrye forage yield for the 5 yr following establishment (Table 5). The grass × intercrop interaction was not significant in any of those years indicating that the two wildrye species responded similarly to competition from the intercrop. The single row of oats did

Table 5. Grass forage yield of Russian and Altai wildryes following establishment with intercrops of slender wheatgrass or oats and with or without alfalfa

Treatment	Year 1981	1982	1983	1984	1985	1986	1987	1988
Intercrop	(kg ha^{-1})							
None	91[z]	368	684	361	496	782	376	606
Oats – 1 row	78	339	678	322	388	712	330	457
Oats – 2 row	56	249	445	270	342	648	331	464
Slender wheatgrass + oats	40	200	271	173	302	671	354	447
Slender wheatgrass – 1 row	63	223	325	167	291	839	399	562
Slender wheatgrass – 2 row	49	170	202	125	240	803	436	550
SEM	17	72	103	57	59	105	45	66
P > F - Intercrop	0.03	0.01	<0.01	<0.01	<0.01	NS[y]	NS	NS
$LSD_{0.05}$	35	145	207	115	118	–	–	–
Mixture								
Russian wildrye	96	469	682	391	483	768	324	512
Russian wildrye + alfalfa	53	180	292	173	467	587	596	351
Altai wildrye	77	358	552	328	384	806	627	732
Altai wildrye + alfalfa	40	126	216	105	143	826	705	517
SEM	40	197	366	207	110	265	95	132
P > F Grass	NS	NS	NS	NS	<0.01	NS	0.01	0.05
P > F Alfalfa	<0.01	<0.01	<0.01	<0.01	<0.01	NS	<0.01	<0.01
P > F G × A	NS	NS	NS	NS	<0.01	NS	NS	NS
CV (%) (log transform)	13.8	10.2	10.2	11.2	8.3	8.0	5.6	6.1

[z]Means were back transformed for presentation. Significance probability and CV values are on transformed variables. SEM values were calculated from original scale variable ANOVA mean squares.
[y]NS indicates $P > 0.10$.

not significantly reduce the grass forage yield during 1981 to 1985. However, the double row of oats treatment reduced grass forage yield in 1983 and 1985. As the oats intercrop was only present during the establishment year (1980), this suggested that competition during seedling development can have continued negative effects on forage productivity of these grasses in this semiarid environment. The slender wheatgrass intercrop treatments reduced grass forage yield during 1981–1985 compared to the control treatment. In 1981 and 1982, however, the single row of slender wheatgrass treatment was not significantly different from the control, while the other slender wheatgrass treatments were less than control. While the slender wheatgrass was present and competing for water and nutrients with these grasses, it reduced their forage productivity.

The presence of alfalfa reduced grass forage yield from 1981 to 1984 and in 1988 (Table 5). This was an expected response because alfalfa was occupying space in that treatment that would be occupied by the grass species in the grass-alone treatment. A different response was observed in 1985 and 1987. The grass × alfalfa interaction was significant in 1985 because Russian wildrye produced similar forage yield when grown with or without alfalfa, while Altai wildrye continued the expected pattern of lower yield in mixture with alfalfa. In 1987, both grasses produced more forage when grown with alfalfa than grown alone. The additional precipitation in 1986 may have produced more N-fixation by the alfalfa and this benefit was captured by the grasses in 1987. By 1988, the space replacement pattern of forage grass yield that was evident in 1981–1984 was observed again.

Alfalfa Forage Yield

Alfalfa productivity was reduced by intercrop treatments in 1982, 1986 and 1987 (Table 6). In 1982, the slender wheatgrass intercrop treatments resulted in a lower alfalfa yield than the control or oats intercrop treatments. In 1986, all intercrop treatments reduced alfalfa forage yield compared to the control, and two rows of slender wheatgrass reduced alfalfa yield more than other intercrop treatments. In 1987, all intercrop treatments reduced alfalfa forage yield compared to the control. While the oats intercrop treatment did not affect alfalfa yield potentials as much as the slender wheatgrass intercrop, the effect of oats intercrop on alfalfa was evident 6 yr after establishment. This indicates that agronomic management of grass-alfalfa mixture seedings is critical to the long-term productivity of alfalfa.

Alfalfa forage yield was greater in mixture with Altai wildrye than Russian wildrye in 1982 and 1983 while the reverse was true in 1986 (Table 6). While both wildrye species are slow to establish, Russian wildrye was more competitive with its alfalfa associate than Altai wildrye.

DISCUSSION

Forage production in the year after establishment depends on how well seedlings have established. Waddington and Malik (1987) suggested that an annual companion crop reduced growth rate of forage seedlings, resulting in a smaller plant at the start of growth the subsequent year. In this study, the intercrops depressed forage yields of wildrye grasses in 1981 as expected (Table 5) and alfalfa forage yield in 1982 (Table 6). Waddington and Bittman (1984)

Table 6. Yield of the alfalfa component when grown with Russian and Altai wildryes following establishment with or without intercrop of oats or slender wheatgrass

