

Research in Western Canada on seeding forages with a Companion Crop

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The climate in the Canadian prairies is one of summer water deficiency to a greater or lesser extent depending on the location and year. Experiments to determine the best way to establish forages under these conditions have been conducted from time to time since the native vegetation was replaced with cultivated crops.

Perennial forages grow and develop slowly from seed, and annual weeds compete strongly, to the detriment of the forage seedlings. The use of annual grain crops to suppress weeds and produce an economic return during the forage establishment year is a practice with an extensive history in Europe prior to the settlement of western Canada.

Experimental Farms were established in western Canada starting in 1886 to research and develop suitable farming techniques for the benefit of new colonists. Initially, experiments on the use of companion crops or “nurse crops” as they were usually called, were not conducted. Rather, several crop rotations some of which included forages underseeded in cereals were started at each experimental farm. These were set up on a small field scale and before the development of modern experimental design and analysis. There was usually only one of each rotation, started in successive years. The commonly-used forages were Slender Wheatgrass (*Elymus trachycaulus*) (called Western Ryegrass in early reports), Smooth Bromegrass (*Bromus inermis*), Alfalfa (*Medicago sativa*, *M. falcata*), and Sweetclover (*Melilotus officinalis*, *M. alba*). The usual seeding method was to mix the forage seed with the cereal in the drill box. This worked well enough for the grasses but the smaller, smoother legume seeds tended to settle down and seed unevenly. Also, hardy alfalfa was in short supply and expensive, and was not always used. Consequently, the legume component tended to die out within a year or two of establishment.

White (1913) commented that at Rosthern Experimental Farm, the particular cereal used as a companion crop was not important, but that lodging of the cereal was very deleterious to the underseeded forages, and this was particularly a problem after seeding on fallow. He considered that barley (*Hordeum vulgare*) was probably the best cereal to use on stubble. Forage seeded alone produced greater yields but did not compensate for the loss of a companion crop yield. The forage mixture used was 11 kg slender wheatgrass, 3.4 kg alfalfa and 3.4 kg red clover (*Trifolium pratense*). No yields were given. A report from Brandon Experimental Farm (Report of the Dominion Experimental Farms for the Fiscal Year Ending March 1918) also stated that the better yield after establishing forage alone did not compensate for the loss of a companion crop yield. The report also stated that forage establishment was most reliable after fallow or a corn crop, and that the more years of successive cereal cropping before seeding forages, the harder it was to get a good forage catch.

Results from Indian Head (Indian Head Experimental Farm, 1920) averaged over the

period 1911-1920 (Table 1) demonstrated the two trends - more forage when seeded alone, and less forage the more years that cereal crops had been grown before seeding forages. Similar results were reported from Brandon (Brandon Experimental Farm, 1921) (Table 2) and Lacombe (Lacombe Experimental Farm, 1921) (Table 3) over a similar period.

Table 1 Average hay yields (kg/ha) from the first and second production years at Indian Head, Saskatchewan, 1911-1920 after seeding with or without a companion crop.

Forage Seeding Method	1 st Year	2 nd year
	----- kg/ha -----	-----
With companion crop, after fallow	5120	5760
Seeded alone, after fallow	7040	7000
With companion crop, after wheat	3790	4760
Seeded alone, after wheat	4840	5190
With companion crop, after 2 wheat crops	4490	-
Seeded alone, after 2 wheat crops	3390	-

Note: Forage mixture = 11 kg Slender wheatgrass + 11 kg Red Clover /ha

Table 2 Six-year average hay yields at Brandon, Manitoba, 1915-1920 after seeding with or without a companion crop.

Forage Seeding Method	Hay Yield (kg/ha)
	1 st production year
With companion crop, after fallow	5290
Seeded alone, after fallow	6370
With companion crop, after hoed crop	5410
Seeded alone, after hoed crop	5850
With companion crop, after wheat	4030
Seeded alone, after wheat	4690
With companion crop, after 2 wheat crops	3540
Seeded alone, after 2 wheat crops	4290

Note: Forage mixture = 11 kg Slender wheatgrass + 11 kg Red Clover /acre

Table 3 Average hay yields at Lacombe, Alberta, 1913-1920 after seeding with or without a

wheat companion crop.

Forage Seeding Method	1 st Year	2 nd year	3 rd year
	----- kg/ha -----		
With wheat companion crop, after fallow	4070	4180	4180
Seeded alone, after fallow	6870	5510	5190
With wheat companion crop, after wheat	3640	3850	-
Seeded alone, after wheat	5070	4560	-

Note: Forage mixture = 11 kg Slender wheatgrass + 11 kg Red Clover /acre.

In the 1920's, experiments were conducted to investigate which of the three cereals, wheat, barley, oats, was the best companion crop, and what were the best seeding rates to use for both forage and cereal. Tinline (1924) at Scott, compared sweetclover production after seeding it at 17 kg/ha with various rates of oats and barley (Table 4). The sweetclover (probably arctic) seed was mixed with the grain and sown through the grain drill on land fallowed the previous year. It seems likely that the poorer yields at the lowest cereal seeding rates were caused by weed competition. In the 1920's, weed control options were very limited. Tinline also reported that in rotation, using a wheat companion crop at 1.5 bus/acre (100 kg/ha) for 11 kg slender wheatgrass + 7 kg sweetclover/ha gave good returns over three years. In dry years, the less rank growth of the companion crop resulted in less light competition for the forages.

Table 4 Sweetclover hay yield after seeding at 17 kg/ha with various rates of Oats and Barley at Scott, Saskatchewan.

Cereal Seeding Rate		Sweetclover Hay Yield (kg/ha)
Oats @ 1/2 bus	(18 kg/ha)	4540
“ 3/4 “	(27 kg/ha)	4990
“ 1.5 “	(54 kg/ha)	4810
“ 2.0 “	(72 kg/ha)	3900
Barley @ 1/2 bus	(27 kg/ha)	3050
“ 3/4 “	(40 kg/ha)	6310
“ 1.0 “	(54 kg/ha)	3270
“ 1.5 “	(81 kg/ha)	2560

A report from Brandon (Brandon Experimental Farm, 1926) showed hay yields of

sweetclover seeded with various rates of wheat and barley (Table 5), although the two cereals were not in direct comparison, as at Scott. There appears to be little effect on sweetclover yields until the highest rate of companion crop seeding is used. Experiments using single rates of companion crop in comparison to no companion crop using alfalfa and sweetclover

Table 5 Sweetclover hay yields after seeding with wheat and barley companion crops at several seeding rates at Brandon, Manitoba.

Companion crop seeding rate	Sweetclover Hay kg/ha
4-yr average yields	
Wheat @ 0.75 bus (50 kg/ha)	7200
“ 1.25 “ (84 kg/ha)	7100
“ 1.75 “ (118 kg/ha)	6900
“ 2.25 “ (151 kg/ha)	6140
2-yr average yields	
Barley @ 1.00 bus (54 kg/ha)	6320
“ 1.75 “ (94 kg/ha)	6010
“ 2.50 “ (134 kg/ha)	5730

Note: Sweetclover seeded at 11 kg/ha

Table 6 Alfalfa and sweetclover hay yields after seeding with several annual crops, averaged over four experiments at Brandon, Manitoba.