	Year							
Treatment	1981	1982	1983	1984	1985	1986	1987	1988
Intercrop	(kg ha^{-1})							
None	811[z]	1497	1235	467	147	913	453	553
Oats – 1 row	738	1541	1366	448	235	516	355	516
Oats – 2 row	706	1749	1315	472	110	679	293	427
Slender wheatgrass + oats	638	1235	1164	436	166	508	311	389
Slender wheatgrass – 1 row	614	1197	1156	455	230	495	268	350
Slender wheatgrass – 2 row	611	1159	1115	450	248	314	243	354
SEM	96	114	110	53	49	79	42	54
$LSD_{0.05}$	–	234	–	–	–	162	85	–
P > F – Intercrop	NS[y]	<0.01	NS	NS	0.06	<0.01	0.04	0.06
Mixture								
Russian wildrye	642	1226	1104	372	115	815	319	435
Altai wildrye	726	1552	1353	557	277	355	309	419
P > F grass	NS	0.03	0.04	0.06	0.07	<0.01	NS	NS
SEM	52	73	65	57	55	60	20	18
CV (%) (log transform)	4.4	2.2	2.4	3.9	10.3	7.5	6.7	5.6

[z]Means were back transformed for presentation. Significance probability and CV values are on transformed variables. SEM values were calculated from original scale variable ANOVA mean squares.
[y]NS indicates $P > 0.10$.

also found that an annual companion crop suppressed Russian wildrye much more severely than it suppressed alfalfa. In the present study, we expected oat would be more aggressive than slender wheatgrass because of its greater growth. This effect was not evident in 1981. Alfalfa produced significantly more dry matter in 1982 and 1983 where oat was used during the establishment year, compared to slender wheatgrass.

This result disagrees with the report of Jefferson and Irvine (1992) where there was no yield advantage to slender wheatgrass in mixture with alfalfa and Russian wildrye. This discrepancy may be related to the spatial separation of the slender wheatgrass from the alfalfa in this study while they were seeded in the same row as alfalfa in the Jefferson and Irvine (1992) report. When each species occupies its own space within the sward, they may be better able to compete for limited soil water and minerals. Both Russian wildrye and Altai wildrye have low seedling vigour (Lawrence and Kilcher 1972) and produce little growth in the first harvest year (Table 4). In subsequent years the yield benefit due to the slender wheatgrass diminished as the other species in the stands developed and the slender wheatgrass began to die out. After that, total forage yields were similar to treatments that were established without an intercrop (Table 3).

Yearly fluctuations in precipitation, as well as the degree of full stand development, were reflected in the yields of the forage crops (Table 3). Although complete separation of the effects of precipitation and age of stand is not possible, the data indicates that the long-term perennial species were well below their maximum yield potential in 1981, the first harvest year, and probably also below in 1982. The results of other studies (Leyshon et al. 1981) indicate that they would still be approaching their maximum yield by the third harvest year.

A further consideration is that precipitation for the first 3 harvest years was about average, which may account for the differences in response of the slender wheatgrass compared to the findings of Jefferson and Irvine (1992).

There was a trend towards a recovery of yields by the companion crop treatments within each long-term perennial crop. This was particularly evident with the Altai wildrye treatments. Perhaps over a very long term, recovery from companion crop effects would have been complete.

In all intercrop treatments, Russian wildrye had not recovered after 7 yr from the stress of competition early in the establishment of the stand. Because Russian wildrye takes more than 1 yr to develop its full yield potential (Leyshon et al. 1981), 1 yr of deleterious treatment to the seedlings prior to complete establishment may be compensated for by additional growth or by continued seedling establishment in subsequent years (Leyshon and Campbell 1992). Several years of competition caused by a short-lived perennial such as slender wheatgrass negates or delays these effects. These observations may have consequences for the use of wide row spacings without companion crops. Under conditions where the distance between row spacings allows weeds to develop and persist, forage productivity of Russian wildrye may be affected.

Altai wildrye, in contrast, was less affected over the duration of the experiment by competition, eventually recovering to produce the same yields as the control (data not shown). The difference in growth form and growth habit between Altai wildrye and Russian wildrye may have contributed to this effect. In addition, the later maturity of Altai wildrye compared with Russian wildrye may enable it to better tolerate competition in its early years.

Other studies on the effects of companion crops (Waddington and Bittman 1983, 1984; Malik and Waddington 1988) have shown that variations in weather and location will cause equally varied responses. However, these studies confirm the conclusions of Waddington (1990) that there is no seeding rate of perennial forage and short-lived companion crop that will permit both maximum crop yield in the establishment year and maximum forage crop production thereafter. This study goes further in showing that the effects continue for much longer than previously realised under semiarid conditions. However, oats at a very low seeding rate combined with slender wheatgrass can be grown as an annual intercrop between rows of perennial forage to maximize total forage production over the long-term and produce a harvestable forage crop in the establishment year.

Seeding a short-lived perennial such as slender wheatgrass between the rows may increase total forage yield in the first few years, which allow the more permanent forages time to establish more fully, thus improving the uniformity of the yield over time. However, slender wheatgrass competition reduced wildrye grass forage production although the competition during the establishment year is less than with an annual such as oats. In addition, slender wheatgrass competition may reduce alfalfa production in mixtures, which would be useful in reducing the bloat hazard of pastures. Consequently, slender wheatgrass intercrops can have both positive and negative aspects to forage productivity and stand composition. The difficulty of seeding complex mixtures in separate rows must be solved in field-scale equipment prior to recommending this practice to producers.

Further research is required to determine whether there are other short-lived perennials that are less competitive and could be used as intercrops or mixtures with long-lived perennials without a negative effect upon longer term yields. Early-maturing oat cultivars might be less competitive with under-seeded forages. There is growing use of triticale (*X Triticosecale* Wittmark) as annual forage in western Canada and future research should evaluate its competitive effects on under-seeded forages. Selective grazing among forage species in pastures should be determined. Also, the problems with frothy ruminant bloat management in alfalfa-wildrye mixtures indicates that future investigations should identify less aggressive or non-bloating legume species to be grown with Russian and Altai wildrye.

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