Companion crop and seeding rate	Alfalfa hay yield	Sweetclover hay yield
	----- (kg/ha) -----	
No companion crop	7070	7470
Flax @ 0.5 bus	6740	7280
Wheat @ 1.0 bus (67 kg/ha)	6070	6790
Oats @ 2.0 bus (72 kg/ha)	5990	6140
Barley @ 1.5 bus (81 kg/ha)	4720	6190

Note: legumes seeded at 11 kg/ha, wheat at 1.25 bus (84 kg/ha) with sweetclover

demonstrated the effect of the companion crop on forage yield the year following the establishment year (Table 6). Neither wheat nor flax had much effect on sweetclover production, but barley and oats appeared to reduce it somewhat. The report notes that in an average year, the sweetclover tended to smother the flax. Alfalfa production was reduced by all cereals but not by flax. The overall conclusions were that flax is the best companion crop to use because it provides less shade and has shallower roots. However, all crops tested were usable as companion crops provided seeding rates were reduced somewhat below those normally used, although barley was the least desirable.

At Swift Current, experiments started in 1924 with grass suggested that best establishment is obtained by seeding the grass alone, but Russian thistle was such a problem that the practice was unwise. Of the companion crops tried, flax was least competitive, but again, Russian thistle created problems. Using a grain companion crop rendered grass establishment doubtful but at least the cereal produced some revenue. As a general practice, the report suggested that seeding with a companion crop on fallow was to be preferred over seeding the grass alone. Wheat was better than barley which was better than oats. Spring rye cut for hay in July might have some merit (Swift Current Experimental Farm, 1926). No numbers were given. The report from Indian Head (Indian Head Experimental Farm, 1926) advised against seeding forages along with fall rye in the fall. It was better to seed the forages in spring. It seems likely that they tried legumes which would not develop enough after fall seeding to survive the winter.

Table 7 Seeding rates used in companion crop tests run at Beaverlodge Experimental Farm, Alberta, from 1918 to 1923.

Barley:	4, 6, 8, 10 pecks	(54, 81, 108, 134 kg/ha)
Wheat:	5, 6, 7, 8 pecks	(84, 101, 118, 134 kg/ha)
Oats:	10, 12, 14, 16 pecks	(90, 108, 126, 143 kg/ha)
Alfalfa, red clover, sweetclover:		11 kg/ha
Alsike Clover (<i>Trifolium hybridum</i>):		5.6 kg/ha
White Clover: (<i>Trifolium repens</i>):		5.6 kg/ha
Timothy (<i>Phleum pratense</i>):		6.7 kg/ha
Slender wheatgrass:		6.7 kg/ha
Meadow Fescue (<i>Festuca elatior</i>):		13 kg/ha
Kentucky Bluegrass (<i>Poa pratensis</i>):		13 kg/ha
Smooth Bromegrass:		13 kg/ha

Beaverlodge Experimental Farm reported (Beaverlodge Experimental Farm, 1926)

reported on an extensive series of companion crop tests started in 1918. The tests used three cereals in strips and ten forages seeded across the cereals (Table 7). Four blocks were used. There was some variation in seeding rates from year to year, and the legumes were not inoculated with rhizobium for the first three tests. The report provides extensive data expressed as averages of various sorts, and admits that a combination of poor establishment on occasion, variation in the number of forage harvests, losses from winterkill, and other vagaries make for problems in assessing the data. Tests were seeded each year from 1918 to 1923 and harvested for three years.

There were substantial gains in forage production when seeded alone compared to using a companion crop (Table 8). However, including a companion crop increased the overall financial returns over a 3-year period more than was gained in forage by not using one. Little difference appeared in forage yields after using any of the cereals as companion crops or over the range of their seeding rates used (Table 9). A problem in the Peace River area was that there was little weather suitable for forage seedling growth after harvesting the companion crop. Consequently, seeding forage alone usually produced the best yield the year after seeding. With a companion crop the best forage yields were usually produced in the second year after seeding. When flax was added to the tests, there was sometimes a problem with excessive growth of some forage seedlings and weeds.

Table 8 Hay yields of three forages after seeding with and without a companion crop, averaged over four experiments at Beaverlodge Experimental Farm, Alberta.

Forage	1 st year		2 nd year	
	With	Without	With	Without
	----- kg/ha -----			
Timothy	1200	3760	1200	1320
Slender wheatgrass	1680	5080	1730	2020
Smooth Bromegrass	1150	5210	1920	2190

Note: Where seeded alone, hay from the seedling year was added to the 1st year yields.

Averaged over 8 cuts and three tests, removing an oats companion crop for hay produced 2070 kg/ha in forages compared to 2300 kg/ha when the oats were pastured and 2940 kg/ha when the forages were grown alone. Presumably, these averages are of the perennial forage harvested in two tests over three years and one test over two years. Also, Dwarf Essex Rape was tried as a companion crop in 1926. This crop is usually grown for pasture. It was not a success because of slow establishment and a limited amount of grazing. Also, subsequent hay yields from the forage were reduced.

Table 9 Effects of companion crop seeding rate on forage hay yields at Beaverlodge Experimental Farm, Alberta.

Companion crop	Seeding rate*			
	1 Lightest	2	3	4 Heaviest
	----- kg/ha -----			
Wheat	1500	1640	1360	1430
Barley	1480	1510	1630	1440
Oats	1370	1440	1370	1370

Notes: For actual seeding rates, see Table 7

Hay yields are averages of four experiments of Timothy, Slender wheatgrass, and Smooth Bromegrass

At Rosthern the sweetclover tended to be finer stemmed when seeded with a companion crop, but yield was lower. Bromegrass seeded with a companion crop needed more than two years to catch up to that seeded alone (Table 10). Slender wheatgrass seed production was greater in the first production year after seeding alone, but in the second year, seed yields were similar whether the crop had been seeded with or without a companion crop (Rosthern Experimental Farm, 1928).

Table 10 Bromegrass and Sweetclover yields after seeding alone and with a companion crop at Rosthern Experimental Farm, Saskatchewan.

Forage and Seeding Method	1 st Year Hay	2 nd Year hay
	----- kg/ha -----	
Bromegrass seeded alone	2780	3510
“ ” with companion crop	1710	2600
Sweetclover seeded alone	6340	-
“ ” with companion crop	2980	-

Note: Sweetclover values are 6-yr averages, bromegrass averages unknown no. of years.

At Swift Current in the early 1920's, establishing forages with a companion crop was successful (Swift Current Experimental Farm, 1924, 1928), judging from reported yields in the first production year (Tables 11, 12). Although forage stands with a wheat companion crop were not as good as those obtained by seeding the forages alone, the benefit to seeding alone did not compensate for the loss of the companion crop income and the increase in weed problems. The

report in 1927 suggested that most forages needed two years to establish a good stand because of moisture limitations, while in 1930, seeding forages alone produced a very thin stand and they failed to establish after seeding with a companion crop (Swift Current Experimental Farm, 1927, 1930).

Table 11 First year forage yields at Swift Current, Saskatchewan, after establishment with a companion crop.

Forage	1923	1924
	----- kg/ha -----	
Slender wheatgrass	4240	1630
Slender wheatgrass + Alfalfa	2730	1510
Slender wheatgrass + White Sweetclover	2190	1140
Yellow Sweetclover	2470	1950
White Sweetclover	3100	1220
Smooth Bromegrass	2160	1620

Table 12 First harvest yields of several forages after seeding alone and with a companion crop at Swift Current.

Forage and seeding method used	6-test average of 1 st yr yields (kg/ha)
Brome and Slender wheatgrasses seeded alone on fallow	5110
“ ” “ with wheat after fallow	3830
“ ” “ with wheat after wheat	2350
White Sweetclover seeded alone on fallow	4170
“ ” with wheat after wheat	3590

Results from tests of Slender wheatgrass and alfalfa mixture with a further combination of companion crops and extended cropping sequences at Indian Head were reported in 1929 (Indian Head Experimental Farm, 1929). The forages seeded alone on wheat stubble produced the best yields in the first production year (Table 13). Seeding with a companion crop on fallow produced no better forage yields the first production year than seeding with a companion crop on stubble. Second year production was perhaps slightly lower where the forages had been established with a companion crop on stubble.

Table 13 Alfalfa-Slender Wheatgrass production at Indian Head Experimental Farm, Saskatchewan, after establishment with various companion crops after one or two cereal crops.

Crop sequences	1 st year	2 nd year
	Hay yield	Hay yield
	----- kg/ha -----	
Seeded alone on wheat stubble	7150	5670
Wheat companion crop on wheat stubble	4730	5340
Oats companion crop - 2 nd crop after fallow	4480	4710
Barley companion crop - 2 nd crop after fallow	4930	4770
Greenfeed oats companion crop - 2 nd crop after fallow	4890	5070
Oats companion crop on fallow	4860	5780
Wheat companion crop on fallow	3880	5380

A series of tests using a range of seeding rates of oats for hay as the companion crop for establishing sweetclover was reported from Scott in 1930 (Scott Experimental Farm, 1930). Each increase of oats seeding rate between ½ and 1 ½ bus/acre (18-54 kg/ha) increased oats hay yield and decreased sweetclover yield the following year. Even though sweetclover seeded alone produced twice the dry matter than when seeded with the oats, the two-year yield of oats and sweetclover always exceeded that of the sweetclover alone (Table 14).

Table 14 Forage dry matter production from oats and underseeded sweetclover at Scott Experimental Farm, Saskatchewan.

Oats Seeding Rate	Oats Yield	Sweetclover Yield
	----- kg/ha -----	
0	-	3560
0.50 bus (18 kg/ha)	3180	1880
0.75 “ (27 kg/ha)	3450	1820
1.00 “ (36 kg/ha)	4150	1730
1.50 “ (54 kg/ha)	4730	1590

It seems likely that most or perhaps all the experiments conducted in Western Canada on forages and companion crops prior to the 1930's were not designed for statistical analysis because the Analysis of Variance techniques were not available. Fisher published “Statistical

Methods for Research Workers” in 1925 and “The Arrangement of Field Experiments” in 1926. However, “Student” developed the t-test in 1915, and Fisher was developing the ANOVA by 1918. Whether correctly designed and analysed or not, by 1930 there was plenty of data from the research conducted in Western Canada for researchers to advise farmers on the merits or otherwise of using companion crops when establishing forages. Kirk (1935) summed up the findings. He noted that in most years there was sufficient moisture near the soil surface in early spring for forage seed germination but that a companion crop made heavy demands on moisture and if timely rains did not occur, underseeded forages might not establish, particularly in the drier areas. With reserve moisture in the soil, such as on summerfallow, a companion crop produced a harvest in the seeding year and the forage established. If there was little moisture in the soil, he advised to seed the forage without a companion crop after the first flush of weeds had been controlled and summer rains had fallen in June. He also recommended that the forages be cross-seeded to the cereal in a separate operation.

Experimental Farms reports provided no experimental data on companion cropping in the 1930's and 1940's, probably because of drought problems followed by wartime limitations. The Swift Current report advised against using a companion crop when establishing forages on dryland because of 15 years of failure. There was an admission that flax could be used on irrigated areas provided it was seeded thinly and harvested as early as possible (Swift Current Experimental Farm, 1937-47). Over the same period at Scott, rotations with grass were not successful, especially in drier years (Scott Experimental Farm, 1937-47). At Agassiz where moisture supply is more plentiful, it was recommended that companion crops be seeded at half the normal rate when underseeded with a forage, but that forage yields were greater after seeding alone (Agassiz Experimental Farm, 1936-47). In Manitoba, alternate rows of forage and wheat companion crop worked well. This effectively seeded the wheat at half the usual rate, the maximum recommended. Fall seeding of grasses produced the best stands at Melita but the use of fall rye as a companion crop was of doubtful value (Manitoba Forage Crops Committee. 1941, 1952).

After 1950, experiments used experimental design and Analysis of Variance techniques with small plots to control variation and provide a measure of random error so that differences between treatments could be assessed with some degree of reliability and precision. Because small plots can be treated better, yields are perhaps 10% higher than a producer would expect on a field scale.

Between 1950 and 1954, Kilcher and Heinrichs (1960) conducted experiments at Swift Current using wheat (34 kg/ha), oats (36 kg/ha), barley (40 kg/ha), and spring rye (34 kg/ha) as companion crops for crested wheatgrass (2.2 kg/ha), bromegrass (4.5 kg/ha), and alfalfa (2.2 kg/ha). The cereals were seeded at 15 cm spacing and at 31 cm spacing. The forages were either seeded in the grain row, or cross-seeded, in all cases at 31 cm row spacing. The cereals were cut at a 5 cm height for hay at the soft dough stage of maturity, or cut at an 20 cm height at grain maturity. The forages were also seeded alone. The various combinations of seeding style of the forage, and row spacing of the cereal had little effect on cereal production whether as hay or grain, but seeding the grain at 15 cm spacing reduced forage yield the following two years

compared to the 31 cm spacing. Cutting the cereals for hay at 5 cm height reduced the forage seedling groundcover when measured the following spring (Table 15). This would remove some leaf area from the seedling forages, and the leaves remaining would be subject to a sudden increase in heat and moisture stress after having developed in a sheltered environment. When the cereal was left until maturity, the increase in light and heat stress would be more gradual, little forage would be removed with an 20 cm cutting height, and more cereal straw remained to shelter the forage seedlings. Whether the lesser ground cover was due to fewer seedlings or smaller seedlings is not known.

Table 15 Basal Ground Cover of Forages in early Spring following the Establishment Year at Swift Current, Saskatchewan.

Companion Crop and Seeding Rate	Cereal Cut as Hay				Cereal Cut as Grain			
	Alfalfa		Grass		Alfalfa		Grass	
	Mixed	Cross	Mixed	Cross	Mixed	Cross	Mixed	Cross
	-----% ground cover-----							
Wheat (34 kg/ha)	0.72	1.17	1.93	3.97	1.10	1.50	3.36	4.31
Oats (36 kg/ha)	0.61	1.04	2.63	3.52	0.79	1.24	2.65	3.94
Barley (40 kg/ha)	0.54	0.92	1.87	3.45	1.12	1.24	2.29	4.02
Spr. Rye (34 kg/ha)	0.56	0.89	1.91	3.44	1.07	1.29	2.56	4.05
None	1.47	1.46	4.35	5.06	1.47	1.46	4.35	5.06

Forage yields in both first year and second year after seeding were reduced where a companion crop had been seeded in 6-inch compared to 12-inch rows (Table 16). Seeding the forage in the same row as the grain also caused a clear reduction in forage the following year when the cereal was cut for hay but not when left to maturity (Table 17). This effect is likely a result of the lesser ground cover of the forages in the spring. Smaller, weaker plants would not respond as vigorously to spring moisture as the larger plants present where better light conditions had been present with the wider cereal row spacing, and even more so where no companion crop was used. Forage production in the second harvest year showed the same pattern, but the differences were less than in the first year.

Table 16 The Effect of Row Spacing of the Companion Crop on Forage Yield in the First and Second Years after Seeding at Swift Current, Saskatchewan.

Companion Crop and Seeding Rate	Companion Crop Row Spacing			
	15 cm		31 cm	
	First Year	Second Year	First year	Second Year
	kg/ha			
Wheat (34 kg/ha)	740	1300	980	1580
Oats (36 kg/ha)	660	1380	880	1420
Barley (40 kg/ha)	680	1360	880	1440
Spr. Rye (34 kg/ha)	680	1240	760	1500
None	1240	1800	1240	1800

Table 17 Production of alfalfa-grass mixtures in first and second years after seeding with and without a companion crop at Swift Current, Saskatchewan.

Companion Crop and Seeding Rate	First Year Yields			
	Cereal Cut for Hay		Cereal Cut for Grain	
	Mixed Seeding	Cross Seeded	Mixed Seeding	Cross Seeded
	kg/ha			
Wheat (34 kg/ha)	540	760	860	900
Oats (36 kg/ha)	500	620	760	780
Barley (40 kg/ha)	600	640	760	800
Spr. Rye (34 kg/ha)	440	680	700	780
None	1180	1120	1180	1120
	Second Year Yields			
Wheat (34 kg/ha)	1160	1520	1380	1700
Oats (36 kg/ha)	2000	1360	1440	1660
Barley (40 kg/ha)	1100	1400	1400	1540
Spr. Rye (34 kg/ha)	1140	1560	1460	1600
None	1760	1800	1760	1800

Kilcher and Heinrichs advised that on dryland, to reduce the deleterious effects of

companion crops when establishing forages, the cereal and forage should be cross-seeded, that wheat was the least damaging companion crop and should be seeded in 12-inch rows at a reduced seeding rate, and that the cereal should be left to mature and cut at a 8-inch or more height. Overall, it was best not to use a companion crop at all.

Table 18 Comparison of Grass Production with and without a companion crop at Brandon Research Station, Manitoba.

Grass Species	With Companion Crop (3-test average)	Without Companion Crop (2-test average)
	----- kg/ha -----	-----
Bromegrass	3700	2870
Intermediate Wheatgrass	3790	3770
Slender Wheatgrass	3430	2620
Russian Wild Rye	2330	1750

There was a clear benefit to seeding grasses without a companion crop at Brandon (Table 18). The adverse effects of the companion crop was greatest in the seedling and first harvest years and had mostly disappeared by the second year (Manitoba Forage Crops Committee 1957, 1958). The effect of the companion crop depended on the species and the length of time it was present, and may be expressed as forage plant numbers, the ratio of species under the companion crop, or reduced vigour of the forages.

In the 1970's, canola emerged as a major crop. Waddington and Bittman (1983, 1984a, b) conducted experiments at Melfort Research Station in Saskatchewan to compare wheat and canola as companion crops for establishing forages. Argentine canola (*Brassica napus*) was seeded at 8 kg/ha, Polish canola (*B. rapa*) at 6 kg/ha, both the standard rates, as well as wheat at 50 and 101 kg/ha, half-normal and the standard seeding rates, all in late May 1972, 1975, and 1976. An additional test of Polish canola was also seeded two weeks later in the same years. Alfalfa (8 kg/ha) and bromegrass (9 kg/ha) were seeded at right-angles to the companion crops in a separate operation. Sainfoin (*Onobrychis viciaefolia*) (34 kg/ha) and Russian wild ryegrass (*Psathyrostachys juncea*) (6 kg/ha) were included in the Polish canola experiments. As well, two methods of seeding: (1) cross-seeding the forage and canola and (2) mixing the two seeds together before seeding were used in the tests with Polish canola. All plot sizes were 3 x 6 m, and 45 kg/ha of 11-48-0 were incorporated prior to seeding into land fallowed the previous year. The companion crops were harvested at grain maturity and a 1 m² area cut for forage yield measurement. In the following years, the forage was harvested in early July when the legumes were in an early flowering stage of growth and the grasses were headed out. Samples were separated into forage and weeds.

Wheat produced 2930 and 2820 kg/ha for the 50 and 101 kg/ha seeding rates, averaged across the three tests. In 1972 the two seeding rates produced the same yield, in 1975 the lower and in 1976 the higher seeding rate produced more grain. Forage production in the year of seeding was substantially lower where underseeded in wheat compared to seeding alone, though

Table 19 Forage yields after establishment with and without a wheat companion crop at Melfort Research Station, average of three experiments.

Companion crop	Year of Seeding	1 st year after Seeding		2 nd year after Seeding		3 rd year after Seeding
		1 st cut	2 nd cut (2 exp ave)	1 st cut	2 nd cut (2 exp ave)	One cut
----- kg/ha -----						
<u>Alfalfa</u>						
Yes	120	3400	2070	3980	2060	3200
No	1990	5680	2890	4160	1950	3280
<u>Bromegrass</u>						
Yes	250	3720	1690	5290	960	3560
No	2740	7020	1940	4750	620	2750

Table 20 Percentage of weeds in the forage, first cut, after establishment with and without a wheat companion crop at Melfort Research Station, Saskatchewan.

Companion crop	Year of Seeding (2 exp ave)	1 st year after Seeding (3 exp ave)	2 nd year after Seeding (2 exp ave)	3 rd year after Seeding (2 exp ave)
<u>Alfalfa</u>				
Yes	14	13	19	32
No	22	8	17	35
<u>Bromegrass</u>				
Yes	5	3	1	4
No	10	2	2	10

there was no measurable difference between the two wheat seeding rates. In the first forage harvest year, both alfalfa and bromegrass yields showed reductions caused by the previous year's

companion crop. Alfalfa showed no yield differences in following years, but brome grass production was higher in the second and third harvest years where it had been established with wheat (Table 19). Both alfalfa and brome grass had more weeds in the seedling year when seeded alone. Other plants in the alfalfa areas were at a minimum the year after seeding but increased in succeeding years, mainly by invasion of brome grass. Brome grass had few weeds after the seedling year following either establishment method (Table 20).

The three-year average yield of Argentine canola was 1890 kg/ha. Its effect on the underseeded alfalfa and brome grass was very similar to that of wheat - a severe depression of seedling growth. Its effect on alfalfa carried forward to include the first cut of the second production year. After that, yields were the same whether established with or without the canola. Brome grass yield was reduced in both cuts of the first production year, and showed an increase only in the third production year where seeded with the companion crop (Table 21). Alfalfa was weedier for two years after being established with the Argentine canola than where established alone (Table 22). The weeds were a mixture of annual weeds, canola and volunteer brome grass. The brome grass areas were almost free of weeds.

Table 21 Forage yields after establishment with and without an Argentine canola companion crop at Melfort Research Station, average of three experiments.

Companion crop	Year of Seeding	1 st year after Seeding		2 nd year after Seeding		3 rd year after Seeding
		1 st cut	2 nd cut (2 exp ave)	1 st cut	2 nd cut (2 exp ave)	One cut
----- kg/ha -----						
<u>Alfalfa</u>						
Yes	60	2850	2055	3010	1850	3480
No	970	5220	2650	3520	2020	3500
<u>Brome grass</u>						
Yes	240	3900	1570	4500	900	4330
No	2032	7810	1940	4700	900	3790

Table 22 Percentage of weeds in the forage, first cut, after establishment with and without an Argentine canola companion crop at Melfort Research Station.

Companion crop	Year of Seeding (2 exp ave)	1 st year after Seeding (3 exp ave)	2 nd year after Seeding (3 exp ave)	3 rd year after Seeding (2 exp ave)
<u>Alfalfa</u>				
Yes	18	30	13	21
No	24	5	9	18
<u>Bromegrass</u>				
Yes	5	1	1	1
No	15	0	1	4

Table 23 Forage yields in seedling year after seeding with and without a Polish canola companion crop at Melfort Research Station, average of three experiments.

	Time of Seeding	
	----- 3 rd wk May	2 nd wk June
	----- kg/ha -----	
<u>Bromegrass</u>		
With comp crop	480	310
Alone	3210	3330
<u>Russian wild rye</u>		
With comp crop	130	40
Alone	480	370
<u>Alfalfa</u>		
With comp crop	260	100
Alone	1860	2740
<u>Sainfoin</u>		
With comp crop	380	150
Alone	2160	2960

Averaged over three tests, Polish canola yielded 1420 and 1560 kg/ha after seeding in May and June respectively. In 1972, the earlier seeding yielded more, in 1975 the later seeding yielded more, and in 1976 seeding time had no effect. There was no effect of the forage on

canola in 1972 and 1976, but in 1975, more canola was produced where alfalfa and Russian wild ryegrass were underseeded. In all tests there was severe reduction of forage growth in the seedling year where underseeded. Also, the later seeding date resulted in poorer forage growth in the seedling year (Table 23). Presumably, the earlier seeding is beneficial to the forage because it has a longer growing season. Forage production the year after establishment showed the same depression following the Polish canola as after wheat or Argentine canola. However, there was a major problem with volunteer canola in Russian wild ryegrass and the two legumes in the first harvest year (Table 24). In later years, canola volunteers were not present, and by the third year, yields were about equal for both establishment methods. Bromegrass suppressed most canola seedlings in the first production year, but yielded less in total over the 3-year duration of the tests where it had been established with canola.

Table 24 Forage yield and percentage of weeds the year after establishment, and yields in succeeding years, with and without a Polish canola companion crop at Melfort Research Station.

	First Year		Second Year	Third Year
	Forage Yield	Weed Content		
	kg/ha	%	kg/ha	kg/ha
<u>Bromegrass</u>				
With comp crop	3770	3	5230	3390
Alone	6510	2	4900	3250
<u>Russian wild rye</u>				
With comp crop	1670	65	3260	2930
Alone	2860	28	3910	2670
<u>Alfalfa</u>				
With comp crop	2600	39	3520	3480
Alone	5140	2	4280	3760
<u>Sainfoin</u>				
With comp crop	2450	51	2740	1970
Alone	4580	10	2860	2070

Polish canola at three seeding rates (3, 5, 7 kg/ha) was also used as a companion crop with yellow sweetclover at four seeding rates (1, 4, 7, 10 kg/ha). Tests were seeded in 1979, 1980, 1982 and 1985 on land fallowed the previous year (Malik and Waddington, 1988). Averaging over the four years of tests, seeding rate had no effect on canola yield (Table 25), although the highest seeding rate produced the lowest yield in 1979, and the lowest rate yielded the least in 1982. Also, canola yield was not affected by the sweetclover. In 1979, a thin sweetclover stand winterkilled. In the other three tests, sweetclover yielded less the year after

establishment when seeded at the lowest rate with canola seeded at the highest rate. When seeded at 7 or 10 kg/ha, sweetclover yield was not affected by any canola seeding rate (Table 25). Volunteer canola was not a problem although annual and biennial weeds were a moderate presence in 1981 and a severe problem in 1986. Weed content decreased as sweetclover seeding rate increased.

Table 25 Yields (kg/ha) of Polish canola and sweetclover dry matter after a canola companion crop at Melfort Research Station.

	Canola seeding rate	Sweetclover seeding rate			
		1	4	7	10
		----- kg/ha -----			
Canola (4-yr average)	3	1930	2040	1970	1960
	5	2000	2150	2040	1970
	7	1980	1970	1950	2030
Sweetclover (3-yr average)	3	3100	3580	3710	3830
	5	2600	3290	3440	4020
	7	1740	2670	3380	3940

Between 1979 and 1981 wheat was used as a companion crop with alfalfa on stubble at 5 sites in northeastern Saskatchewan (Bittman et al. 1991). In each test, all combinations of nitrogen at 0, 57, and 114 kg/ha and phosphorus at 0, 28.5, and 57 kg/ha plus a rate for each indicated by soil tests were incorporated just prior to seeding. Alfalfa was also seeded alone using only the phosphorus treatments. At three sites, nitrogen and phosphorus at 57 kg/ha were included to test the effects of nitrogen on alfalfa. Wheat was harvested at maturity and in succeeding years, alfalfa was cut for forage at 10% bloom (late June) and again in early fall. Adding nitrogen increased wheat yield in four and adding phosphorus in two tests (Table 26). Alfalfa seeded with wheat yielded on average 960 kg/ha less dry matter than alfalfa seeded alone over three years (Table 27). Alfalfa yields decreased as wheat yields increased from 600 to 1800 kg/ha, but changed little as wheat yields increased further to 3800 kg/ha (Table 28). Using less nitrogen to produce less wheat would not be beneficial to the alfalfa overall because wheat yields would have to be drastically less to show much effect on the alfalfa. Adding phosphorus did not benefit the alfalfa unless phosphorus was low (Table 28).

Table 26 Effect of nitrogen and phosphorus on yield of wheat underseeded with alfalfa in northeastern Saskatchewan.

Fertilizer Rate	Choiceland Sites			Tisdale Sites	
	1	2	3	1	2
----- kg/ha -----					
<u>Nitrogen (kg/ha)</u>					
0	760	1270	820	1220	2490
57	1960	1650	2960	2280	2800
114	2280	1690	3200	2700	2770
<u>Phosphorus (kg/ha)</u>					
0	1690	1480	1910	1840	2070
28.5	1610	1550	2360	2180	2840
57	1700	1580	2710	2170	3150

Table 27 Alfalfa yields with and without a wheat companion crop, averaged across phosphorus rates in northeastern Saskatchewan.

With/without Companion crop	Choiceland Sites			Tisdale Sites	
	1	2	3	1	2
----- kg/ha -----					
With	11090	13160	16950	10770	10600
without	11740	14460	18520	11080	11260

Table 28 Effect of nitrogen and phosphorus applied at seeding on average dry matter yield of alfalfa in the three years after establishment with a wheat companion crop in Saskatchewan.

Treatment	Choiceland Sites			Tisdale Sites	
	1	2	3	1	2
	----- kg/ha -----				
<u>Nitrogen</u> (kg/ha)					
0	5550	4390	5650	3590	3530
57	4420	4140	4680	3440	3300
114	4520	4060	4620	3630	3500
<u>Phosphorus</u> (kg/ha)					
0	4710	4010	4820	3560	3040
28.5	4620	4270	5010	3560	3660
57	5160	4300	5120	3540	3640

In 1984 Moyer et al. (1995) compared a barley companion crop with weed control using diclofop (Hoe-grass) + 2,4-DB and no weed control for alfalfa-bromegrass establishment at Westlock, Alberta. The plots were seeded in early June. The barley was cut for silage in mid-August and harvested for grain in late September. In each of two subsequent years, the bromegrass-alfalfa crop was harvested twice, once in early July and again in September. In the establishment year, the barley did an excellent job of suppressing both forages and weeds (Table 29). The application of diclofop controlled the grassy weeds well where no companion crop was used but caused a relatively minor improvement over the suppression caused by the barley. The use of 2,4-DB had no effect on broadleaf weeds where no companion crop was used but improved their control in barley. Overall, application of herbicides improved forage establishment where no companion crop was used and increased barley grain production. In the first production year, where no companion crop had been used, the previous herbicide application resulted in large increases in both alfalfa and bromegrass and decreases in a minor weed presence (Table 30). Removal of the barley companion crop for silage reduced its effect on the forage production compared to leaving it for grain, but led to substantial weed presence. The additional herbicide effect reduced alfalfa production and weed presence and had no effect on bromegrass. Where the barley had been removed as grain, both alfalfa and bromegrass yields were severely reduced. The added herbicide effect improved bromegrass production from very poor to fair, and showed little effect on alfalfa and none on a moderate weed presence.

Moyer et al. (1995) also conducted similar experiments in 1985, 1986 and 1987 at Lethbridge Research Station using irrigation. They used wheat for grain as the companion crop, meadow bromegrass (*Bromus biebersteinii*) instead of smooth bromegrass, and harvested the Table 29 Effect of a barley companion crop and weed control treatments on weed control and

alfalfa-bromegrass in the establishment year at Westlock, Alberta.

Companion crop	Weed control	Dry matter				
		Barley	Alfalfa	Brome	Br. Lf. Weeds	Grassy Weeds
----- kg/ha -----						
None	None	-	580	110	160	4060
"	Diclofop + 2,4-DB	-	1260	350	180	160
Barley (silage)	None	5280	70	10	50	560
"	Diclofop + 2,4-DB	5550	40	10	10	360
Barley (grain)	None	3290	80	10	30	190
"	Diclofop + 2,4-DB	4450	50	10	10	10

Table 30 Effect of a barley companion crop and weed control treatments on weed control and alfalfa-bromegrass production at Westlock, Alberta.

Companion crop	Weed control	Dry matter			
		Alfalfa	Brome	Br. Lf. Weeds	Grassy Weeds
----- kg/ha -----					
<u>First production year</u>					
None	None	3930	1330	190	70
"	Diclofop + 2,4-DB	4800	2590	110	0
Barley (silage)	None	4230	1080	840	170
"	Diclofop + 2,4-DB	3350	1110	490	40
Barley (grain)	None	2770	460	470	190
"	Diclofop + 2,4-DB	2440	740	450	190
<u>Second production year</u>					
None	None	3690	1460	60	0
"	Diclofop + 2,4-DB	4070	1620	20	0
Barley (silage)	None	3860	1270	150	0
"	Diclofop + 2,4-DB	3470	1140	140	0
Barley (grain)	None	3470	800	160	0
"	Diclofop + 2,4-DB	3570	980	300	0

forage for four years: otherwise the experiments were as the one at Westlock. Wheat yields were

4990 and 4390 kg/ha for herbicides applied and not applied respectively. The treatment effects were very similar to those found at Westlock except that the effect of the companion crop disappeared one year earlier (Table 31). The effect of wheat plus herbicide treatment on forage production through to the third harvest year looks like the effect of a poor alfalfa stand. There is clearly a brome increase which was unable to equal the alfalfa loss probably because of insufficient nitrogen.

Table 31 Effects of a wheat companion crop and herbicides on alfalfa-meadow brome production under irrigation over four years at Lethbridge Research Station, Alberta, averaged across three experiments.

Companion crop	Weed control	Dry matter			
		Alfalfa	Brome	Br. Lf. Weeds	Grassy Weeds
		kg/ha			
<u>Establishment year</u>					
None	None	2660	320	790	130
“	Diclofop + 2,4-DB	3940	1040	20	100
Wheat	None	160	30	50	20
“	Diclofop + 2,4-DB	150	>10	0	0
<u>First production year</u>					
None	None	7040	2830	180	10
“	Diclofop + 2,4-DB	7960	3860	10	10
Wheat	None	6570	1370	240	80
“	Diclofop + 2,4-DB	4820	1900	220	80
<u>Second production year</u>					
None	None	9430	2380	10	-
“	Diclofop + 2,4-DB	9260	2520	10	-
Wheat	None	9180	2300	50	-
“	Diclofop + 2,4-DB	7450	3060	20	-
<u>Third production year</u>					
None	None	7830	3590	10	-
“	Diclofop + 2,4-DB	7660	3560	10	-
Wheat	None	8370	3010	50	-
“	Diclofop + 2,4-DB	6780	4260	40	-

Moyer (1985) seeded trials in 1978, 1979 and 1980 on irrigated land at Lethbridge

Research Station, Alberta to compare weed control with herbicides and a barley companion crop with no weed control when establishing alfalfa and sainfoin. The herbicides used singly and in combination were MCPB/MCPA (for sainfoin), 2,4-DB (for alfalfa) for broadleaf weed control, and diclofop for grass weed control. Phosphorus was applied each year at 50 kg/ha. After establishment, alfalfa was harvested three times and sainfoin twice per year. The legumes established well where competition was reduced to a low level by using herbicides to control both broadleaf and grass weeds (Table 32). Whether competition was from an annual companion crop or annual weeds, legume growth was in inverse proportion to the amount of annual growth. In the first production year, the same effect was present, but in second and third production years, all treatments yielded the same amount of forage.

Table 32 Effect of establishment year treatments on alfalfa and sainfoin growth and weed content averaged over three experiments at Lethbridge Research Station, Alberta.

Treatment	Dry matter production					
	Establishment Year				First Production Year	
	Barley	Legume	Broadleaf Weeds	Grass Weeds	Legume	Weeds
	kg/ha					
<u>Alfalfa</u>						
Weedy check	260	1200	890	4600	11380	380
barley companion crop	3400	1140	310	2650	10380	760
2,4-DB	80	1310	110	4490	11200	220
Diclofop	70	2770	2400	400	11670	210
2,4-DB + diclofop	20	4750	160	250	12400	130
<u>Sainfoin</u>						
Weedy check	10	70	1030	4030	7420	1100
barley companion crop	4860	10	180	1700	6950	1230
MCPB/MCPA	580	120	40	4250	7400	1630
Diclofop	20	220	3380	460	7850	1180
MCPB/MCPA + diclofop	280	970	840	330	9400	560

He also conducted similar trials in 1978, 1979 and 1981 using cicer milkvetch (*Astragalus cicer*) and a different selection of herbicides (Moyer 1989). Results were similar to the results with alfalfa and sainfoin. Good weed control with herbicides resulted in better

seedling growth of the cicer milkvetch, better production the following year, and little or no effect lasting into later years. One experiment did not receive irrigation during the establishment year and less than average rainfall. All species present - legume, companion crop and weeds produced much less. Establishment was poor, but was best where herbicides controlled the weeds. There was some carryover benefit to the first production year, but no differences caused by establishment treatments in later years.

At Swift Current, Jefferson and Zentner (1994) seeded oats alone, alfalfa alone, and oats underseeded with alfalfa on irrigated land in 1982, 1983, 1985, and 1988. Nitrogen (2 kg/ha) and phosphorus (11 kg/ha) were applied at seeding time. The plots were irrigated to need except in June 1988. Alfalfa seeded alone produced much less than oats + alfalfa or oats alone in the establishment year. Alfalfa seeded alone outyielded that underseeded consistently with the first cut in the first harvest year and sometimes in later harvests. Over a 3-year period, underseeding and harvesting the oats for hay produced slightly more forage than alfalfa seeded alone (Table 33).

Table 33 Forage production for three years after seeding alfalfa with oats on irrigated land at Swift Current, Saskatchewan, averaged over four tests.

Crop	Yields				
	Establishment Year	First Harvest Year		Second Harvest Year	
		1 st cut	2 nd cut	1 st cut	2 nd cut
----- kg/ha -----					
Oats alone	6930	-	-	-	-
Oats + alfalfa	6350	3090	3670	4660	4360
Alfalfa alone	3790	4180	3750	5020	4600

Jefferson et al. (2003) used Argentine canola, field pea (a leafless variety), and annual ryegrass (*Lolium westerwoldicum*) as companion crops for several grass-alfalfa mixtures at three sites in Saskatchewan - Swift Current, Saskatoon, and Nipawin. The experiments were seeded at each site in 1998, 1999, and 2000 on stubble. Roundup was used to control annual weeds and 50 kg/ha nitrogen and 35 kg/ha phosphorus were applied prior to seeding which was done in late May or June, depending on site and year. Forages were harvested in June or July and depending on regrowth, again in August-September. All three companion crops reduced first cut forage the year after seeding in the order ryegrass - pea - canola at Nipawin and Saskatoon, and canola - pea - ryegrass at Nipawin. At Nipawin where a second cut was taken, there was no clear reduction of forage caused by the previous year's companion crops (Table 34).

Table 34 First cut forage yields at three sites in Saskatchewan after establishment with three companion crops.

Companion Crop	First Cut			Second Cut Nipawin
	Nipawin	Saskatoon	Swift Current	
	----- kg/ha -----			
No companion crop	4780	2850	2690	2510
Argentine canola	4330	2190	1470	2380
Field Pea	4210	1880	1680	2500
Annual Ryegrass	3940	1710	1760	2250

Table 35 Effect of intercropping with short-lived forages on long-term production of perennial forages at Swift Current, Saskatchewan.

Year	Arrangement of Short-lived Forages					
	None	1 row Oats	2 rows Oats	1 row each Oats+Sl.Wht	1 row slender Wheatgrass	2 rows slender Wheatgrass
	----- kg/ha -----					
1980	-	630	900	630	-	-
1981	330	300	210	826	860	1120
1982	970	970	920	1770	1720	1880
1983	1220	1350	1140	1600	1640	1560
1984	590	540	580	610	650	520
1985	610	500	430	550	520	510
1986	1230	1070	1050	1260	1220	1270
1987	630	500	490	520	540	570
1988	900	700	670	660	760	740

At Swift Current, Leyshon et al. included short-lived grasses in rows between rows of Altai wildrye (*Leymus angustus*) and Russian wildrye seeded at a 90 cm row spacing alone or

alternately with alfalfa. The experiment was seeded in 1980. Between the perennial forage rows were seeded one or two rows of oats or slender wheatgrass, or one row of each. In the establishment year, only the oats were harvested. In the two following years, two cuts of forage were taken, in early June and in August. From 1984 to 1988 only one cut was taken. The slender wheatgrass production peaked in 1982 and declined from then on to die out completely by 1987. In the early years its presence increased overall forage production and the wildrye combinations did not catch up until 1984. How much of this is due to a companion crop effect and how much to having a short-term forage between the perennial forage rows is difficult to say. The value of wide row spacings in semi-arid pastures is being re-evaluated.

Blackshaw et al. underseeded flax, oriental mustard (*Brassica juncea*) and field pea (*Pisum sativum*) with sweetclover in 1993, 1995, and 1996 on wheat stubble at Lethbridge, Alberta. Treflan was incorporated for weed control, and 8 kg/ha nitrogen plus 34 kg/ha phosphorus were incorporated before seeding. The intent of the experiments was to find out if sweetclover could be used as a summerfallow substitute in extended crop rotations on dryland. Averaged over the three experiments, sweetclover reduced yields of the annual broadleaf crops, and mustard was more competitive than either pea or flax (Table 36).

Table 36 Effects of underseeded sweetclover on flax, mustard, and field pea grown on dryland at Lethbridge, Alberta.

Annual Crop	Establishment Year Yields		Sweetclover Yields
	Seeded alone	With Sweetclover	The Year Following Establishment
	----- kg/ha -----		
Flax	2070	1126	4130
Mustard	2630	2080	3970
Field Pea	3830	2000	4890

Most of the numbers in Tables 1 through 36 are averages of several experiments seeded in different years. This smooths out much of the variation that occurs because of the differing effects of weather and variations in soil moisture and fertility on the competition between annual and seedling perennial. Hopefully, distractions caused by these variations are avoided while meaningful differences are retained. An example from Malik and Waddington (1988) with canola underseeded with sweetclover shows a threefold range of yield of both crops (Table 37) with a strong negative relationship between them. The 1985 canola yield was very large because the test site had been fallowed for two years. At Lethbridge, Blackshaw et al (2001) reported huge differences in crop yield differences from year to year, largely because of a very dry spring

in 1996 resulting in extremely poor yields. Between 1995 and 1993 yields there was about a 3-fold difference for flax and pea, and a 4-fold difference for mustard. Sweetclover the following year had only 1.5-fold differences overall.

Table 37 Polish Canola and underseeded Sweetclover Yields at Melfort, Saskatchewan.

Establishment Year	Canola Yield	Sweetclover Yield The following Year
	----- kg/ha -----	
1980	1940	3930
1982	1190	5110
1985	3100	1500

Conclusions

Experiments to assess the value of using companion crops while establishing perennial forages have been conducted in western Canada for 100 years and have made one thing abundantly clear. The climate and the weather play a major role in the success or failure to establish forages with a companion crop, and in some locations and some years even without a companion crop.

The climate effect is best expressed by the soil type. In the subhumid climate of the black and grey-wooded soil zones, precipitation and evapotranspiration come nearest into balance on average. There is good spring moisture from snowmelt, and rainfall peaks in late June, just before the hottest time of the summer. There is also some rain in early fall so the forage has some chance to develop a limited amount after the companion crop when grown for its seed, has been removed. Results from Brandon (Manitoba), Indian Head, Melfort, Nipawin, Choiceland (Saskatchewan), and Lacombe and Westlock (Alberta) show that forages seeded with a companion crop can usually be established successfully in this climate zone. However, forage yields after establishing with a companion crop are often less for the first production year than when established alone. Dry conditions can produce a thinner companion crop and allow better light conditions for the underseeded forage, resulting in it establishing better than when growing conditions apparently are more favourable (Tinline 1924, Waddington and Bittman, 1983). Jefferson et al (2003) suggest that inconsistencies in the response of the forages to the different companion crops in their experiments can be explained by the differences in timing of rainfall in relation to the development stages of the companion crops. The companion crop seems to have little effect on forage plant numbers. The influence is on seedling size, with smaller plants unable to produce maximum yields the following spring (Waddington, 1990,

Jefferson et al, 2003). Thereafter, weather and soil fertility are the controlling agents.

In the dark brown soil zone, evapotranspiration is greater and precipitation a little less on average than in the black soil zone. There is usually adequate moisture in the soil from snowmelt in spring for seed germination. Because evapotranspiration normally exceeds summer rainfall, plants come under stress and forage establishment using a companion crop is more uncertain. Scott and Saskatoon (Saskatchewan) are in the dark brown soil zone. It is best to seed forages with a companion crop on land fallowed the previous year. On stubble, better forage establishment will be gained by seeding alone.

The brown soil zone has high evapotranspiration in summer and brisk winds. Precipitation is less than in the dark brown soil zone. Snowfall is less certain so soil moisture in spring may be insufficient for germination. Forage establishment with a companion crop is uncertain, but without one is usually adequate. Swift Current (Saskatchewan) and Lethbridge (Alberta) are in the brown soil zone. Forages established quite well using cereal companion crops at Swift Current in the early 1920's (Swift Current Experimental Farm, 1924, 1928) and the early 1950's (Kilcher and Heinrichs 1960), but in drier periods, forages failed to establish when seeded with a companion crop (Swift Current Experimental Farm, 19030, 1937-47). It usually takes two years before maximum possible yields are attained, and amounts and timing of rainfall has a large effect on production.

A fourth "climate zone" is the result of irrigation. Provided there is water available when required, establishing forages with a companion crop is not a problem. Even if irrigation water is available to the plants, high temperatures and wind speed make the water less effective for growth (Jefferson and Zentner (1994). Swift Current (Saskatchewan) and Lethbridge (Alberta) have irrigation available in some sites.

In all situations, it is best to sow on land with few weeds. Prior to the development of present-day herbicides, there was little choice in weed control. Forages were seeded at higher rates than the 100 seeds per metre of row recommended at present, partly to counteract weed competition, and partly because forages were often seeded too deep in soil that was too loose after cultivations to control the spring flush of weeds. Even at present, weed control is a problem. The combination of a grass and a broadleaf plant, be they annual or perennial, puts severe limitations on the choice of herbicide. As well, herbicides which are usable as far as crop tolerance is concerned may not be registered for forages. Often, herbicides that are registered for annual crops have nothing on their label about forages, or about residues that may remain in the hay or pasture.

Reports on the economics of seeding forages with or without a companion crop are infrequent. Opinions expressed in early reports (White, 1913, Beaverlodge Experimental Farm, 1926) were that a companion crop was economically necessary because the extra hay obtained by establishing the forage alone did not compensate for the money lost by not growing a grain crop for a year. More recent more detailed analyses on irrigation (Jefferson and Zentner, 1994), and in the black soil zone (Smith et al. 1997) are more equivocal, pointing out that it depends on

the relative prices of forage, grain, and cereal hay. As well, it depends on the effect that forages in a rotation have on variability. Producers prefer a rotation that is more likely to produce a steady income rather than big year-to-year fluctuations. In the dark brown soil zone, rotations including underseeded alfalfa were usually not economic in standard farming practices in part because of variability in alfalfa yield with weather fluctuations, compared to all-grain rotations (Zentner et al., 1995). With organic farming methods, the lack of higher organic crop prices for hay made rotations including forages less attractive economically (Zentner et al., 2001)

There is also the effect of the forage crop on grain crops. Zentner et al (1988, 1990) reported that in the black soil zone, wheat following forages that contained a legume component had higher yields or higher protein content. Except for sweetclover with broadleaf annual crops (Brandon, 1926, Blackshaw et al., 2001), underseeded forages appear to have no deleterious effects on the companion crop.

The Bottom Line

On black and Grey-Wooded soils and on irrigation, there is not usually a problem establishing forages with the commonly-grown annual crops provided forages are not seeded too deep. Whether or not a companion crop should be used to establish forages depends on the likely yields of the forages and the companion crops, and their relative values to the producer. On dark brown soils, the most likely success using a companion crop is to seed forages with wheat on fallow. Unfortunately, most of the experimental work has seeded forages with companion crops in rotation after several cereal crops. In this soil zone forages establish better on stubble when seeded alone. In the brown soil zone, it is unwise to use a companion crop to establish forages because the unpredictability of weather conditions. Normally it takes two years to reach full production even when forages are established without a companion crop.

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